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# Age-Related Bias in Age Estimation Based on Facial Images of Others

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## Abstract

**In this study, we hypothesized that the tendency toward an age estimation bias when judging age based on facial images was driven by relative comparison with one's own age, similar to situations of face-to-face communication. Using facial images as stimuli, participants were asked to assess the ages of those in the images in relative terms (younger or older than the participants themselves). We examined the relationship between age estimation bias and participants' age and gender, as well as the type of facial expression in the images (smiling or neutral). This bias was found throughout most gender and age groups, with the exception of the middle-age female group. Moreover, the bias was greater in men than women, and was influenced by both age and type of expression. These results suggest that the main factors responsible for age estimation bias interact in a complex juxtaposition of variables such as sex, age, and expression.**

## Keywords

**Age Estimation, Age Bias, Face Processing, Aging, Non-Linear Regression Analysis**

## 1. Introduction

When individuals engage in communication, they tend to make judgments about the attributes of their partner (e.g., age, gender, ethnicity, social status, or professional background) based on appearance (Berry & McArthur, 1986). When forming attitudes during social interactions, age is one of the most important factors; first impressions are often significantly influenced by the fact that those with whom we communicate are older or younger than ourselves. Individuals tend to unconsciously estimate the ages of those around them based on appearances, and then they use these estimations to establish appropriate social interactions (Rhodes & Anastasi, 2012). De-

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spite this, we often have various age estimation biases (George & Hole, 1995; Rhodes, 2009; Voelkle, Ebner, Lindenberger, & Riediger, 2012), and we address them in potentially inappropriate ways.

One of the most significant findings to emerge from these studies concerning age estimation bias was that participants in each experiment tended to overestimate the ages of the facial images they were shown. George and Hole (1995) found that both younger and older participants tended to estimate age more accurately when assessing images of faces that were within their own age range. However, while younger participants tended to overestimate the age of older faces, older participants tended to overestimate the age of younger faces (George & Hole, 1995). Moreover, Wernick and Manaster (1984) showed that older participants tended to overestimate the age of older faces as well as younger and middle-aged faces. Pittenger and Shaw's (1975) experiment on estimating chronological age revealed that participants estimated age higher, the more a face was masked (masking or hiding everything except the face, masking the shape of the face, etc.). Taken together, these findings suggest that individuals tend to overestimate the ages of masked faces, and this overestimating bias is a direct result of and is expected to interact with changes in age, gender differences, and emotional expressions; however, further studies are needed to provide a systematic quantification of age estimation bias (Voelkle, Ebner, Lindenberger, & Riediger, 2012).

In this study, we hypothesize that the bias toward overestimating the ages of others is driven by an automatic comparison of the face to the perceiver's own age as occurs in face-to-face communication. To this end, we aim to identify how individuals estimate their own age relative to what they see in a facial image, and we used a nonlinear regression model with a logistic curve to calculate an age estimation bias for each participant. We considered their values by estimation to be the dependent variable, and we investigated the relationships between the participants' attributes (gender and age) and their age estimation biases. Not by estimating age itself directly from the facial images of others as was investigated in previous studies but by assessing whether the person in the image was older or younger than themselves by making relative comparisons with their own ages, it is possible to focus on a different aspect of the age estimation bias.

## 2. Methods

### 2.1. Participants

To assess bias of age estimation for each participant, 211 Japanese individuals (113 male, 98 female) aged 25 - 54 years participated in the present study. The participants were recruited from Kwansei Gakuin University and the neighboring community of Hyogo prefecture in Japan. All participants provided written informed consent to participate.

In order to avoid own-race bias (the phenomenon in which individuals find it easier to assess or recollect the face of a person belonging to the same race than that of someone of a different race) (Dehon & Brédart, 2001; Chiroro, Tredoux, Radaelli, & Meissner, 2008; Hancock & Rhodes, 2008; Meissner, Brigham, & Butz, 2005), only Japanese participants and images of Japanese people were assessed in this study.

The study was approved by the ethics committee of the School of Science and Technology of Kwansei Gakuin University and conducted according to the principles set forth in the Declaration of Helsinki.

### 2.2. Experimental Stimuli

We constructed facial image dataset to be used as the experimental stimuli. We used a total of 480 full-color 300 × 350-pixel facial images of Japanese individuals ranging from 20 to 59 years old. The pictures were taken at the laboratory on a white-tinged background under controlled illumination conditions. No restrictions were imposed on the participants concerning clothing and accessories, make-up, hairstyles, etc. (**Figure 1**). The facial images were prepared digitally and were grouped into 22 classes by gender (male or female) and age (at five-year intervals). In regards to the groupings, the participants needed to be exposed to the facial images from as similar an age group to themselves as possible to perform the age judgment task within limited presentation numbers, because relative age judgment is expected to be more difficult when the image one is viewing if closer to one's own age. Therefore, we grouped the participants into various classes by age (at 5-year intervals) because we needed to expose the participants to facial images from a similar age group in an effective and uniform manner. Data on actual age and gender were recorded for all images. Each image showed the same face with two different expressions (neutral and smiling). The reason we used only the smiling face in many of the presented pictures is that smiling has been shown to exert a greater influence on age estimation bias, compared with other expressions (Voelkle, Ebner, Lindenberger, & Riediger, 2012).

### 2.3. Procedure of the Estimation Experiment

For each participant, stimuli were chosen from the facial image dataset according to the participant's age and gender. The selection included images from three age classes: that of the participant, the adjacent younger class, and the adjacent older class. We expected estimated age to vary more widely for stimuli that were close to participants' own age. Therefore, stimuli were limited to adjacent age classes in order to ensure sufficient variation in the data. Five male and five female faces were selected randomly from each class and presented in both neutral and smiling aspect. Thus, each participant was presented with 60 images (5 images/class × 3 age classes × 2 genders × 2 expressions), as shown in **Figure 2**.

During the experiment, participants were shown their assigned facial images at random on a liquid crystal display with a display resolution of 1024 × 768 pixels. The apparent size of each facial image on the display was 75 mm × 87.5 mm. The participants were instructed to judge whether the person in the image was older or younger than themselves and to assess the confidence rating for their judgment on age estimation on a five-point scale that ranged from 2 to −2: definitely older than me (2), probably older than me (1), unable to estimate (0), probably younger than me (−1), and definitely younger than me (−2). Thus, participants judged relative rather than chronological age. Once participants made an assessment, they were presented with the next image. After participants finished evaluating the facial images, their demographic data (age and gender), responses, and the actual difference between their age and that of the individuals depicted in the stimuli were compiled into a text document.

**Figure 1.** Examples of the experimental stimuli.

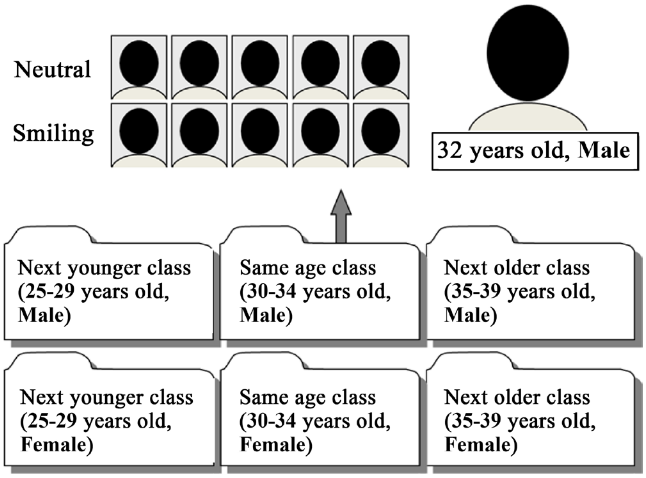


**Figure 2.** Choice of experimental stimuli. Five male and five female faces were chosen at random from three age classes relative to participants' own ages (same age, and the adjacent younger and older classes). Each face was shown twice, once with a neutral expression and once smiling.

## 2.4. Calculation of Age Estimation Bias

**Figure 3(a)** shows the calculation of age estimation bias based on participants' judgment of faces as either older or younger than themselves. The *x*-axis displays the actual age difference, which subtracts the actual ages of the participants from the actual ages of the others' facial images. The *y*-axis displays participants' confidence ratings of relative age estimation for the facial images. We plotted the relationship between these two variables for each stimulus image on a two-dimensional plane, with the difference in actual age on the *x*-axis and participants' confidence ratings of relative age estimation on the *y*-axis. A positive value for *x* indicated that the face in the stimulus image was actually older than the participant, while a negative value indicated a younger face. A positive value for *y* (participants' rating) shows that the participants estimated the facial image to be older than themselves, and a negative value represented an estimate of a face as younger than their own age. As a result, if participants tended to judge the ages of younger persons shown in the facial images to be the same as their own real age, the entire distribution of the data shifted toward the left (into the negative area on the *x*-axis). Conversely, if the participants tended to judge the age of older persons shown in the facial images as being the same as their own real ages, the entire distribution of the data shifted toward the right (the positive area on the *x*-axis). Thus, the participants' tendencies to significantly underestimate or overestimate the age of others was indicated by the shifting of the distribution toward either the positive or negative side of the *x*-axis, respectively. The value of the age estimation bias was then calculated as the distance between the center of the distribution and the origin of the coordinate for the *x*-axis.

When these data were plotted onto the graph shown in **Figure 3(a)**, we assumed that this distribution was approximated by a logistic function, and applied a nonlinear regression analysis to the distribution for each participant. The actual age difference between the facial images and the participants (*x*-axis) was defined as the independent variable, and participants' confidence ratings of relative age estimation for others (*y*-axis) were defined as the dependent variable. The logistic function, which converged at a rating value of ±2, was defined by the following formula:

$$y = \frac{4}{1+\exp\left(-a\left(x-b\right)\right)} - 2 \quad (1)$$

where *a* is the slope of the curve, and *b* is the *x*-intercept of the approximation curve. We used a nonlinear regression analysis to estimate *a* and *b*. The value of parameter *b* corresponded to the point of subjective equality, at which the individual represented the ages of the faces on the images on the *x*-axis as equal to his/her own age. If this value was negative, it meant that the participants perceived faces that are actually younger than themselves to be equal in age. In other words, the value of *b* represented the degree of age estimation bias. As an

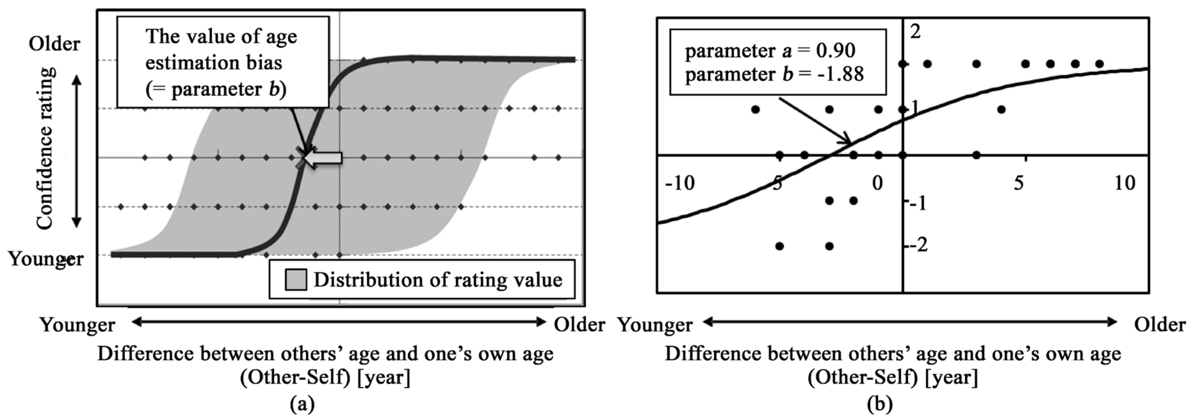


**Figure 3.** (a) Calculating the bias of age estimation. Each data point represents one image judgment. The *x*-axis represents the difference between the actual age of the individuals whose faces were shown and the age of the participant. A positive value for x indicates that the stimulus face is older than the participant, while a negative value indicates an image that showed a face that was younger than the participant's actual age. The *y*-axis represents the participant's confidence rating of their relative age estimation for the image. If this value is negative, it means that the participants perceive younger faces to actually be the same age as themselves; (b) Actual estimated curve and the parameters (*a* and *b*) obtained by applying the non-linear regression analysis to one participant's response.

example, **Figure 3(b)** shows the results of the regression analysis of the estimation data from one participant. In this case, the values of *a* and *b* were estimated as 0.90 and −1.88, respectively. This participant's age estimation bias was therefore −1.88, meaning that he or she perceived faces that are actually 1.88 years younger than themselves to be the same age as them.

We calculated the value of the age estimation bias for all neutral and smiling stimuli of the 211 individuals. **Figure 4** shows an example of the estimation curves and the average values of age estimation bias from ten participants. Next, we identified and eliminated any outliers in each participant group before analyzing the data. We eliminated any participant data where the multiple coefficients of determination of the regression curve given for either neutral or smiling stimuli were under 0.1. This led to the elimination of data from 35 individuals from the original total of 211 participants, leaving a total of 176 participants included in the analysis.

Finally, to examine the effect of gender (male and female), age group (young: 25 - 34 years; young-middle: 35 - 44 years old; middle: 45 - 54 years old), and facial expression (neutral and smiling), the dependent variable of estimated age values were compared using a three-way analysis of variance (ANOVA), with participants' gender and age group as the between-participants factors, and type of expression as a within-participants factor.

## 3. Results

The average of age estimation bias values (*b*) for each group and condition are summarized in **Table 1** and **Table 2**, together with standard deviations. First, to confirm the bias effect in age estimation, the *b* values for each

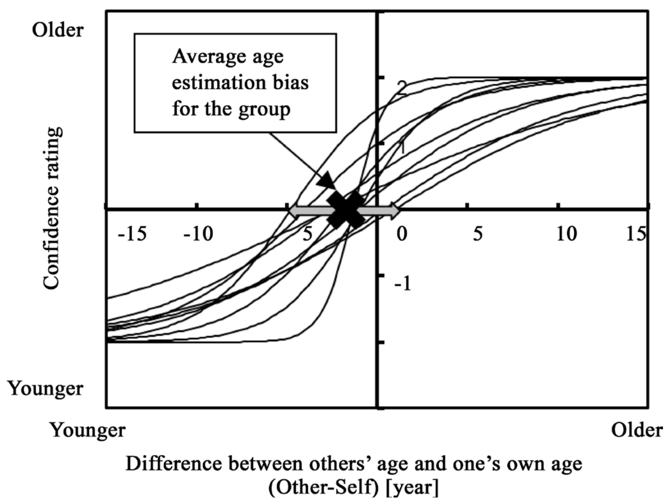


**Figure 4.** An example of the estimation curves and the average values of age estimation bias from 10 participants.

**Table 1.** Statistics related to the age estimation bias value for images of faces with neutral expressions.

| | | 25 - 34 | | 35 - 44 | | 45 - 54 | | Total |
|---|---|---|---|---|---|---|---|---|
| **Male** | *M* | −3.77 | *** | −2.05 | ** | −2.44 | *** | −2.84 |
| | *SD* | (3.73) | | (2.57) | | (3.27) | | (3.35) |
| | *N* | 34 | | 22 | | 36 | | 92 |
| | *t* | 5.89 | | 3.74 | | 4.48 | | |
| **Female** | *M* | −2.54 | *** | −1.14 | + | −0.35 | | −1.34 |
| | *SD* | (2.22) | | (3.00) | | (2.81) | | (2.81) |
| | *N* | 29 | | 25 | | 30 | | 84 |
| | *t* | 6.16 | | 1.91 | | 0.68 | | |
| **Total** | *M* | −3.2 | | −1.57 | | −1.49 | | −2.12 |
| | *SD* | (3.17) | | (2.81) | | (3.22) | | (3.18) |
| | *N* | 63 | | 47 | | 66 | | 176 |

*M*: Mean; *SD*: Standard Deviation; *N*: Number of Participants; *t*: *t* values tested against 0 (baseline) using paired t-tests; $^{+}p < 0.10$; $^{**}p < 0.01$; $^{***}p < 0.001$.

**Table 2.** Statistics related to the age estimation bias value for images of smiling faces.

| | | 25 - 34 | 35 - 44 | 45 - 54 | Total |
|---|---|---|---|---|---|
| **Male** | *M* | −2.87*** | −1.9* | −2.95*** | −2.67 |
| | *SD* | (3.31) | (3.58) | (3.18) | (3.32) |
| | *N* | 34 | 22 | 36 | 92 |
| | *t* | 5.05 | 2.49 | 5.56 | |
| **Female** | *M* | −1.96*** | −1.81* | −0.71 | −1.47 |
| | *SD* | (2.81) | (3.72) | (2.65) | (3.07) |
| | *N* | 29 | 25 | 30 | 84 |
| | *t* | 3.75 | 2.43 | 1.47 | |
| **Total** | *M* | −2.45 | −1.85 | −1.93 | −2.1 |
| | *SD* | (3.10) | (3.62) | (3.14) | (3.25) |
| | *N* | 63 | 47 | 66 | 176 |

*M*: Mean; *SD*: Standard Deviation; *N*: Number of Participants; *t*: *t* values tested against 0 (baseline) using paired t-tests; $^{*}p < 0.05$; $^{***}p < 0.001$.

group (based on gender and age) and condition (neutral vs smiling face) were tested against 0 (baseline) using paired *t*-tests. As shown in **Table 1** and **Table 2**, for both expression conditions, the bias effects in age estimation were found throughout all groups, with the exception of the middle-age female group. Note that the significance level of the bias effect was marginal in the young-middle age group for the neutral expression condition. Bias value means were negative for most groups in both conditions, suggesting that participants tended to overestimate age based on facial images.

Next, to examine the effect of gender, age group, and facial expression on age estimation bias, a three-way ANOVA was performed using participants' gender and age group as between-participants factors, and type of expression as a within-participants factor; the results are shown in **Figure 5**. The analyses revealed a significant main effect of gender ($F(1, 170) = 7.41$, $p < 0.01$, $\eta^2_G = 0.04$) and a significant interaction between age groups and type of facial expression ($F(2, 170) = 7.63$, $p < 0.001$, $\eta^2_G = 0.01$). However, no other main effects were found. The simple main effect was tested on the interaction between age groups and type of facial expression. Type of expression was found to influence age estimation bias in the young age group (25 - 34 years; $F(1, 170) = 10.45$, $p < 0.01$, $\eta^2_G = 0.01$) and the middle age group (45 - 54 years; $F(1, 170) = 3.60$, $p = 0.05$, $\eta^2_G = 0.01$), but not in the young-middle age group (35 - 44 years; $F(1, 170) = 1.24$, $p > 0.10$, $\eta^2_G < 0.01$). On the other hand, the simple main effect of age groups was found to influence age estimation bias for images with a neutral facial expression ($F(2, 340) = 5.44$, $p < 0.001$, $\eta^2_G = 0.07$), but not for smiling faces ($F(2, 340) = 0.64$, $p > 0.10$, $\eta^2_G = 0.01$). Moreover, significant differences emerged from multiple comparisons (Ryan's method) conducted among age groups on neutral expression stimuli. Significant differences were found between the young age group and the middle age group ($t(340) = 3.21$, $p = 0.001$), and between the young age group and the young-middle age group ($t(340) = 2.59$, $p < 0.01$), but not between the young-middle age group and the middle age group.

To summarize, we have analyzed the relationships among age estimation bias, participants' age and gender, and expression in the facial images. The first important finding was that men tended to exhibit a greater bias of age estimation than women. In addition, significant differences were found with neutral stimuli between the biases of the young and young-middle age groups, and between the young and middle age group, but not between the young-middle and middle age group. These results suggested that the younger the participants were, the stronger their tendency to construct a younger identity bias for their age. Moreover, significant differences were identified in age estimation bias according to the facial expression in the stimuli. The extent of this difference varied between age groups, particularly between the young age group and the middle age group. In the young age group, the tendency to postulate a younger identity was weaker for images with smiling expressions than for images with neutral expressions. However, in the middle age group, the reverse tendency was found. These results suggest that age estimation bias varies according to the perceiver's age and the observed person's facial expression.

## 4. Discussion

In this study, we tested the hypothesis that the tendency toward an age estimation bias when judging age based


**Figure 5.** Age estimation bias according to gender and age groups. The analyses revealed a significant main effect of gender and a significant interaction between age group and type of facial expression. The asterisks show a significant simple main effect to be tested on the interaction between age group and type of facial expression.

on facial images is driven by relative comparison with one's own age, similar to situations of face-to-face communication. Moreover, we investigated the relationship between the age estimation bias and participants' age and gender, as well as the facial expressions in the stimuli (neutral or smiling). The results suggest that people tend to show an age estimation bias that extends through most gender and age groups. Moreover, this bias was influenced by gender, age, and type of facial expression, and it was larger in men and the youngest group of participants. These results suggest that the tendency toward bias in estimating the ages of other people when engaging in age perceptions based on facial images is driven by comparisons with the estimator's own age; however, this bias is interpreted as either overestimating others' ages or underestimating one's own age. For methodological reasons related to relative comparison, which accounted for the bias in the present study, we could not distinguish whether this bias was caused by overestimating others' age or underestimating one's own age.

The value of the age estimation bias was found to be negative throughout most gender and age groups, with the exception of the female middle age group. This suggests a general tendency to overestimate others' age (or to underestimate one's own age), regardless of facial expression or a participant's own gender. One possible explanation for this estimation bias is that the amount of information available for the age estimation is asymmetrical between others and oneself. People may possess a sense of their appearance being driven by a general schema for how they should look, perhaps causing an individual to discount obvious signs of aging. In typical face-to-face communication, other people's faces can be observed objectively without any previous knowledge, whereas our perception of our own facial image is affected by a self-schema; that is, the general knowledge structures or sets of beliefs about ourselves that guide our perceptions, organize cognitive information, and reconstruct memory (Bartlett, 1932; Bransford & Johnson, 1973). In other words, the process of estimating other people's ages involves interpreting only data observable at the time of communication, whereas images of one's own self are misperceived in the context of self-schema. Previous research into own-age bias suggests that these biases reflect increased personal and social relevance of and more accessible and elaborated schemas for own-age than other-age faces (He, Ebner, & Johnson, 2011). Similarly, it is plausible that self-schema bias exists, as indicated by our findings suggesting a tendency to underestimate our own age (or overestimate other people's ages) when asked to provide relative age estimates.

The results of the present study found that participants' ages, gender, and facial expression stimuli were related to age estimation bias, in the following ways: a) Differences in age: age estimation bias was larger in the young age group, regardless of facial expression; b) Gender differences: age estimation bias was larger among male than female participants; the female participants' age biases were closer to their real ages; c) Difference in expression: in the young age group, age estimation bias was smaller for the smiling facial expression stimuli than for the neutral expression stimuli; it was also found to be closer to the participants' real age. However, in the middle age group, age estimation bias was larger in the case of the smiling stimuli compared to the neutral expression stimuli.

Finding (a) indicates that participants in the younger age group tended to overestimate others' ages (or to underestimate their own ages) more frequently than did those in the older (middle) age groups. This finding is in line with previous studies using the age estimation itself directly for facial images, in which the young age group overestimated age more for those of a similar age person than did the middle age group (Voelkle, Ebner, Lindenberger, & Riediger, 2012). One possible explanation is that they simply have less practice with age estimation overall compared with the older groups (Sörqvist & Eriksson, 2007). This notion is consistent with a recent study showing that age estimation accuracy increased with age (Van Rijsbergen, Jaworska, Rousselet, & Schyns, 2014).

In finding (b), the gender differences revealed that the female participants tended to perceive age more accurately than did the males. Previous studies have also provided some empirical support for better age estimation performance and less bias among women (Nkengne et al., 2008; Vestlund et al., 2009). Although the reasons for this increased age estimation bias in the male group are unclear, this may be partly because women tend to be more appearance-conscious and more sensitive to their age; it could also be because women tend to observe others and/or themselves in the mirror more frequently than men during the common practice of applying cosmetics.

In addition, finding (c) can be restated as follows: in the younger age groups, participants tended to overestimate the ages of faces with smiling expressions less frequently than those of images with neutral expressions. Thus, the certainty factor of whether the smiling expression stimuli appear younger is higher than with the neutral expression stimuli for the young age group. For the middle age group, however, the opposite is true. Therefore, for the younger participants, it seems that the smiling stimuli gave the impression they were younger than they really were. This finding is in line with previous research, suggesting that a happy expression makes a face look younger (Voelkle, Ebner, Lindenberger, & Riediger, 2012). However, it is clear that as people age, smiling gives others the impression that they are older than they really are. This may be the result of factors related to both the participants and the facial image stimuli: the former may include the perception characteristic of the expressions (based on the age of the participants), whereas the latter may be because smiling increases the appearance of facial wrinkles (Mukaida & Ando, 2004).

Our study has several limitations, the first of which is our modest effect size. Therefore, the relationship between age estimation bias on the participants' attributes and expressions remains tentative. Similarly, because of the size of our sample, the effect of portrayed gender for age estimation, such as own-sex effects (Verdichevski & Steeves, 2013), was not investigated and remains unclear. Replication of our results with a larger sample would be worthwhile. Second, we need to clarify the differences in age estimation when estimating others' age directly and by relative comparison with one's own age, because the latter is expected to be more influenced by the socio-psychological context; i.e., the self-schema and cultural differences. We hope to conduct an experiment in which participants assess relative age estimation with or without schema; for example, acquaintances or not. Regarding these points, we observed in our preliminary studies that people tend to underestimate the ages of well-known others' faces compared to those of people who are unknown to them (Konishi, Katahira, Tobitani, Azuma, Fujisawa, & Nagata, 2013). This same age estimation bias tendency has also been confirmed across different cultures (United States, Korea, and Japan) (Azuma, Miyamoto, Fujisawa, Nagata, & Kosaka, 2009).

The effects of communication channel types or their restrictions by channel for age estimation bias should also be investigated. Concerning other channel types, we reported in our previous study that people also exhibit age estimation biases for voices, but the opposite bias occurs. People tend to overestimate the age of their own voice compared to others' voices (Nishimoto, Azuma, Miyamoto, Fujisawa, & Nagata, 2008). On the other hand, in the context of computer-mediated interaction, text or facial images are very often the only types of information we see about other people and them about us, in social networking service (SNS) communities. Although the presence of facial images has been shown to attract and promote engagement with an audience (Bakhshi, Shamma, & Gilbert, 2014), the relationship between age estimation bias by restricted channel information and online communication social engagement remains unclear. Further investigation is needed to clarify this issue.

## 5. Conclusion

In conclusion, the present results indicate that the tendency for bias in estimating the age of other people when engaging in age perception based on facial images is driven by a comparison with the estimator's own age. The results suggest that people tend to show an age estimation bias that extends throughout most gender and age groups. Moreover, this bias was influenced by gender, age, and type of facial expression, and was larger in men and the youngest group of participants. Combining estimation of others' age using facial images with other tasks will be fruitful in further elucidating the mechanisms underlying age estimation bias.

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