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Research Article

Mortality is Written on the Face

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Abstract

Background: It is unknown whether facial or surrounding (eg, hair and clothing) cues have the strongest influence on the perceived age of subjects in photographic images, and which drives links between perceived age and survival.

Methods: In 2001, 187 Danish twin pairs (*n* = 374) aged 70+ years were photographed generating passport-type images. The faces of the twins in these images were swapped creating two new images per twin pair (748 images in total). Ten nurses rated the perceived age of the twin from the original and swapped facial images. The survival of the twins was determined through to the end of 2013.

Results: Changing the face or its surrounding significantly changed the perceived age of the images, with only a marginal difference between their effect sizes (difference of 0.5 years, 95% confidence interval CI –0.1 to 1.1). Perceived age, adjusting for chronological age, and sex, was a predictor of survival up to 7 years (hazard ratio 1.17, 95% CI 1.10–1.25) and also 7–12 years (hazard ratio 1.06, 95% CI 1.00–1.12) after the photographs were taken. Where the older looking twin died first they had a significantly older looking face (1.4 years older, 95% CI 0.3–2.6) but not surrounding (0.3 years older, 95% CI –0.8 to 1.4) compared to where the older looking twin died second.

Conclusions: Facial visual cues but not hair or clothing cues drive the link between perceived age and survival.

Key Words: Facial aging—Longevity—Perceived age—Hair—Clothing—Skin.

Humans have the capacity to judge an individual's age because of the evolutionary advantage it imparts in being able to establish the competitive and fecundity nature of others (1). The capacity to judge age has been used by physicians to judge the health of a patient and has been exploited more recently by gerontology research to generate the perceived age of an individual (how old the person looks to others) as a measure of biological age—that is, how well an individual is ageing considering their actual/chronological age (2). Measures of biological age are useful for researching factors that influence the ageing process and the more accurately the measure reflects physiological ageing the better the measure will be at detecting such factors (3).

One of the first studies to investigate links between perceived age and blood biomarkers of health and ageing was Borkan and Norris in 1980 (4) who used the judgment of age from one individual (nurse or doctor) in a "live" setting while the subject was fully dressed. Links between perceived age and cholesterol in men and bilirubin levels in women were found. In a similar manner, Wildt and Petermann (5) estimated the age of women when they entered their outpatient clinic, and found links between perceived age and serum oestrodial concentrations. More recently, age assessments of subjects in photographs has been utilized, in part due to the recent improvements in digital photography. We were the first to use perceived age from photographs of 70+ year olds in a prospective study (6,7). Using mortality data up to 7 years after the subject photographs were taken, a significant link between mortality and perceived age was found even across three different groups (female geriatric nurses, 22–37 year old men and 70+ year old women) of age assessors. In support of this, Dykiert and coworkers (8) used photographs and 12 young adults to estimate the age of 80+ year old subjects and also found that perceived age predicted life expectancy in a 7-year follow-up period. Hence, perceived age is a robust biomarker of ageing in elderly populations.

The perceived age of a subject can be altered through changes to the type of image shown to age assessors. Indeed, the more a subject image is altered the more the perceived age of that subject differs in response (9), and individuals who dye their hair look younger only in images that include their hair (10), confirming a causal influence of hair appearance on age perception. However, there have been no studies to date investigating which cues/features, present in passport-type photographic images, predominately drive the perception of age or the link between perceived age and mortality.

We previously demonstrated that the perceived age of 70+ year old twins was associated with mortality in a 7-year follow-up (7). Here, we investigated whether the link between perceived age and mortality held more than 7 years after the photographs were taken using 12 years of follow-up mortality data. The photographs used (passport-type images) for the perceived age study included facial as well as hair and clothing (herein termed surrounding for simplicity) cues in the images. We hypothesized that both the facial and surrounding cues were influencing perceived age and were also equally driving the link between perceived age and mortality; we tested this by digital swapping the face of one twin with their co twin's face in the photographs and studying how the altered images influenced the link between perceived age and mortality.

Methods

Study Population

The Longitudinal Study of Aging Danish Twins (LSADT) is a follow-up study of a population-based cohort of same-sex twins aged 70+ years (please see detailed description in (11)). LSADT began in 1995 with assessments every 2 years upto 2005. In the 2001 wave, 91% of the participants with normal cognition (aged 70–99 years) gave informed written consent for their photographs to be taken. A total of 1,826 twins (840 men and 986 women) had a face-on color photograph taken with a digital camera at a distance of 0.6 m generating passport-type images (Figure 1).

Survival

We used the Danish Civil Registration system, which registers date of death and emigration of all Danish people (12) to follow each participant from the date in spring 2001 when their photograph was taken through to 31 December 2013. No loss of subject follow-up occurred due to emigration.

Face Swapping

Based on our previous perceived age study of the 1,826 twins (pairs and singletons) in 2003 (7), a subgroup of same sex twin pairs were selected with a 2-year or greater difference in perceived age between the twins (235 pairs, 61% of pairs available)—this was the only time the previous perceived age data were used. A 2-year cut-off was selected on the basis it would enrich for images where the link between perceived age and survival was the strongest (7), while retaining enough twin pairs for statistical power.

To swap the faces, the face of one twin was cropped from its image (Photoshop version CS4) and overlaid on their co-twin's face. The faces were cropped from the mid-neck upwards to the top of the forehead where possible (hair fringes sometimes meant only part of the forehead could be swapped). The lightening or other features within the face were not altered, although the interface between the face and the surrounding were sometimes smoothed to reduce the contrast between the two images. Quality checks were performed on

Figure 1. Representative images of twins in their original photographs (top images) and in their swapped images (bottom images). To analyze face controlling for surrounding, perceived ages from vertically opposite images were compared, whereas to analyze the surrounding controlling for face perceived ages from diagonal opposite images were compared. Lighting in the female images and the angle of presentation of the face to the camera in the male images were the two main varying technical parameters between the images; both male faces (upper images) were flipped horizontal (lower images) to compensate for the varying angle. All twins gave written consent for their images to be published.

the images and those of particularly poor quality (eg, blurred image) were excluded. In 71 pairs, both (46 pairs) or one (25 pairs) of the twins' faces were flipped horizontally (mirror image) to ameliorate contrasting angle presentation of the twin faces to the camera. In total, 187 same sex twin pairs (374 subject images) had their face swapped; 178 pairs had a 2-year or greater perceived age difference based on the previous perceived age study, and 9 additional same sex pairs were swapped as "practice" images.

Perceived Age

In December 2012, 748 images (374 original and 374 swapped images) were rated by 10 age assessors. The assessors were not informed beforehand about the age range of the twins or that the images contained face swaps; they assessed the ages of the swapped images first and then later the same day the original images. The assessments were done via presentation of the photographs on a computer screen in a randomly generated but predetermined sequence to reduce variance between assessor age ratings. One of the assessor's ratings was consistently much higher than the others and was excluded. Based on the remaining nine assessors' ratings, the mean ages were calculated for each rated image (three images were based on eight assessors' ratings due to one missing rating and two outlying ratings of 828 years and 808 years); the mean perceived ages had a correlation of 0.87 with the perceived ages from 2003 (7).

Based on the calculated mean perceived ages, the older looking twin was termed twin O and their younger looking co-twin Y. For each twin pair there were two original and two swapped images from 2001, Figure 1. To relate to each image, the following notation is used:

- $O^{face}O^{surr}$ is the face and surrounding of the older looking twin (original image twin O)
- $Y^{face}Y^{surr}$ is the face and surrounding of the younger looking twin (original image twin Y)
- $O^{face}Y^{surr}$ is the face of twin O with surrounding of twin Y (swapped image)
- $Y^{face}O^{surr}$ is the face of twin Y with surrounding of twin O (swapped image)

Analyses

First, we estimated the mean difference in perceived age when swapping the face and then when swapping the surrounding between twin images as well as comparing the difference between the two swapped images (ie, $O^{face}Y^{surr}$ and $Y^{face}O^{surr}$). Next, using the original images (ie, $O^{face}O^{surr}$ and $Y^{face}Y^{surr}$), survival analyses with the Cox proportional hazard model were used to study the association between perceived age and survival since the date of the photograph for a 7-year follow-up period (to replicate our previous findings (7)) and also from 7 to 12 years of follow-up (to test for new associations) for the subsample still alive 7 years after the date of the photograph; data were available for all 374 twins. The analyses also included sex, chronological age, and clustering for the twin pairs. The proportional hazards assumption underlying the Cox model was tested with the Schoenfeld residual test.

To test the association of the perceived age of the face and surrounding with survival, the data were divided into two groups and then compared: The first group contained twin pairs where the older looking twin died first and the second group contained twin pairs where the older looking twin died second. To measure the difference in perceived age between twin pair faces, we used the difference between the faces when with twin O's surrounding ($O^{face}O^{surr}$ minus $Y^{face}O^{surr}$) and then when the faces were with twin Y's surrounding ($O^{face}Y^{surr}$ minus $Y^{face}Y^{surr}$). The mean of these two comparisons were taken as the difference in perceived age of the twins' faces controlling for surrounding. Similar analyses were carried out for the difference in perceived age of the surroundings controlling for face (ie, the average of $O^{face}O^{surr}$ minus $O^{face}Y^{surr}$, and $Y^{face}O^{surr}$ minus $Y^{face}Y^{surr}$). In addition, we also included the perceived ages of twin O's and Y's original images within these two groups, to compare these findings back to the original findings between survival and perceived age. Hence, T-tests were performed to examine if the perceived ages in the group where the older looking died first were significantly different from the group where the older looking died second for (i) Twin O's versus Y's original images, (ii) Twin O's and Y's faces controlling for surrounding, and (iii) Twin O's and Y's surrounding controlling for face. All statistical analyses was done using Stata 13.1.

Results

This study consisted of 187 same sex twin pairs (62% females). All participants were over 70 years of age (mean 76.0 years). Of the 187 twin pairs, there were 140 (74.9%) twin pairs where at least one twin had died within the 12 years of follow-up (Table 1).

Face Versus Hair and Clothing Influences on Perceived Age

The average perceived age for the original and swapped images were compared for all 187 twin pairs, Figure 2. On average, the older looking twin O (image $O^{face}O^{surr}$) looked older than twin Y (image $Y^{face}Y^{surr}$) by 3.5 years (95% confidence interval [CI] 3.2–3.9 years). Replacing twin O's surrounding with twin Y's surrounding (image $O^{face}Y^{surr}$) made the image look younger than image $O^{face}O^{surr}$ by 2.4 years (95% CI 2.0–2.8 years), while replacing twin O's face with twin Y's face (image $Y^{face}O^{surr}$) made the image look younger than

Table 1. The Study Cohort, Which is a Subset of the LSADT Consisting of Twin Pairs Who Had Their Faces Swapped in Photographic Images

	All twins	Where One or Both Twins Have Died In	
		7 Years of Follow-up	7–12 Years of Follow-up
Number of twin pairs	187	83	57
Number of monozygotic twin pairs (%)	83 (44.4)	31 (37.3)	18 (31.6)
Number of female twin pairs (%)	116 (62.0)	47 (56.6)	38 (66.7)
Average age at time of photograph (SD)	76.0 (4.6)	77.8 (5.3)	75.7 (3.5)
Average perceived age of twins in			
Original photographs (SD)	78.8 (4.2)	80.3 (4.3)	78.4 (3.5)
Swapped images (SD)	77.9 (4.5)	79.6 (4.6)	77.9 (3.7)

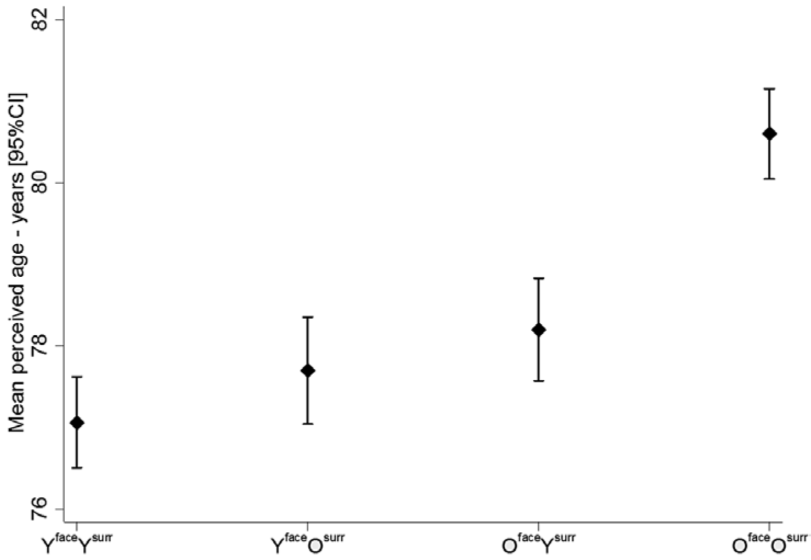

Figure 2. Mean perceived age of all 187 twins in the original images $Y^{face}Y^{surr}$ and $O^{face}O^{surr}$ and swapped images $Y^{face}O^{surr}$ and $O^{face}Y^{surr}$; the vertical lines represent the 95% CI. Mean perceived ages in years from left to right were $Y^{face}Y^{surr}$ 77.1 (95% CI 76.5–77.6), $Y^{face}O^{surr}$ 77.7 (95% CI 77.0–78.4), $O^{face}Y^{surr}$ 78.2 (95% CI 77.6–78.8), and $O^{face}O^{surr}$ 80.6 (95% CI 80.1–81.2).

image $O^{face}O^{surr}$ by 2.9 years (95% CI 2.5–3.3 years). Compared to twin Y's original image $Y^{face}Y^{surr}$, replacing twin Y's surrounding with twin O's (image $Y^{face}O^{surr}$) made the image look 0.6 years older (95% CI 0.3–1.0 years) while replacing twin Y's face with twin O's (image $O^{face}Y^{surr}$) made the image look 1.1 years older (95% CI 0.7–1.5 years). The difference in effect size between changing the face and surrounding in the original images was 0.5 years (ie, $O^{face}Y^{surr}$ 0.5 years older than $Y^{face}O^{surr}$) but this was not significantly different (95% CI -0.1 to 1.1).

Perceived Age and Mortality in 7 Years and 7–12 Years of follow-up

Based on perceived ages from the original images only ($O^{face}O^{surr}$ and $Y^{face}Y^{surr}$) and mortality data, survival analyses were performed. Perceived age, after adjusting for chronological age and sex, was associated with a 17% (95% CI 10% to 25%) increased mortality risk for each year subjects looked older (Table 2) up to 7 years after the photograph was taken. For twins still alive after 7 years of follow-up (270 of 374, 72%), perceived age was associated with a 6% (95% CI 0%–12%) increase in mortality risk per year the subjects looked older, for the subsequent 5 years. For both the 7-year and the 7–12-year follow-up models the proportional hazards assumption was not violated.

The Influence of Face and Surrounding on the Association Between Perceived Age and Mortality

We next investigated whether face or surrounding was predominately responsible for the link between mortality and perceived age over the first 7 years of follow-up. For twin pairs where at least one twin had died in the 7 years of follow-up (83 pairs, 44.4%), we found that on average and when controlling for surrounding, twin O's face was 2.8 years older looking than twin Y's when twin O died first, whereas it was 1.4 years older than twin Y's when twin Y died first—the difference in means attributable to the face and dependent on whether twin O or twin Y died first (1.4 years, 95% CI 0.3–2.6 years) was statistically significant (Table 3).

Table 2. Mortality Risk During 7 Years and Between 7 and 12 Years of Follow-up

	Seven Years of Follow-up (104 of 374 Twins Died During this Period)	Seven to 12 Years of Follow-up (112 of 270 Twins Died During this Period)
	Hazards Ratio (95% CI)	Hazards Ratio (95% CI)
1		
Sex	0.63 (0.43–0.93)	0.74 (0.50–1.09)
Chronological age	1.16 (1.12–1.21)	1.13 (1.08–1.18)
2		
Sex	0.50 (0.33–0.76)	0.71 (0.47–1.08)
Perceived age	1.24 (1.17–1.32)	1.11 (1.05–1.17)
3		
Sex	0.51 (0.34–0.77)	0.68 (0.46–1.02)
Chronological age	1.09 (1.04–1.14)	1.11 (1.06–1.17)
Perceived age	1.17 (1.10–1.25)	1.06 (1.00–1.12)

Notes: Data are given including sex in the model for chronological age (1), perceived age (2), and chronological and perceived age together in the model (3). CI = confidence interval.

This analysis was repeated comparing the surroundings when controlling for the face. Twin O's surrounding was judged as 1.8 years older looking on average than twin Y's when twin O died first whereas twin O's surrounding was 1.6 years older on average than twin Y's when twin Y died first—the difference in perceived age means attributable to the surrounding and dependent on whether twin O or twin Y died first (0.3 years, 95% CI –0.8 to 1.4 years) was not statistically significant (Table 3).

As an expected outcome of the calculations, the difference in face and surrounding when twin O died first compared to when they died second together equaled the perceived age difference for the original images (ie, 1.4 years and 0.3 years difference in face and surrounding, respectively, equaled 1.7 years difference for the original images, Table 3). Hence, 82% (1.4 of the 1.7 years) of the difference

Table 3. Differences in the Perceived Ages of the Face and Surroundings Within Twin Pairs

	Older Looking Twin Dies First (SD)	Older Looking Twin Dies Second (SD)	Difference Between Groups (95% CI)
Seven years of follow-up, number of subjects	48	35	83
Difference in perceived ages*	4.7 (2.6)	2.9 (2.4)	1.7 (0.6 to 2.8)
Difference in face perceived ages†	2.8 (2.9)	1.4 (2.4)	1.4 (0.3 to 2.6)
Difference in surrounding perceived ages‡	1.8 (2.6)	1.6 (2.3)	0.3 (−0.8 to 1.4)
Seven to 12 years of follow-up, number of subjects	32	25	57
Difference in perceived ages*	3.0 (2.2)	3.1 (1.9)	−0.01 (−1.0 to 1.2)
Difference in face perceived ages†	1.5 (2.4)	1.6 (2.2)	−0.1 (−1.3 to 1.2)
Difference in surrounding perceived ages‡	1.5 (2.2)	1.6 (2.3)	−0.1 (−1.3 to 1.1)

Notes: Analyses based on twin pairs where at least one had died before 31st January 2008 (7 years of follow-up) and repeated for twin pairs still alive 7 years after the photograph were taken and where at least one had died before 31st December 2013 (7–12 years of follow-up). CI = confidence interval; SD = standard deviation.

*Mean of the difference in the perceived ages of the original photographs $O^{face}O^{surr} - Y^{face}Y^{surr}$.

†Mean of the difference in the perceived ages of the twins' faces when controlling for the surroundings, that is, mean of $O^{face}O^{surr} - Y^{face}O^{surr}$ & $O^{face}Y^{surr} - Y^{face}Y^{surr}$.

‡Mean of the difference in the perceived ages of the twins' surroundings when controlling for the face, that is, mean of $O^{face}O^{surr} - O^{face}Y^{surr}$ & $Y^{face}O^{surr} - Y^{face}Y^{surr}$. Note, the sum of † and ‡ equals * bar rounding errors.

in perceived age when the older looking twin died first compared to when they died second can be explained by variation in facial appearance. No significant findings were found for 7–12 years of follow-up (Table 3) likely due to the small number of twin pairs available (57 twin pairs) and the reduced association between perceived age and mortality for this period of follow-up.

Discussion

Here we demonstrate associations between mortality and perceived age in both 7 years and 7–12 years of follow-up from when the photographs were taken. Although face had a greater effect than surrounding (hair and clothing) on perceived age on average, the difference between face and surrounding on the perception of age was relatively small and not significantly different. However, facial visual cues and not surrounding cues were responsible for the link between perceived age and mortality.

Perceived age was a significant predictor of life expectancy in elderly twins in our previous study (7) and we confirm that association here in a subset of those twins with de novo perceived age data and the same 7 years of mortality follow-up. Although this finding is biased due to the selection of participants on the previous perceived age data (twin pairs with a 2-year or greater perceived age difference), participant selection was blinded to the mortality data. The association also held for new mortality data between 7 and 12 years of follow-up albeit with reduced effect size. As perceived age was still a marker of survival 7–12 years after the photograph was taken, it suggests perceived age is not solely a marker of terminal conditions and imminent death at the time of the photograph. The reduced association between perceived age and survival in the 7–12-year follow-up could be due to changes to a person's health or lifestyle since the photograph, as both could influence perceived age and mortality risk thereafter. Further investigation into changes to perceived age over time and its correlation to changes in health (eg, markers of frailty, risk of specific diseases etc.) would, therefore, be informative in understanding the weakening effect. In addition, comparisons between perceived age and specific causes of death (eg, cancer vs heart attack) would help elucidate the potential utility of perceived age for physicians or gerontologists.

Previously, it had been shown that changing the cues within an image influences an individual's perceived age (9). Here, we are the first to demonstrate that in passport-type images the face and surrounding have a similar effect on the perceived age of an individual, although the effect of the face was slightly stronger than the surroundings. The mean perceived age of the swapped images was closer to the mean perceived age of the younger looking twin than the older looking twin. This suggests that a youthful face or surrounding partially negates the influence of an older looking face (for the former) or surrounding (for the latter). Hence, it is "easier" to make somebody look younger than older by changing either their face or hair and clothing in photographic images.

The average number of years that twin O's face looked older than twin Y's was significantly greater when twin O died first compared to when twin Y died first; no such difference was found for the surroundings. This demonstrates that the facial visual cues but not surrounding cues used by the nurses to assess the age of the participants were indicative of the twins' life expectancy. The association of perceived age with mortality has previously been shown to be irrespective of assessor age, sex, or medical training (7). Taken together, this indicates that innate judgments of age are indicative of underlying health as might be expected by evolutionary theory (1). However, it is unclear what the specific facial cues are that predict life expectancy and whether these findings are only present in elderly white/Caucasian populations. Men from long-lived families were recently found to be younger looking than age-matched controls and facial wrinkling was not responsible for the link (2) suggesting features such as facial sag, a thin/atrophic face or skin sallowness could be driving the link. The images captured for the participants detailed here are not conducive to accurate assessment of facial features; hence, other prospective studies with better quality photographs would be required to identify the facial features driving the link between perceived age and mortality.

Despite hair and clothing having a similar influence on perceived age as the face, we found that it was the variation in facial appearance that was responsible for the link between perceived age and survival. Hence, these data support an old anecdotal belief—mortality is written on the face. In addition, among the survivors 7 years after the photographs were taken, perceived age was still a predictor of life expectancy in an additional 5 years of follow-up. Future work should focus on which facial features are driving the link with survival, and whether this phenomenon is true for other populations (eg, healthy younger populations or different ethnicities).

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