# Perception of age in adult Caucasian male faces: computer graphic manipulation of shape and colour information

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## SUMMARY

This study investigated visual cues to age using facial composites which blend shape and colour information from multiple faces. Baseline measurements indicated that perceived age of adult male faces is on average an accurate index of their chronological age over the age range 20-60 years. Composite images were made from multiple images of different faces, by averaging face shape and then blending red, green and blue intensity (RGB colour) across comparable pixels. The perceived age of these composite or blended images depended on the age bracket of the component faces. Blended faces were, however, rated younger than their component faces, a trend that became more marked with increased component age. The techniques employed provide an empirical definition of facial changes with age that are biologically consistent across a sample population. The perceived age of a blend of old faces was increased by exaggerating the RGB colour differences of each pixel relative to a blend of young faces. This effect on perceived age was not attributable to enhanced contrast or colour saturation. Age related visual cues defined from the differences between blends of young and old faces were applied to individual faces. These transformations increased perceived age.

## 1. INTRODUCTION

### (a) Visual cues to facial age

There have been few systematic investigations into the visual cues underlying the perception of facial age. Early interest in facial ageing focused on cardioidal strain, a geometric transform approximating the shape changes to the face and skull that take place with growth. Increased cardioidal strain reduces the forehead size, makes the chin more protuberant and moves the facial features up the face. Manipulation of cardioidal strain was found to affect the perceived age of 2-D outlines of face profiles (Pittenger & Shaw 1975). Later studies showed that the transform could be applied also to 3-D head models (Mark & Todd 1983). Cardioidal strain is, however, an ambiguous cue to age since Bruce *et al*. (1989) found that "many subjects did not spontaneously see the supposedly 'younger' versions of the head as younger" (Bruce & Green 1990 p.373).

Cardioidal strain simulates the effects of bone growth on head shape. Such changes are marked during the first 20 years of life but occur little thereafter. Work with cardioidal strain captures several of the shape changes associated with ageing but it neglects a great variety of other potential cues to age. These include the quantity and colour of hair, skin elasticity, texture of skin (size of pores, prevalence of wrinkles and the presence of capillary varicosities), distribution of adipose tissue, length of the nose and ears, thickness and texture of eyebrows, apparent size of the eyes and the shape of the lips (for review see Enlow 1982; Berry & McArthur 1986).

To capture such a variety of cues new more comprehensive transformation processes are called for which extend into the colour domain. This paper describes an attempt to develop procedures for manipulating the perceived facial age that include both shape and colour components. [The term colour is used here to refer to red, green and blue intensity distributions in images and includes specification of hue, saturation and lightness. Colour information therefore encompasses a variety of cues to age e.g. skin pigmentation, wrinkles and hair colour]. The methods described here were designed to utilise information gathered from real face images rather than being restricted to a single mathematically defined formula.

### (b) Application of computer graphics to the study of 2-D facial cues

The method of facial manipulation by computer graphics used here builds on techniques of caricaturing (Brennan 1985; Benson & Perrett

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1991) and averaging or prototyping (Benson & Perrett 1993). Averaging was first reported by Galton (1878) who blended faces photographically by multiple exposure. To minimise blur in the photographic composite, Galton matched the eye positions of each component face.

Galton noted that characteristics which were consistent within the group of faces would be maintained in the resultant composite, allowing, he hoped, a better understanding of the difference in the facial appearance of different groups within the population. Galton argued that his process "enables us to obtain with mechanical precision a generalised picture; one that represents no man in particular, but portrays an imaginary figure, possessing the average features of any given group of men" (Galton 1878, p.97). Galton's technique for forming a facial composite image alignment (on eye positions) and averaging can be reproduced computationally (Langlois & Roggman 1990).

Recent studies of gender differences (Brown & Perrett 1993) and attractiveness (Perrett *et al*. 1994) have refined the procedures of Galton. In these studies computer manipulation of component faces has enabled the position and shape of all the features in a set of images to be matched more precisely. Following procedures of Brennan (1985) 208 predefined points are positioned to describe the shape of major features for each face image (e.g. one point for the tip of the nose). The average shape of a group of faces can then be calculated as the mean position of corresponding feature points across the group. A composite image with the average appearance of the group can be made by first reshaping ('warping') each face into the average shape and then blending images together digitally (Benson & Perrett 1993; Perrett et al. 1994). Such composites are less blurred (see Benson & Perrett 1993) than those generated by Galton's technique or its digital equivalent (Langlois & Roggman 1990).

The average face shape defined in this way can be used as a basis for automated caricaturing of face shape. Caricaturing works by comparing the co-ordinates of each feature point of an individual face with those of the average. Differences in feature position are amplified by a fixed percentage. The resultant image can be more easily identified because individually distinctive shape information has been enhanced (Rhodes *et al*. 1987).

We have applied the composite technique to the study of facial cues to age. In the first part of the study we assessed whether composite images maintain age information of the component faces. Since most previous work has manipulated shape cues to age, the present study attempted to establish graphic processes for manipulating facial qualities in the colour domain. We sought to establish control over colour cues in two ways (i) we attempted to enhance colour information related to age using a caricature algorithm; and (ii) we attempted to manipulate the apparent age of individual faces by transforming their appearance using any colour (and shape) cues to age that could be captured by composites of young and old faces. Overall, the aim of the present study was to obtain an empirical definition of the multiple visual cues to age that are embodied in shape and colour without presumption about the relative importance of particular cues.

## 2. METHODS

### *(a) Image capture and delineation*

147 Caucasian male faces, with neutral expressions, aged between 20 and 62, were frame-grabbed in standardised conditions (531 by 704 pixel resolution, 24-bit colour). All individuals were shaven and wore no make-up or spectacles. The features on the faces were defined using 208 'feature points' placed manually in standardised positions (Benson & Perrett 1991).

### *(b) Making composites*

The faces were split into 7 age groups each spanning 5 years (a total range of 20-54 years). The number of faces available varied across each bracket (20-24 n=22; 25-29 n=37; 30-34 n=19; 35-39 n=18; 40-44 n=20; 45-49 n=14; 50-54 n=17). Using the feature position data from all available faces in a given age bracket, average face shapes were computed. Average feature colour information was then calculated for each age group by digitally averaging corresponding pixels of individual faces from each face in the group after they were 'warped' into the group average shape. Colour information from a constant number of faces (n=12) was included in each composite image. The 7 composites are illustrated in figure 1. An additional composite for the 25-29 age bracket was made by combining 36 faces to check the effect of sample size (n=12 vs 36). The average chronological age of the component faces (used to define shape or colour information) did not differ by more than 1 year from the median age of the group.

### *(c) Caricaturing colour cues to age*

Automated shape caricaturing exaggerates the differences between the feature positions of a target face and those of the population average. The same algorithm was used to caricature colour information associated with age. The blended image of the 50-54 age group (figure 2*b*) was compared to the population average manufactured by combining the 7 composite age group blends in figure 1. To facilitate comparison of colour information this population blend was first shape-warped to match the shape of the 50-54 group blend. The difference in RGB values between corresponding pixels in the target and population blends was then exaggerated by a factor of two. The result is a 'colour caricatured' image (figure 2*a*) which contains double the colour difference between the blend of 50-54 year old faces and the population blend. In a control procedure the 50-54 group blend was also compared with a uniform image set to a mid grey (RGB pixel values 127,127,127). Again the difference in pixel values was doubled to produce a 'colour enhanced' image with twice the contrast and colour saturation of the original 50-54 age blend (figure 2c). This control comparison is digitally equivalent to turning up the colour saturation and contrast on a T.V. set.

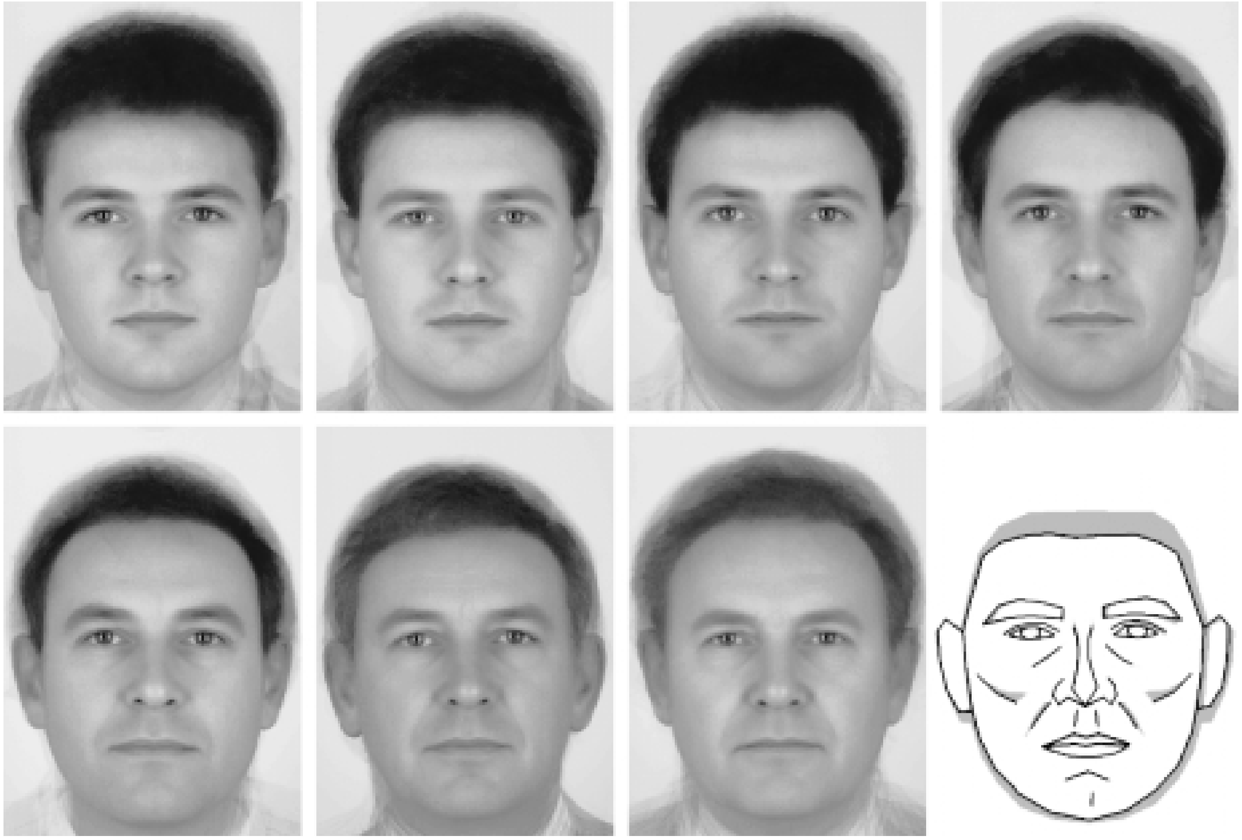

Figure 1. Face blends. Each blend contains the average colour and shape information from individual faces within the same 5 year age bracket *(a)* 20-24, *(b)* 25-29, *(c)* 30-34, *(d)* 35-39, *(e)* 40-44, *(f)* 45-49 and *(g)* 50-54. *(h)* The shaded area illustrates the difference between average face shapes of the 25-29 (dark lines) and 50-54 age brackets.

Figure 2. Enhancing colour cues to age. *(a)* Image caricaturing colour differences between *(b)* the blend of 50-54 year old male faces and a shape matched blend of all age groups (age 20-54). *(c)* Contrast and colour enhanced image made by amplifying RGB pixel differences between original blend and a uniform grey image.

*(d) Age transforms based on shape and colour cues*

Changes in facial appearance with age can be characterised by the average differences between young and old faces. We estimated such changes by comparing a composite of faces aged 25-29 with a composite of faces aged 50-54 (see figure 1h for shape differences). Shape changes associated with ageing were calculated as the vector difference in the position of corresponding feature points between the 'younger' and 'older' composite faces. The vector differences were added to the position of feature points for 6 target faces (two aged 27, two aged 40 and two aged 53). Images of each original target face (figure 3a) were then reshaped to the transformed configuration of feature points (figure 3b).

To induce colour changes associated with age, the 25-29 and 50-54 age group blends were first warped to match the shape of each target face to be transformed. The differences in RGB colour values between corresponding pixels in the shape-matched composite images were then calculated. These colour differences (as 3-D vectors in RGB colour space) were added to the RGB values of the corresponding pixels of the target faces (figure 3c).

Combined shape and colour transformations were made by performing both operations sequentially, modifying the target face shape first and then adding appropriate colour changes (figure 3d).

(e) *Subjects*

Rating of the age of stimuli was performed by 40 subjects. For analysis these were split into two groups comprising 20 young raters (average age 24.5) and 20 older raters (average age 50.8). Each group had equal numbers of female and male raters.

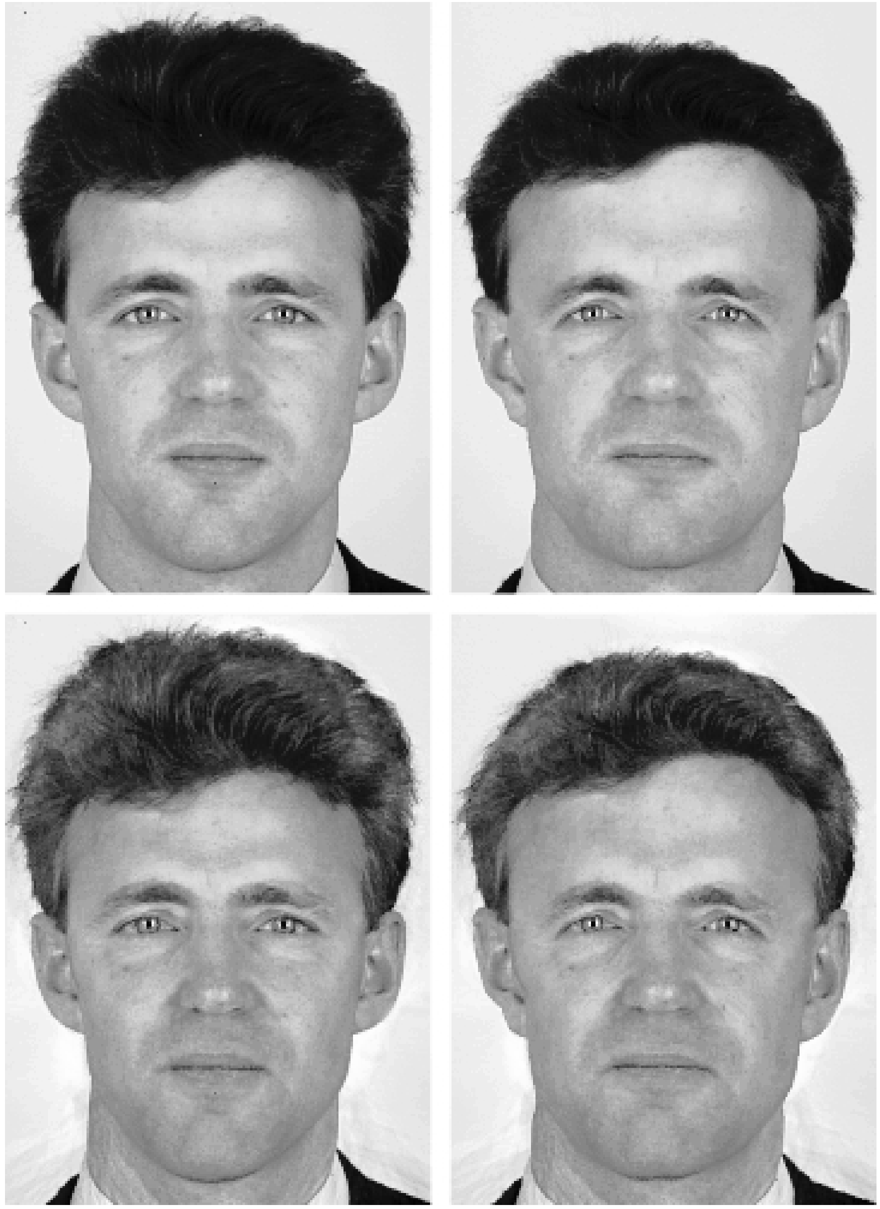

Figure 3. Personal age transforms. From the top left *(a)* An original photograph subjected to *(b)* shape transformation, *(c)* colour transformation and *(d)* combined colour and shape transformation.

*(f) Procedure*

The set of test stimuli consisted of 68 faces of which 28 had been manipulated as described above. The other 40 consisted of untouched faces with a spread of ages from 20 to 62 years. 17 out of these 40 faces were used in generating blends. Photographic prints (15 by 10 cm) were prepared from computer screen images. The stimuli were presented in different random order for each subject. Subjects were asked to estimate the age of each face to the nearest whole year.

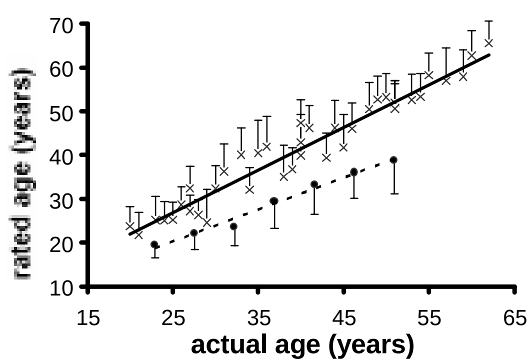


Figure 4. Perceived age of facial images. Mean rated age (+1 s.d.) is plotted (x) against actual age for 40 original images of adult male faces. Actual age of face was taken to be age at last birthday. Mean rated age (-1 s.d.) is given for the seven age group blends (filled circles). Actual age of each blend is expressed as the mean of the 12 faces contributing to the blend's colour.

## 3. RESULTS

### *(a) Perceived age of original and blended face images*

Figure 4 illustrates the relation between the actual age of face stimuli and the age perceived by the entire set of 40 raters. The regression equation for ratings averaged across all subjects was y=0.976x + 2.385; $R^2$=0.939, d.f.=38, p<0.0005 (standard deviation of 40 individual subjects' regression slopes = 0.138 and intercepts = 2.385). Over the 42 year age span tested, the perceived age was, on average, rated the same as chronological age (the slope of the regression line was not different from unity; $t_{37}$=0.6, p>0.5). The young and old groups of raters displayed a similar pattern of age judgements; regression equations for ratings of young observers (y=0.949x + 3.711; $R^2$=0.932, d.f.=38, p<0.0001) and old observers (y=0.986x + 1.540; $R^2$=0.926, d.f.=38, p<0.0001) did not differ in slope ($t_{78}$=0.86, p>0.4) or intercept ($t_{78}$=0.83, p>0.2).

Figure 4 also shows that the perceived age of blended faces increments with age of faces used to make up the blend. The blends are rated younger than the component faces and this underestimation becomes more extreme with blends derived from older faces. The slope of the regression equation for blends (y=0.713x + 4.425; $R^2$=0.991, d.f.=6, p<0.0005) is less than unity ($t_5$=6.5, p<0.001) and less than that for real faces ($t_{78}$=4.06, p<0.001) although intercepts do not differ ($t_{78}$=0.42, p>0.5). The colour information present in the blends appears to be representative since separate blends of 12 and 36 individuals in the same age bracket were not perceived to be aged differently (23.7 and 22.9 years respectively, $t_{39}$=1.5, p>0.1).

### *(b) Caricaturing colour information*

Caricaturing the colour and luminance of the blend of oldest males against the colour information of the population blend produced a significant increase in perceived age (uncaricatured image, 41.4 years; caricatured image 54.8 years; $t_{39}$=10.5, p<0.001). The control process enhancing colour and contrast did not affect perceived age (41.0 years, $t_{39}$=0.35, p>0.5).

### *(c) Transformation of shape and colour*

Effects of colour and shape transforms were analysed by 3 way ANOVA [transform type, 4 levels; starting age, 3 levels; face exemplar, 2 levels (nested within starting age), as fixed factors and subjects as a random factor]. There was a significant main effect of transform type ($F_{3,117}$=127.1, p<0.00005) with each of the three transforms significantly increasing perceived age relative to the original face images (each comparison, p<0.05, Neuman-Keuls). Overall, the combined shape and colour transformation increased age significantly more than either shape or colour transformations alone (each comparison p<0.05).

There was a significant main effect of starting age of target face ($F_{2,78}$=376.8, p<0.00005). Of greater interest was the interaction between transform type and starting age bracket ($F_{6,234}$=8.2, p<0.00005). The effects of transformations were smaller with faces of increased original age (see Table 1). Colour transformation produced a significantly greater effect than shape transformation but only for the youngest faces (p<0.05).

Table 1. *Effect of shape and colour transformations on perceived age.*

The impact of image transformation is expressed as the difference in perceived age (in years) between the transformed and untransformed starting images for three different starting ages.

| | Transformation Type | | |
|---|---|---|---|
| Starting age/years | Shape | Colour | Shape & colour |
| 27 | +5.9 | +8.2 | +12.1 |
| 40 | +3.7 | +4.8 | +8.2 |
| 52 | +3.6 | +4.3 | +5.3 |

## 4. DISCUSSION

This study attempted to extract whatever natural cues to age might be available from a normal population of faces and then to apply this information to manipulate perceived age. The aim was to include age information embodied in facial shape (such as feature growth and change in skin elasticity) and information embodied in colouration (such as change in hair and skin pigmentation). The approach used was empirical in the sense that it began with no assumptions of the full range of cues which might relate to ageing or their relative importance. Previous attempts to manipulate apparent age of faces have focused on particular cues. Such manipulations have taken the form of mathematical transforms of shape (Pittenger & Shaw 1975) and the degree of wrinkling as defined by artistic expertise (Mark *et al*. 1980).

The method we used was based on the idea that composite images made by averaging the shape and colour information across many faces of one age would preserve cues consistently related to that age. This method can be applied to many different dimensions present in faces and to other homogeneous classes of object (Yamada *et al*. 1992; Rowland & Perrett 1995). We assessed the degree to which relevant cues to age could be extracted in two ways, by measuring the perceived age of facial composites and that of individual faces transformed using the difference between composites made with faces from two different age groups.

### *(a) Perceived age of natural face images*

In order to define a baseline against which to assess the effect of image manipulations we first measured observers' age estimates of colour images of real faces. These baseline measurements showed that the perceived age of adult male faces was on average closely matched to the chronological age (over the range 20-62 years). To ensure that the perceptual ratings were representative, subjects were chosen to span a wide age range. Other studies have reported differences in face processing strategy which depend on observer age (e.g. Fulton & Bartlett 1991). In the present study, the function relating perceived and actual age of faces was, however, the same for young observers (mean age 25) and older observers (mean age 50). There was no tendency for the young observers to overestimate the age of older test faces or *vice versa*.

*(b) Composite faces*

The process of blending many faces of one age group into the average shape of the group was found to capture age related information. Composite images of older faces looked correspondingly older than blends of young faces. The colour information present in each blend was based on the faces of 12 individuals. This sample size appeared sufficiently representative since including information from an additional 24 faces had no effect on perceived age. To some the blended images look surprisingly similar (as if they were of one person over a number of years), yet individuals contributed to only one blend. This similarity also suggests that the sample size used was sufficient to capture the 'prototypic' appearance of the Caucasian male population sampled.

Evidently the averaging process failed to capture all the information about age because composite images were rated younger than their component faces, a trend which became more exaggerated with increased component age. This added youthfulness is probably related to the slightly blurred appearance of the composites. Individuals used to make the blends will possess wrinkles and skin features that are not necessarily in the same position. The averaging process will only maintain features with consistent topographic relationships. Thus features with high positional variation will be averaged out. The resultant blends, therefore, have a more even skin texture and fewer wrinkles than component faces which probably accounts for their younger appearance.

*(c) Age transforms*

That 'age transforms' successfully increased the perceived age of target faces provides evidence that the composite process captures cues to age. Transformations based either on the differences in RGB colour or the differences in shape between blends of young and old faces affected perceived age of target faces. Since the composites do not capture all age related information, combined age and shape transformations would not be expected to change the perceived age of target faces by the full chronological age difference of the faces making up the composites. The amount of age related information which the process employed here failed to capture can be estimated from the discrepancy between the mean chronological age difference of two blends used for transformation and the induced change in perceived age. By this estimate the blending and transform processes captured about 48% of the age cues (27 year old target faces were aged by 12.1 years using a transform based on two groups of faces differing in age by 25 years).

Most studies manipulating cues to facial age have used impoverished renditions of faces. A line drawn profile may be judged 60 years of age but by definition the outline contains only a fraction of the age related information that is available from a 60 year old real face. In studies using simplified faces or head models, it is therefore not possible to estimate the proportion of total age related information that has been captured or manipulated. By contrast the realism of the faces used here provided a quantitative method for gauging the effectiveness of the age transforms.

The transform we employed was based on average differences between faces aged 25-29 and 50-54 years. This transform was more effective when applied to faces of 27 years old than to older faces of 40 and 51 years old. There may be two reasons for this. First, younger faces tend to have more even complexions which make superimposed cues more visible. Second, the transform is less applicable to older faces because the ageing process is unlikely to be linear. Different changes may happen at different stages of life; bone growth ceases in mid 20s whereas male pattern balding and loss of hair pigment tend to occur subsequently. Non-linearities of aging need not be a problem since transformation could be based on two appropriately aged blends matched for starting age of the target face and destination age of the transformed face.

Because the composites do not capture wrinkles well, one expects the transformations applied to decrease apparent age to be limited in effectiveness. A transform that ignores wrinkles could not remove them from a face. In this context it is interesting that pilot work attempting to rejuvenate male and female faces (aged 48-50) using the transformation method described here was successful in decreasing perceived age by 10 years.

If image transformations are to be used in a forensic setting (for example to predict the appearance of a person who has been missing for a number of years), then it is essential that projectively aged face images are realistic and maintain as much information as possible about identity. Davies *et al*. (1978) found that recognition of photographs was superior to the recognition of accurate artistic renditions (shaded line drawing) of the same faces. Fully automated computer procedures for projective ageing (extending the methods developed here) may therefore be superior to procedures involving artistic impression.

In this context it is important that the transformation processes we describe here maintain a high degree of realism. Eleven subjects were questioned about the images. None of these subjects differentiated original and shape or colour transformed images in terms of realism, although most commented on the difference between blended images and other images.

*(d) Colour and shape information*

The procedures we used for age transformation relied on two component manipulations of image: shape and colour. Both manipulations applied individually affected perceived age though the combined manipulation was more effective than either alone. We can conclude from this and other studies (e.g. Mark *et al*. 1980) that transformations based solely on 2-D shape will not capture all the available age information. The computations of colour component utilised RGB pixel values. These specify not only the hue and saturation of each point in the image but also local intensity. Shadows are defined by intensity and contain information about 3-D shape. Thus, although colour and shape were nominally separated to compute age transforms, the 'colour component' contains some information relating to 3-D face shape.

The present experiment demonstrates that the colour transform contained considerable information about the age of natural images of faces. The preceding discussion, however, makes it difficult to reach conclusions about the relative importance of 3-D shape of facial features and feature colouration cues to facial age.

*(e) Caricature manipulations of colour*

To examine the role of colour information one procedure employed here was to caricature the RGB colour difference between a blend of old male faces (age 50-54) and a blend of a population of male faces (age 20-54). This procedure was adopted to exaggerate colour in a manner that would be formally equivalent to the algorithm used to caricature shape which compares the shape of an individual with the average shape of the population (Brennan 1985). The colour caricaturing procedure proved effective and increased the perceived age of the old blend by approximately 15 years.

One possible criticism of the colour caricaturing and transformations is that these manipulations may age a face by exaggeration of contrast and colour saturation within the image. Contrast enhancement could increase age by accentuating the visibility of wrinkles, pores, etc. Control procedures, caricaturing the face against a uniform grey image enhanced contrast and saturation but did not affect perceived age. Thus one can conclude that the colour caricaturing and transformation procedures were effective because they manipulated information relevant to age. The success of the manipulations suggests that caricaturing in the colour domain and transformation techniques may have widespread application in facial and object perception.

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