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Measuring and creating different facial images for age and gender

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Abstract

Our study directly compares facial characteristics according to age and gender. This paper presents two studies: one is on measuring faces and the other is on creating face images. The first is a discriminant analysis using configuration data of the face. The second is an experimental study using a new tool for creating face images. Results of the discriminant analysis show that the face's age and gender information are fundamentally different, that is, for age classification the global information of the face is important while for gender classification the local information of the face is important. By reviewing the results of each study, it is concluded that the age-related face images reflected physical information of age, while gender-related face images did not reflect physical information of gender. These results show that the face's age and gender information are fundamentally different from the physical and psychological points of view.

1 Introduction

Numerous studies have been done on cognition of gender and age from the face. However, almost all of these studies were done independently. Therefore, almost no investigation has been made on the relationship between age and gender information from a psychological perspective.

In anthropology and anatomy, there have been systematically conducted studies of race differences and developmental changes of the face (Enlow,1982). In these studies, the cranium was taken into consideration because the cranium provides the most rigid and clear information of the face. In this respect, age is an important factor for face variety because cranium change lead to change in age. In his work, Enlow systematically searched for gender as well as age information from physical traits. This anatomical research aimed at clarifying the face's physical differences. On the other hand, psychological research aimed at clarifying the cognitive aspects of these differences of the face.

Concerning age cognition of the face, ethologists have suggested the existence and function of a "baby schema" of the face. They implied that the prominent cheek bone, round facial outline and small chin induced care-giving behavior (Lorenz, Guthrie, 1976). However, the ethologist have not confirmed the physical traits of the "baby schema" in more detailed experimental studies. Recently, ecological optics researchers have tried to clarify the physical traits of a baby face and the age-related changes of the face (Todd et al., 1980; Pittinger & Shaw, 1975a: Mark et al., 1981; Mark &

Todd, 1985). They thought, like that of the ethologists has been, that age is the most useful information of the face and that craniofacial change is the most important information for perceiving age. Accordingly, they have been trying to ascertain the algorithm for changes in the face according to age. They found that cardioidal strain change provides the most suitable algorithm, which indicates the importance of craniofacial change. They also showed that the vertical placement of configuration, forehead size, chin size, jaw, eye shape, skin quality, and feature length were key to age-related cognition (Berry & McArthur, 1986).

With respect to gender cognition of the face, the main concern has been the dimorphic nature of the human face. In those studies, it was assumed that the human face had an inherent dimorphic nature without giving consideration to body size and shape. Enlow (1982) discussed gender differences in human faces from the viewpoint of evolution and suggested that the important gender cues of the human face are the nose and nasopharynx, which are generally larger for male than female faces. Bruce and her colleagues (e.g. Roberts & Bruce, 1988; Bruce et al., 1993) showed that the nose, eyebrows and skin texture provide important gender information for Caucasian faces, whereas Yamaguchi et al. (1994) reported that for Japanese faces the eyebrows play an important role in gender classification. Recently, Burton et al. (1994) have reported a measurement study that investigated the relationship between the physical measurements of Caucasian faces and the gender classification of those faces performed by discriminant analysis and by human subjects. For their study, they collected data for more than 50 measurement points on each of 200 faces. They showed over 90% discrimination of the gender of their employed faces by using 3-dimensional and configuration data.

More recently, averaged and hyper faces have been introduced in the study of gender differences between human faces (Benson & Perrett, 1991, 1992, 1993; Yamaguchi, Hirukawa & Kanazawa, 1994), with the hyper faces made by exaggerating the differences between male averaged and female averaged faces. Also shown have been male and female differences with typical male and female faces. Furthermore, artificial faces have been made by swapping parts between male and female faces. By using these artificial faces, changes in the judgements of subjects have been investigated while swapping the parts. By using face-image-processing techniques, Benson & Perrett (1993) showed that the important parts for gender judgment were the jaw, eyebrows and chin. Yamaguchi et al. (1995) showed that the important parts for gender judgment were the outline of the face and the eyebrows.

In comparing these age and gender studies, we found the differences between the two types of studies. More specifically, the gender differences focused on the local information of the face such as eyebrows or nose, while age differences relatively focused on global information of the face such as craniofacial change.

In this paper, we first tried to make age and gender classifications of the face by the same method, that is, by using the front view configuration. Next, we compared the age and gender characteristics of face images made by subjects. For this study, subjects created male, female, adult, and child line drawing faces having a front view configuration by using a face image-creating tool developed in our laboratory (Oda & Yamaguchi, 1996).

In these two studies, we tried to identify the age and gender differences of the face in both the physical dimension and psychological dimension. In the physical difference study, we did stepwise discriminant analysis to select the effective variables for gender and age classification of the face from among the configuration variables of the face. In the psychological difference study, we performed experimental study on creating the face image directly. Comparing these two studies, we tried to clarify the physiological differences of the faces and psychological images of the faces.

Previous experimental studies on developmental changes in the face have been done mainly with 3D-information and the side view (Bruce et al, 1993; Mark & Todd, 1985; Mark, Todd & Shaw, 1981; Pittenger & Shaw, 1975a; Pittenger, Shaw & Mark,1979; Todd et al., 1980). However, in this study, we tried to classify age by using only 2-D configuration information.

2. Study 1: Measuring the faces

-Age and gender differences of the face-

In order to examine the differences between the faces of adults and children (or males and females), the measurement data were subjected to stepwise discriminant analysis. The independent variable was age (or gender) of the face, and the dependent variables were the facial characteristics.

2-1. Procedure

2-1-1. Target faces

Sixty Japanese child (30 male and 30 female) faces and 100 Japanese adult (50 male and 50 female) faces were measured. All of the children were 6 years old, and the adults' average age was 23.28 (SD=3.12) years old.

2-1-2. Method

Discriminant analysis was applied to the physical measurements of the male and female (or adult and child) faces in order to estimate the physical discriminability of these faces.

All measurement points are shown in Figure 1. These points were identified manually on each face by using a measurement tool developed on a Silicon Graphics system. We used these measurement points to defined measurement variables.

We used a total of 118 variables as independent variables. Because we used so many variables, we divided them into three groups. The first group included simple measurement values: simple length, area, curve, tilt and so on. These consisted of 43 variables indicating the length, area, curve, and/or tilt measurements of the individual facial parts and configurations containing the lengths and areas defined by the measurement points of at least two different facial parts.

The second group included ratios of one length to another, only between internal features. These consisted of 42 variables.

The third group included ratios of one length to another, containing the outline of the face and chin. These consisted of 33 variables.

All of the above variables for each face were then automatically calculated based on the previously identified measurement points. It should be noted that all of the values were standardized in such a way that they were taken as relative values to the baseline unit which was defined to be the length of the perpendicular line from the line between the center of both eyes to the center of the mouth as shown in Figure 2. All variables were used for only the right side of the face.

This investigation was done in two steps. First, we analyzed in the three groups individually. Then, we analyzed variables selected from the first analysis. All analyses were done by using SAS.

2-2. Results

2-2-1. Age classification

From the results of the first-step analysis, we selected 11 significant variables out of 43 variables in simple measurement variables, 4 significant variables out of 42 variables in ratio between internal feature scores, and 7 significant variables out of 33 variables in ratio concluded face outline scores. The final result of the analysis of these selected variables are shown in Table 1.

From these results, age was successfully classified. Additionally, the effective variables which could classify the faces individually were such as ,"ratio face width / eye width", "ratio face width / brow height", and " ratio brow-chin distance / brow separation". These variables were ratios containing face width and distance between brow and chin. They contained information of face outline, so they were considered global information of the face.

2-2-2. Gender classification

In the first-step analysis, we selected 8 out of 43 variables in simple measurement variables, 3 out of 42 variables in ratio between internal feature scores, and 6 out of 33 variables in ratio concluded face outline scores. The final result of the analysis of these selected variables are shown in Table 2.

Comparing these results with results of a discriminant analysis on Caucasian faces (Burton et al., 1993) , we found differences in the total hit rate. In the Burton study, 94.3% of the male faces and 94.3% of the female faces were successfully classified. In their study, they used 3-dimensional information such as nose height. There are two possible causes for the differences in hit rates between the two studies. One is the differences in variables used in the studies, and the other is the differences in race of the male and female faces.

From our results (Table 2) , the selected parts for gender classification were mainly eye, nose, and brows. They are thus viewed as parts information, that is, local information. Local information like these seem to be specific cues in gender classification.

2-3 Total results

From the discriminant analysis results, we can conclude that age information is mainly based on global information of the face, and gender information is mainly based on local information of the face.

In these studies, the results depended on each subject's ratings of face sets. In this procedure, subjects must rate faces as belonging to face sets with limited variations. In the next step, we had subjects' create face images freely. By using this procedure, we tried to confirm the subjects' face image characteristics indicating age and gender.

3. Experiment
- Create face image -

3-1. Method

Subjects were asked to create their own subjective face images (male, female, adult, child) by using a face-image-creating tool. This tool was run on an Indy workstation.

3-1-1 Subjects

Eighteen Japanese undergraduate students (nine male and nine female) were subjects in each condition. There were four conditions (male face image creating condition, female face image creating condition, adult face image creating condition, child face image creating condition).

3-1-2. Apparatus

We used an experimental tool (Oda,1995) developed in our laboratory (Figure 3). This tool has five windows that show the target face, and 18 bars that show the value of each variable. Each face was 190 X 270 pixels. The variables were ear position, position of the inner corner of the eyebrows, position of the outer corner of the eyebrows, eyebrow position, eyebrow height, eye width, eye height, eye position, distance between eyes, nose width, nose height, nose position, mouth width, mouth height, position of the boundary line between the upper lip and lower lip, face shape, and chin shape. By excluding ear position, we used a total of 17 variables. Before the experiment, the subjects did a practice task. In the practice task, we used two windows, while in the experimental task we used only one window. The unused windows were covered; see the black windows in Figure 3.

First, all faces were shown like the right face of Figure 3. All variables were set at 1.5. In order to modify the shape of the face, the subjects increased or decreased values of each variable by shifting the bar using a mouse. Corresponding to the changing values of each variable, the face shape changed immediately. As subjects observed the changes in the face, they created a target face image.

With this tool, the progress made in creating face images and the final shape of face images were recorded automatically. From these data, we obtained the number of times each subject changed the values of each variable and the final variable values for the final face image.

3-1-2. Procedure

Before the experimental session, the subjects did a practice task in order to learn how to use the face creating tool .

Practice session:

In the practice task, two windows were open. The center window and the window left of the center window were open. The face image of the left window was the target image, and the face image of the center window was the face image that subjects were asked to modify. The target face consisted of randomly selected variables. When the target face was shown, subjects were asked to modify the face image of the center window to match the face image of the target face. Subjects were asked to finish this task within 5 minutes.

Experimental session:

In the experimental session, only the center window was open. Subjects were asked to modify the face image to create an image of a (male, female, adult, child) face. Subjects were allowed 10 minutes to create their face image. Each subject made only one face.

Subjects were just asked to create their own subjective face images (male, female, adult, child); no other verbal or visual instructions were given. The instructions told them that overlapping of the four factors was not permitted.

3-2. Results

We compared the values of the variables used to create the different face images and also the progress in creating each face image.

3-2-1. Variables of final face images

In order to clarify the physical differences between the different face images (male, female, adult, child) and typical physical variables that constructed the final face images, we compared the values of variables between the different face images (male, female, adult, child). The mean values of the variables that constructed each final face image are shown in Figure 4.

First, the physical values of the variables that constructed the face images were subjected to a 2X2 ANOVA to examine the effects of different target face images (male, female, adult, child) and different variables (eyebrows position, eye position, mouth width, etc). There was a significant main effect of the target face images ($F(3,16) = 16.25$, $p < .0001$), a significant main effect of the different variables ($F(3,16) = 30.44$, $p < .0001$), and a significant main effect of the interaction between the target face images X different variables ($F(3,16) = 4.78$, $p < .0001$). A Post hoc Fisher's Protected LSD test ($p = 0.05$) revealed that the female and child face images had significantly larger values than male and adult face images (Table 3).

Next, in order to recognize more detailed differences between the different target face images, we compared each value of the variables separately among the different face images. Each value of the physical variables that constructed the final image were subjected to an ANOVA to examine the effects of the different face images (male, female, adult, child). There was a significant effect of the face images for the inner eyebrow corner ($F(3,76) = 5.28$, $p < .005$), outer eyebrow corner ($F(3,76) = 15.70$, $p < .001$), eyebrow height ($F(3,76) = 14.92$, $p < .001$), eye height ($F(3,76) = 9.95$, $p < .001$), eye width ($F(3,76) = 2.97$, $p < .05$), eye position ($F(3,76) = 8.07$, $p < .001$), nose width ($F(3,76) = 7.40$, $p < .001$), nose height ($F(3,76) = 2.85$, $p < .05$), mouth width ($F(3,76) = 5.46$, $p < .005$), face shape ($F(3,76) = 3.34$, $p < .05$), and chin shape ($F(3,76) = 4.34$, $p < .001$). The significant differences revealed by the Post hoc Fisher's Protected LSD test ($p = 0.05$) are shown in Table 3.

From these results, we can consider face images as being divided into two groups. One consists of female and child face images, and the other consists of male and adult face images.

3-2-2. Number of modifications of the face parts

We analyzed the number of times each variable was modified in creating the final face images. The mean numbers of modifications for each variable are shown in Figure 5. The modification counts for each variable were subjected to a 2X2 ANOVA to examine the effects of the different face images (male, female, adult, child), and different variables. There was a significant main effect of the variables ($F(3,16) = 2.74$, $p < .0005$), but not of the face images ($F(3,16) = 11.89$, $p < .1$) and not of the interation between the face images X variables ($F(3,16) = 0.86$, $p = 0.75$). A Post hoc Fisher's Protected LSD test ($p = 0.05$) revealed that the male face images were more often modified than the adult face images.

In order to recognize more detailed differences between the different target face images, we compared each modification count separately among the different face images. We found a significant main effect of the different face images only for the eye distance ($F(3,76) = 3.81$, $p < .05$). A Post hoc Fisher's Protected LSD test ($p = 0.05$) revealed that for the eye distance, the child face images were more often modified than the other face images.

For the child face images, eye distances were more often modified. This result suggests that subjects carefully changed eye distances in making the child face images. This result is also consistent with the age classification result. In both studies, the eye distance was a typical age-related variable.

3-2-3. Total results

From these results, we found that face images can be divided into two groups. One group consists of female and child face images and the other consists of male and adult face images.

Next, we looked at differences between female and child face images. Results showed that the main differences between female face images and child face images were only in the outline of the face. This suggests that child face images had larger face outlines. Additionally, from progress results, it was found that the child face images' eye distances were more often modified. This suggests that subjects are more concerned with eye distances for child face images. The outline of the face and eye distance are typical physical traits that are significant for child face images. These results are shown in Figure 6.

5. General Discussion

From measurements of the physical traits of the face, that is, from the results of discriminant analyses, we found that age involves global information of the face while gender involves local information of the face.

From the measurement study, it was found that the age discrimination was successful for 2-dimensional front view faces. This result seems to contradict studies suggesting that age-related face change is produced by such 3-dimensional change as craniofacial change (Bruce et al., 1989; Todd et al., 1980). However, we can assume that the vertical placement of configuration had enough of an effect on age discrimination in this study as Berry & McArthur (1986) has mentioned. On the other hand, compared to a previous study (Burton et al., 1993), gender discrimination was not so successful here. In order to increase the discrimination score for gender classification, it will be necessary to obtain other information such as texture and color information.

From the measurement study and face-image-creating study, we found that the subjects' child face images, that is, age-related face images, seemingly reflected the physical differences in age. The important variables for the child face images, that is, the chin form and eye distance, were consistent with the important variables for age classification.

For subjects, the images of different age faces were clearly related to physical differences. However, the images of different gender faces were not related to physical differences. Consequently, we concluded that the subjects' face images of age were strongly related to physical traits of the face, while the subjects' face images of gender were weakly related to physical traits of the face. This finding for gender is consistent with the results of our previous research on the relationship between physical facial differences of gender and rating facial gender. This study showed that the important variables in the physical differences of gender, and the important variables in rating gender were different (Yamaguchi et al.,1995).

From the face-image-creating study, we found that face images divided into two groups. One group consisted of female and child face images and the other consisted of male and adult face images. This is consistent with results of earlier studies on face rating (Yamaguchi et al.,1995; Cunningham, 1986; Cunningham et al.,1990). These studies showed that the masculinity rating and adult-like rating were in high correlation, especially in male faces. They suggest that for human images masculine faces and mature faces are the same and that feminine faces and child faces are the same. In this study, we give further support to this effect's significance directly by analyzing the creation of face images.

Our results suggest that in psychological images, the age and gender categories overlap. That is, for subjects' images, female face images and child face images were similar, and adult face images and male face images were similar. However, for the results of adult and male face images, there is the possibility that subjects will think that the adult face images and male face images are equally adult male face images. For the female and child face images, in contrast, no such confusion should occur.

These results suggest that the way we form face images from age and gender information are different. That is, subjects noticed the physical variables for age but not for gender. For subjects' face images of gender, the psychological and physical aspects seemed to be distinct. In order to explain these results, we can make two assumptions. The first is that humans have a strong innate system for recognizing age-related face forms, such as a baby schema, but do not have such a system for gender. The second is that a human's images of gender depend on other information such as body size and body movement. In fact, the main dimorphic nature involves body size. In order to solve this problem, further experimental study is needed.

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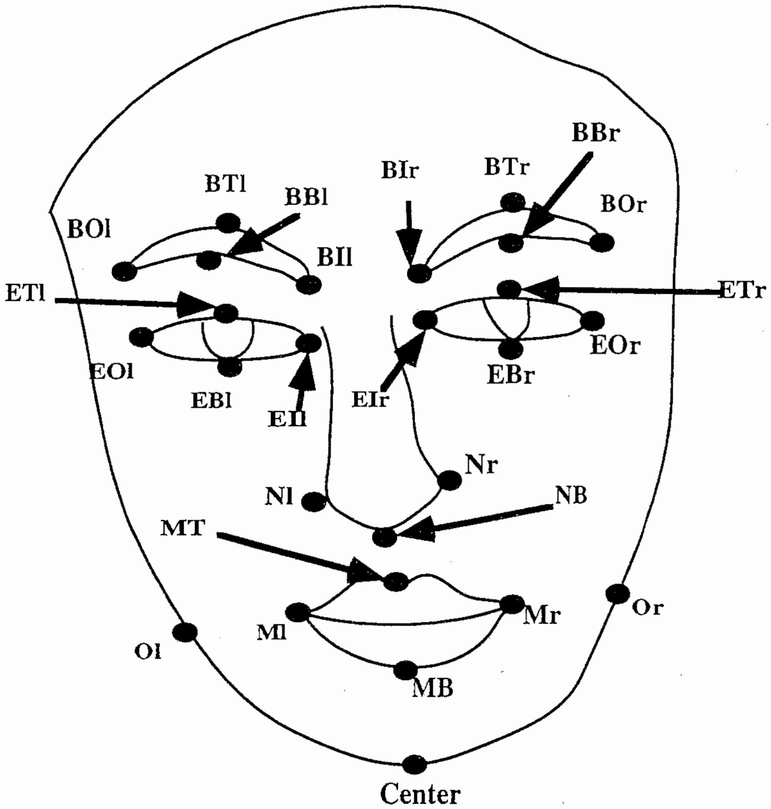

Figure 1 Measurement poins in our study

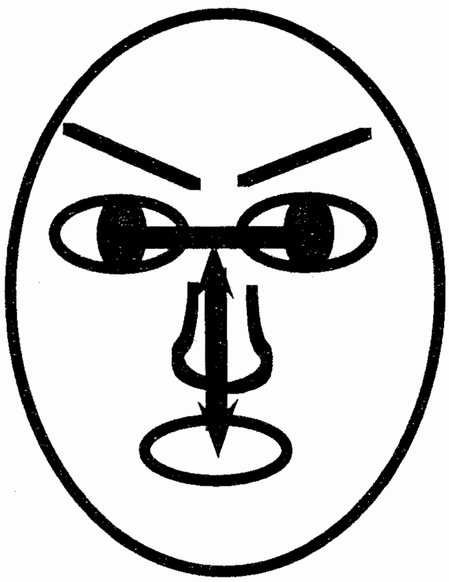

Figure 2 Line for standarding the measure

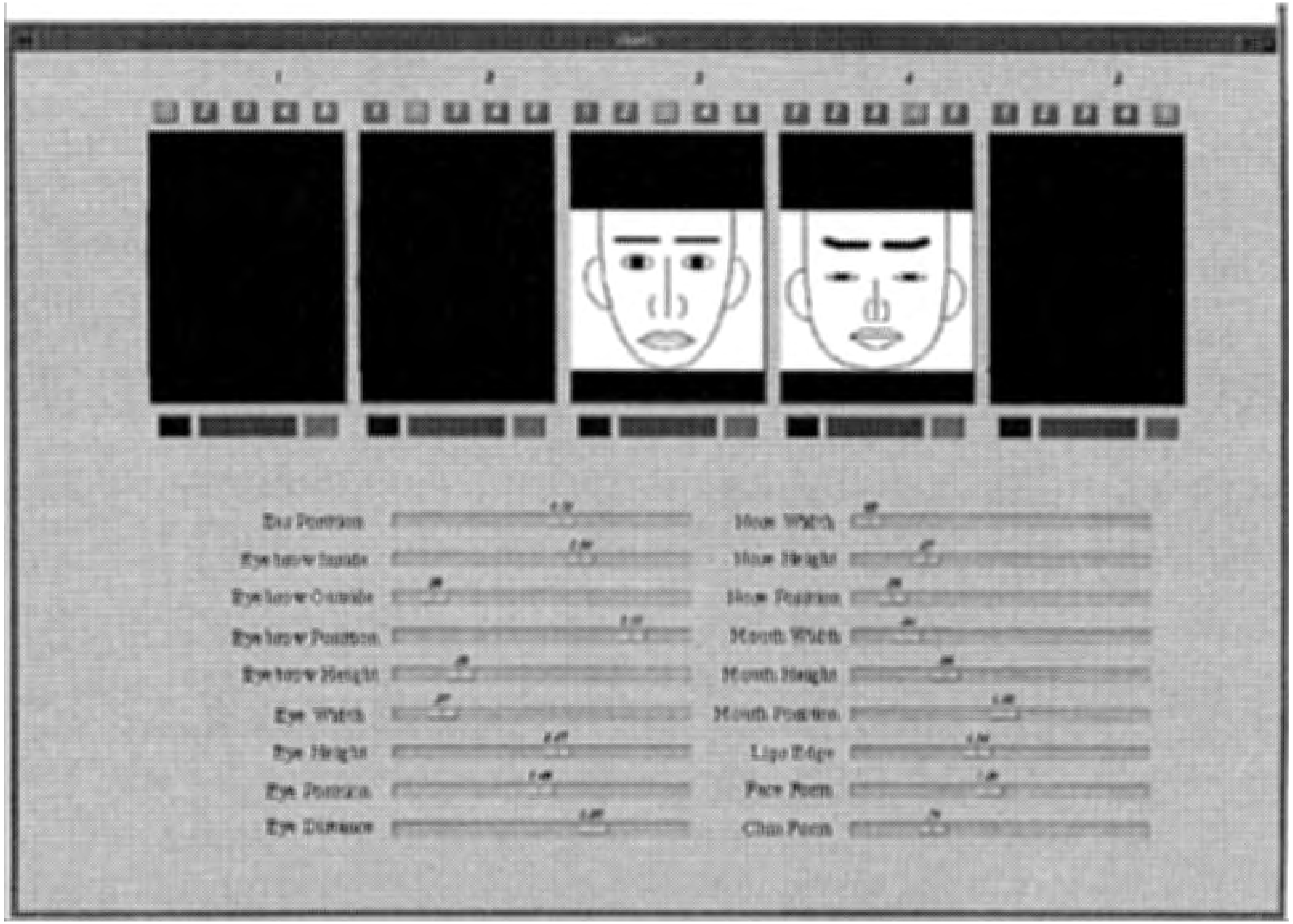

Figure 3 Example of windows in face image creating tool

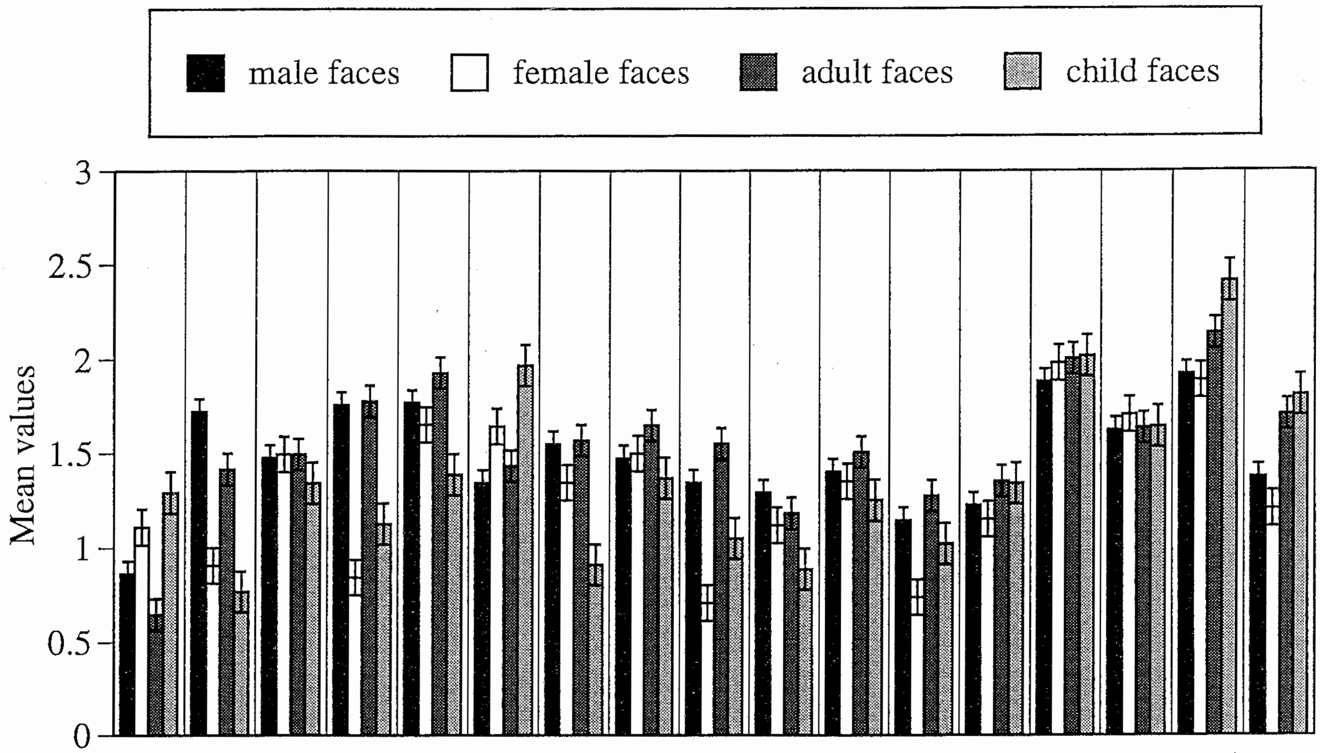

Figure 4 Mean values of variables for each face images

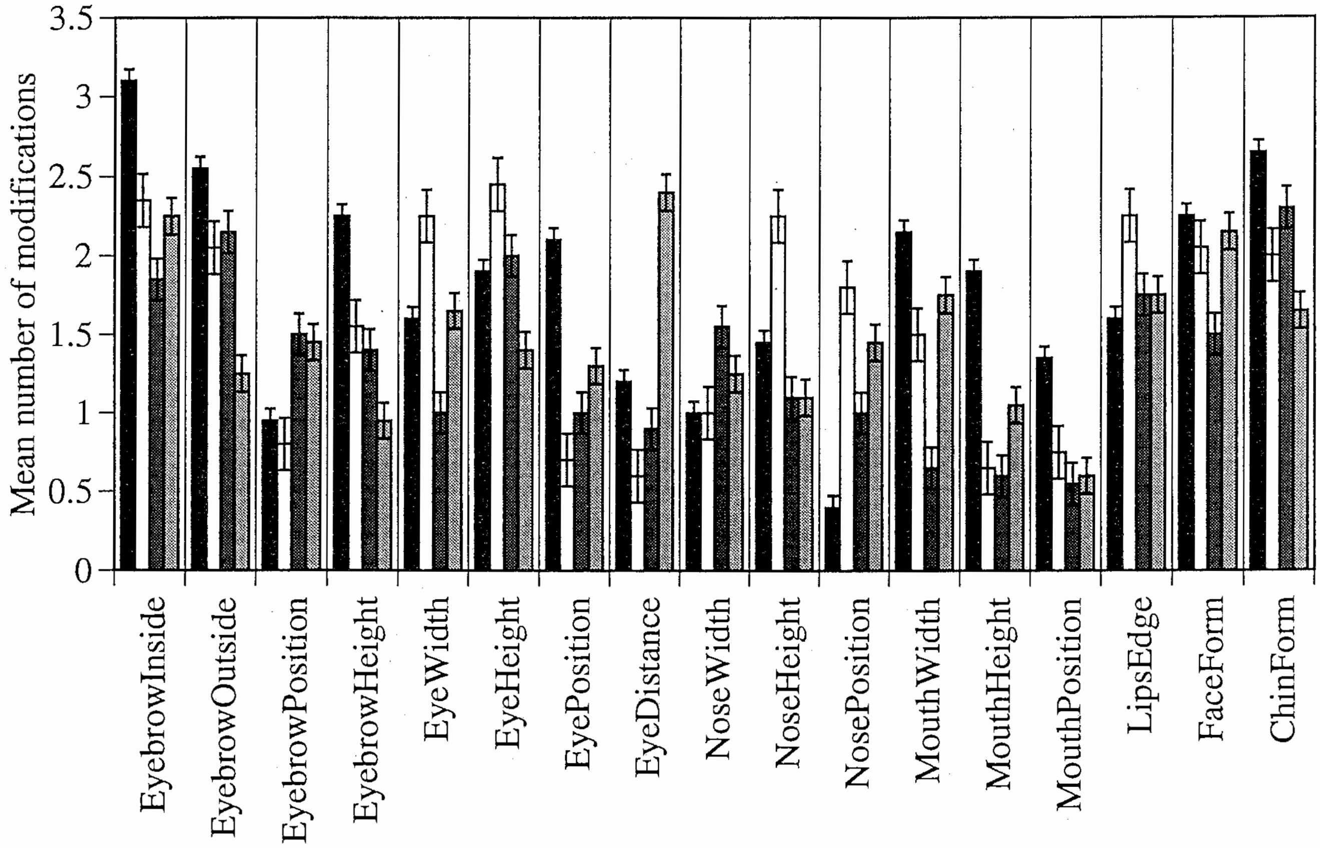

Figure 5 Number of modifications for each variables

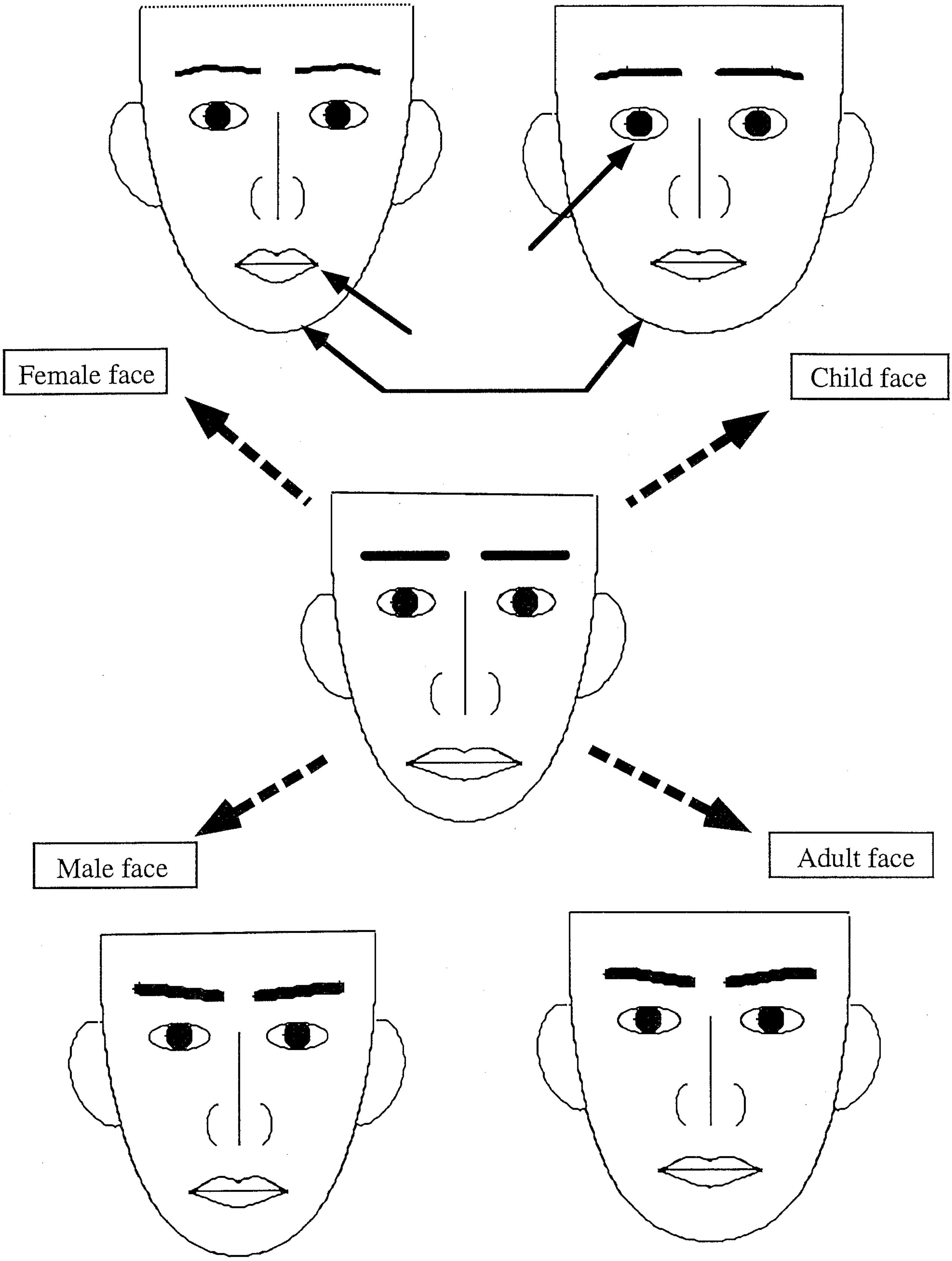

Figure 6 Typical physical traits of each face image

Table 1 Variables selected in age classification

Variable	Wilk's Lambda	Hit Rate	
ratio Face width /Eye width	0.26	81.13	child
		85.44	adult
ratio Eye separation /Mouth height	0.23	69.81	child
		91.26	adult
Brow height	0.21	88.68	child
		78.64	adult
Brow separation	0.20	75.47	child
		86.41	adult
Nose - mouth distance	0.19	77.36	child
		75.73	adult
ratio Face width /Brow height	0.18	86.79	child
		93.20	adult
ratio Brow - chin distance /Brow separation	0.18	83.02	child
		70.87	adult
Brow curve	0.17	64.15	child
		59.22	adult
Total		98.11	child
		99.03	adult

Table 2 Variables selected in gender classification

Variable	Wilk's Lambda	Hit Rate	
ratio Eye height /Brow height	0.56	80.39	male
		80.77	female
Brows-eyes area	0.51	70.59	male
		67.31	female
Brow-chin distance	0.46	39.22	male
		75.00	female
Brow separation	0.42	78.43	mele
		40.38	female
Brow curve	0.39	54.90	male
		51.46	female
Nose width	0.38	68.63	male
		67.31	female
Eyes-nose area	0.35	72.55	male
		36.54	female
Eye height	0.34	80.39	male
		69.23	female
Total		84.31	male
		84.62	female

Table 3 Results of Post hoc test

Total variables

	child	male	adult
female	=	>	>
child		>	>
male			=

Position of eybrow inside

	child	male	adult
female	=	=	>
child		>	>
male			=

Position of eyebrow outside

	child	male	adult
female	=	<	<
child		<	<
male			=

Eyebrow Height

	child	male	adult
female	=	<	<
child		<	<
male			=

Eye height

	child	male	adult
female	<	>	=
child		>	>
male			=

Eye width

	child	male	adult
female	=	=	=
child		<	<
male			=

Eye position

	child	male	adult
female	>	=	=
child		<	<
male			=

Nose width

	child	male	adult
female	=	<	<
child		=	<
male			=

Nose height

	child	male	adult
female	=	=	=
child		<	<
male			=

Mouth width

	child	male	adult
female	<	<	<
child		=	=
male			=

Face shape

	child	male	adult
female	<	=	=
child		>	=
male			=

Chin shape

	child	male	adult
female	<	=	<
child		>	=
male			=

<, >; p<.05, = ; n.s.