EFFECT OF SYMMETRY ON RECOGNITION OF UNFAMILIAR FACES

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ABSTRACT

EFFECT OF SYMMETRY ON RECOGNITION OF UNFAMILIAR FACES

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In the literature, there exist several studies on recognition memory performance for faces and related facial characteristics such as distinctiveness, typicality, attractiveness. In our study, we examined the relationship between symmetry and human face recognition for the first time. In order to have symmetry as the only manipulated factor in our stimuli, we constructed a unique face database, METU-FaceTwo, which contains standardized symmetric and asymmetric face images without facial textures. In our study, we assumed that faces and related features such as symmetry are perceived holistically, and defined facial symmetry with two different measures: entropy calculations and perceived symmetry values. Our fundamental finding is that symmetry increases recognition performance. This increase seems to be due to the additional study time or additional effort spent for symmetric face images during the recall period rather than the encoding period. More studies need to be performed in order to isolate the causes of this surprising finding.

Keywords: Face Recognition, Symmetry, Attractiveness, Symmetric Face Database

ÖZ

SİMETRİNİN YÜZ HATIRLAMA ÜZERİNE ETKİSİ

Yıldırım, Gülsen
Yüksek Lisans, Bilişsel Bilimler Bölümü
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Literatürde, yüz hatırlama üzerine birçok çalışma bulunmaktadır. Bu çalışmalar ,genellikle, farklılık, çekicilik, sıradanlık gibi yüzün karakteristiği ile ilgili olan özelliklerle yüz hatırlama performansının ilişkisine odaklanmışlardır. Bu çalışmada, ilk defa, insandaki yüz hatırlama süreci ile simetrinin ilişkisi araştırılmıştır. Simetrinin tek değişen faktör olarak kullanılabilmesi için, literatürde eşine rastlanmamış bir yüz veritabanı, METU-FaceTwo, yaratılmıştır. Bu veri tabanında, standartlaştırılmış, tüm yüz örüntülerinden arındırılmış simetrik ve asimetrik yüz imajları bulunmaktadır. Bu çalışmada, yüz ve simetri gibi ilintili özelliklerin bütünsel olarak algılandığı varsayılmıştır. Yüz simetrisi iki tip ölçüm ile tanımlanmıştır: entropi ve algılanan simetri değerleri. Temel bulgumuz, simetri arttıkça hatırlama performansının da arttığı yönündedir. Bu artışın ana nedeni de, çalışma evresinde, simetrik yüzler için harcanan daha fazla zaman ve efor gibi görünmektedir.

Anahtar Kelimeler: Yüz Tanıma, Yüz Hatırlama, Simetri, Çekicilik, Simetrik Yüz Veritabanı

To My Grandfather, Ali Aksu

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I dedicate this thesis to my grandfather, Ali Aksu who passed away in September 25th, 2010. He is the one who taught us to stay steady under hard circumstances and who showed us that love can be expressed in many different ways. Thank you Dede: for your love and passion…

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Humans are expert at recognizing a large number of different faces under different conditions. In our daily lives, we meet faces intertwined within different lighting conditions, color changes containing personal features such as beard, make-up, glasses, jewelry etc. Moreover, these faces usually occur as a part of a noisy background which contains other objects and faces with different viewpoints and under various lighting conditions. However, human face recognition is robust to such challenges, and recognition performance is remarkable despite these inconsistencies.

Success of face recognition in humans encouraged many researches in this area. Some of the fundamental topics that have been examined for many years are: differences and relationship between face recognition and object recognition, essential characteristics of faces handled in face recognition, participating brain areas in recognition of faces.

On the other hand, face recognition has become one of the most important areas in computer vision. Numerous face recognition algorithms have been developed handling both 2D and 3D face pictures. Those algorithms are sensitive to features such as changes in illumination, size, position (Tsao & Livingstone, 2008), which are sometimes treated as invariant in human recognition. Together with the effect of non-facial areas in the input, the performance of automatic face recognition methods highly decrease. Understanding the underlying processes in the human face recognition may give hints to improve performance of face recognition systems.

There are two main approaches trying to explain the mechanisms involved in face recognition: feature-based and holistic. According to the feature-based approach, faces are represented with independent facial features such as eyes, nose, and mouth. On the contrary, holistic face recognition states that faces are represented as indecomposable wholes rather than independently represented features. Although it has been widely believed that human face recognition is feature-based, recent studies support the view of holistic processing. Moreover, symmetry, which is the main concept of this study, is a holistic feature of faces and it can be measured objectively. Another holistic characteristic is attractiveness. However unlike symmetry, it is measured in a subjective manner.

In this thesis, we concentrate on the effect of an intrinsic feature of faces, symmetry, in face recognition. Our main hypothesis is that if the amount of information provided affects the performance of recognition of unfamiliar faces, then symmetric faces will be less remembered because they contain less information. The research questions of the current study as well as facts from literature which support our hypotheses are given in Chapter 2. In order to verify our hypotheses, we have developed a new 2D face database, METU-FaceTwo. The details about the procedures used in the development of this database are given in Chapter 3. Finally, the details of the experiments designed to test our main hypothesis and results are revealed in Chapter 4, providing a concise discussion.

CHAPTER 2

LITERATURE REVIEW

Humans handle the process of face recognition under extremely different occasions in daily life. In the routine of our lives, we do not meet isolated faces in experimental setups purified from the background, different lighting conditions, colors and personal features such as beard, make-up, glasses, jewelry etc. Instead, faces are usually part of a noisy background which contains other objects or faces with different viewpoints under various lighting conditions. However, human face recognition is robust to such challenges. Although recognition performance of faces in routine environments of daily life is much lower than the ones in laboratory conditions, humans achieve significant recognition performance when such variances are considered[1].

There are many studies in the literature which highlight the factors affecting recognition performance. We will present these factors under two main titles: imaging-related factors (e.g. environmental conditions) and structure-related factors (e.g. facial features such as distinctiveness, attractiveness). These studies are important for the current study as they inform us about: (i) the standardization criteria for a face database, (ii) the research questions of the current study, and (iii) the contributing factors for face recognition.

[1] As cited in Hancock (2000), a recognition performance of 49% was observed in a task based on identification of images in a video sequence.

On another front, face recognition have always been compared to object recognition. The underlying processes related with recognition in our brains are important, as outlined in the subsection called ‘Faces versus Objects‘.

2.1. Factors Related to the Imaging Process

This section presents the effects of environmental and spatial conditions on recognition performance.

2.1.1. Viewpoint Changes

One of the widely investigated topics in face recognition is the effect of viewpoint changes. Variations in face recognition performance are observed with the changes in viewpoint for both natural (Hill et al., 1997; O’Toole et al., 1998; Newel et al., 1999; Liu & Chaudhuri, 2003) and synthetic (Lee et al., 2006) faces. It is frequently reported that best recognition performance is obtained when the orientation in vertical axis is aligned between the test and recognition cases (Hill et al., 1997; O’Toole et al., 1998; Newel et al., 1999; Liu & Chaudhuri, 2003).

Moreover, although some contradictory results exist [2], the best recognition performance is obtained when the images in both the test and recognition phases are given in ¾ (three-quarter) view which can be defined as approximately 45° rotation of the front full-face view (Hill et al., 1997; O’Toole et al., 1998; Liu & Chaudhuri, 2003). Examples of ¾ and other views are given in Figure 2.1. The effect of ¾ view is robust to subtle changes in the rotation angle: both the rotations of 45° (i.e. O’Toole et al., 1998) and 42° (Liu & Chaudhuri, 2003) result in the same distinction in recognition performances.

[2] Examples of opposing studies in the early literature are given in Table 1. For a detailed survey about the fuzzy nature of face recognition, the reviews of Liu and Chaudhuri (2002), and Linde and Watson (2010) may be examined.

Figure 2.1: Full-face, ¾ and profile (O'Toole et al., 1998)

Higher recognition rates in the three-quarter view can be explained with the distinction between the amount of information encapsulated in this view and the other views rather than representation of faces in the brain (Hill et al., 1997; Liu & Chaudhuri, 2002). The amount of information embodied in the picture is directly related with the research questions of the current thesis. ¾ view keeps more distinguishing information related with the characteristics (and features) of a face, information about both sides of the face, and therefore, most of the facial features on both sides are provided in three-quarter view.

Rotations toward the inverse view are also studied. For orientations around vertical axis (Figure 2.2), Linde and Watson (2010) found the same results with the previous findings. Recognition performance varies with orientation. ¾ view at both study and recognition phases give the best performance rate. However, they also reported a remarkable outcome such that the rotation in front view (yaw angle) is more harmful to recognition than the rotation in inverted view (roll angle).

Table 2.1: A summary of the early literature on the recognition performance of 3/4 view. The last column denotes the answer whether the study proved that “a 3/4 view shown at study or test produces better recognition performance than the other views" (Liu & Chaudhuri, 2002, p. 34). This table is given in order to emphasize the fuzzy nature of face recognition independent of the type of the studied task or the face images used.

Study	Task	Views tested	L/T	Conclusion
Patterson and Baddeley (1977)	Recognition	3/4, P	T	Yes
Woodhead, Baddeley, and Simmons (1979)	Recognition	3/4, P	T	Yes
Krouse (1981)	Recognition	F, 3/4	L	Yes
Baddeley and Woodhead (1983)	Recognition	F, 3/4, P	L	Yes
Logie, Baddeley, and Woodhead (1987)	Recognition	F, 3/4, P	L, T	Yes
Schyns and Bülthoff (1994)	Recognition	F, 3/4, etc.	L, T	Yes
Troje and Bülthoff (1996)	Sequential matching	F, 3/4, P, etc.	L, T	Yes
Valentin, Abdi, and Edelman (1997)	Recognition	F, 3/4, P	L, T	Yes
O'Toole, Edelman, and Bülthoff (1998)	Recognition	F, 3/4, P	L, T	Yes
Laughery, Alexander, and Lane (1971)	Recognition	F, 3/4, P	T	No
Davies, Ellis, and Shepherd (1978)	Recognition	F, 3/4	L, T	No
Bruce, Valentine, and Baddeley (1987)	Sequential matching	F, 3/4, P	L, T	No
Hill, Schyns, and Akamatsu (1997)	Recognition	F, 3/4, P	L, T	No
Liu and Chaudhuri (1998)	Recognition	F, 3/4	L, T	No
Liu, Collin, Burton, and Chaudhuri (1999)	Sequential matching	F, 3/4	L, T	No
Fagan (1979)	Discrimination	3/4, P	T	?

[a] F, full-face view; P, profile view; L, learning; T, testing.

2.1.2. Inversion and Negation

Inverted images are less recognized than upright ones (Valentine, 1988; Hancock, 2000). However, the impairment in the recognition of inverted faces is larger than the case of inverted objects. These inversion differences have been accepted as evidence for the discrimination of face and object processing. In addition, it is worth mentioning that negative images get the worst place in the rank of recognition performance. They cause worse results than inverted images (Bruce & Langton, 1994) which are much less recognized than upright ones.

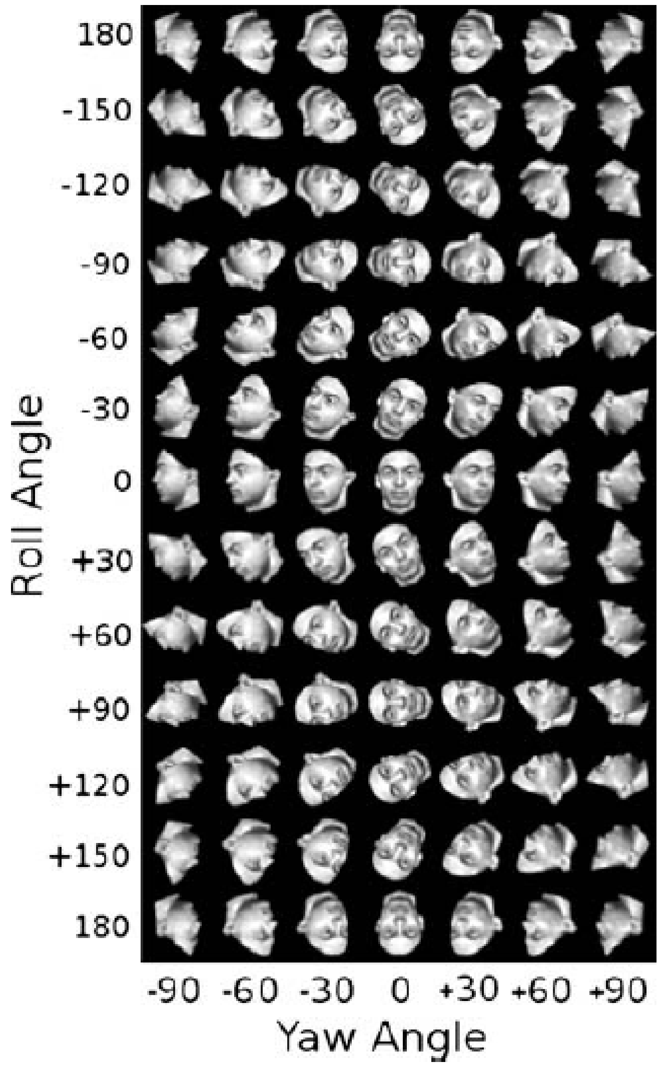

Figure 2.2: Example face images after rotations in front (yaw) and inverted (roll) views (Linde & Watson, 2010, p. 524)

2.1.3. Lighting

Kemp et al. (1996) demonstrated that recognition of unfamiliar faces was affected by the changes in hue as well as luminance. However, recognition of familiar faces was impaired when luminance but not hue was altered. Consequently, in the construction phase of image database (Chapter 3), the faces were captured in the same lighting conditions.

2.2. Factors Related to the Structural Features

Structural features in a face can be captured either as feature-based or as holistically. According to Maurer (as cited in Mondloch & Maurer, 2008, p. 1175), theories about feature-based face processing are addressed under two perspectives:

a) *Featural Processing* highlights the "sensitivity to differences among faces in the appearance of individual features"
b) *Second-order Relational Processing* denotes the "sensitivity to differences among faces in the spacing (i.e. configural aspects) of facial features"

The approaches based on feature-based face recognition are not introduced here as our study in this thesis concentrates on the holistic processing of faces.

Holistic face recognition approach has gained impetus over the last decade. Holistic face recognition states that faces are represented as indecomposable wholes rather than the configuration of independently represented features like eyes, nose, mouth and the spatial relations between them such as their positions and the distance between them (Farah et al., 1998; Hancock, 2000; Riesenhuber & Wolff, 2009). According to this definition, holistic approach resembles Gestalt systems (Mondloch & Maurer, 2008) because, although facial features are meaningful alone, when aggregated they form a bigger whole which is different than the sum of the parts.

Two paradigms, part-whole and composite effects, are the motivators of holistic approach (Tsao & Livingstone, 2008) as well as the evidence gathered from face and object processing. **Part-whole effect** denotes the fact that face parts are better recognized when they are placed in whole face rather than presented separately (Tanaka & Farah 1993). In addition, faces with misaligned parts are better recognized than the faces with inconsistent parts (Young et al. 1987). On the other hand, **composite effect** highlights the fact that faces are better processed with their original parts even if these parts are misaligned. These two paradigms empower the idea of holistic recognition of faces as both propose that faces are processed as indecomposable wholes.

Holistic processing of a face produces structure-related features such as familiarity, distinctiveness, attractiveness, memorability, typicality and resemblance. There are only few studies exploring the effect on recognition of these features in a separate fashion. Currently, it is known that most of these features are related with each other and affect face recognition. However, in both the early and recent studies, some contradictions exist as summarized throughout this subsection.

Distinctiveness seems to be the most prominent attribute among all the other structural properties. A face can be categorized as distinctive if it has "any attribute which can serve to discriminate faces" (Bruce et al., 1994, p. 120) and it has been widely proved that distinctiveness affects recognition performance positively: more distinct faces are better recognized (Vokey & Read, 1992; Bruce et al., 1994; Newell et al. 1999; Wickham & Morris, 2003). This is valid not only for immediate recognition but also for delayed measurements. Wickham et al. (2000) proved that distinctive faces were remembered better than the others even after a 5-week delay. Besides, distinctiveness causes quicker responses in face recognition (Valentine & Bruce, 1986).

Distinctiveness also correlates with the other features. For instance, Bruce et al. (1994) reported that there was a negative correlation between distinctiveness and familiarity although distinctiveness and memorability was positively correlated. Wickham and Morris (2003) showed that distinctiveness and attractiveness were positively correlated.

Dewhurst et al. (2005) reported the relationship between distinctiveness and recognition as well as other features. Dewhurst et al. (2005) investigated the correlation of six properties (familiarity, distinctiveness, attractiveness, memorability, typicality, and resemblance) and their impact on the recognition of unfamiliar faces. This study is valuable mainly due to two reasons: (i) six structural quantities were tested together and (ii) all the ratings and recognition task were carried out by the same subjects. The study was conducted with 150 gray-level face images by 80 participants. First, face images were rated on 6 dimensions. Later, the participants went through a remember-know procedure. For the K(now) responses, all dimensions except typicality correlated with recognition performance. Distinctiveness was the fundamental factor for K responses according to principal component analysis. The correlations found are given in Table 2.2.

Familiarity is usually tested with the faces of famous people as a face is usually called familiar when the participants have seen that face for many times. For instance, "famous faces that are rated as distinctive in appearance (i.e. those that would stand out in a crowd) are recognized as familiar more quickly than those rated as more typical in appearance" (Bruce et al., 1994, p. 120).

There are contradictory results about the influence of other components on familiarity (and vice versa). Along with Vokey and Read (1992), Bruce et al. (1994) showed that distinctiveness can be divided into two main components one of which was familiarity. But, the correlation between distinctiveness and familiarity was negative. On the contrary, Dewhurst et al. (2005) reported positive correlation between distinctiveness and familiarity. As for another opposing result, Morris and Wickham (2001) found no correlation between them. [3]

Attractiveness is usually referred together with being pretty, handsome, or beautiful[4]. It is believed that attractiveness is related to recognition performance as attractiveness causes arousal which facilitates recognition (Morris & Wickham, 2001). However, opposing results have been reported for the relation between attractiveness and recognition performance. Wickham and Morris (2003) found that attractiveness did not affect recognition although it had an effect on distinctiveness. On the contrary, Dewhurst et al. (2005) reported a positive effect of attractiveness on recognition.

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[3] The impact of familiarity on recognition is a large area of face recognition showing similar characteristics to the recognition of unfamiliar faces. This part is excluded from this study. However, understanding the correlation between familiarity and other components is essential to standardize the image set and experimental conditions.

[4] Attractiveness is also correlated with healthiness and symmetry (Zaidel et al., 1995).

Table 2.2: The relationship of structural components and their impact on recognition and their correlations presented in a matrix form. The references noted in number format are given at the right-hand of the matrix.

	Distinctiveness	Familiarity	Typicality	Attractiveness	Memorability	Similiarity
Distinctiveness	-					
Familiarity	**Negative** (2) & **Positive** (8) & **No Effect** (6)	-				
Typicality	**Positive** (8)	**Positive** (1; 8) & **No Effect** (6)	-			
Attractiveness	**Positive** (7; 8)	**Positive** (6; 8)	**Positive** (3; 8)	-		
Memorability	**Positive** (2; 8)	**Positive** (1; 2; 8) & **No Effect** (6)	**Positive** (1; 2; 3; 8)	**Positive** (8)	-	
Similiarity	**Positive** (8)	**Positive** (8)	**Positive** (8)	**Positive** (8)	**Positive** (8)	-
Recognition	**Positive** (1; 4; 5; 7; 8)		**No Effect** (1; 2; 3; 6; 7)	**Positive** (8) & **No Effect** (7)	**Positive** (8)	

1. Vokey & Read, 1992
2. Bruce et al., 1994
3. O'Toole et al. 1994
4. Newell et al. 1999
5. Wickham et al., 2000
6. Morris & Wickham, 2001
7. Wickham and Morris, 2003
8. Dewhurst et al., 2005

Memorability is defined as "the metamemory judgments of participants on the ease of remembering the faces" (Morris & Wickham, 2001) and has a positive effect on recognition (Dewhurst et al., 2005). One of the most widely discussed topics is the correlation of memorability and familiarity. Although a positive correlation between them has been reported (Vokey & Read, 1992; Bruce et al., 1994; Dewhurst et al., 2005), there exist studies which demonstrate no correlation (Morris & Wickham, 2001).

Typicality is sometimes referred as the lack of distinctiveness (Vokey & Read, 1992; Bruce et al., 1994). On the other hand, in some studies, typicality refers to the similarity of a face to the average of all faces in the database used as stimuli (Wickham et al., 2000). Therefore, when typicality is assessed as 'the similarity to average' rather than 'the lack of distinctiveness', a face can be typical and distinctive at the same time. In spite of the uncertainty in the definition of typicality, it was shown that typicality had no direct effect on recognition (e.g.: Vokey & Read, 1992;

Bruce et al., 1994; Morris & Wickham, 2001; Wickham & Morris, 2003) although it was correlated with other features such as memorability (e.g.: Vokey & Read, 1992; Bruce et al., 1994; O'Toole et al. 1994) and attractiveness (O'Toole et al. 1994; Dewhurst et al. 2005).

The relationship between typicality, similarity, and distinctiveness is puzzling when we refer to the findings in the literature. This is partly due to the arbitrariness of the naming with respect to the underlying computational procedures. There have been attempts to formalize identification and detection of these components using representation of faces in a multidimensional space (O'Toole et al., 1994; O'Toole et al., 1998; Busey, 2001). In face space approaches (Figure 2.3), a face is described with a number of dimensions and handled according to either its absolute spatial location (Busey, 2001) or deviation from other faces (Or & Hugh, 2010). Besides, dimensions are obtained either experimentally from human participants (Busey, 2001) or statistically computed (O'Toole et al., 1994). In addition, it is proposed that face space presentation is essential to "conceptualize our internal representation" of faces (Hancock, 2000, p. 332).

To conclude, holistic structural features such as distinctiveness, attractiveness, memorability are as important as facial features such as hair, beard, shape etc. as they influence recognition performance. In the early literature, the effects of these features are examined separately however recent studies concentrate on both the correlation and effect of multiple features in recognition. This perspective is valuable and might explain the contradictory results in the literature. However, when the image set is not standardized in terms of control variables, their effect on recognition performance induces a noise on the results. For instance, in order to explore the effect of attractiveness on recognition of faces the normalization of the stimuli in terms of distinctiveness may be required. Representation of faces in structural dimensions (i.e. a face space with axes of structural features) seems to be crucial.

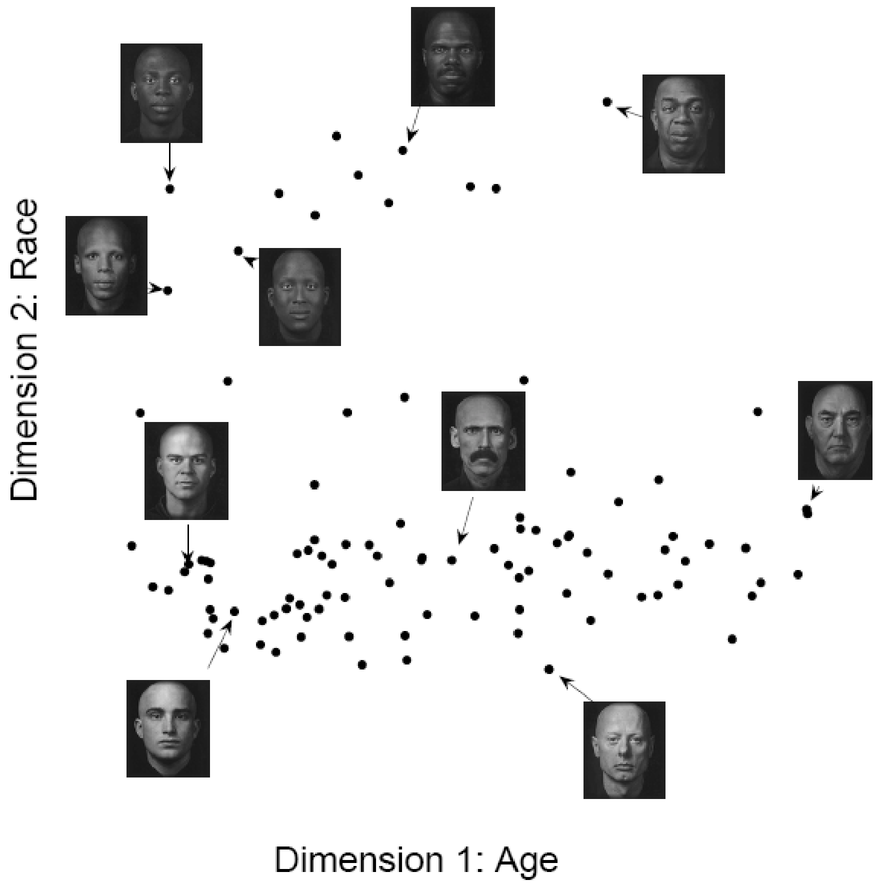

Figure 2.3: Example of face space derived from similarity ratings (Busey, 2001)

2.3.Effect of Symmetry

In the literature, symmetry is usually examined to discover subjective judgments such as attractiveness, healthiness, and trustworthiness. Throughout this thesis, symmetry is used for bilateral symmetry which denotes the symmetry of the halves around vertical axis. It has been reported that symmetry has an effect on the perceived attractiveness on faces: either positive (e.g. Dövencioğlu, 2008; Grammer & Thornhill, 1994) or negative (e.g. Swaddle & Cuthill, 1995). On the other hand, as indicated by Zaidel and colleagues (2003) symmetry and trustworthiness are correlated as well.

However, the effect of symmetry in recognition of faces has not been examined as widely as its effect in face perception. There are only a few studies on this field. Busey and Zaki (2004) examined the recognition of faces in correlation with symmetry and viewpoint changes. During the study phase, 3D face images were given to the participants in changing viewpoints, and in the test phase, recognition performance of initially presented faces were examined in different viewpoints. Examples of these symmetric and original images are given in Figure 2.4. According to the results presented in Figure 2.5, symmetric and original faces cause different behavioral patterns.

In subsection 'Factors Related to the Imaging Process', it is mentioned that viewpoint changes, especially the viewpoint differences in the test and recognition stages, reduce recognition performance. The same angle in both test and recognition phases result in the best recognition performance. Keeping this fact in mind, according to the results of Busey and Zaki (2004), there is no significant difference in the recognition performance of symmetric and unsymmetric faces at the original angle. However, at different angles for recognition phase, symmetric images yield better performance except frontal view. Exclusion of diagnostic information in symmetrized faces impairs recognition performance in front view. However, when the mirror of study face is presented to the participant in test phase, symmetric images result in better performance than the original ones.

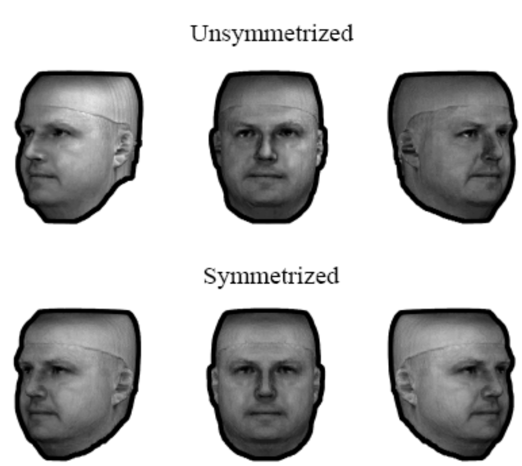

Figure 2.4: Difference between symmetric and unsymmetric images in 3D (Busey & Zaki, 2004).

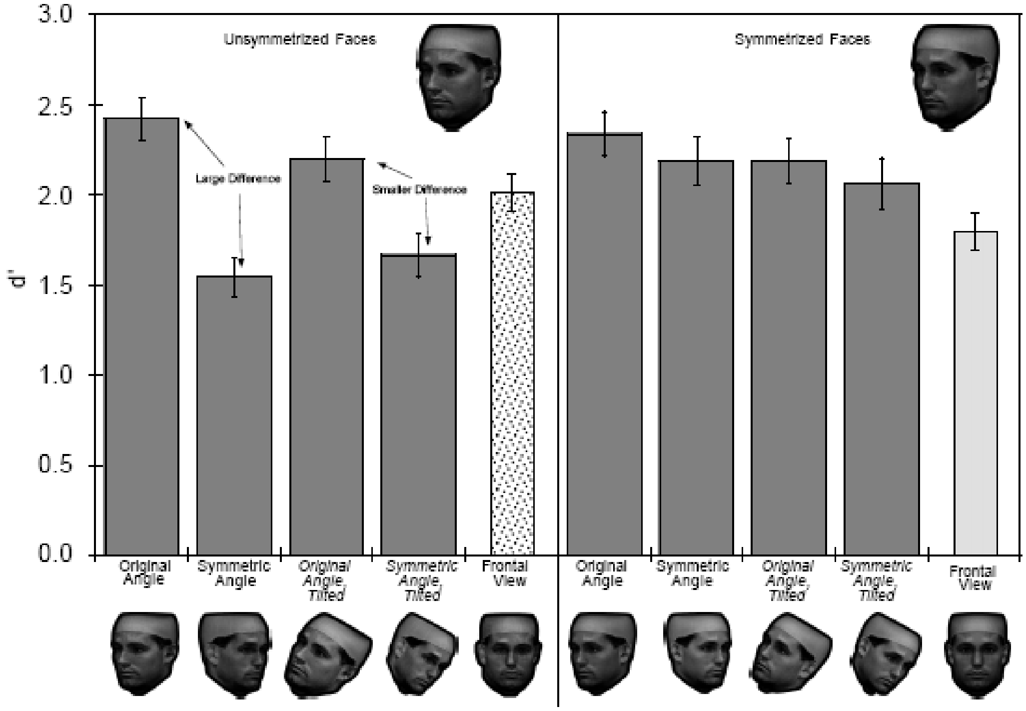

Figure 2.5: The results of recognition memory test by Busey and Zaki (2004) presented according to signal detection theory. The left figure shows the results for original faces whereas the right one represents the statistics for symmetrized faces.

Troje and Bülthoff (1998) also investigated the role of symmetric orientation and illumination in face recognition. This study considered symmetry as reflected in orientation and illumination rather than the intrinsic symmetry of facial features. Two different types of stimuli were used in their study: oriented and illuminated faces. Either oriented or illuminated faces were introduced to the participants in the study phase. In the recognition phase, symmetrically or asymmetrically manipulated versions of the stimulus as well as the original one were tested. For instance, to test the effect of symmetric orientation: a ¾ view of the face was presented in the study phase, and the symmetric ¾ view of the same face was given in the test phase. Similarly, to test the effect of symmetric illumination: a half of the face was lightened in the study condition, and the other half was lightened in the test phase.

The authors found that there was a decrease in performance if the symmetry between the intensity patterns of the study and test view was disturbed by an asymmetric illumination. In addition, there was no significant difference between recognition performances of symmetric illumination and orientation conditions. In other words, the faces carrying similar information is hardly discriminated regarding recognition performance.

On the other hand, in our study, symmetry is associated with the bilateral symmetry embodied within the face itself. To assess a face as symmetric, the parts of the two vertical sides of a face which are in equal distance from vertical axis must be the same. The faces that violate this constraint are called asymmetric (or original in our case).

Three quantification metrics are used to define intrinsic facial symmetry throughout this thesis:

a. **Classified symmetry values** indicate whether the face image belongs to the original or symmetric face groups (0 for original images and 1 for symmetric ones).
b. **Calculated symmetry values** indicating entropy of the faces. Entropy is calculated using the difference image of the original and mirror-reversed faces.
c. **Perceived symmetry values** are subjective quantifications of symmetry based on evaluation of human participants. A range varying between 1 to 9 is used to quantify how asymmetric versus symmetric face is.

2.4. Faces versus Objects

It can be supposed that faces represent a ‘special’ category of objects and therefore, faces and objects are processed by the same cognitive systems. However, it is commonly believed that due to the social relevance of face recognition, humans might have evolved special mechanisms dedicated to face processing.

Evidences for the discrimination of face and object processing can be listed as follows (Valentine, 1988; Riesenhuber & Wolff, 2009):

1) *Neuropsychology*: Neuropsychological studies have confirmed that people use different brain areas for face recognition and object recognition (Farah et al., 1995). A strong confirmation for this dissociation comes from the studies on prosopagnosia. Prosopagnosia is "highly specific inability to recognize faces, due to either congenital brain miswiring (developmental prosopagnosia) or focal brain lesions (acquired prosopagnosia)" (Tsao & Livingstone, 2008, p. 420). Prosopagnosics have problems with faces but not objects (DeRenzi, 1986). On the other hand, patients who have problems with objects but not faces also exist (McCarthy & Warrington, 1986).
2) *Ontogeny:* Face recognition has innate components. For instance, infants track a moving face rather than other moving non-face objects (Johnson et al., 1991).
3) *Face-inversion Effect*: Yin (1969) demonstrated that faces in upside-down orientation were recognized worse than the ones in normal view. This effect had not been observed in object recognition. A similar result was obtained by Farah et al. (1998). They gave participants pairs of images in study session and then, participants were asked to indicate whether or not the given images were identical. It was found that performance worsened for inverted faces more than that of inverted images of houses or words.

Therefore, recognition of faces is clearly different from object recognition. This fact has given rise to the idea of holistic processing of faces which will be presented in the next subsection.

2.5.Neural Correlates of Face Recognition

The fusiform face area (FFA), lateral side of the bilateral mid-fusiform gyrus, is found to be activated strongly by faces (Kanwisher et al., 1997; Haxby et al., 2000; Grill-Spector et al., 2004; Tsao & Livingstone, 2008). However, activation (i.e. increased blood flow to this area) has been observed for only whole faces such as profile photographs of faces, line drawings of faces, and animal faces etc., but not for facial parts or features (Tsao & Livingstone, 2008).

Activation in FFA for non-face objects have also been observed (Gauthier, 1997). This characteristic is explained with two hypotheses:

a) *Expertise Hypothesis* (Gauthier, 1997) states that FFA participates in processing of "any stimuli sharing a common shape and visual expertise" rather than operating only in face processing.
b) *Distributed Coding Hypothesis* (Tsao & Livingstone, 2008, p. 423) assumes that objects and faces are processed via not a modular but a distributed mechanism of "neuronal activity across much of the ventral visual pathway". An illustration of distributed coding model is given in Figure 2.8. Note that the limbic system is included in this model for emotion processing. Recent studies show that, especially amygdala is involved in the processing of face in terms of pleasantness both emotional and neutral faces (Todorov & Engell, 2008).

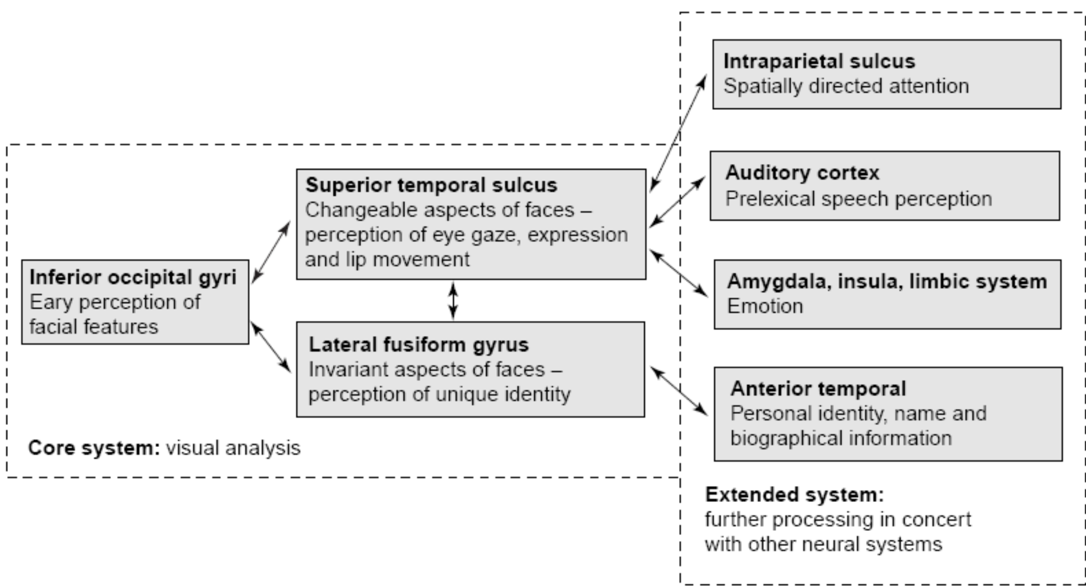

Figure 2.6: A model for distributed coding hypothesis considering different processes in face perception such as expression, visual configuration (Haxby et al., 2000, p.230).

2.6.Synopsis of the Face Recognition Experiments

Classic recognition memory tasks are used in face recognition studies as well (e.g. Wickham et al., 2000). In these tasks, the participants are initially asked to study a set of face images. In the later stage of the experiment, a larger set of face images including the studied ones are given to the participants and they are asked to recognize the images (providing a yes/no response) studied in the former phase.

However, in recent literature, block designs are frequently used in the experiments of face recognition. Instead of splitting test and recognition phases, those phases are combined and proceeded in blocks (e.g. Chen and Liu, 2009; Van der Linde and Watson, 2010; Or and Hugh, 2010). In each block, an image is studied and recognition procedure is given subsequently. The reliability of the task is provided with the collection of many data: either trial count per subject or number of stimuli is extremely high. For instance, Or and Hugh (2010) collected 420 trials for each subject per task although only 7 subjects participated in all 6 tasks. As for extremely high number of inputs, Van der Linde and Watson (2010) used 1400 images to cope the tasks on identification of the effect of head orientation on recognition.

In our study, we used a classical yes/no recognition memory experiment using original and manipulated face images. The manipulated face images contained almost perfect bilateral symmetry. Based on the information provided earlier, we know that both facial properties as well as lighting and orientation conditions affect recognition performance. Therefore we used a standardized face image database in terms of these aspects. We specifically tested whether the original (hence bilaterally asymmetric) face images are better recognized than face images with perfect bilateral symmetry. Our research questions and related hypotheses are as follows:

RQ1: What is the role of symmetry in face recognition?

Hypothesis: Symmetric faces contain less information than original ones. If the amount of information provided affects the recognition of unfamiliar faces positively, then symmetric faces will be less remembered than original ones.

Rationale: As discussed in the subsection 'Viewpoint Changes', recognition performance is directly related with the amount of diagnostic information encapsulated in a face image.

RQ2: What are the other factors influencing face recognition?

Hypothesis: Subjective factors such as attractiveness may affect face recognition. If a face picture is more attractive then it is recognized more.

Rationale: Effect of attractiveness on recognition performance is somehow indefinite. Wickham and Morris (2003) found that attractiveness did not affect recognition whereas Dewhurst et al. (2005) reported a positive effect of attractiveness on recognition. Since attention is captured more by factors such as attractiveness, recognition for attractive faces might be better.

These questions and hypotheses are studied with METU-FaceTwo (Chapter 3) and the results of the experimental study are presented in Chapter 4.

CHAPTER 3

CREATION OF STIMULI

Properties like color, lighting and viewpoint orientation were proven to affect recognition performance as presented in the previous chapter. Therefore in order to study face recognition, the stimuli must be standardized according to these features. Moreover, in our study where the effect of symmetry on recognition of faces was explored, the face pictures must also be standardized according to properties related with the configuration of the face such as face size and aspect ratio allowing for the exclusive manipulation of the symmetry feature.

In an earlier thesis, 2D face pictures have been collected and standardized according to the above mentioned attributes (METU-Face: Dövencioğlu, 2008). However, image quality of these pictures was low and standardization with respect to many characteristics (e.g. texture) was poor, probably due to the adoption of manual image processing methods at various steps. In addition, recognition memory experiments require stimuli on the order of hundreds, but METU-Face contained pictures on the order of fifty. It was inevitable to develop a new face database containing a larger number of high quality pictures standardized for contrast, brightness, and face sizes. The development of this new face database, METU-FaceTwo, is described in detail in this chapter. One of the major difficulties faced in the development of the new database was the compatibility of the image standardization steps with the earlier database, METU-Face. All of the manual image processing modules in METU-Face are replaced with automatic counterparts written in MATLAB. And for compatibility, the standardization procedures in METU-Face are rerun using these new automatic procedures.

In its current form, METU- FaceTwo contains 100 pictures, of which 52 are new and upgraded versions of METU-Face (Dövencioğlu, 2008), and 48 are new collections. All face pictures are provided both in original RGB and standardized forms, and are annotated with landmarks, automated symmetry measures and perceived attractiveness and symmetry measures.

3.1. Background

Symmetry has been one of widely studied topics in face perception literature, especially in quantification of attractiveness. These studies have also given rise to the creation of face databases containing symmetric images. So far, several different techniques have been proposed for composing symmetric faces (Mealey et al., 1999; Swaddle & Cuthill, 1995; Chen et al., 2006). Older techniques like cutting the face vertically along a facial midline and replacing the removed half face with its mirror image (Mealey et al., 1999) resulted in symmetric but unnatural faces leading to the adoption of newer techniques such as that of Komotori et al. (2009) which produced natural symmetry.

Komotori et al. (2009) created symmetric faces based on the Euclidian distance between original and mirror-reversed face images in a face space. In the preprocessing step, face images were standardized according to some facial features. Then, both the original and mirror-reversed images were placed as points on a hyperplane in the face space. Symmetric image was obtained by calculating the middle point of the distance between them. The symmetric images computed were then underwent an averaging algorithm in order to standardize facial texture. The resultant averaged symmetric images and the examples of facial features used for standardization are shown in Figure 3.1.

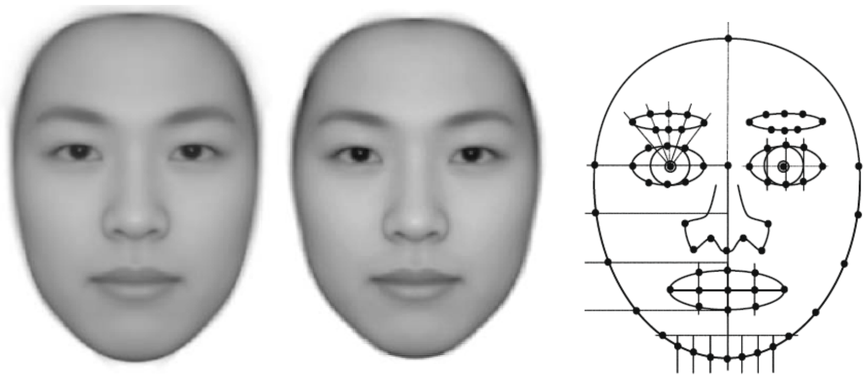

Figure 3.1: Resultant male and female faces, and facial features used in shape standardization by Komori et al. (2009, p. 138 & 139)

Our attempts to produce high-quality symmetrized faces started with Dövencioğlu (2008). Our procedure consisting of morphed faces to achieve symmetrical alignment of landmark points on the right and left parts of the face was adopted from Swaddle & Cuthill (1995). In Figure 3.2, an example output of this approach is shown. In this procedure, the original face image and the mirror-reversed face image are used to generate several morphed images. The mirror-reversed face image acts as a target, onto which the original face image is must be warped. Morphing starts with image number 1, which is the original face image, and ends with image number N, which is the mirror-reversed face image.

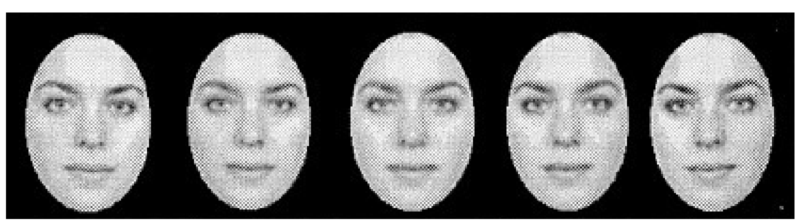

Figure 3.2: Face images at different symmetry levels by Swaddle & Cuthill (1995).

Differently, in our study, the process of morphing is executed according to the landmarks previously determined on the original face image. The symmetric face image is defined as the middle (N/2) image which is obtained during a continual morphing procedure that generates N images. This procedure is illustrated in Figure

3.3. Needless to say, when the number of landmarks increases, accuracy of the morphed images increases.

Figure 3.3: Face images at different symmetry levels obtained in the morphing: original (DBO), intermediate original (DBIO), symmetric (DBS), intermediate mirror (DBIM) and mirror (DBM) faces respectively

3.2. METU-FaceTwo

Our methodology is based on 2 main processing steps: preprocessing and morphing (Figure 3.6). The aim of the preprocessing step is to alter image to produce a uniformly localized and resized gray form in order to prepare for morphing. All the relocating and resizing calculations are made according to the extreme points which are shown in the left image of Figure 3.5. After images are standardized and mirror-reversed faces are obtained, morphing process starts according to the determined landmarks (the right side of Figure 3.5). Morphing stage gives us 5 levels of symmetry which are coded as Original (DBO), Original Symmetric (DBOI), Symmetric (DBS), Mirror Symmetric (DBIM) and Mirror (DBM) in the above Figure 3.3. We will introduce the details of the preprocessing and morphing steps in this section, but beforehand, the image capturing process must be summarized.

3.2.1. Capturing Face Images

The capturing methodology is strictly applied in the same way as described in Dövencioğlu (2008). The location of the equipments such as halogen lamps with 250W, camera etc. is given in Figure 3.4.

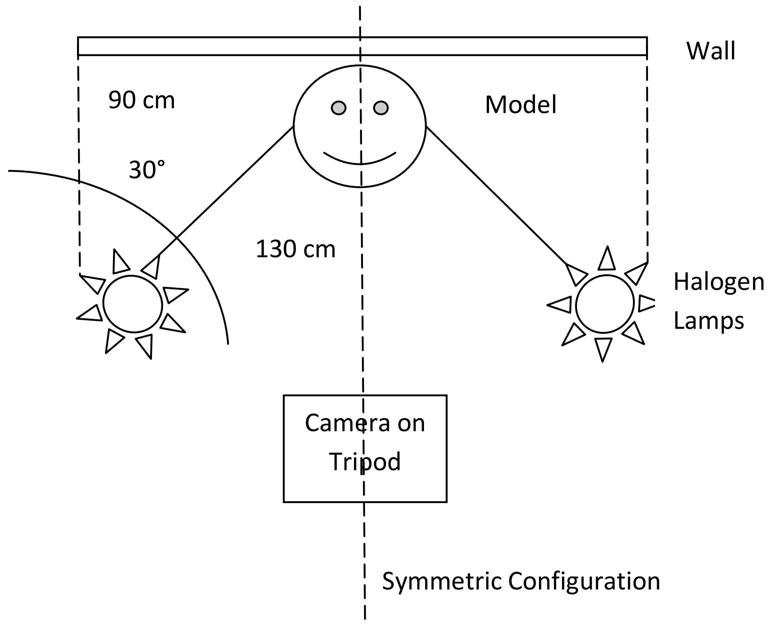

Figure 3.4: Configuration for image capturing

The set-up illustrated in Figure 3.4 is implemented in the METU-Neuro Lab of the METU Informatics Institute. Room lights, as well as external lighting were off. The participants (models) who were admitted without any external facial features such as earring, make-up, glasses, beard etc. were instructed to stay in a forward looking position with no mimics on their faces.

In addition, the rotation of head in both vertical and horizontal positions was controlled. Multiple images per model were recorded, and then some of the images were discarded according to their orientation and expression. Images bearing a neutral expression with no tilt were chosen to be processed. Although face images of more than 50 models were taken, 48 of them were accepted into the database. The models were either graduate students or university graduates, imposing a homogeneous age range within our database. Gender was also balanced among the admitted face pictures.

Landmarking was done according to the facial anatomy (Simmons et al, 2004). Initially, the extreme points, r, l, u, w are marked to point the right, left, top and bottom extreme parts of the face. These 4 landmarks are used to derive a vertical line, v, and a horizontal line, h, as indicated in Figure 3.5. Later, the internal face landmarks are marked such that: en is the inner corner of the eye, ex is the outer corner of the eye, na is the outermost point of the side of the nose, ch is the outer corner of the mouth. These landmarks are used for morphing as mentioned earlier. Calculations regarding landmarks are given in Appendix D. Locations of extremities and landmarks, as well as asymmetry quantification based on landmarks are presented in the subsections of Appendix D.

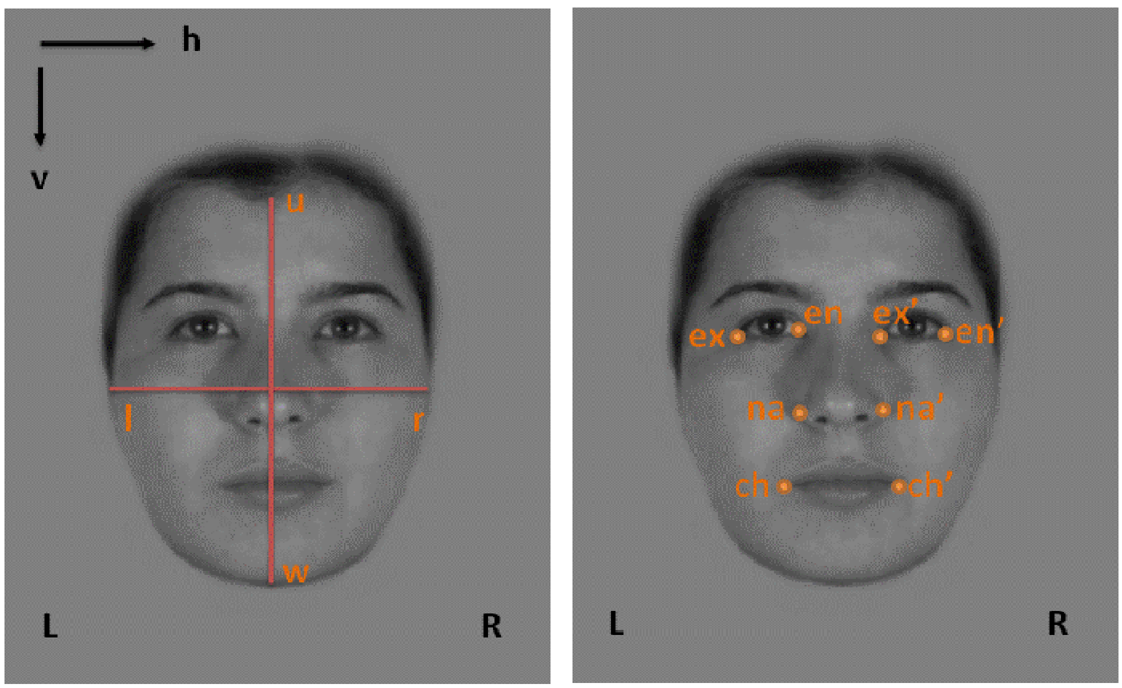

Figure 3.5: Extreme points (left) and landmarks (right).

3.2.2. Preprocessing

All of the processing steps used in the development of METU-FaceTwo are given in Figure 3.6 as well as the input and output face samples. In addition to the flow of process, each step is explained throughout this section.

Cropping

Facial parts in the original images are cropped semi-automatically in order to remove unnecessary background material. This step is handled via MATLAB. The user of the program prepared in MATLAB has to define 4 corner points for the cropping rectangle. These 4 points must be located at outer part of the face and preferably contain the least part of the background. The rest, cropping the image and saving the cropped area into another file, is accomplished by MATLAB. The resultant images are RGB and the sizes of the cropped areas differ according to the face size of the models.

Head Orientation

Although tilted images are excluded in the capturing process, the orientation of head in images is controlled once again and through a tuning function in MATLAB. The endocanthions, of which examples are given in Figure 3.5 with the abbreviation 'en', are given to this MATLAB module and the line passing through left and right endocanthion points are rotated to become horizontal.

Relocating

Using the same MATLAB function above, the face images are aligned such that the middle point of the line connecting endocanthions are placed at (x,y) = (250, 300).

Resizing

Using another MATLAB procedure, the face sizes are adjusted based on boundary points of the face: uppermost (u), lowermost (w), leftmost (l) and rightmost (r). After the user of the program determines these boundary points, the width of the face is set to 383 pixels. But the original aspect ratio of the face is preserved such that the length of each face is reshaped according to its original width versus height ratio.

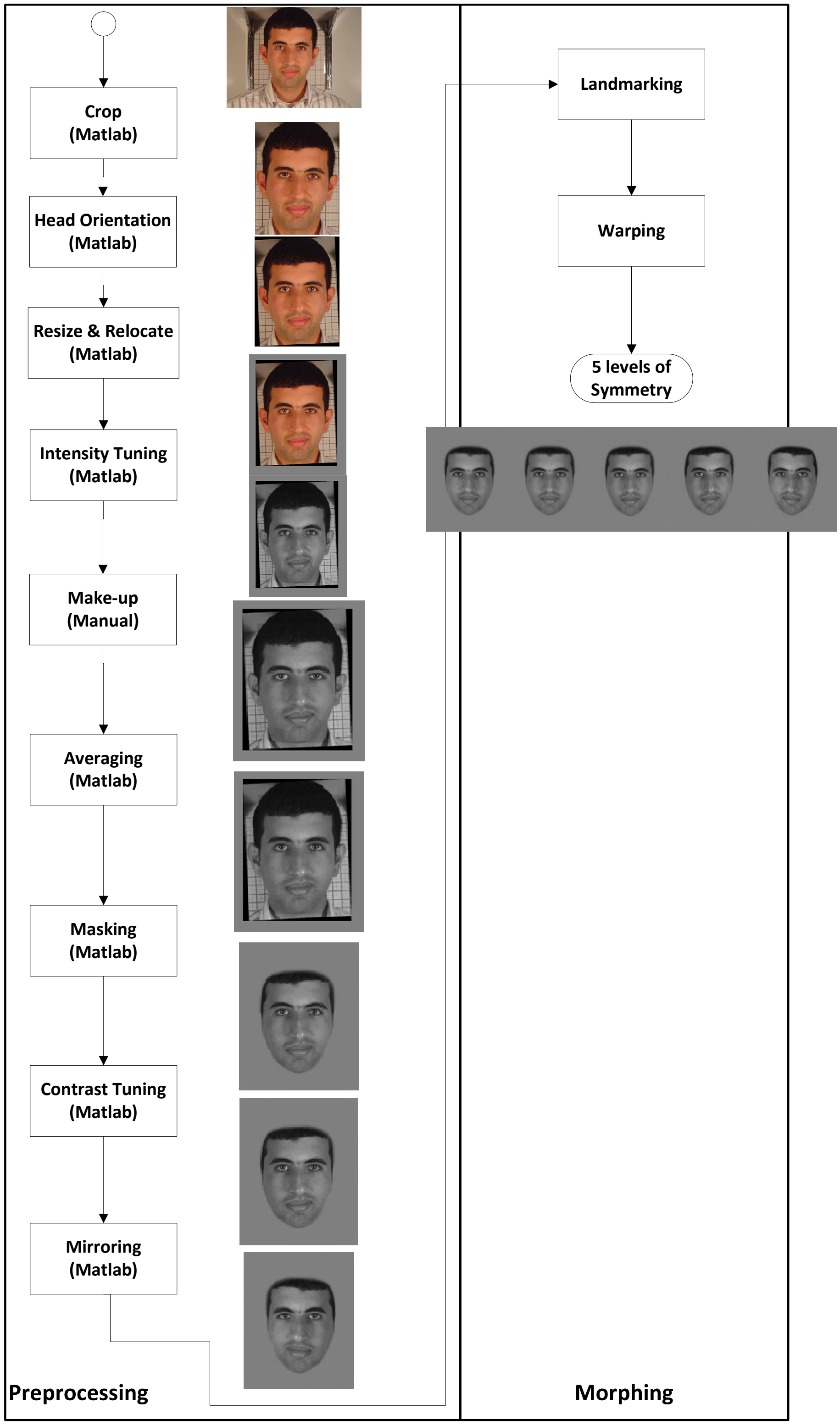

Figure 3.6: Processing steps in METU-FaceTwo

Intensity Tuning

Up to this step, all the images are RGB. These RGB images are likely to contain different contrast and illumination mainly due to the different reflectance properties of skins. Examples of these differences in RGB images are given in Figure 3.8. Therefore an intensity tuning algorithm is applied to equate the intensities of face images. A histogram matching algorithm is use for this purpose. Given a base image of ideal RGB saturation and skin reflectance, the algorithm shifts the histogram of the target image to overlap with the base histogram (Jäger & Hornegger, 2009). Example results from this intensity tuning algorithm are given in Figure 3.7. In all of the histograms, there are peaks around gray values as the images have a lot of gray pixels due to the background. In addition, faces themselves have a lot of gray values and extreme values like black and white pixels only appear in the parts related with features such as hair, eyebrows, eyes etc. In this example, the base image (1^{st} histogram) is darker than the given image (2^{nd} histogram). Also, the given image has less contrast than the base image as the histogram of the given image has a sharp peak around white levels. After applying the intensity standardization algorithm, we obtain a new image with the 3^{rd} histogram. Comparing the histograms of the base (1^{st}) and resultant (3^{rd}) images, it can be concluded that the histogram of actual target image is shifted and reconfigured according to the histogram of the atlas image.

In this histogram matching process, a standard rectangular area is processed, because we did not want effects introduced by the background areas. In Figure 3.8, the intensity standardization effects are demonstrated in multiple subjects.

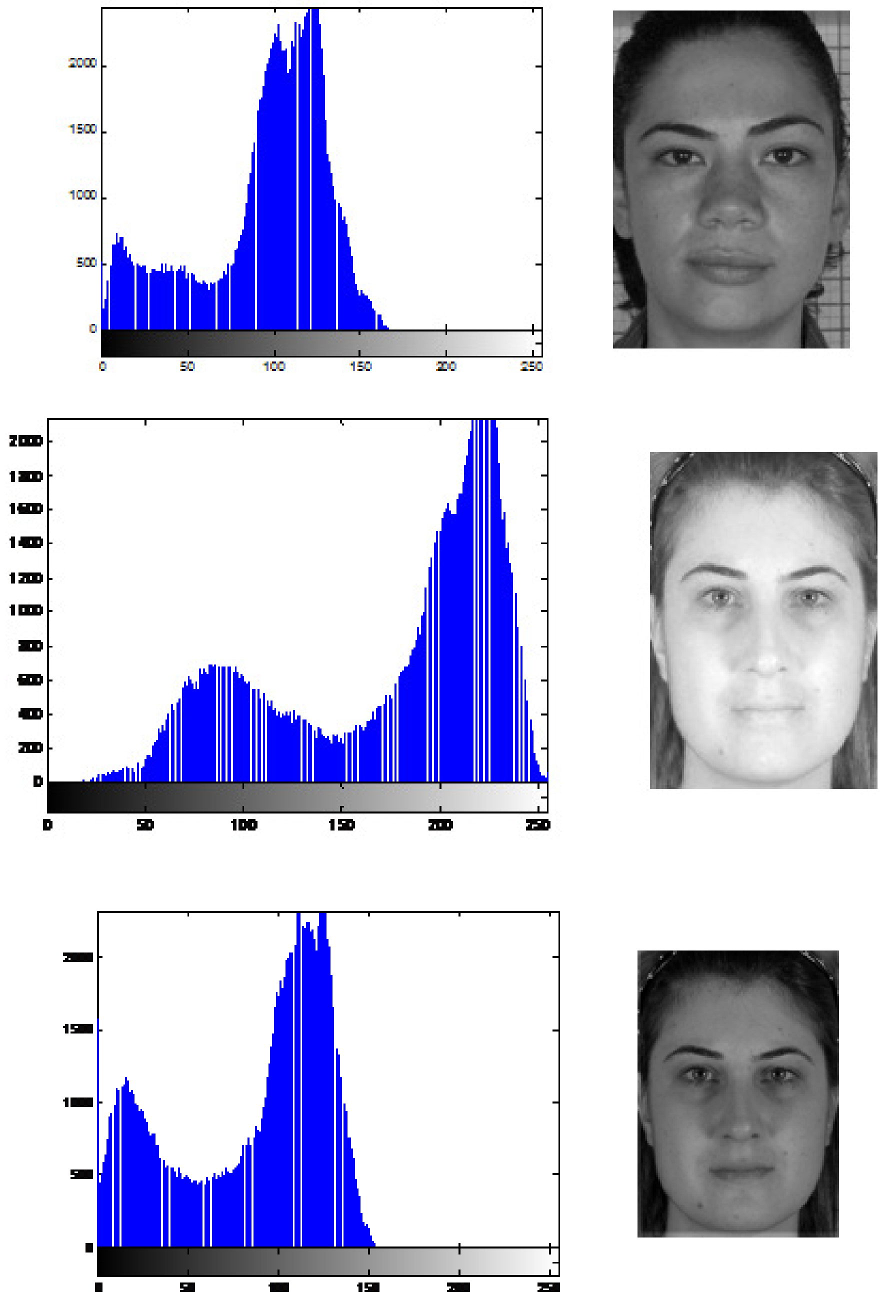

Figure 3.7: Histograms of atlas and face before and after histogram matching algorithm

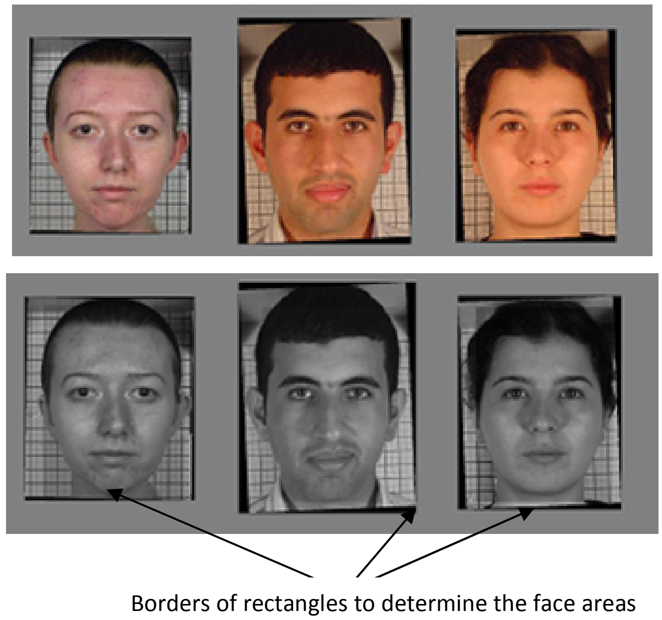

Figure 3.8: Face images before and after intensity tuning algorithm applied in the first and second rows respectively

Make-up

At this point, differentiating textures in face images (such as freckles, moles, scars) must be removed. Otherwise, these features become much more differentiating when the symmetric images are created. For instance, if an original face has a mole on the right-side, this mole is transferred to the left-side of the mirror-reversed version of this face. Consequently, these moles appear on both sides of the symmetric face, as morphing process somehow averages the original and mirror-reversed face images. An example of this situation is given in Figure 3.9. Duplication of such features may interfere with recognition performance, which is the reason for their removal. The resultant image when make-up procedure is applied is given in Figure 3.10, b.

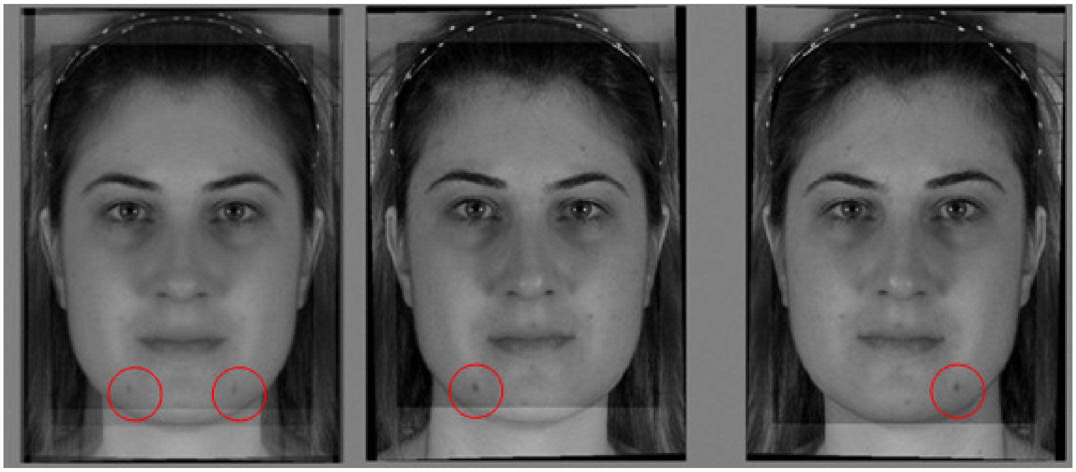

Figure 3.9: Differentiating facial texture in symmetric image as a consequence of preserved textures in original and mirror reversed symmetric images respectively.

Smoothing

Texture discontinuities produced after the above make-up process and some local contrast differences are eliminated with a moving average filter (MAF) having a window size of 9 (Figure 3.10, c). A weighted approach is adopted in the MAF, similar to Gaussian smoothing, such that the pixels in the center of the target window affect the final value of the target pixel, more than the other pixels near the boundaries.

Figure 3.10: Original face (a), and results of make-up (b), smoothing (c) and masking (d) procedures.

Masking

Unwanted features such as hair, ears, neck etc. as well as background parts are removed to keep only facial features and the shape of the face with the help of an additional masking layer of value 128 in GIMP. Some of the hairline is preserved not to cause unnatural looking faces (Figure 3.10, d).

Quality Control

In order to emphasize facial features more and remove any unwanted blur in the images due to previous manipulation procedures, each image is examined and a manual contrast enhancement process via GIMP is applied when necessary.

3.2.3. Morphing

Mirroring

At the final stage before morphing, the mirror-reversed versions of the processed faces are obtained in MATLAB.

Warping

Warping procedures are also handled in accordance with Dövencioğlu (2008):

> For the remaining three databases, Fantamorph software is utilized using the DBO and DBM datasets. With Fantamorph, we created a morphing video between two corresponding source images taken from DBO and DBM. While morphing a certain image to its mirror version, we extracted the middle frame (50%) during the course of movie. This frame is the half way through original to mirror, thus it displays a [naturally morphed] symmetrical face. (p. 37)

An example of resultant image sequence has been provided in Figure 3.3. Obtaining DBIO, DBS and DBIS images terminate the process of image manipulation. At the end of this step, five levels of symmetric images (DBO, DBIO, DBS, DBIM and DBM) are obtained. However within the scope of this study, only the original (DBO) and full symmetric (DBS) face images are used. All the quantification sections from now on are based exclusively on the comparison of the original and full symmetric images.

3.3. Automatic Quantification of Asymmetry

3.3.1. Feature-based Asymmetry

Feature-based quantification of asymmetry based on the landmarks introduced in section 1.2 is given in Appendix D. Quantification procedure is based on the definition in Dövencioğlu (2008). All asymmetry indices including global asymmetries are calculated. Landmark generation process is validated by calculating the divergence of our extremity and internal landmarks from that of METU-Face. The highest divergence is found as 3 pixels, which we concluded as an acceptable match between the two databases (Appendix D). Landmarks were not transformed to the morphed symmetric faces, hence we were unable to investigate the effects of landmark-based symmetry in recognition performance.

3.3.2. Entropy-based Asymmetry

Entropy has been a metric for the amount of information encapsulated in the images (Escolano Ruiz et al., 2009). However, we concentrate on asymmetry information which is slightly different from the mere entropy of a face image. For this purpose, the difference image is created by subtracting the mirror reversed images from the original images. Entropy is calculated over this difference image.

To examine the relation between the entropy values in original and symmetric images[5], a non-parametric t-test test was conducted. The reason for using a non-parametric test is that although entropy values for original images are normally distributed, entropies of symmetric images form a non-normal distribution. As

[5] In fact, symmetric images are expected to have zero difference entropy as the both halves of the faces are expected to be equal for symmetric images. However, due to the averaging procedure in morphing, some of the pixel values differ in a way that cause a difference between each part of the face. Nevertheless, this difference can hardly be detected perceptually.

symmetric images are manipulated synthetic entities, their non-normal distribution is apprehensible. Figure 3.11 shows the distributions for each group.

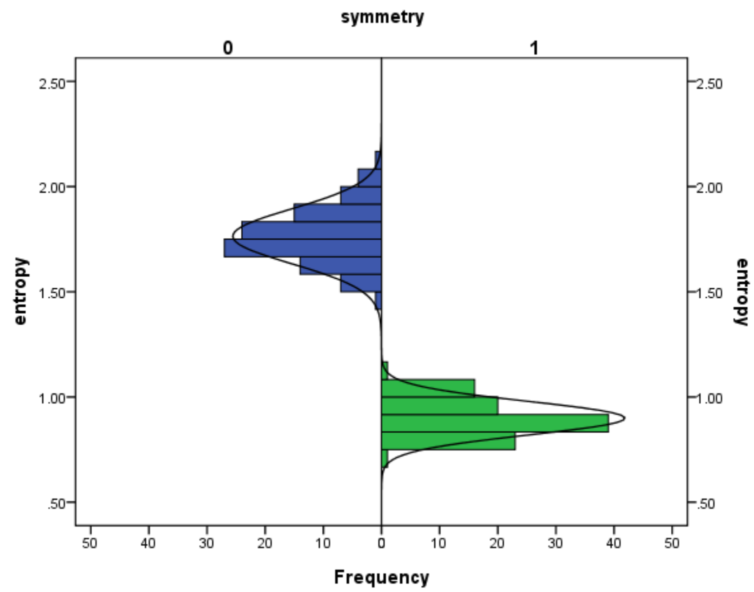

Figure 3.11: Distribution of entropy values for original (0) and symmetric (1) images.

The resulting entropies of images from DBO and DBS are given in Figure 3.12. The asymmetry values of original images (Mdn = 1.75) are significantly higher than the ones of symmetric images (Mdn = .89, T=100, $p < .01$). In terms of compatibility of entropies with METU-Face, no difference is detected in terms of entropy (T=95, p =.305; METU-Face: Mdn = 1.26, METU-FaceTwo: Mdn = 1.33) .

3.4. Quantification of Perceived Attractiveness

To quantify perceived attractiveness, all of the DBO and DBS images in METU-FaceTwo are rated by humans.

3.4.1. Participants

100 original and 100 full-symmetric images in METU-FaceTwo were rated by 10 participants (5 male and 5 female) of mean age 30 (SD = 2.18). All the participants were unfamiliar to the face images.

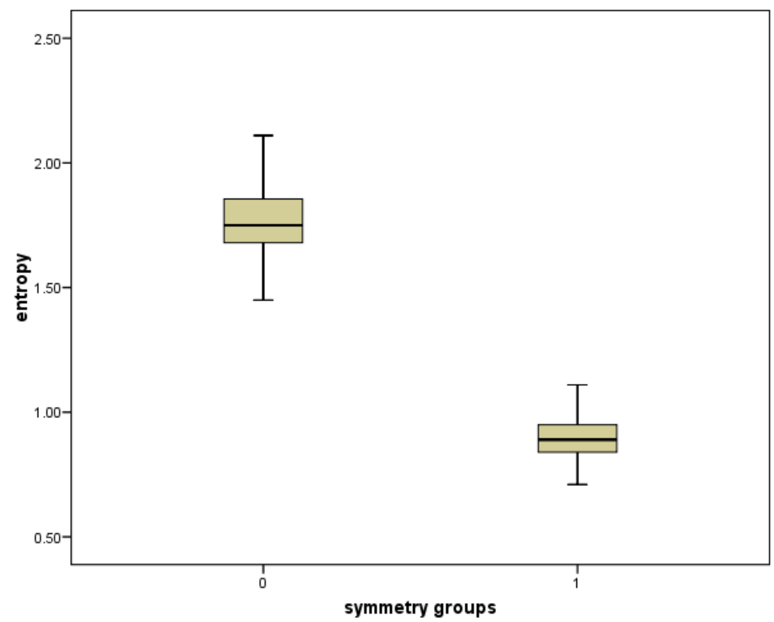

Figure 3.12: Entropy values for original and symmetric images contained in DBO and DBS. 0 and 1 denote original and symmetric images respectively.

3.4.2. Procedure

Each face image was introduced in random order and images belonging to the same face were distanced apart from each other to avoid coupling of rating. Attractiveness rating was collected according to a scale from 1 to 9 (1 = not attractive at all, 9 = very attractive). Every image was shown in the screen for 5 seconds and a fixation slide was presented in between for 2 seconds.

3.4.3. Results

To compare the means of attractiveness ratings for original and symmetric faces, independent t-test was conducted. According to the results, symmetric images ($M = 2.98$, $SE = .05$) are found to be more attractive than original images ($M = 2.64$, $SE =$

.06, t(191) = -4.127, p < .01, r = .27)[6] similar to the reports of Dövencioğlu (2008). The medians of symmetry groups are shown in Figure 3.13.

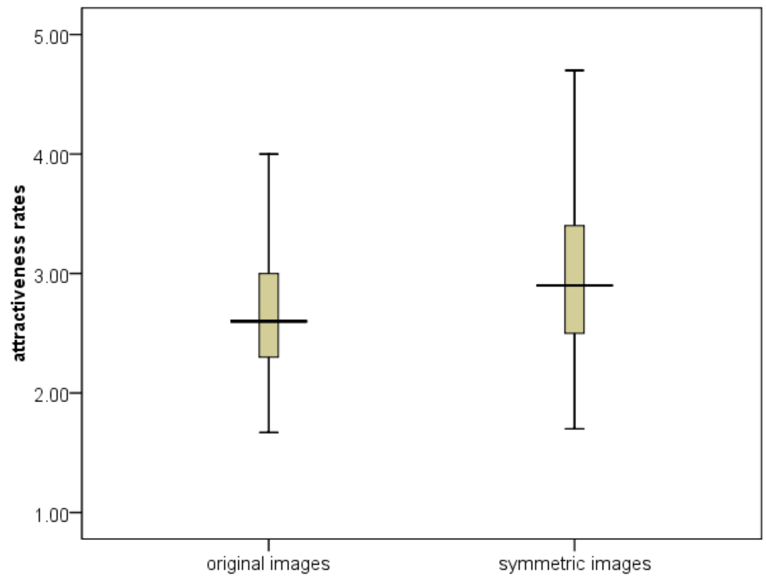

Figure 3.13: Attractiveness ratings for original and symmetric images.

Attractiveness ratings are also correlated with entropy: there is a negative correlation between attractiveness ratings and entropy (r = -.276, p < .01). As the image gets more symmetric, the entropy of the image decreases (see section 3.3.2), and attractiveness of the face image increases. This fact proves the hypothesis that attractiveness is negatively correlated with the amount of information carried in the face image given that symmetric images carry less information.

Additionally, we also analyzed response times for original and symmetric faces in attractiveness quantification with an independent t-test. Response times for symmetric images (M = 1867, SE = 28.43) are significantly higher than the ones for original images (M = 1750, SE = 25.43, t(195) = -3.048, p < .01, r = .21). Medians

[6] Although the experiment was carried out with 200 face images, degrees of freedom (DoF) value is 191. This decrease in DoF is because of the decrease in number of stimuli to make the distribution normal by removing outliers. This situation is valid for the rest of the analysis in this study.

for response times are given in Figure 3.14. As the image gets more symmetric, time consumed to examine the face increases as well. Attractiveness detection is a natural process which does not usually need inference. Therefore, a difference between the response times for original and symmetric images in attractiveness quantification is not expected. However, existence of such a difference can be considered as a cue for the lack of differentiating information in symmetric images; as the face is purified from diagnostic features, the duration for examination process increases.

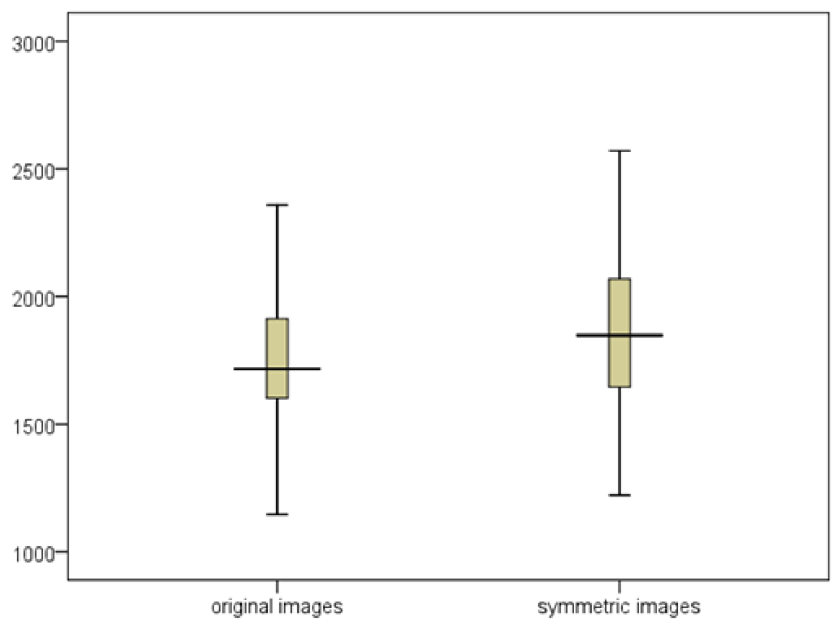

Figure 3.14: Response times in attractiveness ratings for original and symmetric images.

3.5. Quantification of Perceived Symmetry

To quantify perceived symmetry, all of the DBO and DBS images in METU-FaceTwo are rated by humans.

3.5.1. Participants

100 original and 100 full-symmetric images in METU-FaceTwo were rated by 10 participants (5 male and 5 female) of mean age 30 (SD = 2.18). All the participants were unfamiliar to the face images.

3.5.2. Procedure

Each face image was introduced in random order and images belonging to the same face were distanced apart to avoid sequential rating. Symmetry rating was collected according to a scale from 1 to 9 (1 = not symmetric at all, 9 = very symmetric). Every image was shown in the screen for 5 seconds and a fixation slide was presented in between for 2 seconds.

3.5.3. Results

To compare the means of symmetry ratings for original and symmetric faces, independent t-test was conducted. As expected, symmetric images ($M = 6.39$, $SE = .06$) are found to be more symmetric than original images ($M = 4.34$, $SE = .06$, $t(192) = -23.430$, $p < .01$, $r = .86$). Medians of perceived symmetry values for image groups are also given in Figure 3.15.

Symmetry ratings are strongly correlated with entropy: there is a negative correlation between perceived symmetry and entropy values ($r = -.851$, $p < .01$). We know that as the image gets more symmetric, the entropy of the image decreases (see section 3.3.2). Therefore, the power of entropy to explain the symmetry of face images is supported by this correlation once more.

Attractiveness ratings are also correlated with perceived symmetry: there is a positive correlation between attractiveness ratings and perceived symmetry ($r = .484$, $p < .01$). Once more, this result proves the hypothesis that attractiveness is negatively correlated with the amount of information carried in the face image given that symmetric images carry less information.

We also analyzed response times for original and symmetric faces in symmetry quantification with an independent t-test. There is no difference in response times for symmetric ($M = 1968$, $SE = 25.31$) and original ($M = 2028$, $SE = 27.15$), images ($t(198) = -1.612$, $p = .109$, $r = .75$). Medians for response times are given in Figure 3.16. Quantification of symmetry is an inferential procedure. Therefore, in symmetry quantification, all the images are examined according to the same criteria of symmetry, which makes the response times for each symmetry group close. This is also the reason for higher response times in symmetry quantification than the ones in attractiveness evaluation. Response times in symmetry quantification (M = 1996, SE = 18.93) are higher than response times in attractiveness quantification (M = 1801, SE = .18.91, t(196) = 7.727, p < .01, r = .48). As the quantification of attractiveness is a process which does not require inference, response times are lower than the ones for symmetry quantification.

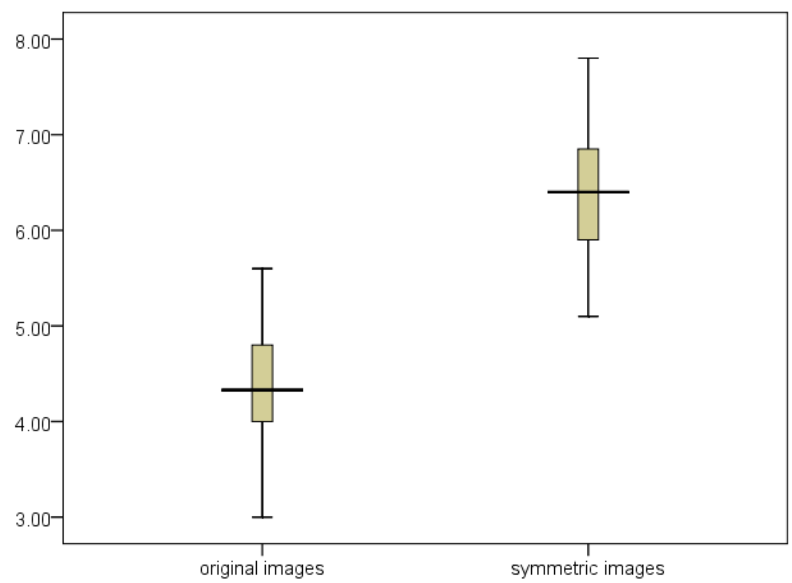

Figure 3.15: Symmetry ratings for original and symmetric images.

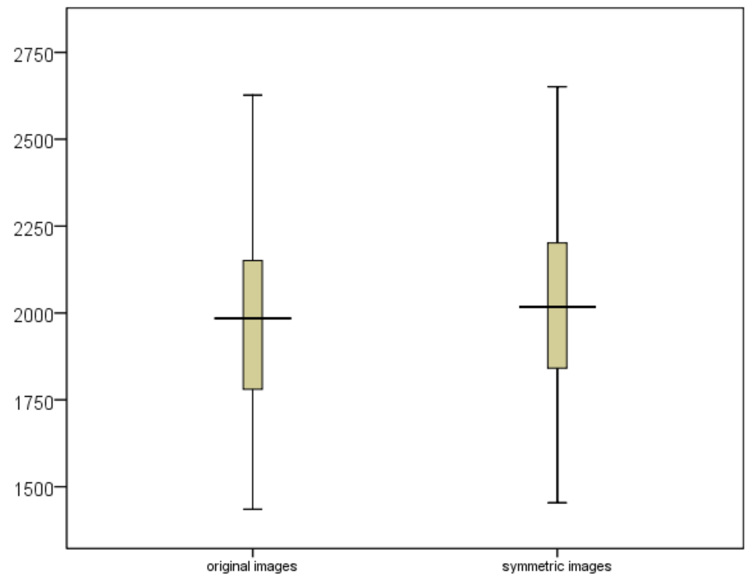

Figure 3.16: Response times in symmetry ratings for original and symmetric images.

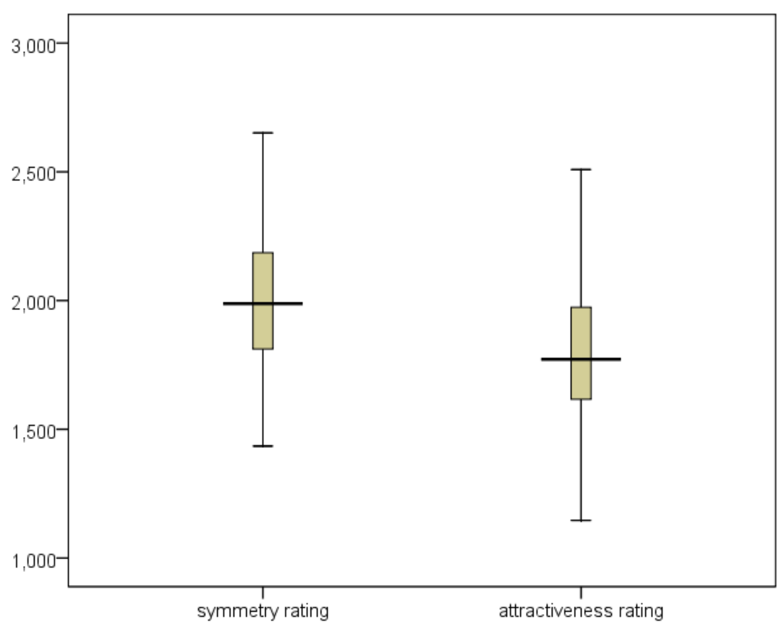

Figure 3.17: Response times for symmetry and attractiveness quantification.

In this chapter, details regarding the production of a new 2D face database, METU-FaceTwo are described in detail. This database consists of standardized images with respect to illumination, contrast, face size, and face texture and contains symmetry manipulations of each face image, annotated with landmarks, and objective and subjective holistic features such as symmetry, and attractiveness.

CHAPTER 4

RESULTS AND DISCUSSION

In order to explore the role of symmetry in recognition, a classic recognition memory task (e.g. Wickham et al., 2000) is used. In this task, the participants are initially asked to study a rather small set of face images. After a short break, a larger set of face images including the ones shown before are administered to the participants. The participants are asked whether they recognized these pictures. The details about the memory task, participants, procedure and the results of the experiment will be presented in the following sections.

4.1. The Memory Experiment

In designing a memory task for face recognition, parameters such as the number of images to be remembered, the study question asked in the first phase, the length of the resting interval are important as they may affect the performance of recognition. We have examined different approaches for tuning these parameters in the literature (Table 4.1).

We conducted a pilot experiment in order to use the right settings in the memory task. According to the results of pilot experiment (Appendix L), best recognition performance is obtained when 50-60 faces was studied with the following study question 'Have you seen this face before?'. Based on our findings in this pilot study, the memory experiment to be conducted is formalized in three distinct phases (study, break and recognition) with 50 images to be studied, 50 extra images in the test phase. Break period is decided to be around 10 min due to satisfactory recognition performance within this amount of waiting period.

Table 4.1: Examples of parameters used in recognition memory tasks

Reference	Number of Stimuli	Number of Subjects	Length of Interval	Task Type
Hancock et al. (1996)	174	34	10 min	Scaling
Morris & Wickham (2001)	88	28	5 weeks	
O'Toole et al. (1998)	72	90		Yes/No
Leveroni et al. (2000)	150	11	12 min	Yes/No
Newel et al. (1999)	12	18	1 min	Yes/No

Phase – 1: Study

In the study phase, 50 face images with approximately equal numbers of female and male pictures are administered. The participants examined the faces in a fixed time interval of 4 seconds with a study question on trustworthiness: 'Is the face in the image trustworthy?' Regardless of the length of reply, each image is presented on the screen for a fixed time interval and a fixation slide appeared between each face image for 2 seconds. The study question is selected according to the possible length of the answer. For more simple questions like determining the gender of the face in the image, the response times are extremely low (Appendix L). However, the study question must increase both the attention paid to the picture and time devoted for the examination of the face in the image. Therefore, we chose a complex evaluation criterion, trustworthiness, which invokes more face processing on the subjects. Another advantage of using such a question is to make the participants realize that the images contained faces of real individuals, and initiate face processing rather than simple picture processing.

Phase – 2: Break

Participants are released for 10 minutes before moving to the recognition stage. The amount of this time interval has previously been validated via the pilot experiment presented in Appendix L. No distraction activities are involved within this interval.

Phase – 3: Test

In the recognition phase, participants are asked to recognize the face images within a limited time interval. They performed a Yes/No button press task in response to the question ‘Have you seen this face before?’ As soon as they gave the answer for one image, they could pass to the next image after a fixation slide of 2 seconds. The stimuli set given in this part is composed of 100 images, 50 of which are new. The participants are simply asked to determine whether they have seen the face in the image before or not.

Phases 1 and 3 are both preceded with a training session in which participants practiced with 10 images from the face database of The University of Texas at Dallas[7] (Minear and Park, 2004).

4.1.1. Stimuli and Task Lists

In METU-FaceTwo, there are 100 original images (49 female and 51 male faces). As each image also has a symmetric version, the total number of images to be examined is 200. It is unlikely for a subject to get acquaintance with, and then recognize this amount of stimuli in a limited time. Along with the fact that approximately 50 face images are sufficient for a good recognition rate. 200 face images were divided to 4 lists. Each list had equal number of face images: 25 symmetric and 25 original images (Table 4.3). In addition, 49 female and 52 male face images, and their symmetric versions were homogeneously distributed over lists (Table 4.4). To examine the similarity of old and new face pictures, older-newer image pairs were also homogeneously distributed over lists (Table 4.2).

In the study phase, participants are presented a collection of 50 images from one of the lists. In the test stage, this list of 50 study images is combined with 50 new images from another list. For instance, while subject a is exposed to List 1 in the study phase and lists 1 and 2 in the recognition phase, subject b may be exposed to

[7] Those face images are captured in a non-standard front view and they also include both facial and personal features such as hair, clothes etc. Examples of those images are given in Appendix K.

List 2 in the study phase and lists 1 and 2 in the recognition phase. In this manner, all lists are administered to at least 10 valid subjects during the experiment. The formation of the lists is presented with detail table in Appendix E.

Table 4.2: Distribution of new and old versions of METU-FaceTwo over groups

Type	List-1	List-2	List-3	List-4
New	24	24	24	24
Old	26	26	26	26
Total	50	50	50	50

Table 4.3: Distribution of symmetric and original images over groups

Type	List-1	List-2	List-3	List-4
Symmetric	25	25	25	25
Original	25	25	25	25
Total	50	50	50	50

Table 4.4: Distribution of female and male faces over groups

Type	List-1	List-2	List-3	List-4
Female	24	24	25	25
Male	26	26	25	25
Total	50	50	50	50

4.1.2. Participants

72 participants have attended the face recognition experiment. Participants with recognition rates below chance level were removed. There were quite many participants performing below chance level. Possible reasons behind this are discussed in the limitations section of the discussion. Data from participants performing above chance level (40 subjects with a mean age of 26, SE = 1.63) is forwarded to statistical analysis.[8]

[8] Performances of all participants are given in Appendix A as well as the performances of the selected ones (Appendix B).

The participants were students or graduates from Okan University, Türksat A.Ş. and GATA. As familiarity is an undesirable factor in our experiments and METU-FaceTwo is composed of pictures of the individuals at METU, picking up subjects who does not have familiarity with the faces in METU-FaceTwo was essential for conducting the experiments.

All participants were voluntarily involved and they were asked for permission of their participation (Appendix I) before taking the experiment. In addition, participants were asked to complete the Edinburgh Handedness Inventory (Appendix H). According to the results of this inventory, only 2 of the participants were left-handed and the rest was evaluated as right-handed.

4.1.3. The Experimental Procedure

The experiment was prepared using E-Prime (1.2.1.844). All the stimuli are presented with a screen resolution of 1280x768 on a 32 bit true color display. In all phases, the answers are given using 'A' (yes) and 'L' (no) keys of the notebooks' keyboards. These keys are selected as they are aligned horizontally and can be separated from the other keys easily. All the experiments are conducted individually in silent and isolated rooms.

In the study phase, each of the 50 images is presented once for a fixed interval of 4 seconds regardless of the subject's response timing. After each face image, a fixation slide is presented for an interval of 2 seconds. Each face image is located at the center of the screen whereas fixation symbol '+' is located at the top. During picture presentations, subjects are asked to evaluate the trustworthiness of the face shown on the screen with a Yes/No answer. As soon as this part is accomplished, a break of 10 minutes is given. After the resting interval, an image set of 100 faces which contained the studied 50 images as well as 50 new images are presented to the participants in order to identify which one of these faces are recognized correctly. Each of the images in this stage is presented for at most 4 seconds as the program skipped to the fixation image as soon as the participant gave his/her answer. The fixation slide appeared on the screen for 2 seconds.

The aim of the study is not revealed before the experiment. But the participants were informed about the stimuli both orally and in writing (Appendix I). In addition to the information about the flow of experiment, participants are given the following instructions before the experiment and they are also told that obeying these instructions are essential for the result of the experiment:

a) ‘There is no right or wrong answer and the results will not be evaluated individually so please feel free to answer with your initial judgment for every picture’
b) ‘Give the answer that comes to your mind and try to answer as quickly as possible as we concentrate on the first impression’
c) ‘Give the answers with the single hand you feel comfortable in daily use and position this hand just in a middle position between yes and no keys’

At the end, the aim of the study is explained to the participants and also an information form was delivered (Appendix J).

4.2. Results

In both the study and test phases, responses of participants (yes/no) as well as response durations are recorded. The analyses in the study phase are done for the quantification of trustworthiness[9]. For the test phase, the analyses are done for response times, hit and false alarm rates, and those variables are examined as dependent variables where symmetry denoted independent variable. In addition to the between-subjects analyses, item-wise analyses are also performed for the recognition task.

[9] The trustworthiness responses in study phase is not a major concern of this study. Still statistical analyses were performed.

All of the analyses are handled in SPSS 16.0.0. For all of the analyses, confidence interval was chosen as 95%. In addition, for each the analysis, all outliers are removed from the data. Iteratively, descriptive statistics of the data are examined for outliers, and after the removal of the outliers, descriptive statistics are checked again. Besides, normality of the data was examined. Some of the non-normal distributions changed into normal distribution after the removal of the outliers. Otherwise, z and log transformations are applied to ensure normality. In the worst case, non-parametric tests are used for non-normal distributions. These are explained below in the individual tests.

4.2.1. Validation of Equivalence of Lists for Recognition Memory Performance

According to the results of one-way ANOVA, there is no significant difference between lists on recognition rate (F (3,35) = 1.84, p = .158). List-based testing of the images does not affect the recognition rates because the performance of the subjects across the lists does not differ with respect to recognition. Additionally, the lists do not have different variances according to Levene's test ($p > .05$). Medians and ranges for recognition rates per list along with their upper quartile and highest observation as well as their lower quartile and their lower observation are given in Figure 4.1.

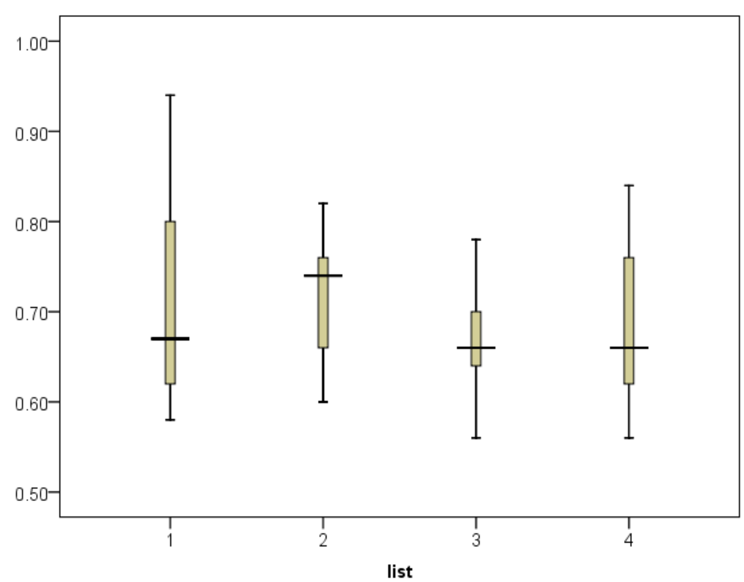

Figure 4.1: Recognition performances of lists

Furthermore there is no significant effect of list-based testing on response times for symmetric (F (3,34) = .64, p = .60) and original image types (F (3,33) = .01, p = .99). The detailed list-based statistics per image type is provided in Table 4.5.

Having no difference in the recognition performances of lists indicate that we can combine data across lists for analyses. The homogeneity of the database (i.e. no outliers in terms of face images in the image sets of the lists) is validated.

Table 4.5: List-based hit and false alarm rate statistics and response times

Measurement Type		List-1	List-2	List-3	List-4
Hit Rate	All	71%	72%	69%	68%
	Symmetric	76%	74%	70%	71%
	Original	65%	71%	67%	64%
False Alarm Rate	All	29%	26%	26%	26%
	Symmetric	27%	29%	32%	26%
	Original	31%	23%	20%	26%
Response Time	Symmetric	1535	1688	1685	1522
	Original	1514	1594	1654	1516

4.2.2. Analysis of the Test Phase

Our main research question is about the effect of symmetry on recognition rate. Our main assumption is that the recognition of unfamiliar faces is contingent upon the information carried by the image. Since symmetric faces carry less information, we hypothesized that they will be remembered less in comparison to original faces. In order to investigate this hypothesis, we analyzed the recognition rates for the symmetric and original images separately.

The difference between the recognition rates and response times of symmetric and original images for 40 subjects are analyzed with paired-samples t-tests. According to the results:

a. **Hit Rates:** Symmetric (M = .73, SE = .02) face images are recognized better than the original (M = .67, SE = .02) images (t(39) = 2.63, p < .05, r = .39).

b. **Response Times:** Symmetric (M = 1560, SE = 44.48) face images are recognized slower than the original (M = 1525, SE = 38.98) ones ($t(37) = 2.41$, $p < .05$, $r = .37$).
c. **False Alarm Rates:** No significant difference is observed between the false alarm rates of original (M = .28, SE = .02) and symmetric (M = .25, SE = .02) face images ($t(37) = 1.36$, $p = .18$).

The results are also examined with item-wise analyses. Accordingly:

a. **Hit Rates:** The relationship of recognition performance and symmetry is examined with a non-parametric t-test[10]. Recognition performance for symmetric faces (Mdn = .78) is significantly higher than that of original images (Mdn = .67; $U = 3.7$, $p < .01$, $r = -.20$)
b. **Response Times:** The relationship of response times and symmetry is examined with an independent t-test. There is no difference between the response times of symmetric (M = 1556, SE = 19.94) and original (M = 1552, SE = 16.66) images ($t(196) = -1.64$, $p > .05$, $r = .12$).
c. **False Alarm Rates:** The relationship of false alarm rates and symmetry is examined with a non-parametric t-test. No significant difference is observed between the false alarm rates of original (Mdn = .20) and symmetric (Mdn = .26) images ($U = 4.5$, $p > .05$, $r = -.07$).

There is a significant relationship between recognition performance and symmetry which is observed in both subject and item-wise analyses. Although a significant difference between the response times of symmetric and original images was found in subject-wise analysis, this effect could not be observed in item-wise analysis. This finding needs further investigation. One possible explanation might be that for the response times, the results of subjects-wise analysis is more remarkable as reaction time is an intrinsic characteristic of a subject, not an image. On a minor note, the false alarm rates for different symmetry groups did not differ, as revealed by both

[10] In subject-wise analyses, these distributions are normal. However, when the data is organized for item-wise analysis, the distributions turn into non-normal.

subject and item wise analyses. This indicates that the subjects are not misguided differently when the symmetry group of the face images differs.

The significant difference observed in recognition performance of original and symmetric images is contradictory to our initial hypothesis. According to the results, surprisingly, symmetric images are better recognized than original asymmetric ones. This result indicates that the larger amount of information present in the original images is counterproductive for face recognition. Another factor must exist for the enhanced recognition performance in symmetric faces. Perhaps attractiveness or some other internal quality present in the symmetric images has more powerful effects on face recognition.

On another front, the difference in response times for symmetric and original images seems to support for our initial assumption: original images, although they contain more information, are processed more rapidly, probably due to the existence of differentiating information. On another interesting account, memory literature states that fast response times are indicators of confidence. Usually better hit rates also accompany faster response times, but we have found an interaction between response times and hit rates in our experiment. Definitely this finding should be addressed in the future.

The correlation between entropy and recognition performance is investigated with a bivariate correlation. There is a subtle negative correlation between recognition performance and entropy of a face ($r = -.15$, $p < .05$). Accordingly, if the asymmetry information in the image, in other words, entropy, increases, the face image gets less recognizable.

The correlation between recognition rates and perceived symmetry ratings is investigated with Spearman's Correlation (1-tailed) as the variables measured were on an ordinal scale. Accordingly, there is no correlation between recognition performance and perceived symmetry ($r = .11$, $p = .057$). Still, this value is close to be significant. This is probably due to the low sample size (n==10) and the correlation might turn out to be significant with a larger sample size.

The correlation between attractiveness ratings and recognition performance is investigated with a bivariate correlation. Accordingly, there is no correlation between recognition performance and perceived attractiveness of a face ($r = .05$, $p = .46$). One reason for this finding may be due to the rating methodology in the quantification of attractiveness. Attractiveness rating was collected according to a scale from 1 to 9 (1 = not attractive at all, 9 = very attractive), and the overall mean values for attractiveness rating is lower than 3. Therefore changing the scale in attractiveness quantification and rerunning the attractiveness quantification task may result in a significant correlation.

4.2.3. Analysis of the Study Phase

The relationship between trust ratings and recognition performances and effect of symmetry and entropy on trustworthiness are analyzed. As mentioned before, these analyses were not central to our question, but we performed them in case a surprise finding might be revealed:

1. No correlation between trust ratings and recognition rates for neither symmetric ($r = .08$, $p = .30$) and original ($r = -.07$, $p = .38$) images is observed.
2. The relationship of trust ratings and symmetry was analyzed with a non-parametric t-test: there is no effect of symmetry on trust ratings ($T = 41$, $p = .34$). However, response times for trust ratings are significantly related with symmetry type ($t(90) = -2, 32$, $p < .05$, $r = .37$): response times for original images ($M = 1859$, $SE = 25.46$) are lower than symmetric ones ($M = 1929$, $SE = 18.68$).
3. There is no correlation between response times of trust ratings and entropy ($r = -.05$, $p = .35$). The correlation between trust rate and difference entropy is also insignificant ($r = -.06$, $p = .25$).

4.3. Discussion

The main goal of this study was to find the relation between symmetry and face recognition. For this aim, a recognition memory experiment was conducted. According to the results which are presented in Figure 5.1, symmetry and recognition performance is positively correlated. As the image gets more symmetric, it becomes more recognizable.

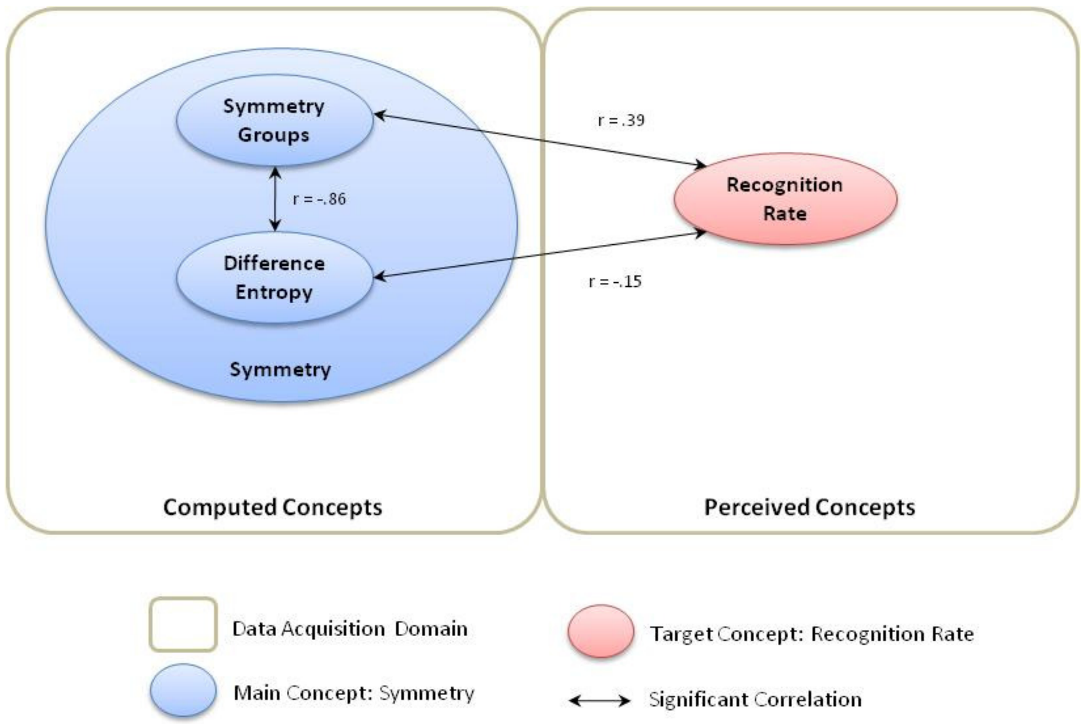

Figure 5.1: Relationship of symmetry, entropy and recognition performance.

Entropy is the metric we used to compute the amount of information encapsulated in the face image. Increasing entropy denotes increasing asymmetry of the face, hence entropy is negatively correlated with symmetry. Our results indicate that recognition performance is negatively correlated with entropy. In other words, recognition performance decreases as the entropy (or asymmetry), increases.

The reason for the positive effect of symmetry on recognition performance might be explained by the resonance of an additional group of neurons. Symmetry information might trigger the activation of an additional group of neurons and this extra activation might help recognize the symmetric faces better than original ones. Although this explanation is highly speculative, it is plausible and can be tested with future neuroimaging studies. Alternatively, another factor associated with symmetric faces, which was not measured within the scope of this thesis (for ex. beauty) might be the main factor improving recognition performance.

On another front, relationship between symmetry and attractiveness was also examined in this study (Figure 5.2). The main concept of our study, symmetry, was defined by three quantification metrics: symmetry (0 for original images and 1 for symmetric ones), entropy (computed asymmetry), and perceived symmetry (rated subjectively by participants in a range from 1 to 9). According to the results, the two symmetry classes can be explained both by entropy and perceived symmetry. Symmetry and perceived symmetry are positively correlated. Entropy is negatively correlated with symmetry and perceived symmetry.

In the literature, it has been reported that symmetry has an effect on the perceived attractiveness of faces, either positively (e.g. Grammer & Thornhill, 1994) or negatively (e.g. Swaddle & Cuthill, 1995). According to the results of our study, symmetric faces are found to be more attractive. In addition, attractiveness is correlated with perceived symmetry and entropy.

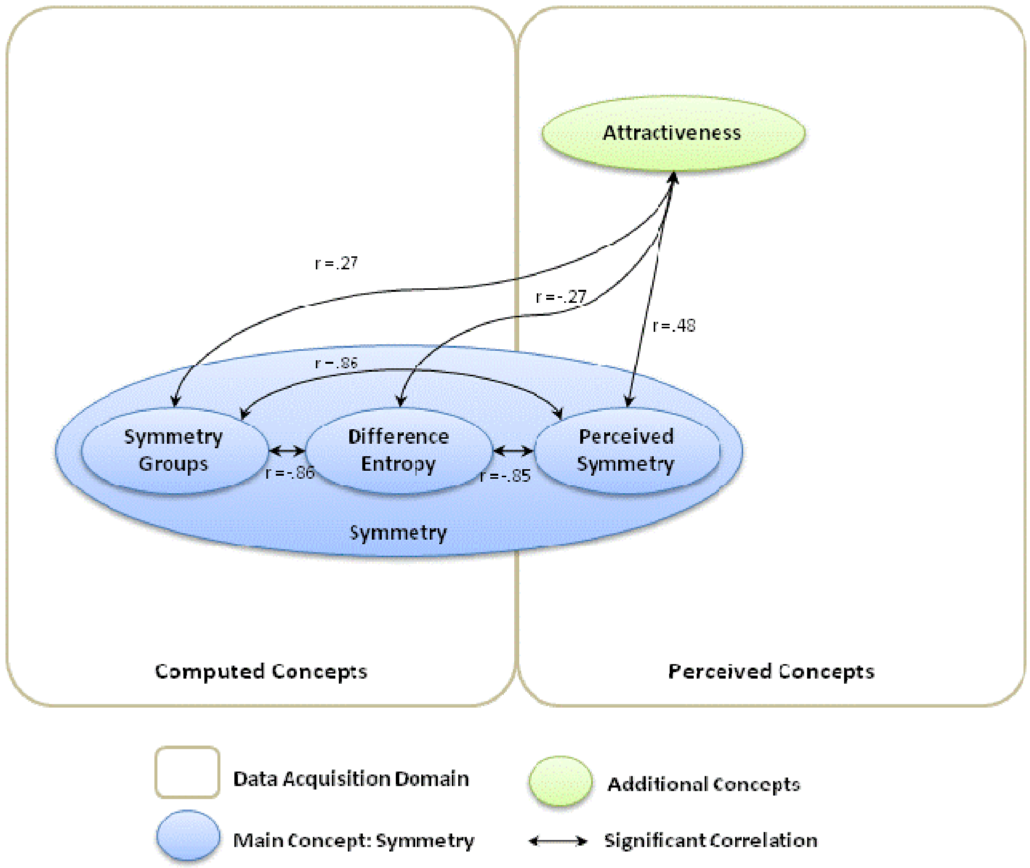

Figure 5.2: Relationship of symmetry and attractiveness.

For the recognition memory task, we used stimuli purified from all the facial textures and environmental factors such as lighting and pose. The reason for this massive manipulation was our goal to leave symmetry as the only manipulated factor across the stimuli. However, this massive editing of face images produced an unexpected consequence: only 42 of the 72 participants in the recognition memory task performed better than chance level. In other words, removing the entire set of textual/environmental features caused lower recognition performance. This unprecedented performance reduction uncovers the importance of facial textures and outside factors such as illumination and pose in human face recognition. To validate the effect of facial textures in recognition, the recognition performance for standardized and original (not manipulated) faces have to be compared in a future study. We speculate that the features such as pose, illumination and texture are crucial for human face recognition although these features are treated as noise in automatic face recognition (Tsao & Livingstone, 2008).

In our study, only holistic factors are investigated. However, quite a few studies in the literature (e.g. Bruce et al., 1994) have examined human face recognition in a feature-based manner. The reason for us to concentrate on holistic processing is the current trend that prefers holistic components in automatic recognition in recent years (Tsao & Livingstone, 2008). To integrate our results with feature-based analysis, the landmarks which are used to define reference points in faces might be analyzed in terms of asymmetry, and the lists in recognition memory task might be reconstructed according to the asymmetry groups driven from landmarks.

We conducted both subject- and item-wise analyses in our study. Both analyses produced the same results: (i) there is a significant relationship between recognition performance and symmetry and (ii) there is an insignificant difference between false alarm rates for different symmetry groups. However, although a significant difference between the response times of symmetric and original images was found in subject-wise analysis, this effect could not be observed in item-wise analysis. This difference needs further investigation. One possible explanation might be that for the response times, the results of subjects-wise analysis is more valid as reaction time is an intrinsic characteristic of a subject, not an image.

In our study, response times differ significantly for different symmetry groups: response times for symmetric images are higher than those of original images in both recognition memory and attractiveness quantification tasks. However, this distinction in response times disappears when the subjects are explicitly asked to evaluate symmetry. Explicit symmetry quantification requires checking of both parts of the face continually using saccades, and initiates an inferential process different than the indirect face processing involved in recognition or attractiveness evaluation. Hence, the reaction times for rating symmetry between original and symmetric images become closer. On the other hand, the reaction time results for the intrinsic procedures involved in recognition and quantification of attractiveness may be interpreted as follows. In general, low reaction times show the confidence of the participants in the response. Therefore, for the cases of high hit rates, reaction times are expected to be lower. However, in our study, response times are also higher for the case of high hit rates. There might be several reasons for that:

1. In the test phase, symmetric images are examined longer than the original ones. Recognition performance of symmetric images might be higher just due to this longer inspection, showing a prolonged recall process.
2. Symmetric faces contain less information. Participants might be becoming more effortful to process the low information in symmetric faces, and thus, they might be not only spending more time to study these faces, but also activate more resources to be able to process them. This effort might in turn result in a better performance in recognition. A comparison of the fixations in original and symmetric face images with an eye-tracker may validate of this argument. If the suggestion above is true, the number of fixations at special features of original images is expected to be more stable than that of symmetric images. Moreover, the fixations in the symmetric images are expected to be more volatile as the participants will tend to drag over the face continuously to explore little amount of information stored in symmetric faces.
3. Perfect symmetry is less frequent in the nature. Similarly, full symmetric faces are not an intrinsic member of our daily lives. Therefore, when we meet with symmetric faces, a different face perception process might be triggered. As a result of this process, both the time of study and hit rate might be increasing.

4.4. Limitations

The face images constructed in our study decrease the overall recognition performance. The low amount of success rate for many subjects in our recognition performance task is an indicator of this fact. This limitation may be defeated with stimuli which are less standardized or contain less number of face images.

Another limitation of this study is the low number of participants in both attractiveness and perceived symmetry quantification tasks. Some of the correlations like the correlation between perceived symmetry and recognition performance are not significant due to this reason. Therefore, increasing the sample size for quantifying these two subjective measures (attractiveness and perceived symmetry) may result in significant correlations with recognition performance.

CHAPTER 5

CONCLUSION

In this study, we constructed a face database, METU-FaceTwo. The database contains 200 2D gray-level original and full-symmetric face images. The faces in this database are purified from all the facial textures, standardized with respect to size, illumination and contrast and quantified in terms of landmark and holistic asymmetry values mostly using automatic procedures. The database is also annotated with perceived attractiveness and perceived symmetry evaluations for each original and symmetrized image. To our knowledge, METU- FaceTwo is unique in terms of these characteristics.

METU-FaceTwo facilitated our investigation of the effect of symmetry on recognition of unfamiliar faces. Since all the stimuli are controlled on all image-related aspects (eg. texture, orientation, color, intensity, face size) we were able to study the manipulation due to symmetry exclusively. Our fundamental finding is that, symmetry increases recognition performance. This is contradictory to our initial hypothesis which stated that: there is more information in original faces than in symmetric ones, hence original faces will be remembered better. It is difficult to explain why the additional information contained in original faces does not increase but decrease recognition performance. There might be 3 reasons for this.

First, the entropy measure is insufficient to characterize facial asymmetry, more specifically, the richness of information regarding both parts of the face. Entropy is one of the most valid techniques according to information theory. However, if evidence theory is used, there are other measures such as confusion, discord, strife, which might indicate features related to the original faces better.

Second, there are significant reaction time differences between original versus symmetric faces during the test phase, which indicates that the recall processes between the original versus symmetric faces are not the same. More specifically, it has been found that the RT during decision making regarding whether the current face on the screen has been seen in the study phase, is larger for symmetric faces than for original faces. Perhaps, the recognition performance differences are related to the recall phase rather than the encoding phase. The more observed a face is, the more correct the recalling is.

Third, other unmeasured subjective factors such as distinctiveness, typicality may contribute to recognition performance. We have investigated the effect of two perceived subjective factors such as perceived attractiveness and perceived symmetry in recognition performance, but the results was not conclusive due to very few subjects evaluating these perceived measures.

Based on our findings in this study, several studies can be initiated in the future: first of all, we assumed that symmetry is perceived holistically. However, we also have feature-based asymmetries in our database indicated through the landmark coordinates. The relationship of these with recognition performance can also be studied. Furthermore another study on recognition performance can be conducted, in which all the contributing factors other than symmetry such as attractiveness, distinctiveness, typicality are included. And then, the most prominent attributes contributing to face recognition can be identified using factor analysis. Additionally, structural equation modeling might be used to demonstrate the relationship of these factors with each other.

We will conclude by saying that this study is unique in terms of the stimuli set used and the fundamental concept studied. Although symmetry is an intrinsic property of faces, and humans seem to exhibit expertise in facial symmetry detection, the relationship of facial symmetry with recognition of faces has not been studied before. Our study introduces preliminary results regarding this relationship, in favor of symmetry for better face recognition and offers many potential investigation topics for the future.

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APPENDICES

APPENDIX A: RECOGNITION PERFORMANCE FOR LISTS

List-1 Statistics	Average	S01	S02	S03	S04	S05	S06	S07	S08	S09	S10	S11	S12	S13	S14	S15
Hit Rate (Overall)	59%	46%	66%	86%	50%	68%	62%	44%	34%	80%	72%	6%	58%	58%	94%	62%
Hit Rate (Symmetry)	62%	44%	68%	88%	48%	64%	76%	40%	28%	80%	96%	4%	64%	64%	100%	64%
Hit Rate (Asymetry)	56%	48%	64%	84%	52%	72%	48%	48%	40%	80%	48%	8%	52%	52%	88%	60%
False Alarm Rate (Overall)	24%	10%	12%	38%	22%	48%	36%	12%	16%	36%	18%	6%	44%	16%	10%	32%
False Alarm Rate (Symmetry)	22%	8%	16%	44%	20%	36%	36%	8%	12%	32%	12%	12%	40%	16%	12%	28%
False Alarm Rate (Asymmetry)	25%	12%	8%	32%	24%	60%	36%	16%	20%	40%	24%	0%	48%	16%	8%	36%
Response Times (Symmetry)	1441	1128	1173	1531	1537	1551	1197	1253	1293	1666	1217	1052	2043	1756	1817	1400
Response Times (Asymmetry)	1424	1164	1198	1542	1592	1522	1314	1273	1389	1620	1166	806	1932	1666	1713	1467
Gender		E	E	K	K	K	K	K	E	K	E	E	E	E	K	E

List-2 Statistics	Average	S01	S02	S03	S04	S05	S06	S07	S08	S09	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21
Hit Rate (Overall)	57%	52%	48%	26%	72%	66%	46%	72%	34%	24%	50%	38%	64%	78%	54%	60%	76%	52%	48%	76%	82%	76%
Hit Rate (Symmetry)	57%	48%	44%	20%	76%	68%	48%	68%	32%	28%	44%	36%	64%	80%	48%	68%	76%	52%	56%	80%	84%	72%
Hit Rate (Asymetry)	57%	56%	52%	32%	68%	64%	44%	76%	36%	20%	56%	40%	64%	76%	60%	52%	76%	52%	40%	72%	80%	80%
False Alarm Rate (Overall)	22%	22%	30%	8%	6%	28%	40%	18%	8%	2%	20%	18%	26%	42%	22%	32%	22%	18%	22%	40%	10%	36%
False Alarm Rate (Symmetry)	26%	24%	36%	4%	8%	32%	24%	20%	12%	4%	36%	28%	32%	36%	28%	36%	28%	20%	36%	40%	12%	44%
False Alarm Rate (Asymmetry)	19%	20%	24%	12%	4%	24%	56%	16%	4%	0%	4%	8%	20%	48%	16%	28%	16%	16%	8%	40%	8%	28%
Response Times (Symmetry)	1613	1497	1333	2499	1587	1251	1130	1249	1572	1767	1462	1333	1541	1829	1775	1353	2048	1474	1164	1703	1781	2534
Response Times (Asymmetry)	1576	1650	1364	2449	1567	1217	1116	1253	1610	1671	1612	1299	1452	1741	1692	1340	1783	1487	1212	1684	1445	2460
Gender		K	E	K	K	E	K	K	K	K	E	E	K	E	K	E	E	E	K	K	K	E

List-3 Statistics	Avg	S01	S02	S03	S04	S05	S06	S07	S08	S09	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19
Hit Rate (Overall)	56%	64%	30%	34%	64%	34%	68%	42%	66%	56%	36%	40%	52%	52%	70%	72%	78%	58%	90%	80%
Hit Rate (Symmetry)	58%	64%	36%	32%	72%	44%	72%	48%	64%	48%	36%	44%	48%	52%	72%	76%	80%	72%	84%	76%
Hit Rate (Asymetry)	54%	64%	24%	36%	56%	24%	64%	36%	68%	64%	36%	36%	56%	52%	68%	68%	76%	44%	96%	84%
False Alarm Rate (Overall)	23%	30%	16%	10%	22%	40%	38%	10%	22%	2%	12%	20%	30%	20%	32%	12%	36%	26%	38%	38%
False Alarm Rate (Symmetry)	28%	24%	16%	12%	32%	52%	44%	16%	28%	0%	4%	24%	36%	24%	36%	16%	52%	48%	36%	40%
False Alarm Rate (Asymmetry)	18%	36%	16%	8%	12%	28%	32%	4%	16%	4%	20%	16%	24%	16%	28%	8%	20%	4%	40%	36%
Response Times (Symmetry)	1614	1437	1004	1326	1656	1779	1537	1116	1483	1649	1667	1445	1715	2149	2110	2449	1349	1650	1525	2176
Response Times (Asymmetry)	1619	1337	958	1195	1498	1682	1618	1116	1470	1722	1880	1369	2106	2306	2029	2353	1306	1647	1558	1945
Gender		K	K	K	E	E	E	K	K	K	E	E	E	E	K	E	K	E	E	E

List-4 Statistics	Avg	S01	S02	S03	S04	S05	S06	S07	S08	S09	S10	S11	S12	S13	S14	S15	S16	S17
Hit Rate (Overall)	52%	50%	62%	50%	14%	56%	62%	54%	42%	76%	46%	64%	82%	68%	34%	68%	84%	56%
Hit Rate (Symmetry)	52%	36%	80%	48%	16%	52%	52%	44%	40%	84%	52%	68%	92%	52%	24%	72%	92%	68%
Hit Rate (Asymetry)	53%	64%	44%	52%	12%	60%	72%	64%	44%	68%	40%	60%	72%	84%	44%	64%	76%	44%
False Alarm Rate (Overall)	19%	12%	4%	22%	0%	22%	24%	4%	24%	32%	18%	52%	30%	26%	24%	18%	42%	14%
False Alarm Rate (Symmetry)	17%	16%	8%	12%	0%	24%	20%	4%	20%	24%	8%	56%	36%	24%	24%	28%	36%	8%
False Alarm Rate (Asymmetry)	21%	8%	0%	32%	0%	20%	28%	4%	28%	40%	28%	48%	24%	28%	24%	8%	48%	20%
Response Times (Symmetry)	1536	1631	1261	939	1302	1637	1389	1281	1742	2056	1691	1968	1648	1663	1618	1045	1193	1359
Response Times (Asymmetry)	1518	1541	1308	939	1218	1568	1379	1287	1854	2037	1688	1883	1733	1643	1652	1054	1275	1279
Gender		E	K	K	K	K	K	K	K	E	E	E	K	E	E	E	K	E

APPENDIX B: RECOGNITION PERFORMANCE FOR THE SELECTED PARTICIPANTS

List-1 Statistics	Average	S02	S03	S05	S06	S09	S10	S12	S13	S14	S15
Hit Rate (Overall)	71%	66%	86%	68%	62%	80%	72%	58%	58%	94%	62%
Hit Rate (Symmetry)	76%	68%	88%	64%	76%	80%	96%	64%	64%	100%	64%
Hit Rate (Asymetry)	65%	64%	84%	72%	48%	80%	48%	52%	52%	88%	60%
False Alarm Rate (Overall)	29%	12%	38%	48%	36%	36%	18%	44%	16%	10%	32%
False Alarm Rate (Symmetry)	27%	16%	44%	36%	36%	32%	12%	40%	16%	12%	28%
False Alarm Rate (Asymmetry)	31%	8%	32%	60%	36%	40%	24%	48%	16%	8%	36%
Response Times (Symmetry)	1535	1173	1531	1551	1197	1666	1217	2043	1756	1817	1400
Response Times (Asymmetry)	1514	1198	1542	1522	1314	1620	1166	1932	1666	1713	1467
Gender		E	K	K	K	K	E	E	E	K	E

List-2 Statistics	Avg	S04	S05	S07	S12	S13	S15	S16	S19	S20	S21
Hit Rate (Overall)	72%	72%	66%	72%	64%	78%	60%	76%	76%	82%	76%
Hit Rate (Symmetry)	74%	76%	68%	68%	64%	80%	68%	76%	80%	84%	72%
Hit Rate (Asymetry)	71%	68%	64%	76%	64%	76%	52%	76%	72%	80%	80%
False Alarm Rate (Overall)	26%	6%	28%	18%	26%	42%	32%	22%	40%	10%	36%
False Alarm Rate (Symmetry)	29%	8%	32%	20%	32%	36%	36%	28%	40%	12%	44%
False Alarm Rate (Asymmetry)	23%	4%	24%	16%	20%	48%	28%	16%	40%	8%	28%
Response Times (Symmetry)	1688	1587	1251	1249	1541	1829	1353	2048	1703	1781	2534
Response Times (Asymmetry)	1594	1567	1217	1253	1452	1741	1340	1783	1684	1445	2460
Gender		K	E	K	K	E	E	E	K	K	E

List-3 Statistics	Avg	S01	S04	S06	S08	S09	S14	S15	S16	S17	S18
Hit Rate (Overall)	69%	64%	64%	68%	66%	56%	70%	72%	78%	58%	90%
Hit Rate (Symmetry)	70%	64%	72%	72%	64%	48%	72%	76%	80%	72%	84%
Hit Rate (Asymetry)	67%	64%	56%	64%	68%	64%	68%	68%	76%	44%	96%
False Alarm Rate (Overall)	26%	30%	22%	38%	22%	2%	32%	12%	36%	26%	38%
False Alarm Rate (Symmetry)	32%	24%	32%	44%	28%	0%	36%	16%	52%	48%	36%
False Alarm Rate (Asymmetry)	20%	36%	12%	32%	16%	4%	28%	8%	20%	4%	40%
Response Times (Symmetry)	1685	1437	1656	1537	1483	1649	2110	2449	1349	1650	1525
Response Times (Asymmetry)	1654	1337	1498	1618	1470	1722	2029	2353	1306	1647	1558
Gender		K	E	E	K	K	K	E	K	E	E

List-4 Statistics	Avg	S02	S05	S06	S09	S11	S12	S13	S15	S16	S17
Hit Rate (Overall)	68%	62%	56%	62%	76%	64%	82%	68%	68%	84%	56%
Hit Rate (Symmetry)	71%	80%	52%	52%	84%	68%	92%	52%	72%	92%	68%
Hit Rate (Asymetry)	64%	44%	60%	72%	68%	60%	72%	84%	64%	76%	44%
False Alarm Rate (Overall)	26%	4%	22%	24%	32%	52%	30%	26%	18%	42%	14%
False Alarm Rate (Symmetry)	26%	8%	24%	20%	24%	56%	36%	24%	28%	36%	8%
False Alarm Rate (Asymmetry)	26%	0%	20%	28%	40%	48%	24%	28%	8%	48%	20%
Response Times (Symmetry)	1522	1261	1637	1389	2056	1968	1648	1663	1045	1193	1359
Response Times (Asymmetry)	1516	1308	1568	1379	2037	1883	1733	1643	1054	1275	1279
Gender		K	K	K	E	E	K	E	E	K	E

APENDIX C: PILOT EXPERIMENT FOR ATTRACTIVENESS

Participants & Procedure

235 images in METU-FaceTwo were rated by 13 participants of mean age 25 (SD = 2.43). Procedure was appropriate to the one described in Dövencioğlu (2008). The experiment was composed of two stages: attractiveness and symmetry ratings. Each image was introduced in random order and images belonging to the same face was distracted by the other images to avoid sequential rating. Attractiveness rating was collected according to a scale from 1 to 9 (1 = not attractive at all, 9 = very attractive). Every image was shown in the screen for 5 seconds and a fixation slide was presented between every face pairs for 2 seconds.

Results

According to ANOVA results, there was no difference between the attractiveness ratings of symmetry levels as found Dövencioğlu (2008). The means of symmetry groups are given in the following figure. However, when compared in pairs, attractiveness ratings of symmetric images (M = 2.63, SE = .21) were significantly higher than attractiveness of original ones (M = 2.47, SE = .17, t(12) = -2.68, $p <$ .05).

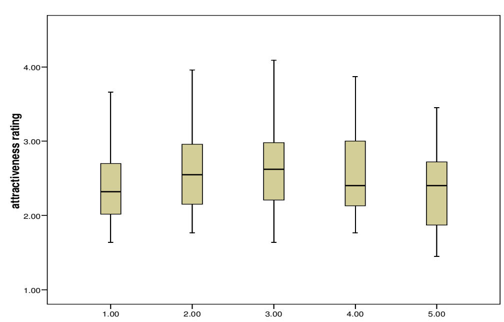


Figure: Attractiveness ratings for DBO, DBIO, DBS, DBIM, and DBM images

APPENDIX D: DATABASE QUANTIFICATION

On the contrary to Dövencioğlu (2008), the y locations given in this part of Appendix are calculated according to conventional software axes. Therefore, in our calculations, the top-left corner of the image is the point (0, 0) and y values are increased towards the bottom of the image. Whereas Dövencioğlu (2008) assigned (0, 0) point to the bottom-left corner of the face image.

Horizontal Coordinates of Landmarks

Image Id	x ex	x en	x en'	x ex'	x na	x na'	x ch	x ch'
001	159	209	288	338	211	281	199	296
002	157	209	290	337	213	285	202	298
003	156	214	293	342	215	292	204	308
004	145	204	294	345	216	290	199	303
005	158	204	292	339	206	294	196	309
006	154	209	292	344	211	289	195	296
007	164	209	290	333	211	284	191	301
008	150	200	297	347	215	288	189	308
009	156	204	291	342	205	284	190	303
010	152	206	291	345	208	295	190	313
011	157	206	295	341	217	291	195	309
012	154	210	293	340	215	289	199	301
013	160	206	291	345	208	291	194	312
014	157	207	295	344	207	292	187	312
015	164	211	293	335	213	290	202	299
016	153	201	299	345	208	295	198	309
017	154	206	294	345	207	297	194	312
018	164	206	294	336	213	289	202	305

019	155	206	289	341	214	288	194	305
020	161	203	294	336	207	285	184	308
021	159	205	296	339	212	285	190	308
022	155	209	289	341	208	289	199	295
023	153	210	288	341	212	287	196	292
024	146	207	292	347	206	290	193	311
025	148	206	292	348	216	287	193	308
026	148	206	292	348	215	289	191	311
027	147	202	296	349	209	286	191	313
028	151	213	290	345	211	283	192	305
029	153	204	293	345	206	284	188	305
030	149	204	295	346	205	285	192	302
031	147	209	291	352	209	287	183	303
032	148	204	295	345	208	284	193	300
033	154	204	294	346	211	287	199	295
034	159	212	290	342	208	291	187	307
035	155	208	291	348	206	293	197	306
036	155	208	290	345	208	290	196	305
037	155	208	290	345	207	287	195	298
038	161	208	290	341	203	289	195	298
039	149	208	287	346	213	291	191	307
040	154	209	292	346	205	287	196	297
041	158	206	293	348	215	291	198	301
042	154	206	294	346	214	289	195	307
043	152	209	289	346	206	286	187	304
044	155	205	296	346	211	292	200	302
045	155	205	292	339	206	285	196	296
046	150	212	292	349	214	289	201	301
047	158	206	289	337	205	290	198	298
048	154	206	287	336	207	290	188	297
049	155	206	295	350	203	296	185	304
050	159	206	294	338	210	293	197	309

051	159	204	296	338	210	294	195	309
052	157	204	291	342	201	287	191	299
053	164	208	290	331	206	286	197	299
054	161	213	287	341	206	290	187	308
055	158	212	287	341	205	287	189	294
056	158	205	291	340	205	288	196	306
057	141	205	294	354	211	300	204	313
058	154	205	285	342	200	290	186	301
059	155	202	295	338	210	290	193	311
060	160	208	292	334	209	289	203	301
061	157	204	293	342	201	289	193	305
062	166	208	286	331	204	296	191	302
063	163	206	286	335	209	293	203	296
064	152	201	293	340	202	282	190	295
065	159	203	296	340	214	285	194	299
066	156	201	293	338	198	297	194	308
067	160	204	291	336	204	293	198	307
068	159	210	288	335	208	289	190	299
069	157	204	293	342	203	290	198	299
070	156	208	291	344	209	290	197	300
071	153	208	289	344	210	293	194	305
072	156	204	292	341	206	288	189	305
073	157	204	291	342	200	290	191	306
074	156	204	292	337	205	292	185	311
075	164	212	292	339	211	293	198	301
076	161	204	294	339	199	292	190	308
077	152	206	293	344	198	289	188	303
078	158	206	293	341	207	297	189	310
079	159	203	295	340	203	287	192	297
080	162	210	293	341	207	287	189	305
081	157	210	288	338	207	292	198	300
082	154	210	288	345	209	299	197	307

083	152	207	294	344	206	294	193	305
084	156	207	300	346	206	290	199	298
085	152	206	293	346	213	293	200	304
086	156	207	291	338	208	294	194	312
087	156	207	291	341	202	294	190	313
088	160	212	292	337	211	289	204	294
089	166	212	287	337	211	289	204	300
090	158	207	291	335	210	287	197	294
091	156	209	291	342	206	292	195	310
092	153	204	291	352	201	293	196	308
093	162	209	291	339	206	290	194	305
094	158	207	291	342	204	301	192	308
095	148	203	293	348	208	291	201	304
096	159	207	294	339	205	295	197	309
097	159	208	292	335	209	295	197	298
098	158	208	289	341	202	289	192	298
099	160	210	288	338	206	291	188	300
100	164	205	295	340	203	298	196	305
AVERAGE	156	207	292	342	208	290	194	304
STD DEV	4,78	2,95	2,82	4,63	4,31	3,94	4,93	5,38

Vertical Coordinates of Landmarks

Image Id	y ex	y en	y en'	y ex'	y na	y na'	y ch	y ch'
001	297	299	300	296	375	376	441	439
002	302	301	300	300	380	380	436	437
003	294	298	298	292	389	385	450	447
004	300	298	299	296	385	380	446	448
005	296	296	295	297	373	373	438	438
006	298	299	299	299	381	377	442	443

007	298	297	298	299	391	381	440	439
008	295	297	295	296	389	390	456	455
009	302	300	298	303	379	378	443	441
010	291	297	298	292	378	374	442	440
011	300	297	300	298	374	365	438	436
012	296	295	295	297	369	368	426	428
013	292	297	298	294	378	375	433	434
014	295	295	295	294	373	367	435	434
015	298	295	296	295	371	366	427	426
016	298	298	297	297	378	372	454	445
017	291	295	295	290	385	380	444	440
018	292	295	295	293	368	367	428	429
019	291	296	295	292	385	382	441	437
020	298	297	295	294	374	371	441	441
021	292	293	293	292	372	371	430	425
022	293	298	297	297	368	371	441	443
023	291	295	298	293	378	378	438	446
024	298	298	298	299	376	373	432	432
025	297	297	298	295	390	385	450	448
026	297	297	298	295	391	388	446	445
027	293	296	297	293	385	381	441	437
028	302	301	297	299	381	379	452	449
029	295	296	296	296	373	371	446	448
030	299	297	295	294	393	386	452	452
031	298	298	295	297	388	385	445	451
032	294	297	295	293	387	381	447	445
033	298	297	296	298	378	379	439	439
034	294	297	296	294	389	388	443	445
035	296	297	297	296	383	383	449	447
036	296	297	298	299	378	377	445	446
037	296	297	298	299	367	370	433	435
038	296	297	298	298	375	373	433	435

039	295	297	299	294	387	383	440	440
040	293	299	295	294	381	380	449	446
041	297	297	298	297	384	379	439	440
042	296	297	296	295	376	374	432	428
043	292	298	297	292	387	389	450	449
044	295	295	295	292	373	371	432	433
045	295	295	297	293	375	374	435	441
046	304	297	297	298	376	374	441	442
047	297	297	295	298	380	377	439	441
048	296	297	298	297	386	384	448	449
049	294	294	296	291	377	377	437	443
050	298	295	295	295	395	379	449	439
051	298	298	297	295	377	373	443	439
052	295	296	296	296	382	381	444	449
053	295	297	297	293	377	380	439	434
054	294	296	299	296	377	376	441	442
055	299	299	299	298	382	380	438	436
056	299	297	298	296	382	377	442	439
057	298	297	295	294	385	383	450	446
058	299	297	298	297	380	370	434	435
059	301	298	298	303	376	370	445	435
060	294	298	295	296	384	384	444	440
061	295	296	296	296	378	372	442	448
062	294	298	297	294	367	371	430	431
063	299	297	297	299	383	379	448	447
064	299	297	298	301	384	380	442	444
065	301	299	298	302	374	375	436	437
066	299	297	298	299	386	383	445	441
067	299	296	296	298	375	375	438	435
068	299	297	296	295	372	371	433	433
069	295	296	301	296	383	386	457	456
070	301	299	299	299	386	380	450	449

071	298	299	297	299	388	384	453	455
072	296	299	297	296	380	383	447	447
073	295	296	296	296	388	386	444	443
074	296	294	297	299	362	361	433	436
075	295	297	297	297	378	377	441	440
076	294	296	297	297	372	363	428	427
077	296	292	296	294	375	375	445	448
078	298	297	297	298	370	368	443	444
079	296	297	297	301	386	385	456	458
080	296	296	297	298	370	371	443	441
081	300	296	296	300	365	367	434	433
082	294	296	296	294	381	379	448	445
083	298	298	296	299	378	379	454	448
084	297	298	297	296	378	380	442	440
085	294	297	293	296	378	371	441	439
086	299	298	298	299	373	373	436	433
087	297	298	298	296	387	383	442	442
088	299	297	297	298	374	367	430	426
089	296	297	298	298	374	371	430	427
090	297	298	298	298	363	361	426	427
091	296	297	298	296	370	366	439	438
092	295	296	296	294	382	376	448	444
093	296	297	298	296	370	368	437	435
094	297	298	298	297	375	375	438	441
095	297	296	298	297	379	379	450	449
096	296	298	295	296	360	357	434	429
097	296	296	295	300	368	368	434	433
098	303	296	295	301	384	374	448	443
099	298	298	297	299	381	381	450	453
100	298	295	295	301	386	380	451	450
AVERAGE	297	297	297	296	379	376	441	441

STD DEV	2,71	1,45	1,51	2,68	7,20	6,75	7,31	7,36

Extremity and Medial Axes Coordinates

Image Id	**x**	**x**	**x**	**x**	**y**	**y**	**y**	**y**		
	Left	**Right**	**Upper**	**Lower**	**Left**	**Right**	**Upper**	**Lower**	**V Axis**	**H Axis**
001	99	387	244	250	341	322	175	529	243	352
002	107	391	248	254	339	355	156	522	249	339
003	108	394	221	251	348	343	130	547	251	339
004	107	396	253	259	357	348	129	548	252	339
005	103	394	249	252	358	361	130	535	249	333
006	99	391	249	255	346	341	145	536	245	341
007	98	393	245	252	327	343	128	538	246	333
008	101	392	247	257	343	340	122	541	247	332
009	100	389	254	244	333	340	137	536	245	337
010	107	393	253	252	346	350	119	529	250	324
011	107	396	251	252	328	327	138	532	252	335
012	98	389	249	252	324	342	143	505	244	324
013	105	390	250	251	347	351	134	526	248	330
014	100	392	251	250	352	341	144	529	246	337
015	100	389	251	254	352	342	144	514	245	329
016	104	397	251	250	349	343	134	534	251	334
017	101	394	253	251	350	343	116	527	248	322
018	105	389	252	248	347	343	145	504	247	325
019	103	389	253	251	304	299	111	527	246	319
020	95	389	252	246	347	343	114	536	242	325
021	101	391	246	250	343	341	148	515	246	332
022	103	395	252	247	336	348	141	542	249	342
023	99	391	252	239	311	316	129	527	245	328
024	101	393	248	254	319	328	122	517	247	320
025	104	398	251	251	318	328	148	543	251	346
026	99	394	250	252	318	330	127	534	247	331

027	101	393	250	252	331	320	127	534	247	331
028	98	388	253	252	332	339	139	542	243	341
029	103	397	258	247	358	371	150	557	250	354
030	104	393	252	246	332	328	106	535	249	321
031	102	392	252	247	304	314	107	542	247	325
032	104	391	254	247	332	331	117	540	248	329
033	104	397	253	249	332	331	144	517	251	331
034	101	393	253	248	331	333	144	546	247	345
035	104	393	250	248	331	333	121	546	249	334
036	100	394	261	253	337	336	145	542	247	344
037	104	392	244	246	338	342	155	526	248	341
038	106	397	254	255	327	330	122	513	252	318
039	98	391	252	255	329	330	129	529	245	329
040	108	396	251	248	332	322	128	529	252	329
041	109	388	250	250	361	360	137	532	249	335
042	109	386	254	253	360	358	127	518	248	323
043	101	389	252	247	344	348	127	542	245	335
044	109	392	253	247	342	345	132	518	251	325
045	105	392	253	248	343	345	132	528	249	330
046	102	393	254	251	365	370	127	532	248	330
047	109	388	250	250	361	360	137	523	249	330
048	104	397	250	244	363	359	122	533	251	328
049	106	392	250	246	340	322	119	533	249	326
050	100	389	237	249	363	363	178	546	245	362
051	105	389	255	249	363	363	144	538	247	341
052	93	385	255	245	350	353	136	543	239	340
053	101	392	255	253	369	360	144	531	247	338
054	101	391	246	250	369	341	140	538	246	339
055	104	396	254	248	336	354	173	524	250	349
056	101	390	251	246	385	372	194	542	246	368
057	102	399	256	264	370	352	126	549	251	338
058	100	396	256	242	359	359	126	544	248	335

059	100	393	253	252	359	361	148	544	247	346
060	103	387	252	248	377	358	128	542	245	335
061	103	390	245	244	358	347	135	541	247	338
062	100	392	252	248	358	354	128	529	246	329
063	99	389	253	252	380	378	138	547	244	343
064	94	383	250	243	376	389	137	537	239	337
065	99	392	251	249	373	376	143	525	246	334
066	103	392	250	243	377	384	137	537	248	337
067	101	392	250	259	372	376	134	528	247	331
068	98	394	254	238	338	343	149	517	246	333
069	103	400	257	244	358	350	145	561	252	353
070	100	394	253	252	337	343	152	542	247	347
071	97	391	253	248	338	343	129	548	244	339
072	99	390	253	249	337	342	127	540	245	334
073	100	396	255	244	358	349	136	561	248	349
074	99	391	251	248	337	340	150	532	245	341
075	102	394	253	250	345	340	133	528	248	331
076	103	394	249	247	358	361	160	525	249	343
077	101	391	255	243	345	346	154	555	246	355
078	105	395	260	251	358	372	142	548	250	345
079	101	396	255	243	345	345	154	563	249	359
080	107	393	252	248	359	367	123	529	250	326
081	100	393	254	248	359	353	139	529	247	334
082	104	394	254	252	357	335	139	542	249	341
083	101	392	250	254	347	348	129	549	247	339
084	108	400	253	247	347	350	142	534	254	338
085	101	393	255	249	348	350	137	530	247	334
086	103	387	250	248	377	384	137	531	245	334
087	105	393	250	249	328	334	137	537	249	337
088	104	403	255	250	343	341	192	520	254	356
089	104	395	259	250	343	341	126	520	250	323
090	105	393	250	248	333	340	137	517	249	327

091	101	394	251	250	348	349	114	541	248	328
092	108	398	255	255	345	344	154	549	253	352
093	102	398	251	252	347	349	146	534	250	340
094	103	395	251	250	336	339	165	528	249	347
095	100	397	250	253	360	360	137	548	249	343
096	98	392	251	252	348	350	146	530	245	338
097	105	397	249	252	348	350	108	530	251	319
098	101	390	249	251	363	355	130	542	246	336
099	97	391	250	238	361	362	117	551	244	334
100	105	398	256	253	344	345	144	559	252	352
AVERAGE	102	393	251	249	347	347	137	535	247	336
STD DEV	3,35	3,46	4,58	4,19	16,32	15,68	15,92	11,84	2,78	9,83

Local and Global Asymmetry Indices

Image Id	**X**	**X**	**X**	**X**	**Y**	**Y**	**Y**		
	EXv	**NAv**	**CHv**	**ENv**	**Exh**	**NAh**	**CHh**	**AIv**	**AIh**
001	11	6	9	11	1	-1	2	37	2
002	-4	0	2	1	2	0	-1	-1	1
003	-4	5	10	5	2	4	3	16	9
004	-13	3	-1	-5	4	5	-2	-16	7
005	0	3	8	-1	-1	0	0	10	-1
006	8	10	1	11	-1	4	-1	30	2
007	6	4	1	8	-1	10	1	19	10
008	4	10	4	4	-1	-1	1	22	-1
009	9	0	4	6	-1	1	2	19	2
010	-3	3	3	-3	-1	4	2	0	5
011	-5	5	1	-2	2	9	2	-1	13
012	7	17	13	16	-1	1	-2	53	-2
013	10	4	11	2	-2	3	-1	27	0
014	9	7	7	10	1	6	1	33	8

015	10	14	12	15	3	5	1	51	9
016	-3	2	6	-1	1	6	9	4	16
017	4	9	11	5	1	5	4	29	10
018	6	8	13	6	-1	1	-1	33	-1
019	4	10	7	3	-1	3	4	24	6
020	13	8	8	13	4	3	0	42	7
021	6	5	6	9	0	1	5	26	6
022	-2	-1	-4	0	-4	-3	-2	-7	-9
023	4	9	-2	8	-2	0	-8	19	-10
024	-1	2	10	5	-1	3	0	16	2
025	-6	1	-1	-4	2	5	2	-10	9
026	3	11	9	5	2	3	1	28	6
027	2	1	10	4	0	4	4	17	8
028	10	8	11	17	3	2	3	46	8
029	-2	-10	-7	-3	-1	2	-2	-22	-1
030	-2	-7	-3	2	5	7	0	-10	12
031	5	2	-8	6	1	3	-6	5	-2
032	-2	-3	-2	4	1	6	2	-3	9
033	-1	-3	-7	-3	0	-1	0	-14	-1
034	7	5	0	8	0	1	-2	20	-1
035	6	2	6	2	0	0	2	16	2
036	6	4	7	4	-3	1	-1	21	-3
037	4	-2	-3	2	-3	-3	-2	1	-8
038	-1	-11	-10	-5	-2	2	-2	-27	-2
039	6	15	9	6	1	4	0	36	5
040	-4	-12	-11	-3	-1	1	3	-30	3
041	9	9	2	2	0	5	-1	22	4
042	5	8	7	5	1	2	4	25	7
043	8	2	1	8	0	-2	1	19	-1
044	0	2	1	0	3	2	-1	3	4
045	-3	-6	-5	0	2	1	-6	-14	-3
046	4	8	7	9	6	2	-1	28	7

047	-2	-2	-1	-2	-1	3	-2	-7	0
048	-11	-4	-16	-8	-1	2	-1	-39	0
049	7	1	-9	3	3	0	-6	2	-3
050	8	14	17	11	3	16	10	50	29
051	3	10	10	6	3	4	4	29	11
052	21	10	12	17	-1	1	-5	60	-5
053	2	-1	3	5	2	-3	5	9	4
054	10	4	3	8	-2	1	-1	25	-2
055	-1	-8	-17	-1	1	2	2	-27	5
056	7	2	11	5	3	5	3	25	11
057	-6	10	16	-2	4	2	4	18	10
058	0	-6	-9	-6	2	10	-1	-21	11
059	0	7	11	4	-2	6	10	22	14
060	4	8	14	10	-2	0	4	36	2
061	6	-3	5	4	-1	6	-6	12	-1
062	5	8	1	2	0	-4	-1	16	-5
063	10	14	11	4	0	4	1	39	5
064	15	7	8	17	-2	4	-2	47	0
065	8	8	2	8	-1	-1	-1	26	-3
066	-1	0	7	-1	0	3	4	5	7
067	3	4	12	2	1	0	3	21	4
068	2	5	-3	6	4	1	0	10	5
069	-4	-10	-6	-6	-1	-3	1	-26	-3
070	6	5	3	5	2	6	1	19	9
071	9	15	11	9	-1	4	-2	44	1
072	8	5	5	7	0	-3	0	25	-3
073	3	-6	1	-1	-1	2	1	-3	2
074	3	7	6	6	-3	1	-3	22	-5
075	7	8	3	8	-2	1	1	26	0
076	3	-6	1	1	-3	9	1	-1	7
077	4	-5	-1	7	2	0	-3	5	-1
078	-1	4	-1	-1	0	2	-1	1	1

079	2	-7	-8	1	-5	1	-2	-12	-6
080	3	-6	-6	3	-2	-1	2	-6	-1
081	2	6	5	5	0	-2	1	18	-1
082	1	10	6	0	0	2	3	17	5
083	3	7	5	8	-1	-1	6	23	4
084	-6	-12	-11	-1	1	-2	2	-30	1
085	4	12	10	5	-2	7	2	31	7
086	4	12	16	8	0	0	3	40	3
087	-1	-2	5	0	1	4	0	2	5
088	-10	-7	-9	-3	1	7	4	-29	12
089	4	1	5	0	-2	3	3	10	4
090	-5	-1	-7	0	-1	2	-1	-13	0
091	3	3	10	5	0	4	1	21	5
092	-1	-12	-2	-11	1	6	4	-26	11
093	1	-4	-1	0	0	2	2	-4	4
094	2	7	2	0	0	0	-3	11	-3
095	-1	2	8	-1	0	0	1	8	1
096	8	10	16	11	0	3	5	45	8
097	-8	2	-7	-2	-4	0	1	-15	-3
098	8	0	-1	6	2	10	5	13	17
099	10	9	0	10	-1	0	-3	29	-4
100	1	-2	-2	-3	-3	6	1	-6	4
AVERAGE	3	3	3	4	0	2	1	12	3
STD DEV	5,65	6,74	7,41	5,56	2,04	3,34	3,16	21,55	6,09

APPENDIX E: IMAGE DISTRIBUTION FOR TASK LISTS

Count	Name	Type	Version	Gender	Learning List	Recognition Lists
10x2 Images	001o	Original	New	Female	1	1,3
	001s	Symmetric	New	Female	2	2,4
	002o	Original	New	Female	2	2,4
	002s	Symmetric	New	Female	1	1,3
				……………		
	009o	Original	New	Female	1	1,3
	009s	Symmetric	New	Female	2	2,4
	010o	Original	New	Female	2	2,4
	010s	Symmetric	New	Female	1	1,3
11x2 Images	011o	Original	New	Female	3	1,3
	011s	Symmetric	New	Female	4	2,4
	012o	Original	New	Female	4	2,4
	012s	Symmetric	New	Female	3	1,3
				……………		
	020o	Original	New	Female	4	2,4
	020s	Symmetric	New	Female	3	1,3
	021o	Original	New	Female	3	1,3
	021s	Symmetric	New	Female	4	2,4
14x2 Images	022o	Original	Old	Female	1	1,3
	022s	Symmetric	Old	Female	2	2,4
	023o	Original	Old	Female	2	2,4
	023s	Symmetric	Old	Female	1	1,3
				……………		
	034o	Original	Old	Female	1	1,3
	034s	Symmetric	Old	Female	2	2,4

	035o	Original	Old	Female	2	2,4
	035s	Symmetric	Old	Female	1	1,3
14x2 Images	036o	Original	Old	Female	4	2,4
	036s	Symmetric	Old	Female	3	1,3
	037o	Original	Old	Female	3	1,3
	037s	Symmetric	Old	Female	4	2,4
				....		
	048o	Original	Old	Female	4	2,4
	048s	Symmetric	Old	Female	3	1,3
	049o	Original	Old	Female	3	1,3
	049s	Symmetric	Old	Female	4	2,4
14x2 Images	050o	Original	New	Male	1	1,3
	050s	Symmetric	New	Male	2	2,4
	050o	Original	New	Male	2	2,4
	050s	Symmetric	New	Male	1	1,3
				....		
	062o	Original	New	Male	1	1,3
	062s	Symmetric	New	Male	2	2,4
	063o	Original	New	Male	2	2,4
	063s	Symmetric	New	Male	1	1,3
13x2 Images	064o	Original	New	Male	4	2,4
	064s	Symmetric	New	Male	3	1,3
	065o	Original	New	Male	3	1,3
	065s	Symmetric	New	Male	4	2,4
				....		
	075o	Original	New	Male	3	2,4
	075s	Symmetric	New	Male	4	1,3
	076o	Original	New	Male	4	1,3
	076s	Symmetric	New	Male	3	2,4
12x2 Images	077o	Original	Old	Male	1	1,3
	077s	Symmetric	Old	Male	2	2,4

	078o	Original	Old	Male	2	2,4
	078s	Symmetric	Old	Male	1	1,3
				……………		
	087o	Original	Old	Male	1	1,3
	087s	Symmetric	Old	Male	2	2,4
	088o	Original	Old	Male	2	2,4
	088s	Symmetric	Old	Male	1	1,3
12x2 Images	089o	Original	Old	Male	3	1,3
	089s	Symmetric	Old	Male	4	2,4
	090o	Original	Old	Male	4	2,4
	090s	Symmetric	Old	Male	3	1,3
				……………		
	099o	Original	Old	Male	3	2,4
	099s	Symmetric	Old	Male	4	1,3
	100o	Original	Old	Male	4	1,3
	100s	Symmetric	Old	Male	3	2,4

APPENDIX F: RECOGNITION RATINGS & REACTION TIMES

Image Id	Original		Symmetric	
	Response Time	Recognition Rate	Response Time	Recognition Rate
001	1649	.40	1350	.50
002	1304	.60	1195	.70
003	1433	.80	1364	.80
004	1333	.30	1279	.60
005	1342	.60	1223	.60
006	1319	.40	1617	.60
007	1556	.60	1612	.60
008	1645	.60	1543	.50
009	1616	.80	1279	.80
010	1390	.50	1325	.60
011	2025	.50	1717	.50
012	1605	.60	1399	.70
013	1806	.40	1483	.80
014	1669	.40	1516	.60
015	1530	.30	1459	.60
016	1380	.80	1356	.40
017	1580	.90	1688	.50
018	1751	.40	1702	.50
019	1726	.50	1834	.60
020	1702	.70	1304	.40
021	1421	.60	1069	.90
022	1307	.50	1218	.40
023	1471	.50	1470	.70

024	1588	.60	1371	.50
025	1134	.80	1208	.90
026	1398	.50	1446	.50
027	1567	.40	1421	.70
028	1130	.60	1202	.30
029	1199	.50	1250	.70
030	1223	.20	1121	.10
031	1174	.60	1630	.40
032	1524	.60	1424	.40
033	1342	.90	1450	.50
034	1256	.60	1379	.50
035	1516	.60	1433	.90
036	1479	.50	1657	.40
037	1820	.40	1990	.50
038	1553	.50	2045	.40
039	1779	.80	1178	.60
040	1424	.70	1717	.80
041	1896	.50	1869	.50
042	1435	.70	1419	.50
043	2025	.60	1371	.80
044	1326	.60	1921	.60
045	1697	.40	1894	.70
046	1752	.80	1782	.60
047	1668	.40	1400	.60
048	1559	.60	1765	.20
049	1833	.60	1510	.50
050	1432	.80	1283	.80
051	1368	.80	1548	.70
052	1505	.90	1502	.50
053	1347	1.00	1252	.90
054	1571	.30	1538	.50
055	1490	.70	1425	.80

056	1273	.70	1363	.70
057	1441	.70	1237	.90
058	1463	.60	1455	.80
059	1542	1.00	1514	.90
060	1506	.30	1306	.40
061	1234	.90	1377	.60
062	1354	.60	1572	.60
063	1711	.50	1492	.60
064	1581	.50	1468	.80
065	1561	.70	1457	.60
066	1773	.30	1613	.50
067	1485	.40	1591	.60
068	1633	.80	1596	.80
069	1630	.70	1241	.70
070	1512	.50	1465	.80
071	1655	.30	1396	.20
072	1801	.20	1834	.40
073	1489	.70	1342	.80
074	1163	.60	1359	.70
075	2115	.70	1676	.30
076	1397	.40	1421	.70
077	1539	.80	1161	.80
078	1260	.60	1295	.50
079	1519	.60	1496	.60
080	1498	.40	1332	.80
081	1306	.70	1459	.80
082	1395	.50	1526	.40
083	1418	.80	1492	.70
084	1471	.20	1528	.80
085	1500	.40	1182	.50
086	1394	.40	1465	.40
087	1669	.60	1483	.70

088	1407	.50	1339	.60
089	1390	.40	1735	.30
090	1589	.60	1596	.70
091	1597	.40	1750	.40
092	1695	.60	1412	.10
093	1140	.80	1667	.60
094	1539	.50	1273	.30
095	1451	.50	1721	.40
096	1317	.80	1544	.70
097	1851	.30	1331	.40
098	1991	.40	1819	.60
099	1925	.50	1842	.50
100	1384	.70	1628	.50

APPENDIX G: TRUST RATINGS & REACTION TIMES

Image	Original		Symmetric	
Id	Response Time	Trust Rating	Response Time	Trust Rating
001	1940	.92	1894	.69
002	2067	.69	2162	.42
003	2120	.67	2192	.77
004	1796	.38	2151	.25
005	2157	.67	1924	.62
006	1794	.77	1823	.58
007	2117	.50	2440	.46
008	1819	.15	2028	.25
009	1960	.58	1917	.62
010	1919	.38	1997	.33
011	1960	.69	1674	.64
012	1595	.27	2045	.31
013	1524	.92	1673	.73
014	1504	.36	1633	.38
015	1787	.31	1548	.18
016	1762	.45	1464	.38
017	1767	.46	2079	.18
018	1711	.36	1973	.15
019	1856	.38	1683	.64
020	1722	.45	2322	.31
021	1774	.62	1918	.55
022	1741	.08	1547	.23
023	1868	.62	1935	.42
024	2270	.67	2076	.62
025	2092	.54	1976	.58

026	2150	.42	2031	.69
027	1857	.92	1897	.75
028	1712	.33	2080	.31
029	1774	.62	2040	.33
030	2116	.17	1913	.46
031	2136	.62	2103	.50
032	1850	.50	1733	.54
033	1874	.15	1685	.58
034	2012	.58	1971	.62
035	1749	.54	2114	.50
036	1452	.64	2119	.69
037	1911	.08	1717	.55
038	1656	.45	2193	.69
039	1949	.77	1680	.55
040	1832	.36	1872	.31
041	1718	.31	2079	.18
042	1742	.55	1959	.54
043	2104	.62	1507	.64
044	1736	.82	1860	.77
045	2356	.15	1995	.36
046	1437	.27	1877	.69
047	1763	.77	1713	.73
048	1737	.27	2122	.54
049	1425	.23	2100	.64
050	2168	.33	2232	.77
051	1808	.31	1525	.17
052	1620	.17	1969	.08
053	1915	.31	2042	.58
054	1899	.50	2003	.46
055	2176	.69	2131	.50
056	1932	.17	1443	.15
057	2068	.15	2113	.33

058	2069	.50	1855	.69
059	1644	.08	2126	.17
060	2062	.25	1985	.23
061	2097	.62	2150	.58
062	1920	.83	1995	.69
063	1941	.69	2055	.50
064	1476	.36	1946	.62
065	2041	.54	1641	.55
066	1729	.27	1912	.69
067	1894	.38	1826	.36
068	1444	.18	1911	.31
069	1979	.38	1906	.64
070	1683	.45	2001	.54
071	1827	.69	1919	.91
072	1778	.45	1860	.31
073	1555	.46	1764	.55
074	1630	.27	1711	.15
075	2406	.23	1814	.27
076	1878	.18	1771	.15
077	1528	.17	1817	.15
078	1861	.23	1815	.33
079	2139	.50	1828	.62
080	1920	.62	2048	.50
081	1803	.33	2131	.46
082	1516	.31	2025	.17
083	2040	.33	1839	.62
084	1712	.54	1959	.67
085	1798	.42	1747	.69
086	1843	.46	1916	.17
087	1761	.25	1973	.23
088	1759	.23	1848	.33
089	2331	.54	2109	.73

090	1553	.27	1739	.08
091	1824	.38	1711	.55
092	1733	.36	1231	.23
093	1652	.15	1568	.45
094	1537	.27	1955	.31
095	2050	.23	2072	.55
096	1339	.27	1703	.15
097	2347	.23	1988	.82
098	1573	.45	1862	.69
099	1867	.31	1898	.73
100	1999	.36	2119	.46

APPENDIX H: EDINBURGH HANDEDNESS INVENTORY

The following table was adapted from Oldfield (1971).

Sol	Sağ	
		Yazma
		Çizme
		Atma
		Makas
		Diş Fırçası
		Bıçak (çatal olmadan, tek başına kullanırken)
		Kaşık
		Süpürge (üstte duran el)
		Kibrit Yakmak
		Kutu Kapağı Açmak
		Tekmelemek için hangi ayağı kullanırsınız?
		Sadece bir gözünüzü kullanırken hangisini kullanırsınız?

APPENDIX I: CONCENT FORM

Gönüllü Katılım Formu

Öncelikle katıldığınız için teşekkürler. Dr. Didem Gökçay danışmanlığında Gülsen Yıldırım tarafından yapılan bu çalışma, yüz algısıyla ilgilidir. Çalışmada insanların çeşitli yüz resimlerine nasıl tepki verdiklerini ölçüyoruz. Ekranda siyah-beyaz ve rötuşlanmış yüz resimleri göreceksiniz. Fotoğraflar Enformatik Enstitüsü'nde oluşturulmuş ODTÜ Yüz Veritabanı'ndan alınmıştır. Sizden istediğimiz, bir resme bakarken sizde ilk uyandırdığı etkiyi derecelendirmeniz. Çalışmaya katılım tamamıyla gönüllülük temelindedir. Kimliğinizle birlikte cevaplarınız tamamıyla gizli tutulacak ve sadece araştırmacılar tarafından değerlendirilecektir; elde edilecek bilgiler bilimsel yayımlarda kullanılacaktır.

Çalışmamız iki kısımdan oluşmaktadır. Ilk kısımda ekranda peş peşe yüz resimleri görünecektir. Her resim 4 sn boyunca görüntülenecek, ve bu süre içinde yüz ile ilgili değerlendirmenizi belirtmeniz beklenecektir. Deney yapısında bir önceki resme geri dönmek mümkün değildir. Bu nedenle eğer beş saniye içinde cevap vermediyseniz o resim değerlendirilmeyecek ve bir sonraki resme geçilecektir.

Çalışmanın ilk kısmında derecelendirmeyi şu soruya göre yapmanız istenmektedir: **"Yüzünü gördüğünüz kişi sizce güvenilir birisi midir?"** Güvenilmez olan bir kişi için A tuşuna, güvenilir olan bir kişi için ise L tuşuna basınız.

Ilk kısmın bitişinden sonra 10 dakikalık bir ara verilecektir. Çalışmanın ikinci kısmındaki değerlendirme süreci, size ikinci kısım başlamadan önce sözlü olarak belirtilecektir.

Lütfen her resmi çok fazla düşünmeden değerlendirin; resmi ilk gördüğünüzdeki tepkinize göre bir cevap vermeye çalışın.

Katılım sırasında sorulardan ya da herhangi başka bir nedenden ötürü kendinizi rahatsız hissederseniz, deneyi yarıda bırakıp çıkmakta serbestsiniz. Böyle bir durumda deneyi uygulayan kişiye, deneyi tamamlamayacağınızı söylemeniz yeterli olacaktır.

Çalışma ile ilgili daha fazla bilgi almak için Bilişsel Bilimler yüksek lisans öğrencisi Gülsen YILDIRIM ile iletişim kurabilirsiniz (email: gulsen@ii.metu.edu.tr tlf: 535 2821962).

Bu çalışmaya tamamen gönüllü olarak katılıyorum ve istediğim zaman yarıda kesip çıkabileceğimi biliyorum. Verdiğim bilgilerin bilimsel amaçlı yayımlarda kullanılmasını kabul ediyorum.

İsim Soyad

Yaş

Eğitim durumu

Kadın______ Erkek ________

Tarih

İmza

APPENDIX J: INFORMATION FORM

Katılım Sonrası Bilgi Formu

Yüz algılama ve tanıma insanlar için önemli bir sosyal ve bilişsel süreçtir. İnsanda yüz tanıma sürecinin obje tanıma süreçlerinden farklı olduğu, bütünsel olduğu, duruş, ışıklandırma, yüzün çekiciliği gibi özelliklerin belleği etkilediğine dair çalışmalar literatürde mevcuttur.

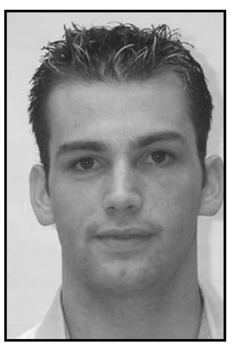
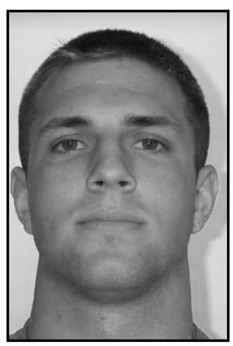
Bu çalışmada yüzdeki simetrinin ve çekiciliğin hatırlanma üzerindeki etkisi incelenmektedir. Bu nedenle bitirmiş olduğunuz deneyde, size gösterilen yüzlerin bir kısmı orijinal fotoğraflardan, bir kısmı ise simetrik hale getirilecek şekilde rötuşlanmış fotoğraflardan oluşmaktadır.

Simetrik yüzlerin daha az bilgi taşıdıkları ve taşınan bilgi miktarının hatırlamayı etkilediği bilinmektedir. Bu nedenle, daha az bilgi taşıyan simetrik yüzlerin daha az hatırlanacağı öngörülmektedir. Öte yandan, çekicilik ve simetri arasındaki ilişki daha önce araştırılmış olup, simetrik yüzlerin daha çekici bulunduğu tespit edilmiştir. Bu şekilde yaklaşıldığında, çekici yüzlerin, daha az bilgi taşısalar bile, daha çok hatırlanması beklenebilir. Çalışmamız sonrasında, daha fazla bilgi içeren orijinal yüzlerin mi daha çok hatırlandığı, yoksa daha az bilgi içerse de simetri ve çekicilik oranı daha yüksek olan yüzlerin mi daha çok hatırlandığı sorusu çözümlenecektir. Bunun için, görmüş olduğunuz her fotografın simetri değeri ve çekicilik değeri önceden tarafımızdan hesaplanmış bulunmaktadır. Bu değerler ile hatırlanma oranları karşılaştırılarak yüz tanıma belleğinde asimetrinin mi yoksa çekiciliğin mi daha etkin olduğu belirlenebilecektir.

Izlemiş olduğunuz fotoğraflara dair yorumlarınız varsa, bizimle paylaşırsanız seviniriz.

APPENDIX K: FACE DATABASE OF THE UNIVERSITY OF TEXAS AT DALLAS

The images below are taken form face database of The University of Texas at Dallas (Minear and Park, 2004). The images were downloaded and authorization was taken from the authors via email and registration submission form. 10 samples (5 male and 5 female) were presented in the trial procedure of both learning and recognition tasks. The samples below are given in order to prove that the faces are captured in a non-standard front view and they also include both facial and personal features such as hair, clothes, make-up etc.

APPENDIX L: PILOT EXPERIMENT FOR RECOGNITION TASK

Three classical recognition memory experiments were carried out to identify the effect of parameters in recognition performance:

- Experiment 1: 20 face images were presented in the study phase and 40 faces were administered in test phase. The question given to study the image in the former phase was ”Is it a Man or Woman?”
- Experiment 2: By changing the number of images to be remembered, 60 face images were presented in the study phase and 120 faces were administered in test phase. The question given to study the image in the former phase was still”Is it a Man or Woman?”
- Experiment 3: This group was examined to see the effect of study question on recognition performance. Number of images to be remembered did not change: 60 face images were presented in the study phase and 120 faces were administered in test phase. For this group, the question given to study the image in the former phase was ”Is the face in the image trustworthy?”.

For all of the experiments, face database of The University of Texas at Dallas (Minear and Park, 2004) was used. 9 participants were attended to each experiment. A resting interval of 10 minutes was allowed between the study and test phases.

According to the results, both the number of stimuli and the study question affected recognition performance. Best recognition performance was obtained in experiment 3. 60 faces with a more concentration demanding study question influenced the best recognition performance.

The means for the recognition performances in each experiment are given in the following figure.