THE ROLE OF SYMMETRY AND FACIAL EXPRESSIONS OF EMOTIONS IN EVALUATION OF ATTRACTIVENESS AND PERCEIVED SYMMETRY: AN EYE TRACKING STUDY

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ABSTRACT

THE ROLE OF SYMMETRY AND FACIAL EXPRESSIONS OF EMOTIONS IN EVALUATION OF ATTRACTIVENESS AND PERCEIVED SYMMETRY: AN EYE TRACKING STUDY

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In social interaction, faces convey plenty of information such as gender, age, attractiveness and expressions of emotions. Amongst these cues, attractiveness and facial expressions of emotions are considered more substantial, since processing and evaluation of such information rapidly has adaptive relevance in order to avoid or approach. One of the indicators of attractiveness, symmetry, is preferred by many species and it is known that symmetrical faces are rated as more attractive by humans. Moreover, facial expressions of emotions contribute to attractiveness judgements. The aim of the current study is to investigate attractiveness and perceived symmetry judgements for symmetric or original (asymmetric) facial expressions while physiological responses are collected through an eye-tracking system. We used a subset of expressions and images from the Karolinska Directed Emotional Faces (KDEF) as stimuli. The experimental conditions consisted of original and bi-laterally symmetric forms of face images. Three facial expressions are chosen from the KDEF with neutral, highly arousing positive (surprise) and highly arousing negative (angry) facial expressions. The subjects are asked to evaluate the face images in two phases: phase I consisted of attractiveness judgement and phase II consisted of symmetry judgement, both on a 9 point Likert scale. During experimentation, The TOBII T120 eye tracker that has pupillary response collection ability is used to facilitate interpretation of fixation duration as well as pupil diameter responses in terms of cognitive load, attention, and arousal. In this study, when the subjects judged attractiveness, the finding that symmetrical images are rated as more attractive is replicated. Moreover, we found that fixation durations to symmetrical images are longer while pupil diameters are smaller with respect to their original counterparts. Since, longer fixation durations are related with attention, and focused attention constricts pupil, we conclude that symmetrical faces capture attention during judgement of attractiveness. While considering emotions, neutral facial expressions were rated as more attractive than angry and surprised facial expressions. Furthermore, fixation durations and pupillary diameters are observed to be longer and bigger for highly arousing affective stimuli. These findings implicate that the survival value of the stimuli (i.e. arousal) play an important part in initiating physiological responses during attractiveness judgement. Physiological responses did not differ when subjects were asked to judge symmetry of the facial stimulus instead of their attractiveness leading into a conclusion that attractiveness judgements involve cognitive processes that interact with emotion compared to symmetry judgements, while symmetry judgements are limited to automatic processes. To the best of our knowledge this is the first study that investigates subjective judgments of faces under different symmetry and facial expression conditions along with physiological responses such as eye fixation duration and pupillary response.

Keywords: facial expression, attractiveness, symmetry, pupillary response, fixation

ÖZ

ÇEKİCİLİĞİN VE ALGILANAN SİMETRİNİN DEĞERLENDİRİLMESİNDE SİMETRİNİN VE YÜZ İFADELERİNİN ROLÜ: GÖZ İZLEME ÇALIŞMASI

Hepsomalı, Pırıl
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Sosyal etkileşimde yüzler, cinsiyet, yaş, çekicilik ve duyguların ifadesi gibi birçok bilgi taşır. Bu ipuçları arasından, çekicilik ve duyguların yüzsel ifadesi, bu bilgilerin adaptif öneminden ötürü daha hızlı işlenip değerlendirdikleri için daha yaşamsal olarak nitelendirilir. Çekiciliğin göstergelerinden biri olan simetri, birçok tür tarafından tercih edilir ve simetrik yüzler insanlar tarafından daha çekici olarak değerlendirilir. Bununla birlikte, duyguların yüzsel ifadeleri çekicilik değerlendirmelerine katkıda bulunur. Halihazırdaki araştırmanın amacı, çekiciliğin ve algılanan simetrinin değerlendirilmesinde simetrik ve orijinal yüz ifadelerinin rolünün, fizyolojik tepki toplayarak, göz izleme sistemi kullanarak incelenmesidir. Çalışmada Karolinska Directed Emotional Faces (KDEF) veri tabanından seçilen imajlar uyarıcı olarak kullanımıştır. Deneysel koşullar, imajların orijinal ve bilateral simetrik formlarının değerlendirilmesinden oluşur. KDEF'ten üç yüz ifadesi, nötr, yüksek uyarıcı pozitif (şaşkın) ve yüksek uyarıcı negatif (kızgın) olacak şekilde seçilmiştir. Katılımcılardan yüz imajlarını iki aşamada 9'lu Likert tipi ölçekte değerlendirmeleri istenmiştir: aşama I çekicilik değerlendirmesini ve aşama II simetri değerlendirmesini içerir. Deney sırasında fiksasyon süresini ve gözbebeği çapınının bilişsel yük, dikkat ve uyarılma açısından yorumlanması için göz bebeği tepkisi toplayabilen TOBII T120 göz izleme cihazı kullanılmıştır. Bu tez, katılımcıların çekicililik değerlendirmesi esnasında simetrik imajların daha çekici olarak değerlendirildiği bulgusunu replike etmiştir. Ek olarak, simetrik imajlara yapılan fiksasyon süresi uzun iken, gözbebeği çaplarının orijinal eşlerine oranla küçük olduğu bulunmuştur. Uzun fiksasyon süreleri dikkatle ilişkili olduğu için ve odaklanmış dikkat gözbebeğini küçülttüğü için, simetrik yüzlerin çekicilik değerlendirmesi sırasında dikkati yakaladığını söyleyebiliriz. Duyguları hesaba kattığımızda, nötr yüz ifadeleri, şaşkın ve kızgın yüz ifadelerinden daha fazla çekici olarak değerlendirmiştir. Ayrıca, yüksek uyaran afektif uyarıcılara yönelik fiksasyon süresi uzun ve gözbebeği çapı büyük bulunmuştur. Bu bulgular uyarıcının yaşam-kalımsal değerinin (uyarıcı) çekicilik değerlendirmesi esnasında fizyolojik tepki başlatmada önemli bir rol aldığını işaret eder. Fizyolojik tepkilerin, simetri değerlendirirken ortaya çıkmaması, simetri değerlendirmesinin otomatik işlemlemesine karşın, çekicilik değerlendirmesinde duyguyla etkileşime giren bilişsel süreçlerin varlığına işarettir. Bilgimiz dahilinde, bu çalışma, farklı simetri ve yüz ifadeleri koşullarında, yüzlerin öznel değerlendirilmesini, fiksasyon süresi ve gözbebeği tepkisi gibi fizyolojik tepkilerle beraber inceleyen ilk çalışmadır.

Anahtar Kelimeler: yüz ifadesi, çekicilik, simetri, gözbebeği tepkisi, fiksasyon

To Zoltan and My Grandmother

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CHAPTER 1

INTRODUCTION

In a visual environment, one cannot explore and attend to all the details simultaneously. At first, all related stimuli in the visual environment undergo a prioritization process according to criteria such as importance, emotional significance or survival value, as selection prosecutes antecedent prioritization.

Beside aforementioned criteria, numerous scientists from different backgrounds showed that faces are the most important stimulus in the prioritization process both in humans and non-human primates as well as their infants. The reasons behind this empirical fact are as follows: faces are perceived and processed (1) regularly and without an effort (automatically/pre-attentively) in our daily lives (Öhman, 2002), (2) differently from other non-face objects (Little et al., 2011) and (3) with a predisposed manner (e.g. one can see face-like patterns in non-face objects like houses, USB cables, sockets, cars and etc. (see Figure 1 in Little et al., 2011)).

Importance of faces is not limited to these arguments. Faces also convey information about attractiveness and emotions which carry various cues that shape our judgements. In other words, the perception of attractiveness and emotion provides fundamental social information that guides social interactions between individuals.

The first of these factors that influence our judgements, attractiveness, has been widely studied in evolutionary context. Although there are many forms, outcomes and indicators of attractiveness, symmetry is the most widely studied feature. Since symmetry is found to be an indicator of genetic quality, developmental stability, and hereby health, researchers replicate the findings that symmetrical bodies and faces are found to be more attractive, approachable and healthy than original ones.

Emotion is another factor that has an impact in our judgements which has been studied widely in different cultures and species. Through facial expressions one can express many things that cannot be expressed by language. In fact, language acquisition originates later than spontaneous production of facial expressions since emotions are conveyed more accurately, rapidly and effectively by facial expressions rather than by word (Bates & Cleese, 2001). One can say that these two factors influence each other because social interactions frequently involve demonstration of facial expressions of emotions (Ekman, 2003), and it is steered by attractiveness judgments (Reis et al., 1982). Earlier studies found a positive effect of happy face stimulus on female attractiveness (Penton-Voak & Chang, 2008) but a systematic investigation of how distinct facial expressions of emotions influence attractiveness judgement is lacking.

The common point about the preferences for faces, facial expressions of emotions and symmetrical faces is that they are all culture-independent and they have similar impacts in both humans and non-human primates. Thus, the preference for faces, facial expressions of emotions and symmetrical faces may reflect common psychological mechanisms that have evolutionary roots. Hence, the rapid, mandatory, and effortless processing of faces, facial expressions of emotions and symmetrical faces may underlie similar biological significance.

Visual exploration involves a series of saccadic eye movements, fixations and pupillary response fluctuations. During prioritization process, eye movements and pupillary responses are found to be important indicators of attention to the stimulus since they reflect reactions of the nervous system. Especially, longer fixation durations and bigger pupil diameters are associated with increasing attention, interest and arousal (Beatty, 1982; Beatty & Lucero-Wagoner, 2000; Bradley et al. 2008). As biologically important stimulus is selected in the prioritization process, changes in fixation durations and pupil diameters might occur in response to increasing attention, interest and arousal for that stimulus.

In the current thesis, effects of symmetry and emotions in faces are investigated with the help of subjective judgements (i.e. attractiveness and perceived symmetry), eye movements (i.e. fixation durations) and pupillary responses (i.e. dilation and constriction). It is hypothesised that there may be significant differences between symmetrical and affective faces in terms of subjective judgements, eye movements and pupillary responses.

Remainder of the current thesis comprises of five chapters. In chapter 2, literature review includes introduction to face and emotion perception and their neural correlates, an evolutionary view of attractiveness and symmetry, brief information of the structure of the eye and its movements, compilation of relevant literature as well as motivations for the thesis. The subsequent section, chapter 3, covers the stimuli and preparation of the stimuli, and methods. Results of the experiments as well as limitations of the study are presented in chapter 4. In the chapter 5, results are interpreted and discussed in a comprehensive manner. Finally, chapter 6, presents a concise conclusion.

CHAPTER 2

LITERATURE REVIEW

This chapter comprises of five sections in which relevant aspects of the literature in faces, facial expressions of emotions, attractiveness, symmetry, eye/pupil movements and measurements are presented. In the first section, developmental, comparative and cognitive aspects and neural correlates of face and emotion perception are reviewed. Then, a brief background on the types and outcomes of attractiveness and symmetry are given with respect to evolutionary theory. In the third part, all aspects of eye and eye tracking are discussed including eye movements, pupillary responses. This part is followed by a compilation of fixation duration and pupillary response studies in face and affect research. Motivation for the initiation of this thesis, research questions and hypotheses are indicated in the last part.

2.1. Face and Facial Expression Perception

2.1.1. Face Perception: Developmental, Comparative and Cognitive Aspects

Face perception and recognition have long been studied in various populations with different methods. In other words, there exists innumerable work in this field with humans, non-human primates and their infants using behavioural, lesion, neuroimaging, and electrophysiological techniques. These studies improve the theoretical knowledge about face perception and recognition in cognitive, evolutionary, and developmental psychology; cognitive neuroscience and cognitive science fields.

In his comprehensive review, Nelson (2001) stated that face perception and recognition (1) emerges during early months of life, even after few hours of birth, (2) have a right hemisphere bias (3) are different from object perception and recognition, (4) develop simultaneously with facial expression perception and recognition, and (5) lesions to the regions that are responsible face recognition leads long-term deficiencies.

In developmental field, numerous studies found that infants prefer to look at faces starting from very early days. Thus, researchers stated that infants have an innate predisposition to perceive and recognize faces (Nelson, 2001). It is important for an infant to recognize potential caretakers and/or emotional signals carried by the face due to its adaptive significance (Nelson, 2001). According to Parr's (2011) review, new-born babies look more on face-like patterns such as three dots in an inverted triangular form than non-face-like patterns. It is reported that even 30 minutes old human infants track a moving face farther than other moving patterns consisting of comparable contrast, complexity, symmetry (Johnson et al, 1991). Nelson (2001) stated that faces are seen as a distinct form of objects within the first 6 months and expectedly, the neural systems that underlie face recognition are also formed in this period of time.

Comparative studies suggested that in non-human primates medium of communication depends on face perception and recognition due to lack of language. Hence, monkeys are competent in not only face recognition but also emotion recognition (Nelson, 2001). In Pascalis et al.'s (1999) study, it is found that many species of monkeys have an own-species bias. In other words, they can distinguish and recognize members of their own species (Nelson, 2001). New-born Japanese macaques (*Macaca fuscata*) prefer to look at face-like dot patterns, 13-days-old infant gibbons (*Hylobates agilis*) look at face-like drawings and 4-weeks-old gibbons look at familiar faces more (Parr, 2011).

Experiments on face perception within cognitive psychology and science domains reveal two effects: face superiority and face inversion. In *face superiority effect,* face parts are found to be perceived better when they are presented in their normal orientations whereas perception is disrupted when face parts are scrambled (Purcell and Stewart, 1988). On the other hand, in *face inversion effect,* faces in an inverted orientation are harder to recognize than inverted objects (for a review, Valentine, 1988). These two effects prove that faces and objects are processed in a different manner. Furthermore, face perception and recognition are somewhat special compared to object perception and recognition. Thus, researchers conclude that faces are exceptional and superior in terms of their processing.

2.1.2. Neural Correlates of Face Perception

Face perception and recognition research in neuroscience began with a syndrome called *prosopagnosia.* In Nelson's (2001) review it is reported that patient L.H. is impaired in recognizing faces but his object perception is intact. In contrast, Patient C.K. is impaired in object recognition but intact in face processing. These examples suggest that face and object perception could be dissociated. It is reported, either a bilateral lesion in ventral occipitotemporal cortex or a unilateral lesion in the right occipitotemporal cortex and causes an impaired recognition of faces but not objects (Damasio, 1982).

Single cell recordings in monkeys follow lesion studies. Face-responsive cells are found in several areas of the temporal lobe, particularly the temporal polysensory area (the superior TPO), areas TEa and TEm of the inferior temporal (IT) cortex and along the ventral bank of the superior temporal sulcus (STS) (Baylis et al., 1987). In Figure 1, a meta-analysis by Tsao et al. (2006) shows the location of face responsive cells. They reported that at the location of the black circle, 500 face cells were encountered (Tsao & Livingstone, 2008).

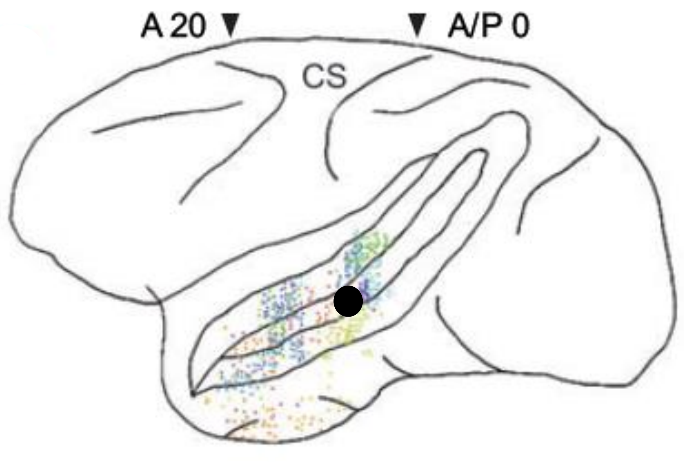

Figure 1. Face responsive cells (Tsao & Livingstone, 2008)

Face cells comprise up to 20 per cent of the cells in the anterior STS (Baylis et al 1987). Usually, face cells respond to intact faces and they are not responsive for features of the faces alone (Tsao & Livingstone, 2008). There is slight counterevidence about the response of face-cells to non-face objects or arrays of face parts (Figure 2). Few studies report that face cells respond to non-face objects, exhibiting less amount of signal in comparison to their response for faces (Farah, 2000). According to Farah (2000), face cells are distinctive, because, while monkeys recognize food, cages, other laboratory apparatus, no area has been found with 20 per cent of the cells responding selectively to any of these objects.

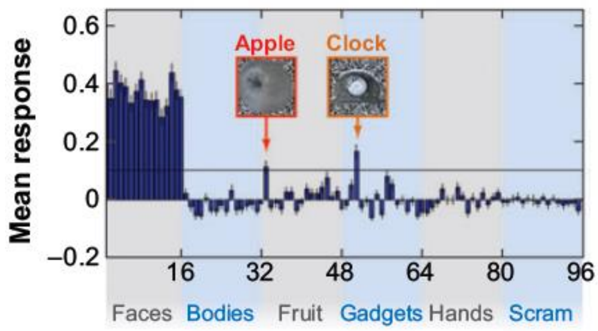

Figure 2. Cell response to each image in STS (Tsao & Livingstone, 2008)

In addition to IT and STS, Farah (2000) reported that a nucleus in the amygdala is face responsive whereas other nuclei respond to facial expressions of emotion. She concludes that since IT and STS project to lateral nucleus in amygdala, different regions of IT and STS and amygdala might work together.

In EEG studies, event-related potentials (ERP) are shown to contain negative face-specific responses at T5 and T6 sites approximately around 170 ms (N170). In a series of studies, Bentin et al. (1996) found that ERPs in T5 and T6 are (1) sensitive to face stimuli (2) robust for faces than cars, butterflies, hands and monkey faces, (3) robust for both upright and inverted faces, (4) not sensitive to other body parts, and (5) not sensitive to distorted faces (Figure 3). Similarly, Haxby et al. (2000) reported face specific potentials of N200 and N700 on ventral occipitotemporal and lateral temporal cortex bilaterally.

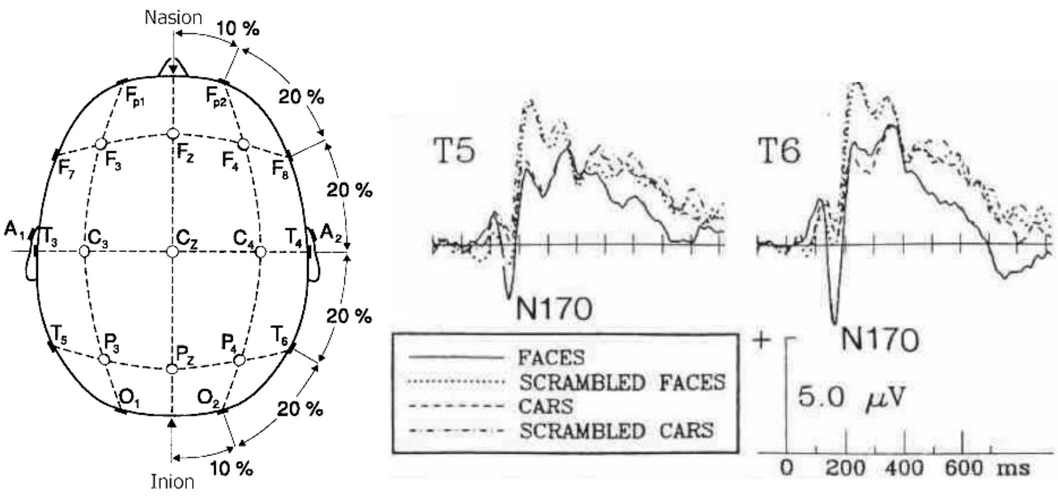

Figure 3. ERPs elicited by different kind of objects and faces for electrodes placed in temporal lobe location of T5 & T6 (adapted from Bentin et al., 1996)

Recent functional neuroimaging studies accelerated and revealed remarkable results about face perception and recognition. Atkinson & Adolphs (2011) stated that brain regions of face processing are distributed, differentiating higher level perceptions (judging identity, emotion from faces) from lower level perceptions (discriminating faces from objects). Occipital face area (OFA) is activated when higher level perceptions are in progress. Higher level face perception reflects a complex interplay between different brain regions. The strongest face selective activation is found on the lateral side of the right mid-fusiform gyrus, the fusiform face area (FFA). Also superior temporal sulcus (STS) and the occipital face area (OFA) are found to be activated in response to faces (Tsao and Livingstone, 2008).

Kanwisher and her colleagues (1997) found that right fusiform gyrus (FFA) is responsive to the faces compared to non-face objects such as objects, houses, scrambled faces and so on. In their review, Tsao and Livingstone (2008) added that FFA is activated when faces are compared to letter strings and textures, flowers, objects, houses, hands and activation is still preserved even in the front and profile photographs of line drawings of faces, animal faces, upright Mooney faces and face-vase illusion.

However, it is found that FFA not only responds to faces but also non-face objects. In line with these findings, *expertise hypothesis* and *distributed coding hypothesis* try to explain non-face BOLD increase in FFA. *Expertise hypothesis* suggests that the FFA is found to be activated while processing stimuli for which we have attained expertise

(Gauthier, 1997). *Distributed coding hypothesis* challenges modular processing of faces and suggests that faces are processed in a distributed manner (Tsao & Livingstone, 2008). All aforementioned neuroscientific studies helped Haxby to build up a model that is a follower and supporter of distributed coding hypothesis (Figure4).

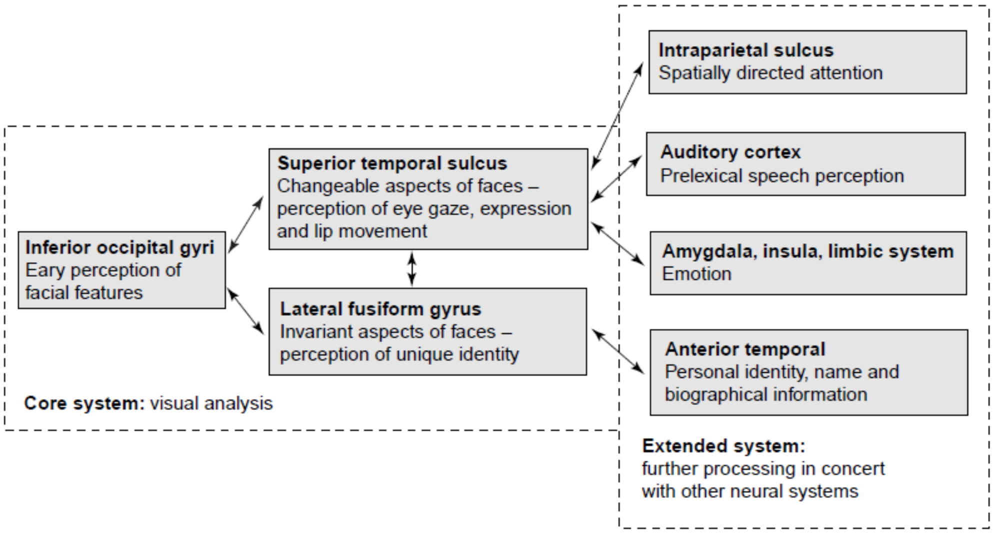

Figure 4. Haxby's model for face perception (Haxby et al., 2000, p.230)

According to Haxby et al. (2000), the representation of invariant and changeable aspects of faces subserves different mechanisms: recognition of individuals and perception of information that facilitates social communication, respectively. Haxby's model is composed of two systems: core and extended. The core system is responsible for visual analysis, while the extended system performs further processing of stimuli. The core system is composed of three bilateral regions in occipitotemporal visual extrastriate cortex namely the inferior occipital gyri, the lateral fusiform gyrus, and the superior temporal sulcus. Inferior occipital gyri are responsible for early perception. Additionally, lateral fusiform gyrus is responsible for representation of identity whereas superior temporal sulcus is responsible for representation of changeable aspects of faces. It is also found that inferior occipital gyrus provide inputs to both the lateral fusiform and superior temporal sulcal regions. In the extended system, superior temporal sulcus has connections with intraparietal sulcus, auditory cortex, and the limbic system. Meanwhile lateral fusiform gyrus only sends signals to anterior temporal sites.

2.1.3. Facial Expression Perception

According to Adolphs (2002) "Neurobiologists and psychologists alike have conceptualized emotion as a concerted, generally adaptive, phasic change in multiple physiological systems (including both somatic and neural components) in response to the value of a stimulus." (p.24). Although there are different ways to classify emotions through behavioural states, motivational states, and moods, the best known and studied types of emotions are basic emotions (see Figure 5 for a classification of emotions). Basic emotions include happiness, fear, anger, disgust, sadness and surprise. These emotions and alter the somatic system and endocrine, visceral, autonomic, and musculoskeletal changes occur as a consequence (Adolphs, 2002).

Behavioral State	*Motivational State*	*Moods, Background Emotion*	*Emotion System*	*Basic Emotion*	*Social Emotion*
Approach	Reward	Depression	Seeking	Happiness	Pride
Withdrawal	Punishment	Anxiety	Panic	Fear	Embarrassment
		Mania	Rage	Anger	Guilt
	Thirst		Fear	Disgust	Shame
	Hunger	Cheerfulness		Sadness	Maternal love
	Pain	Contentment		Surprise	Sexual love
	Craving	Worry		Contempt	Infatuation
					Admiration
					Jealousy

Figure 5. Categorization of emotions (Adolphs, 2002)

Emotions externalize themselves in very different ways and modalities but facial expressions are the most used and encountered medium of emotional expressions in humans and non-human primates. "Facial expressions […] considered as aspects both of an emotional response and of social communication. These dual aspects generally occur together in shaping a facial expression." (Adolphs, 2002 p.23).

Researchers have not yet arrived at a consensus about the structure of the emotion categories. In other words, some researchers indicate that emotions are discrete units whereas others suggest that emotions can be mapped onto a continuum. Adolphs (2002) stated that in a study by Bimler and Kirkland, facial expressions of emotions were averaged and put on a multidimensional scale (see Figure 6). All dots represent a photograph of visual expression of emotion and as dots get distant, their similarity diminished. In the figure there is a circular and clustering pattern of emotions and there might be two axes of valence and arousal that represent categorization of emotions. Although facial expressions of emotions are clustered in a discrete manner, there are also overlaps between some emotions.

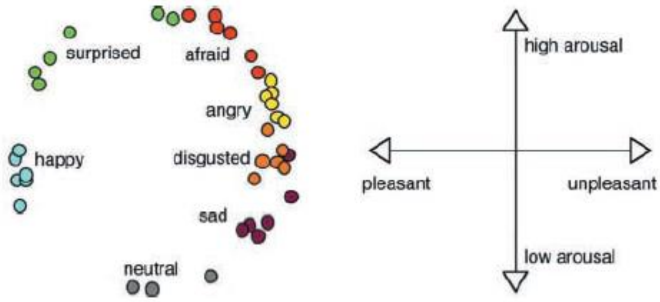

Figure 6. Dimensional structure of emotions

In addition to dimensionality, basic emotions are hierarchically related (Adolphs, 2002). Healthy participants categorize the intensity of facial expressions of basic emotions into not only superordinate categories (e.g. happy and unhappy) but also subordinate categories. However, patient B. who has a bilateral lesion in temporal cortices could categorize superordinate levels but fails to categorize subordinate levels (see figure 7) such that patient B. is able to categorize only happy and sad expressions but not other expressions. Also, the borders of emotions are apparent for healthy participants whereas these borders are vaguely recognised by patient B.

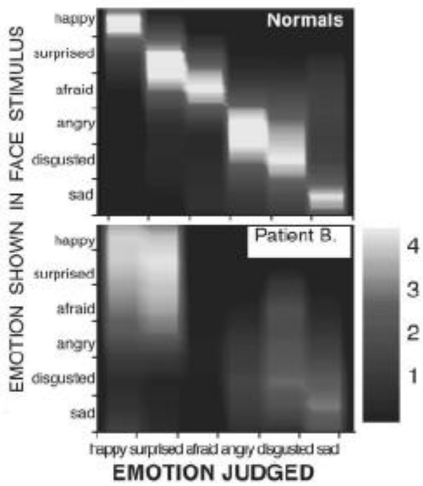

Figure 7. Hierarchical organizations of emotions

Amongst properties of emotions such as its reflections (e.g. facial expressions), dimensions and hierarchical organizations, the most important one is its relationship with culture. In 1871, Charles Darwin reported in his famous book "*Expressions of the Emotions in Man and Animals*" that mammals have facial expressions of emotions and these expressions have an adaptive value since they reflect the inner state of the owner of that facial expression (Buck & VanLear, 2002). Unlike Darwin, other scientists think that facial expressions of emotions are not an adaptation but a by-product of the culture. This view was falsified by several studies of Paul Ekman and comparative studies. In one of his studies, Ekman (1971) gathered data about facial expressions of emotions in an isolated community in New Guinea. He tells various stories that induce emotions and asks participants to select appropriate facial expressions in cards. Results reveal that facial expressions of emotions are accurately identified not only in Western population but also in an isolated community like Guineans. In other words, they found that facial expressions of emotions are culture-independent. On the other hand, recent research underlies the influence of culture beside universality of emotions. Experience, expression and recognition of emotions are found to be affected by individual and culture (e.g. Tsai, Knutson, & Fung, 2006). So, researchers have not yet arrived at a consensus on the role of culture in recognition of facial expressions. Other comparative studies showed that there is a homology in facial expressions. In other words, non-human animals and humans share similar facial expressions in reaction to same emotions (Schmidt & Cohn, 2001).

2.1.4. Neural Correlates of Facial Expression Perception

Perception and recognition of facial expressions of emotion is widely distributed over (1) visual and temporal cortices, (2) limbic system (e.g. amygdala), (3) orbitofrontal, and (4) frontoparietal cortices.

Within the visual and temporal cortices, superior temporal sulcus, fusiform gyrus and inferior occipital cortex are responsive to facial expressions of emotions. The superior temporal sulcus responds more to facial expressions of emotion than neutral facial expressions. Also this region contains distributed representations of facial expressions (Said et al., 2011).

Processing of facial expressions of emotions in the amygdala comprises of both cortical and subcortical routes. Subcortical route involves the superior colliculus and the pulvinar thalamus whereas cortical route involves visual cortex. Bilateral amygdala damage causes deficits in recognition of facial expressions of emotion, especially for fear (Adolphs, 2002). In line with this finding, fMRI studies found that amygdala is responsive to facial expressions of fear more than other facial expressions of emotions (Adolphs, 2002).

Damage to the orbitofrontal cortex may result in an impairment of recognition of facial expressions of emotions. Especially, recognition of anger but not sadness increases the BOLD responses in orbitofrontal and anterior cingulate cortex (Adolphs, 2002).

In the frontoparietal cortices, frontal operculum (FO), premotor cortex and somatosensory cortex respond to faces (Said et al., 2011). Said et al. (2011) added that "transcranial magnetic stimulation (TMS) of the nearby right somatosensory cortex disrupts the perception of facial expressions, but not identity" (p. 1663)

A study by Adolphs (2000) found that lesions in the right ventral primary and secondary somatosensory areas, insula and anterior supramarginal gyrus disrupt emotion recognition. They interpret these findings as "knowledge of other people's emotions may rely on simulating the observed emotion"(Adolphs, 2000, p.3).

Adolphs (2000) amass these findings and proposed a model for recognition of facial expressions of emotion (Figure 8). In this model, there are 3 phases: early perception, detailed perception and bodily reactions, and conceptual knowledge. The first two phases correspond to core and extended systems in the Haxby's model. First phase begins after 120 ms of the stimulus onset and affects both subcortical (superior colliculus and pulvinar thalamus) and cortical structures (striate cortex). Information from the pulvinar thalamus feeds into early processing within amygdala. LGN sends signals to striate cortex. At nearly 170 ms visual cortices feed both STG and FFA. Then FFA sends signals to not only amygdala but also orbitofrontal cortex. They modulate brainstem and cause bodily reactions. At the third phase, body sends signals to somatosensory cortex around 300 ms. Orbitofrontal cortex sends input to somatosensory cortex within the insula and to the FFA.

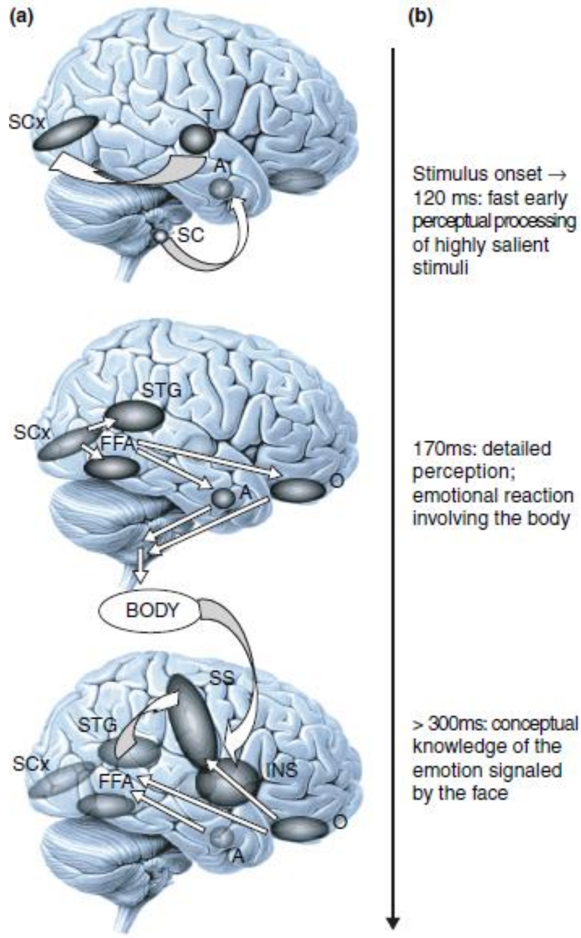

Figure 8. Neural substrates of facial expression perception Adolphs (2002)

2.2. Attractiveness and symmetry: an evolutionary view

2.2.1. Attractiveness

Attractiveness judgment of faces is a central issue not only in the literature but also in our everyday life since it influences our mate, date, employer, and vote choices (see Jones et al., 2003 for a review).

As Rhodes (2006) stated, there are different kinds of attractiveness including sexual attractiveness, attractiveness as a potential confederate and cuteness, each stemming from different affective and motivational states. Sexual arousal, competitiveness and caregiving create personal dispositions regarding types of attractiveness judgements. However, researchers are mainly dealing with sexual attractiveness/sexual arousal aspect of attractiveness because it is thought to be an indicator of good physical and mental health, positive trait (e.g. extraversion…etc.), with high mate and survival value.

For many years, attractiveness is thought to be in the eye of the beholder and it is assumed to be culture-bounded. However, evidence from developmental and comparative studies suggests that judgment of facial attractiveness is culture-independent. Different studies replicated the findings that, infants prefer to look at more on attractive faces before the possible development on culture concept (Langlois et al., 1991). Additionally, people from different cultures, social classes, ages and sexes agree on attractiveness judgments (Rhodes, 2006; Fink, Penton- Voak, 2002). Aforementioned researches reject the culture-dependency of attractiveness.

There exist several cues that signal facial attractiveness such as averageness, symmetry and sexual dimorphism. Facial attractiveness judgments are influenced by these major cues. Besides, a pleasant expression, good grooming, and youthfulness may have an effect on attractiveness judgments (see Rhodes, 2006 for a review). Recent studies suggest that hormone markers and menstrual cycle also affect the evaluation of facial attractiveness (Fink, Penton- Voak, 2002).

Attractive faces activate reward centres in the brain (Rhodes, 2006). A study by Cloutier and his colleagues (2008) examined brain regions regarding attractiveness and found that the putative reward circuitry (e.g., nucleus accumbens, orbito-frontal cortex) show increased activation with increased judgments of attractiveness (Figure 9).

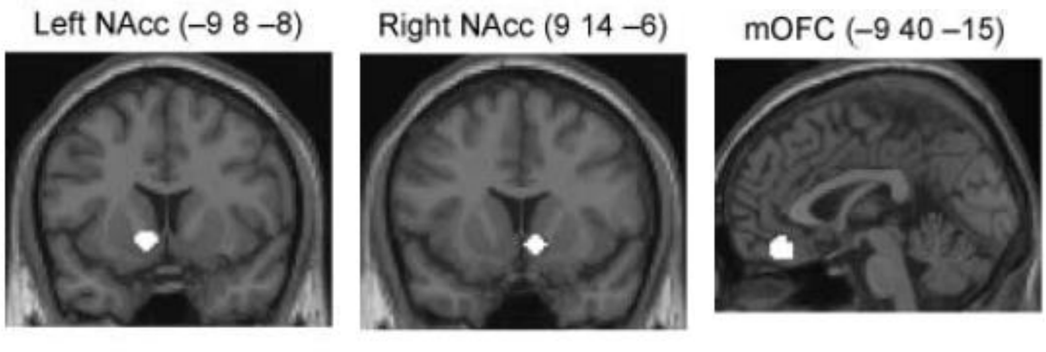

Figure 9. Activations in nucleus accumbens and medial orbito-frontal cortex while viewing attractive faces (Cloutier et al., 2008)

Specifically, activation increases in the medial orbito-frontal cortex (mOFC), nucleus accumbens (NAcc), medial prefrontal cortex (MPFC) and anterior cingulate cortex (ACC) as a result of increased attractiveness judgments. Activation in the ACC might reflect the autonomic arousal since ACC is involved in generation and monitoring autonomic states (Cloutier et al., 2008).

2.2.2. Symmetry

Symmetry has long been studied by different branches of science such as mathematics, physics, chemistry, biology, philosophy, art and psychology. According to Hon and Goldstein (2008)

> "Its [symmetry's] usage can be distinguished by the contexts in which it was invoked: (1) in a mathematical context it means that two quantities share a common measure (i.e. they are commensurable), and (2) in an evaluative context (e.g., appraising the beautiful), it means well proportioned. [...] The coherence of these two trajectories corresponds to two distinct senses of the concept of symmetry: (1) a relation between two entities, and (2) a property of a unified whole, respectively. (p.2)"

Despite having equivocal definitions, basic types of symmetry are incontrovertible such as *mirror* (reflection), *rotational* and *translational* symmetry (Figure 10). Also, in biology, there are three kind of symmetry: *radial, bilateral and spherical* (Figure 11). In the context of this thesis, the symmetry term will be used to denote bilateral symmetry since human body and face denotes this kind of symmetry.

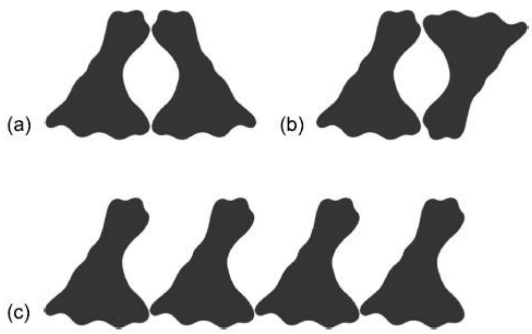

Figure 10. Forms of symmetry; (a) mirror symmetry (b) rotational symmetry (c) translational symmetry (Sawada, 2010)

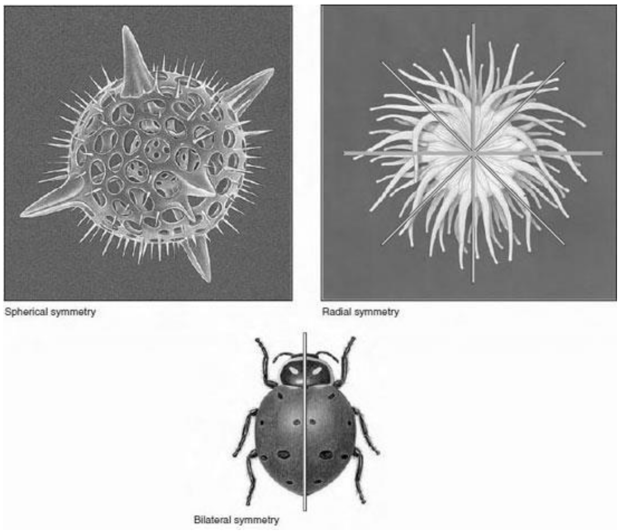

Figure 11. Forms of biological symmetry in animals
(Left) spherical symmetry (Right) radial symmetry (Bottom) bilateral symmetry

The deviation from perfect symmetry is called asymmetry and it is measured by the right minus the left value of the bilaterally paired trait. Asymmetry could be grouped into three types such as *directional asymmetry, fluctuating asymmetry and antisymmetry*.

Directional asymmetry (DS) occurs when one trait is larger in one side than the other side. The mammalian heart is a good example for directional symmetry (Van Valen, 1962). F*luctuation asymmetry* (FA) occurs when a trait deviates randomly from perfect symmetry in and its mean show a nearly normal distribution around zero (Tomkins & Kotiaho, 2001). *Antisymmetry* (AS) refers to a variable development in one side of the trait.

FA is not only a minor developmental error but also a marker of developmental instability (DI) which indicates capability for sustaining good health (Gangestad & Simpson, 2000). In non-human animals genetic anomalies (inbreeding, hybridization, homozygosity, mutations) and environmental stress (temperature, food quality and quantity, pollutants and parasitism) that are experienced during development are revealed by DI. In humans FA and accordingly DI increases with inbreeding, premature birth, psychosis, and mental retardation (Livshits & Kobylianski 1991). Møller (1999) argued that FA has a relationship with stress and having a low FA or fully symmetrical traits relate to fitness, health and quality of that individual (i.e. reproductive success). Thus, one can conclude that having a low FA and a high developmental stability might be a marker of phenotypic and genotypic quality of an individual.

Since FA relates to DI, one can say that symmetry relates to developmental stability and health. As evidence to this view, there are various studies that show the relationship between facial appearance (i.e. symmetry) and a facial trait (i.e. DI) that is linked to health (Jones et al., 2001). Due to the fact that symmetry is linked with quality, symmetrical faces are perceived as healthier than original faces (Jones et al., 2001). Additionally, a negative relationship between health and facial asymmetry is found (Thornhill & Gangestad, 2006).

It is known that humans and non-human animals prefer symmetry to asymmetry (e.g. Møller, 1992). Even 4 month old human infants are able to discriminate symmetrical patterns from asymmetrical ones (Bornstein et al, 1981). Not only humans but also rhesus macaques (*Macaca mulatta*) (Sasaki et al., 2005), pigeons (*Columba livia*) (Delius and Habers, 1978), bees (*Bombus terrestris*) (Rodriguez et al, 2004), flower-visiting insects (Menzel et al, 1996), chicks (*Gallus gallus*) (Mascalzoni et al, 2012), female swordtail fish (*Xiphophorus malinche*) (Tudor and Morris, 2009) and bottlenose dolphins (*Tursiops truncatus*) (von Fersen et al, 1992) show symmetry preference.

Symmetry also influences subjective judgments of attractiveness. Symmetric bodies are attractive to many animals, including humans (Rhodes, 2006). Together with the symmetrical bodies, symmetrical faces are found to be more attractive (e.g. Thornhill & Gangestad, 1993). Similar to attractiveness judgments, ratings of symmetrical faces according to its attractiveness is found to be culture-independent (Little et al., 2007). Furthermore, it is found that not only symmetrical bodies and faces but also many types of symmetric objects and decorative art are judged as attractive (Jones et al., 2003).

Symmetry preference brings out two different views: good-genes hypothesis and perceptual bias hypothesis. *Good-genes hypothesis* support the view that symmetry is linked with facial attractiveness judgments because symmetry is an essential cue for qualities that are important adaptation for mate choice (Thornhill & Gangestad 1993). In addition to the adaptive qualities, symmetric faces might reflect an ''attractiveness halo'' which represents positive attributes such as extraversion, stability, and good health (Penton-Voak et al., 2001). Jones and his colleagues (2001) studied the relationship between facial symmetry, attractiveness and health and found that health mediated the relationship between symmetry and attractiveness.

On the other hand, *perceptual bias hypothesis* suggest that visual mechanisms might be innately sensitive to symmetry. In other words, symmetrical faces are judged as attractive due to the effect of exposure to prototype resembled stimuli on the human nervous system (Enquist et al., 2002). Unlike good-genes hypothesis' adaptationist view, perceptual bias hypothesis suggest that preference of symmetry might be a by-product of the way brains process information (Enquist et al., 2002).

2.3. Fixations and Pupillary Responses

Fixations

Eye movements, either voluntary or involuntary, acquire, fixate and track visual stimuli (see Appendix A for eye anatomy and eye movements). In humans and primates, in order to change the position of the fovea, there are combinations of six basic types of eye movements: saccadic, smooth pursuit, vergence, vestibular, physiological nystagmus, and optokinetic. Among these, saccadic, smooth pursuit and vergence movements occur when head is stable and object is moving whereas vestibular and optokinetic movements occur when object is stable and head is moving. Although aforementioned eye movements are important for eye tracking research, most of visual perception occurs during sequences of fixations. Fixations are characterized by the small eye movements: tremor, drift, and microsaccades. Duration of the fixations range from 150 ms to 600 ms and amount to 90% of viewing time is devoted to fixations (Irwin, 1992).

According to Poole and his colleagues (2004) the spatial locus of cognitive processing can be quantified by fixations per area of interest. This quantification in turn shows regions that are more significant to the viewer than others. Moreover, fixation duration of an area of interest indicates that (1) a person is having difficulty in extracting information, (2) object in the area of interest is absorbing the attention, and (3) the amount of processing being applied to objects at the area of interest is higher than its counterparts (Poole & Ball, 2010).

Pupil Dilation and Constriction

Under normal conditions, pupil constriction and dilation result from light and accommodation reflexes (Andreassi, 2007). In intense light, pupils constrict whereas in dim light, pupils dilate (see Appendix B for pupil anatomy and pupillary responses). In humans, pupil diameter ranges between 1.5 mm and 8-9 mm. Pupils' reaction to light and stimuli occurs in 0.2 seconds and peaks at 0.5 and 1.0 seconds in humans (Lowenstein & Loewenfeld, 1962; Beatty &Lucero-Wagoner, 2000).

In stable lighting conditions, pupil size which is less than 0.5mm have been found as an indicator of cognitive processing (see, Beatty, 1982; Beatty & Lucero-Wagoner, 2000) and named as task-evoked pupillary response (TEPR). In some tasks that examine attention, memory, decision-making, and problem solving, a change in the pupil size is a reliable measure in terms of cognitive load, arousal and interest indication (Beatty, 1982; Beatty & Lucero-Wagoner, 2000; Hess & Polt, 1960).

Pupillary responses can be measured continuously and non-invasively throughout a task but their latencies and peaks depend on the task type. For instance, while viewing visual and emotional stimuli, dilation occurs after 2-7 seconds, whereas while listening to auditory and emotional stimuli (laughing, crying…etc.) dilation occurs after 2-3 seconds (Hess, 1972; Partala & Surakka, 2003). Hoeks and Levelt (1993) reported a peak in pupillary response 930 ms after the stimulus presentation. In contrast, Just and Carpenter (1993) suggested pupillary responses peak at 1.3 seconds after the stimulus presentation.

2.3.1. Measurement Techniques

Eye Tracking

The use of the eye tracking technology is demonstrated in reading research over 100 years ago (Rayner & Pollatsek, 1989). There are various techniques such as electro-oculography (EOG), scleral search coils, photo-video oculography (POG-VOG) and pupil/corneal reflections (dual purkinje method) to track eye movements.

EOG detects eye movements by measuring electrical potential differences on electrodes placed near the eyes. Scleral search coils involve wearing contact-lens-like material with a metal coil in it; as metal coil moved along with the eyes, fluctuations in an electromagnetic field are measured as eye movements (Duchowski, 2003). In photo-video oculography, eye movements are recorded via digital video cameras. The most recently used eye tracking method, pupil/corneal reflections (dual purkinje method), comprises of a desktop computer with an infrared camera beneath the monitor and special software in it (see Figure 12 for an eye tracking system).

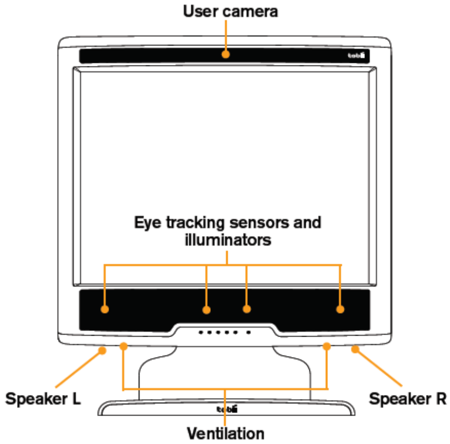

Figure 12. Eye Tracking System
(Tobii T60 & T120 Eye Tracker User Manual 4.0v, 2011)

In this method, infrared camera gives off infrared light to the eye in order to generate reflections. As the light enters the retina, a large amount of it is reflected back, and creates a bright pupil effect for detection. The corneal reflection (first Purkinje image) is also generated by the infrared light, as a small glint (Figure 13). As soon as the eye tracking software recognized the centre of the pupil and the corneal reflection, their distance is measured and point of fixation can be found. Although it is easy to determine point of regard with corneal reflection only, it is crucial to discriminate eye movements from head movements. So, pupil brightness is a key measure in determining point of regard (Duchowski, 2003).

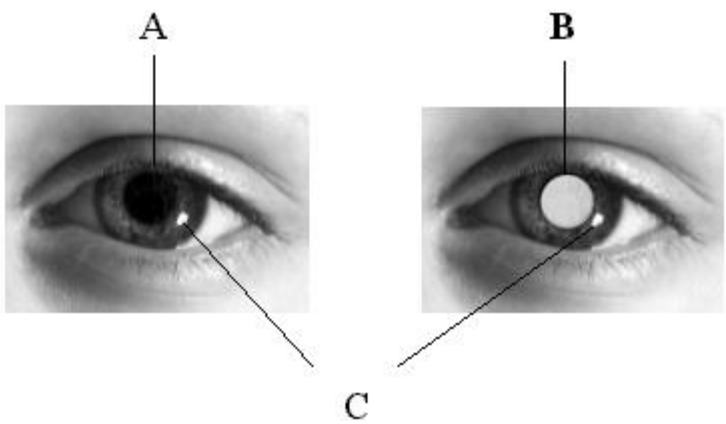

Figure 13. (a) Dark pupil (b) Bright pupil (c) Corneal reflections (Milekic, 2003)

In all video based eye trackers, including pupil/corneal reflection method, a calibration process is required. In the calibration, participants are presented dots at different locations on the screen upon which participants have to fixate repeatedly 9- 13 times in order to excess a limited threshold (Wang, 2009).

Pupillary Responses

In addition to measuring fixations and eye movements, eye trackers are also having capability of measuring pupillary responses. While measuring pupillary responses, various methods such as entoptic methods, mirror comparison, scales and callipers, filming, Bellarminow apparatus, Lowenstein pupillograms and infrared photography can be used (see Hakerem, 1967 for a complete review of pupil measurement history). Latest eye trackers measure pupillary activity by pixel-counting or ellipse-fitting methods. In the pixel counting method, by counting the number of pixels in the pupillary area, pupil size is measured. On the other hand, in the ellipse-fitting method, the length of the major axis of an ellipse fitted to the pupil is calculated (Klinger et al., 2008).

2.4. A Survey on Fixation Duration and Pupillary Response in Cognition

In previous sections, factors important in face and facial expression perception were introduced by reviewing various findings. There are innumerable studies that investigate fixation duration and pupillary response in cognition. Therefore, this section aims to provide only a concise view of the literature.

Guo et al. (2006) examined the effect of faces by using monkeys as participants and found that fixation durations for faces are longer than for neutral scenes. Similarly, Kret et al. (2013) found that fixation durations for faces are longer than for bodies in humans. On the other hand, studies that examine the relationship between fixation durations and affective stimuli found contradictive findings. A recent study by Scott and his colleagues (2012) studied the effect of emotional words on fixation durations and found that fixation durations on emotion words (positive or negative) are longer than neutral words. Researchers studied the effect of facial expressions of emotions and they found that fixation durations to angry faces are longer than neutral and happy faces (Bate et. al, 2009). Another study found that 6-month-old infants prefer looking more at negative facial expressions but 12- month-olds prefer looking more at both positive and negative facial expressions compared to neutral facial expressions (Geangu et al., 2011). In addition, Kret et al. (2013) stated that people prefer to fixate more on angry and fearful facial expressions than happy ones.

On the other hand, Hunnius and his friends (2010) found that adults fixate more on neutral and happy faces than angry and fearful ones. Likewise, Racca et al. (2012) added that even 4-year old children's fixation durations to happy faces are longer than negative and neutral ones. As seen from here, there is no consensus on whether affective faces initiate longer fixation durations.

In the literature there are various fields and tasks that reported pupil dilation activity. Stimulus properties such as interestingness, painfulness, task difficulty, probability, and processes such as sexual arousal, affective processing, mental multiplication, short term memory processing, information processing, and learning cause pupil dilation (Andreassi, 2007). Although there are various studies that use affective stimuli to study pupillary responses, there is still no consensus about which stimuli cause constriction or dilation. If we disregard very early studies such as Hess and Polt (1960) and Libby (1973) due to possible measurement differences introduced by old technology, Janisse (1984) and Bradley (2008) proposed that both pleasant and unpleasant stimuli cause dilation whereas neutral stimuli cause constriction. Bradley et al. (2008) reported bigger pupil diameters for both pleasant and unpleasant emotionally arousing images. They concluded that pupillary changes occur in reaction to increasing emotional arousal levels regardless of the pleasantness of affective stimuli. A recent study by Geangu et al. (2011) revealed that 6 months old infants' perception of others' happiness induces larger pupil diameters but for shorter time intervals whereas, another's distress for a bit longer time intervals. Accordingly, one can assume that there might be changes in pupil diameter as a result of perception and recognition of different facial expressions.

To sum up in a holistic manner, while human adults, infants and monkeys prefer to look at faces and affective stimuli more, it is not clear which emotions draw more attention. Also, it is found that many activities change the pupil diameter but the role of pleasantness/ unpleasantness is not apparent. Interestingly, in the literature, although it is reported that fixation durations to attractive faces are longer than non-attractive ones (Leder et. al, 2010), there is no study that examined the role of biological importance of fixation duration along with pupillary responses. Since both facial expressions of emotions and symmetrical faces have an importance over their counterparts, we speculate that there might be a difference in fixation durations and pupillary responses for these stimuli.

2.5. Motivation, Research Questions and Hypotheses

Faces are important because humans and non-human primates have an innate mechanism to perceive and respond to faces. Moreover, researchers demonstrated that some regions and even some cells are specialized for face perception and recognition. It is obvious that faces have a biological importance and they are processed in a specialized manner than other objects.

Evolutionary psychologists are interested in faces, attractiveness and emotions for long years. They suggested that different parameters such as dimorphism, averageness, symmetry, hormone markers and even menstrual cycle might be cues while judging facial attractiveness. Among these, symmetry is thought to be more important because humans and non-human animals show symmetry preferences. In addition to the importance of symmetry in facial attractiveness judgments, culture-freeness of facial expressions of emotions reveals that they have an evolutionary root which cannot be underestimated.

On the other side, stimuli that have a biological importance and affective value generate reactions in our body. In this case, a symmetrical face and/or facial expression might cause different responses in our body like sweating, increased heart and blood rate and pupil dilation in case symmetry is correlated with attractiveness. Although researchers found an effect of interesting, arousing and cognitively demanding stimuli in pupillary responses and fixation durations, it might be the case that a symmetrical face and/or facial expressions may cause differential eye and pupillary responses. In other words, in addition to interest, arousal and demand, biological/ evolutionary importance and affective value may also have an effect on eye movements and pupillary responses.

The aim of the current thesis is to investigate attractiveness and perceived symmetry derived from symmetrical and original facial expressions via eye tracking methodology. Ratings of attractiveness and perceived symmetry, fixation durations and pupillary responses of the participants will be measured and analysed. By manipulating the amount of symmetry on face stimuli and facial expressions, we wanted to explore how attractiveness and symmetry perceptions differed and whether these had biological relevance as measured by fixation duration and pupillary responses. Our research questions and hypotheses are as follows

Research Question 1: How does symmetry on faces and facial expressions affect attractiveness judgements?

*Hypothesis 1***:** Since symmetry is found to be related with quality and health, symmetrical faces will be rated as more attractive than original ones.

Hypothesis 2: Faces with pleasant expressions of emotions (i.e. surprised) will be rated as more attractive than neutral and unpleasant faces because pleasant expressions might cue positive traits.

Research Question 2: How does symmetry on faces and facial expressions affect perceived symmetry judgements?

*Hypothesis 3***:** Symmetrical faces will be rated as more symmetrical than original faces due to the easy and low-level perceptual nature of symmetry judgement.

Research Question 3: How does symmetry on faces and facial expressions affect fixation durations while judging attractiveness or symmetry?

*Hypothesis 4***:** Since longer fixation duration is an indicator of increased attention, evaluation of symmetrical faces will differ in terms of fixation duration because of biological importance of symmetry. Thus, fixation durations on symmetrical faces will be longer than original ones.

Hypothesis 5: Evaluation of faces with expressions of emotions will elicit longer fixation durations as affective stimuli (both pleasant and unpleasant) are important than neutral ones.

Research Question 4: How does symmetry on faces and facial expressions affect pupil size while judging attractiveness or symmetry?

*Hypothesis 6***:** Since pupillary changes signal increasing attention, arousal and interest, symmetrical faces will differ in terms of initiation of pupillary responses. Thus, symmetrical faces will elicit bigger pupil diameters if symmetrical images are found attractive as in the first hypothesis.

Hypothesis 7: Evaluation of faces with expressions of emotions will differ in terms of pupillary responses because both attention to and arousal levels of affective stimuli are different compared to neutral expressions. Therefore, if attractiveness counts, pupil diameter will be bigger while viewing pleasant stimuli compared to unpleasant and neutral ones. However, if survival counts, both pleasant and unpleasant images with high arousal will elicit bigger pupil diameters than neutral ones.

These hypotheses are summarized below in table 1.

Table 1

Hypotheses

	Symmetry Manipulation *(S-Symmetrical O-Original)*	**Facial Expression Manipulation** *(P-Positive N-Negative Ne-Neutral)*
Attractiveness Judgement	**H1**: S>O	**H2**: P>N ; P>Ne
Symmetrical Judgement	**H3**: S>O	Unknown
Fixation Duration	**H4**: S>O	**H5**: P>Ne ; N> Ne
Pupillary Responses	**H6**: S>O if H1: S>O	If survival counts, **H7**: P>Ne ; N> Ne If attractiveness counts, **H7**: P>N ; P> Ne

CHAPTER 3

METHOD

In this chapter, stimulus generation and manipulation steps, and experiments are covered. In the facial expression manipulation, participants indicate the name of six basic emotions to facilitate selection of the two most recognised facial expressions of emotions. In the experiment, original and symmetric forms of previously selected facial expressions of emotions (e.g. angry and surprise) and one neutral facial expression are presented in two phases. In the first and second phases, participants rate the attractiveness and perceived symmetry of the images, respectively. Between phases, Positive and Negative Affect Scale is administered.

3.1. Materials

Materials include the Karolinska Directed Emotional Faces database and Positive and Negative Affect Scale.

3.1.1. Karolinska Directed Emotional Faces (KDEF) Database

The Karolinska Directed Emotional Faces (KDEF) consists of 4900 pictures of human facial expressions of emotion (Lundqvist et al 1998). The database is used for psychological and medical research purposes for task development in perception, attention, emotion, and memory research. The set contains 2 sets of images of 70 (35 females and 35 males) individuals with an age range of 20-30, each displaying 7 different emotional expressions (happy, sad, angry, disgust, surprise, fear, neutral) in 5 angles, wearing uniform grey T-shirt. Participants have no beards, moustaches, earrings, eyeglasses, and make-up.

During photographing, participants were placed three meters away from the camera (Camera: Pentax LX, Lens: Pentax Original 135 mm) and 3 x 500 W lamps were used. Digitizing was done by a Macintosh 8500/120 based computer with Adobe Photoshop 4. Positives (36 x 24 mm) were scanned in RGB colour, in 625 dpi resolution. After these processes images in JPEG format are obtained with 562 x 762 pixels size, 72x72 dpi resolution, 16.7 million (32 bit) colours.

3.1.2. Positive and Negative Affect Scale (PANAS)

The Positive and Negative Affect Scale (Watson et al., 1988) is a standardized test that is used to assess the affect or mood. As presented in Appendix C the scale is composed of 20 items in which there are two 10-item positive and negative sets. Positive set reflects the participants' degree of alertness and activeness whereas negative set reflects anger and fear that a person feels.

In the scale, participants have to evaluate each item on a 5-point Likert type scale *(1 – very slightly/not at all, 5- extremely)*. In order to reach the positive affect score, items 1, 3, 5, 9, 10, 12, 14, 16, 17, and 19 are summed. In each set, scores can range from 10 – 50, with higher scores representing higher levels of positive affect. Remainder items are summed for negative affect, so, higher scores indicating higher levels of negative affect. Watson and his colleagues found internal consistencies (Cronbach's α) for positive set as .88 and for negative sets as .87.

Adaptation and standardization of the scale into its Turkish form were done by Gençöz (2000) in which the internal consistencies (Cronbach's α) for positive and negative sets were found as .86 and .83, respectively. Also, she found test-retest reliability for positive set as .40 and for negative set as .54.

In the current thesis PANAS scores are used in order to remove outlier participants from the data since both positive and negative emotions have significant effects on cognition.

3.2. Stimuli Creation

Although KDEF is a well-controlled database, there are still some variations within the images. In order to reduce these variations, pre-processing was applied to the database. After the completion of the pre-processing, morphing was accomplished in order to obtain fully symmetrical images (see Appendix D for the list of steps and methods used in pre-processing and morphing). Both pre-processing and morphing was done by using the methods of Dövencioğlu (2008) and Yıldırım (2010) (see Figure 14 for a flowchart of the processing of the images)

3.2.1. Image Pre-processing

Pre-processing includes converting images from RGB to grayscale, face size rescaling, head orientation adjustment, cropping, masking and make-up, intensity adjustment and blurring. Pre-processing is accomplished by using Adobe Photoshop Portable PS 8.

RGB to Grayscale

Three coloured (RGB) images are converted into grey scale. Conversion of the grayscale is done in order to reduce the effect of illumination changes on pupillary responses.

Face Size Rescaling

In order to control the head size differences, four extreme points on the each face are selected; uppermost (*u*), lowermost (*w*), leftmost (*l*) and rightmost (*r*). After the completion of the selection, these points are used to find the vertical and horizontal axes for faces (Figure 15). In order to find the *width* of the face left and right extremes are subtracted. Likewise, lower and upper extremes are subtracted to find the *length* of the face. Since the average width and length of the faces are 313 and 450 pixels, respectively, all images are rescaled in order to keep a constant aspect ratio of 1.43.

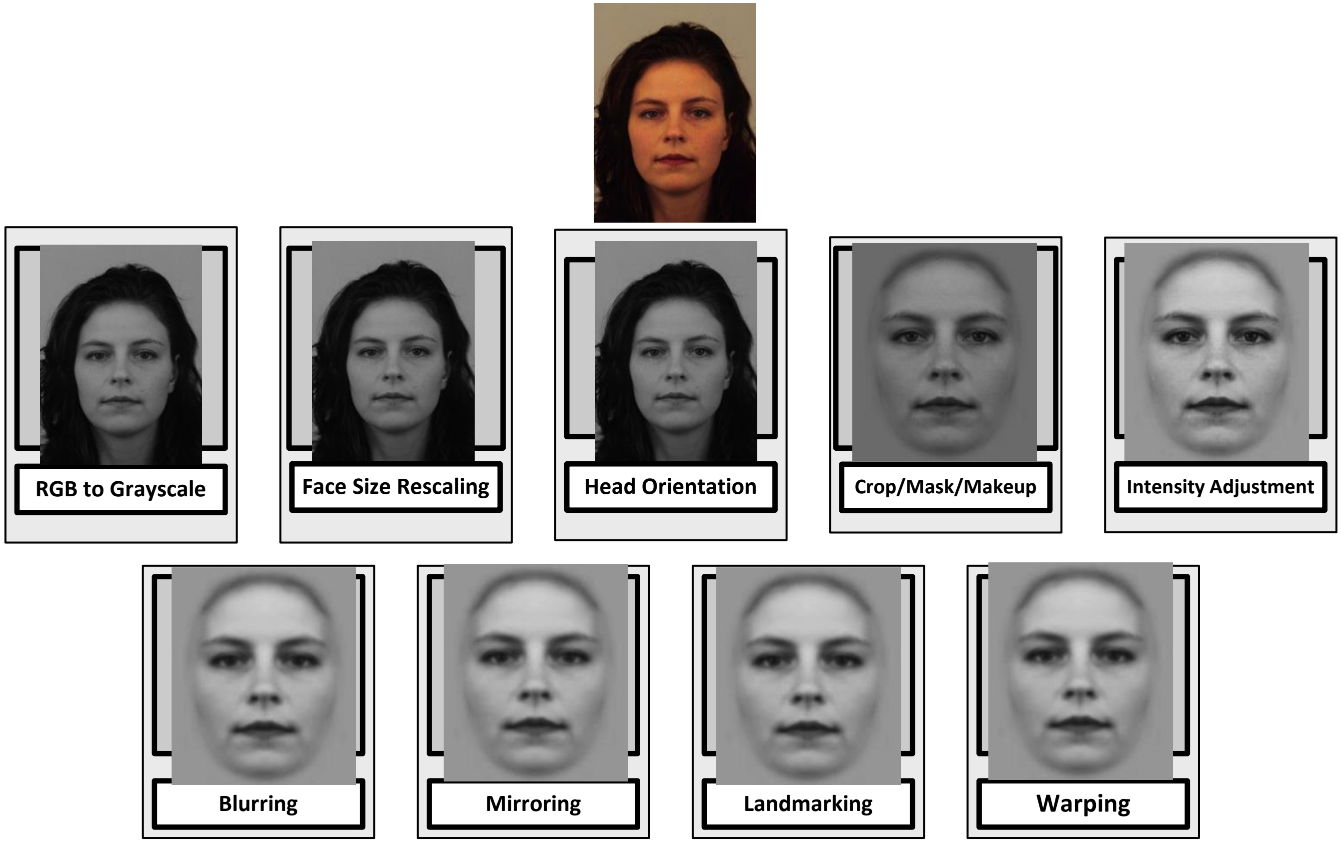

Figure 14. Flowchart of the image processing

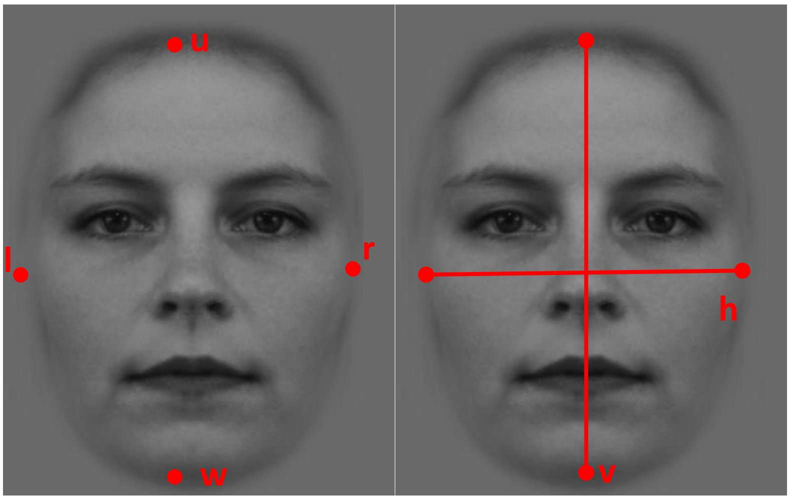

Figure 15. Extreme points of the face: uppermost (u), lowermost (w), leftmost (l) and rightmost (r) and the horizontal (h) and vertical (v) axes

Head Orientation Adjustment

While making facial expressions of emotions, especially anger, participants change their head orientation. For correction, endocanthion line (the line that connects *en* and *en'*) of the each image are rotated to become horizontal. After, midpoint of the endocanthion line is set to a stable coordinate (x= 280, y=370) for each face. Definition of facial landmark points is provided in figure 17.

Cropping, Masking and Make-up

In order to keep the least part of the background and remove unnecessary parts of the face and body (e.g. neck, ears, hair), all images are cropped to 400 x 543 pixels by using crop tool. Then, a grey mask is applied around each face with an additional layer mask (R: 106 G: 106 B: 106) with brush tool. After masking, scars, spots or remained beards and moustaches are removed with healing brush tool in order not to duplicate these characteristics on both sides of face images after creation of the symmetrical images. Also, in order to have similar looking hair for all pictures, smudge tool was used.

Intensity Adjustment

Intensity values of black lines and white squares are set to 79 and 121, respectively, in order to obtain a stable contrast and illumination. Moreover, mean intensity values of all images were computed and outliers were set to the values that are similar to mean intensity values. After adjustment, mean intensity of the entire image set was 103.91 and standard deviation was 14.25. Intensity adjustment is crucial in this thesis since it is important to control the effect of different contrast and illumination on pupillary responses.

Blurring

All images in the original database (KDEF) are smoothed with Gaussian blur filter (1 pixels radius).

3.2.2. Symmetry Manipulation

Obtaining a fully symmetrical image is essential in order to measure the real effects of symmetry. Although there are plenty of researches in symmetry perception, methods for obtaining symmetrical images are divergent. Chimeric faces, facial metrics and blending/morphing techniques are frequently used to create symmetrical images.

In chimeric faces technique (Samuels et al. 1994), each halves of the face are reflected to the other side vertically. After this procedure, two symmetric chimeras are obtained. However, chimeras demonstrate abnormalities in aspect ratios.

In the facial metric technique, face image is rotated to a standard inter-pupillary space. Then, a horizontal axis is formed that divides pupil centres. Afterwards, a vertical axis that bisects the horizontal axis is created. In order to find symmetry scores, distances between the vertical axis and 12 points are measured parallel to horizontal axis (Thornhill & Gangestad, 1994; Jones, et al., 2003).

In blending/morphing technique (Swaddle & Cuthill, 1995), original (normal) and mirror form of the normal image are blended by using a morping programme. As a result of morphing, a fully symmetrical image is obtained. However, this image has lower resolution than the original and mirror forms due to smoothing during morphing.

In the current thesis, a combination of facial metric and morping technique is used on a subset of KDEF images. Creation of full symmetrical images is done in three steps: mirroring, landmarking and warping.

Mirroring

Adobe Photoshop Portable PS 8 is used to create a mirror image of each image in KDEF, resulting in another database named KDEF mirror (KDEFm) (Figure 16).

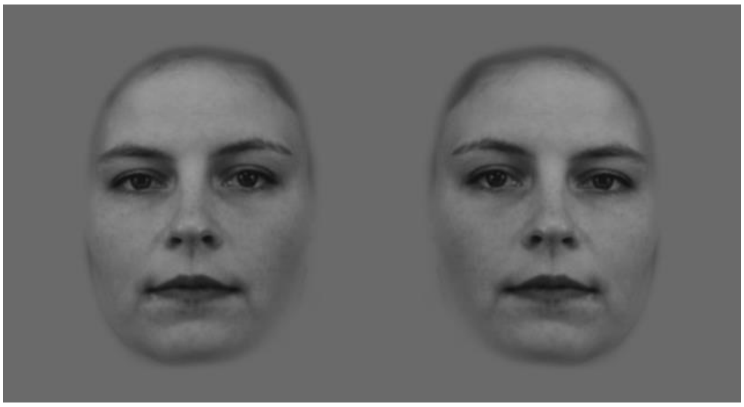

Figure 16. Original and mirror forms of the images
(*KDEF on the left, KDEFm on the right*)

Landmarking

TPSDIG software (Rholf, 2001) is used for landmarking the important anatomical points on the faces such as *exocanthion (ex), endocanthion (en), nasalion (na),* and *cheilion (ch)* as stated in Ras et al. (1995). Since the faces are bilateral, all four points are represented on each halves of the face (1: *ex*, *ex'*; 2: *en*, *en'*; 3: *na*, *na'*; 4: *ch*, *ch'*), resulting eight points in total (Figure 17). Not only important anatomical points but also extreme landmarks are marked via software. After the completion of landmarking, each face has 24 coordinates (anatomical landmarks: ex, ex′, en, en′, na, na′, ch, ch′, extreme points: u, w, l, r) (see Appendices E and F). These landmarks and extreme points are used not only to find local and global asymmetry scores of each faces in KDEF (see Appendix G but also Appendix H for equations of local and global asymmetry) but also to create a morphing video between KFEF and KDEFm.

Figure 17. Eight anatomical landmarks

Warping

By using Abrosoft FantaMorph 5.2.6 software, a morphing video between an image in KDEF to its mirror form in KDEFm is produced. During the video, the middle frame (50%) is exported. The middle frame represents the full symmetrical image since it is an image of a transition between original face (KDEF) and its mirror version (KDEFm). At the end of warping, a new database, KDEF symmetrical (KDEFs) which is composed of full symmetrical versions of the images in KDEF, is obtained (Figure 18) (see Appendix I for sample processed images).

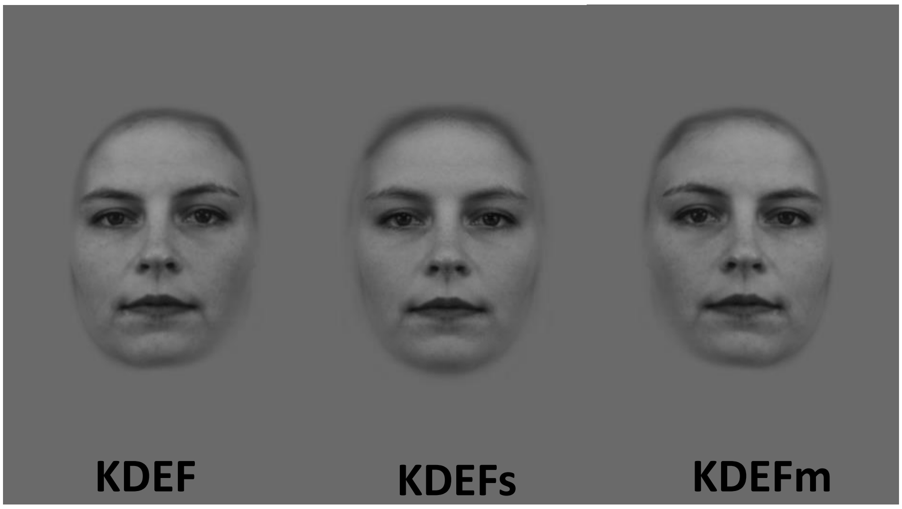

Figure 18. Face images derived after morphing. KDEF, KDEFs and KDEFm represent original, symmetrical and mirror forms of images on the database

3.2.3. Facial Expression Manipulation

In this step, most recognizable facial expressions are chosen from the KDEF. The reason for this is because subjectively, some of the expressions were found to be weak. We wanted to include only strongly recognizable, positively and negatively arousing facial expression images.

Participants

7 participants (4 female and 3 male) between ages of 23-39 (*M* = 28.28, *S.D.* = 7.13) with normal or corrected to normal visual ability were chosen. Participants with any neurological or psychological disorders were omitted from the study.

Apparatus

DirectRT v2012 software was used for presentation of experiment and data collection in Windows 7 based laptop computer. All original KDEF images with an image dimension of 330 pixels by 448 pixels were presented on the centre of black background (R: 000 G: 000 B: 000) on the monitor (17”).

Procedure

In the experiment, participants were seated in a quiet and well-lit room. Demographic information (age and gender) was taken from the participants. Completion of the procedure generally took 10 minutes.

After verbal instruction, participants were randomly presented one of the 294 images that are belonging to 42 different persons (21 female-21 male). 28 persons are eliminated from the KDEF database due to the variations in facial expression generation. Each person has six basic facial expressions of emotion and one neutral facial expression.

A random image of a facial expression was presented until the response of the participant is entered. Participants were asked to designate the facial expression of emotion according to a numerical setting. They had to press 1-happy, 2-sad, 3-angry, 4-disgust, 5-surprise, 6-fear or 7-neutral in order to name the facial expression of emotion on the screen (see Figure 19).

Figure 19. Screenshot from facial expression manipulation

Results

Statistical Package for the Social Sciences (SPSS) 15.0 was used to analyse the data. Descriptive analysis was applied to both accuracy and reaction times. According to accuracy, the most identifiable facial expressions are happy, angry, surprise and neutral. Also, these four emotions are detectable faster than others according to reaction time data (see Table 2 and Table 3; Figure 20). In order to keep arousal level of the facial expressions balanced, angry, surprise and neutral facial expressions were selected to be used in the second experiment. Happy facial expression is discarded from the study because its reaction time was an outlier when compared to other expressions' reaction times. Including happy facial expression in the experiment would have incorporated faster processing confounds on the fixation and pupil responses.

Table 2

Mean Reaction Times

	Mean	S.D.
Happy	1893	1048
Sad	3916	1574
Angry	3409	1110
Disgusted	3804	1111
Surprised	3437	1260
Afraid	4033	1020
Neutral	2477	1638

Table 3

Accuracy (%)

	Mean	S.D.
Happy	91	7
Sad	77	5
Angry	92	8
Disgusted	77	8
Surprised	86	10
Afraid	52	12
Neutral	93	7

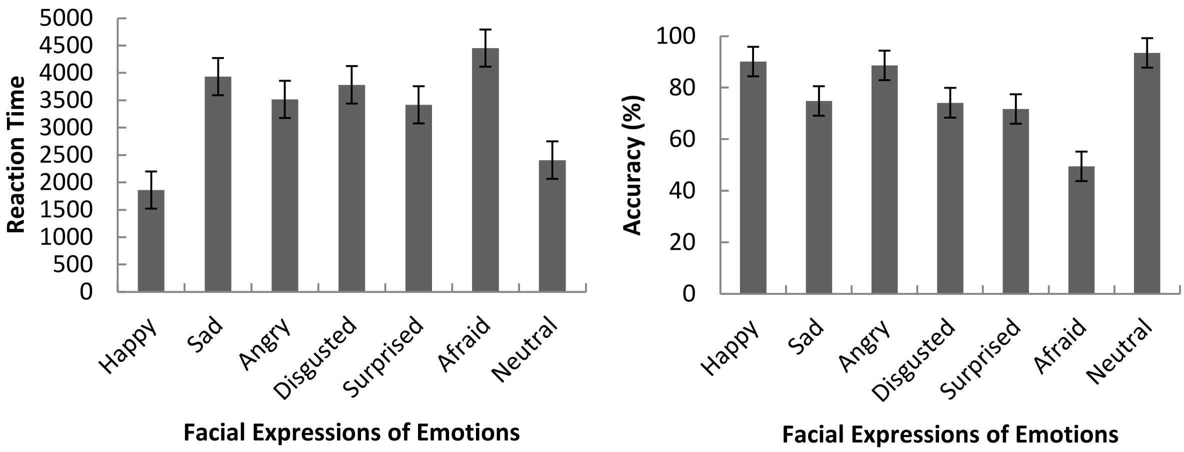

Figure 20. Accuracy and reaction times of different facial expressions of emotions *(Error bars represent standard error)*

3.3. Experiment

The aim of the experiment is to find differences on fixation durations, pupillary responses, attractiveness and perceived symmetry ratings of angry, surprised and neutral facial expressions in a subset of KDEF and KDEFs databases.

3.3.1. Participants

30 right handed participants (18 male, 12 female) between ages of 18-33 (*M*= 22.9, *S.D*= 4.16) with normal or corrected to normal visual ability participated in the study. Participants with any neurological (e.g. photosensitive epilepsy) or psychological disorders (e.g. anxiety disorders) and who wear two-focal or tri-focal glasses, and hard contact lenses were excluded from the study. Since PANAS scores of positive (*M*= 34.73 *S.D.* = 6.25) and negative (*M*= 15.10 *S.D.* = 4.56) sub-tests were acceptable (for positive sub-test: all higher than 20, for the negative sub-test: all below 20) none of the participants were considered as outliers in terms of mood.

3.3.2. Apparatus

Tobii Studio (TS) 3.1.3 software and Tobii Eye Tracking System (TETS) T120 were used to present stimuli and record data, respectively. All stimuli were presented by TS with 1280 x 1024 pixels resolution and eye movements and pupillary responses were collected by TETS on a 17" TFT monitor under the control of Windows 7 based desktop computer in Human Computer Interaction (HCI) Laboratory in Middle East Technical University Computer Centre with data rate of 120 Hz, tracking distance of 50-80 cm and latency of 33ms.

3.3.3. Procedure

In the experiment, participants were seated in HCI Laboratory. After filling the Edinburgh Handedness Inventory by Oldfield (1971) (see Appendix J), written consent (Appendix K) and demographic information were taken from the participants. Completion of admission procedure generally took 10 minutes.

There were two phases in the experiment. Each phase was administrated back to back to three different groups of participants. In the first phase, participants rated the attractiveness whereas in the second phase they rated the perceived symmetry of the images. In order to counterbalance images, three participant group lists were formed (see Appendix L for image presentation chart of the participant groups). Participants in one group are only exposed to both forms (e.g. original and symmetric) of one facial expression of one individual in KDEF. For instance, participant A saw symmetrical and original forms of angry facial expression of individual 1, but did not see the neutral or surprised facial expressions of individual 1. Instead, participant B and C saw the surprised and neutral facial expressions of individual 1, respectively. Each group of participants were exposed to equal numbers of angry, surprised and neutral images with both original and symmetrical manipulations, totalling 48 face pictures in each experiment phase.

Before the initiation of the experiment, 9-dot calibration was applied. On the first phase, participants were shown 48 images on the centre of grey background (R: 106 G: 106 B: 106) with 15° visual angle (see Appendix M for visual angle computation). Images are distributed as follows: 24 female: 12 original-12 symmetric and 24 male: 12 original-12 symmetric. These 48 pictures are chosen from 3 facial expression categories: 16 angry, 16 surprised and 16 neutral. After the presentation of each image for 3 seconds, participants were asked to rate the attractiveness on a 9 point Likert scale (*1- Not attractive/ 9- Very attractive*) (see Appendix N for selected images from KDEF and KDEFs in stimulus presentation). Between stimuli, a fixation cross was presented with an interstimulus interval of 1 second (see Figure 21 for flowchart of the phase 1). Fixation durations and pupil dilations are collected throughout the experiment, but among these, only data during stimulus presentation was used for analysis.

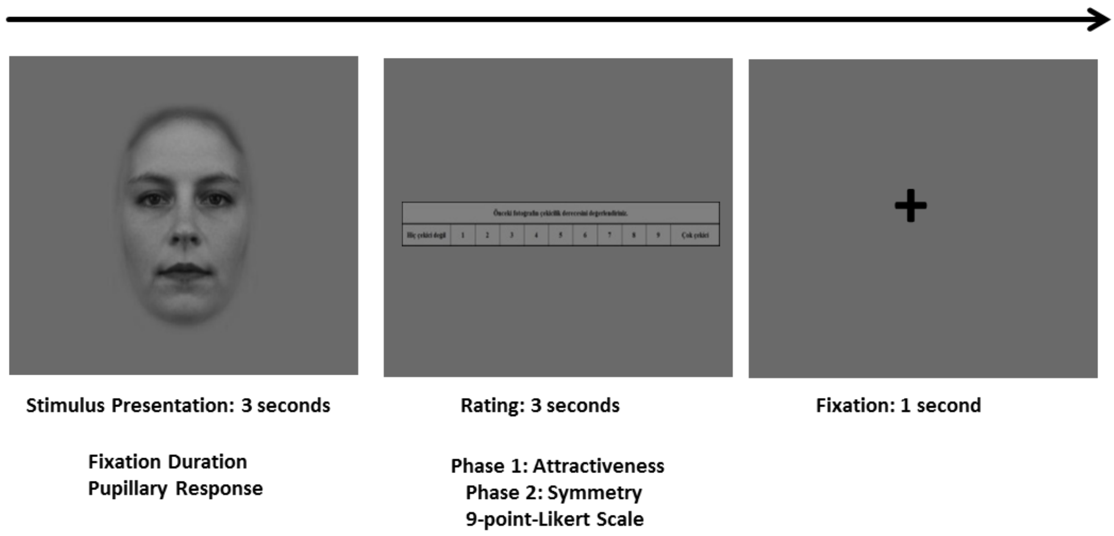

Figure 21. Flowchart of the experiment

Before administering the second phase of the experiment, participants were asked to fill PANAS. In the second phase, with the same procedure as the first phase, participants were asked to rate the perceived symmetry of the same images that were used in the first phase on a 9 point Likert scale (*1- Not symmetric at all/ 9- Very symmetric*). After the completion of the two phases, participants were given a debriefing form that explains the aims and possible results of the experiment (Appendix O).

3.3.4. Analysis

Kolmogorov-Smirnov tests were performed in order to check the normality assumption of the data. Since, p values were all above 0.05 and showed a normal distribution, separate 2x3 repeated measures of analysis of variances (ANOVAs) were applied for attractiveness and perceived symmetry ratings, fixation durations and pupillary responses. Symmetry condition (2: symmetrical, asymmetrical) and emotions (3: angry, surprised, neutral) were taken as within subject factors. Significant main effects were followed up by Bonferroni-corrected pairwise comparisons (see Table 4 for ANOVA results). Experimental conditions from both genders are analysed together since no gender effects are found among participants for attractiveness ratings ($F_{(1, 28)}=1.708$, $p= .202$), symmetry ratings ($F_{(1, 27)}=0.824$, $p= .372$), fixation durations while judging attractiveness ($F_{(1, 23)}=0.040$, $p= .844$), fixation durations while judging symmetry ($F_{(1, 20)}=0.003$, $p= .959$), pupillary responses while judging attractiveness ($F_{(1, 18)}=0.216$, $p= .648$) and pupillary responses while judging symmetry ($F_{(1, 18)}=0.731$, $p= .225$).

CHAPTER 4

RESULTS

4.1. Ratings

Attractiveness Ratings

The ANOVA revealed significant main effects of the symmetry condition ($F_{(1, 29)}$ = 23.769, p = .000, η^2 = .450) and emotion ($F_{(2, 58)}$ = 6.194, p = .004, η^2 = .176). In terms of symmetry condition main effect, symmetrical images (*M* = 3.70, *S.E.* = 0.190) were rated as more attractive than original ones (*M* = 3.01, *S.E.* = 0.202) (Figure 22). In terms of emotion main effect, pairwise comparisons showed that neutral facial expressions (*M* = 3.63, *S.E.* =0.182) were rated as more attractive than surprised (*M* = 3.29, *S.E.* = 0.217) and angry (*M* = 3.14, *S.E.* = 0.200) facial expressions (Figure 23) but there were not any difference between angry and surprised facial expressions of emotions. Moreover, there was no interaction between symmetry condition and emotion ($F_{(2, 58)}$ =1.693, p= .193).

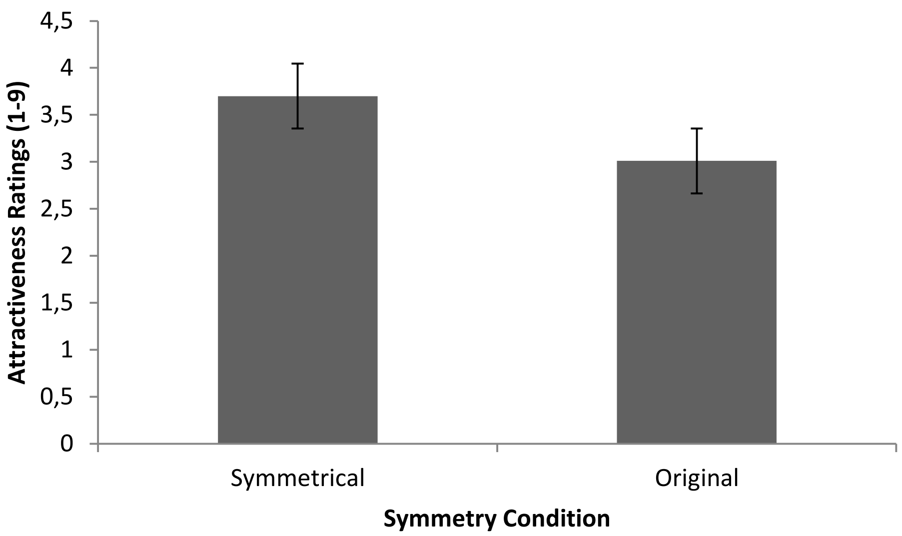

Figure 22. Attractiveness ratings of symmetrical and original images (*Error bars represent standard error*)

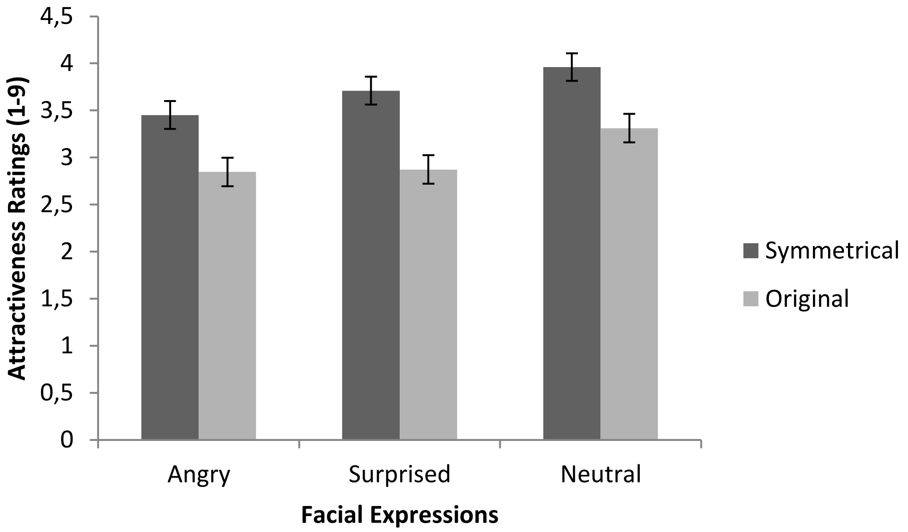

Figure 23. Attractiveness ratings of both symmetrical and original forms of angry, surprised and neutral facial expressions images
(*Error bars represent standard error*)

Perceived Symmetry Ratings

The ANOVA revealed significant main effects of the symmetry condition ($F_{(1, 28)}$ = 87.185, p = .000, η^2 = .757) and emotion ($F_{(2, 56)}$ = 10.212, p = .000, η^2 = .267). In terms of symmetry condition main effect, symmetrical images (*M* =7.225, *S.E.* = 0.213) were rated as more symmetrical than original ones (*M* =4.087, *S.E.* = 0.250) (Figure 24). In terms of emotion main effect, pairwise comparisons showed that neutral facial expressions (*M* = 5.93, *S.E.* =0.167) were rated as more symmetrical than surprised (*M* = 5.60, *S.E.* = 0.176) and angry (*M* = 5.46, *S.E.* = 0.166) facial expressions (Figure 25) but there was no difference between angry and surprised facial expressions. Also, there was an interaction between symmetry condition and emotion ($F_{(2, 56)}$ = 3.158, p = .050, η^2 = .101). For symmetrical images, ratings for neutral and surprised facial expressions were not different; however, neutral facial expressions of emotions were rated as more symmetrical than angry facial expressions. For original images, angry and surprised facial expressions of emotions were rated as more asymmetrical than neutral ones.

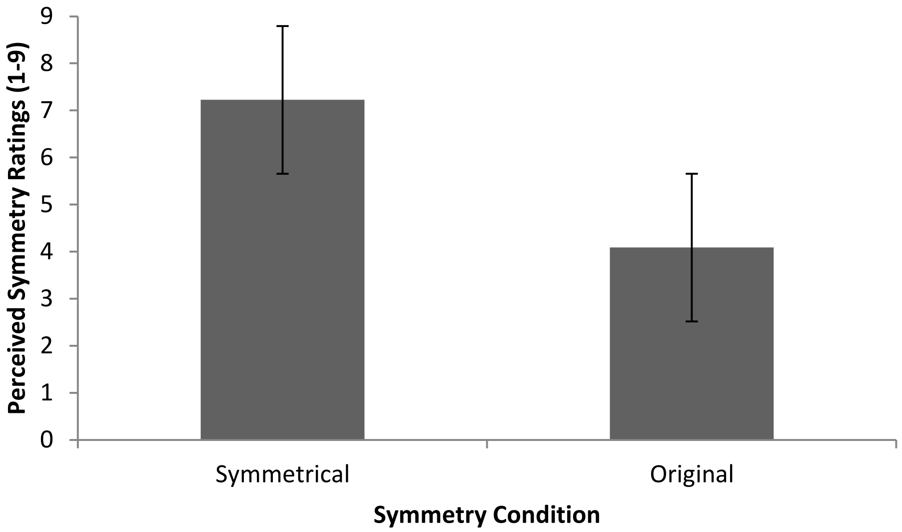

Figure 24. Perceived symmetry ratings of symmetrical and original images
(*Error bars represent standard error*)

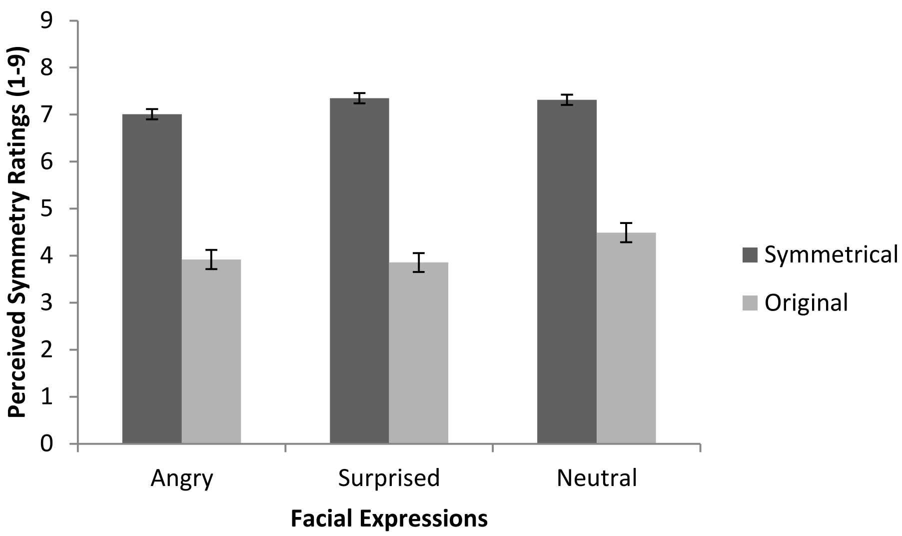

Figure 25. Perceived symmetry ratings of both symmetrical and original forms of angry, surprised and neutral facial expressions images
(*Error bars represent standard error*)

4.2. Physiological data

Fixation Duration

To analyse the fixation duration data, an ellipse-shaped region of interest (ROI) was created manually. This ROI was defined exclusively on faces (see Figure 26). Also, IV-T fixation filter was used in order to classify fixations in which interpolation (gap fill-in) is enabled (75ms), noise reduction is disabled, and short fixations below 60 ms are discarded. Also, durations of each fixation inside this ROI were summed in order to use in further analyses.

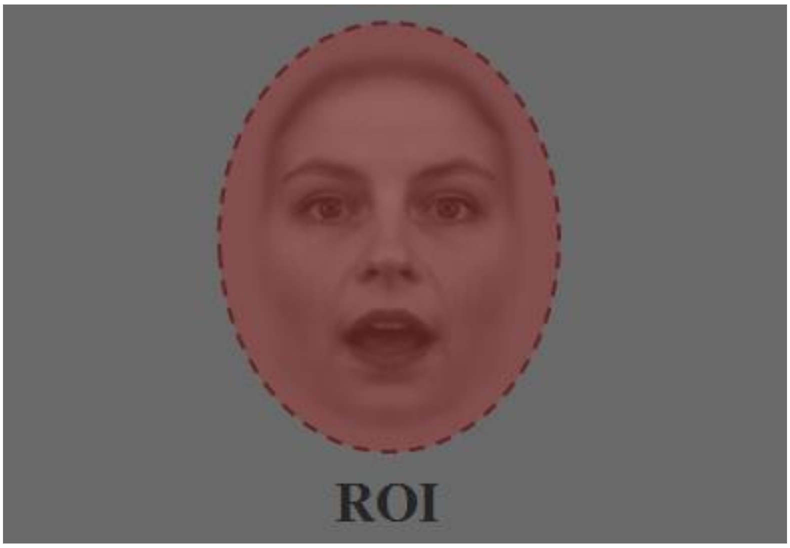

Figure 26. Region of Interest Selection

When fixation durations are analysed while judging attractiveness, the ANOVA revealed significant main effects of the symmetry condition ($F_{(1, 24)}$ = 4.680, p = .041, η^2 = .163) and emotion ($F_{(2, 48)}$ = 5.004, p = .011, η^2 = .172). In terms of symmetry condition main effect, fixation duration of symmetrical images (*M* =2.33, *S.E.* = 0.081) were longer than original ones (*M* =2.16, *S.E.* = 0.060) (Figure 27). In terms of emotion main effect, pairwise comparisons showed that fixation duration of neutral facial expressions (*M* = 2.12, *S.E.* =0.064) were shorter than angry (*M* = 2.34, *S.E.* = 0.064) facial expressions (Figure 28) but there was not any difference between angry-surprised and neutral-surprise facial expressions.

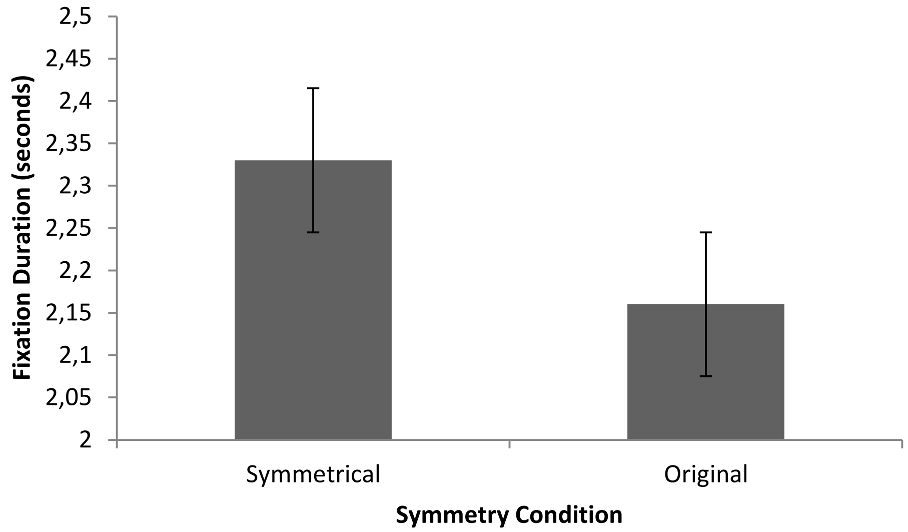

Figure 27. Fixation durations of symmetrical and original images
(*Error bars represent standard error*)

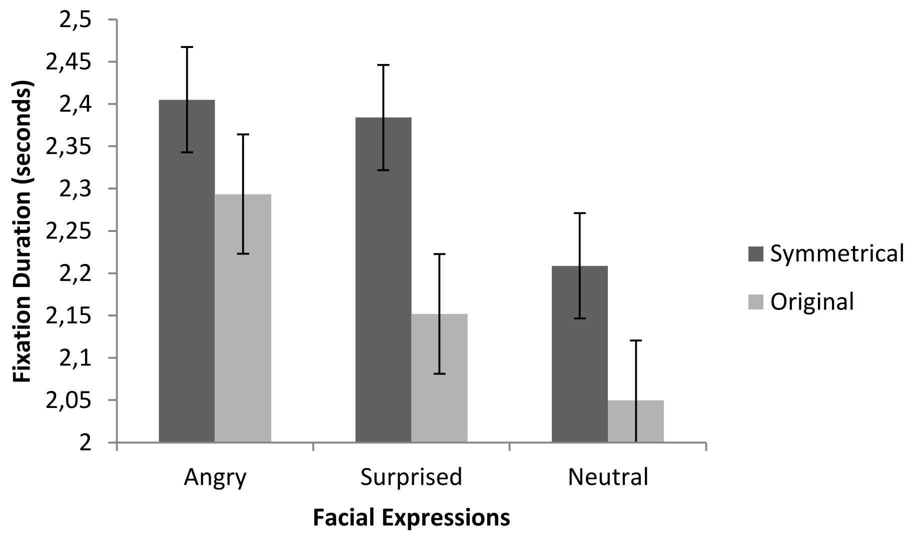

Figure 28. Fixation durations of both symmetrical and original forms of angry, surprised and neutral facial expressions images
(*Error bars represent standard error*)

When fixation durations are analysed while judging perceived symmetry, main effects of symmetry condition ($F_{(1, 21)}$ =0.025, p=.876) and emotion ($F_{(2, 42)}$ =0.761, p=.473) and interaction ($F_{(2, 42)}$ =0.405, p=.670) between them was absent. None of the statistics revealed significant differences of fixation durations between symmetry and emotion manipulations during symmetry perception.

Pupillary Responses

Very short increases or decreases of at least 0.375mm within 20 ms were considered as eye-blinks or artefacts (Partala & Surakka, 2003) and thus removed from the data. Then, data were pre-processed by linear interpolation in order to fill in the gaps that resulted from blinking head movements or artefacts. When more than 30% of the data of a participant had to be interpolated, pupillary response is assumed to be unreliable and the pupil data of that participant was discarded. Within the entire dataset, 8 participants' pupil data was excluded due to this reason. Therefore only 22 participants' data was used in further analyses. Pupil responses during the 3-second stimulus presentation section of the trials are extracted. In other words, only passive viewing sections of the experiment was taken into consideration, disregarding fixation and judgement sections. At the end of the extraction, 180 data points (60 Hz x 3 seconds) were obtained for each image. Since healthy people have equal pupils (*isocoria*), a correlation must be observed between left and right pupil sizes. Correlation analysis revealed a statistically significant correlation (r= 0.940, p=.000) between left and right pupil sizes and thus data from left and right pupils were averaged for each subject in order to use in further analysis. For each trial, the initial pupil diameter was subtracted from each of the following samples so the initial pupil diameter was set to zero in all of the stimulus onsets. Then, only the peak values of pupil diameter were used in analysis below. This way, changes from the stimulus onsets (i.e. baselines) are normalized between different trials.

When pupil diameters are analysed while judging attractiveness, ANOVA revealed significant main effects of the symmetry condition ($F_{(1, 19)} = 4.56$, $p = .046$, $\eta^2 = .194$) and emotion ($F_{(2, 38)} = 3.51$, $p = .040$, $\eta^2 = .156$). In terms of symmetry condition main effect, pupil diameter changes from baseline was bigger for original images (*M* =0.212, *S.E.* = 0.015) compared to symmetrical ones (*M* =0.173, *S.E.* = 0.015) (Figure 29). In terms of emotion main effect, angry (*M* =0.214, *S.E.* =0.20) and surprised (*M* =0.20, *S.E.* =0.17) facial expressions of emotions elicited larger pupil diameter increases than the neutral (*M* =0.161, *S.E.* =0.13) facial expression (Figure 30). There was no interaction between symmetry condition and emotion in pupillary responses ($F_{(2, 38)}$ =.124, p=.884).

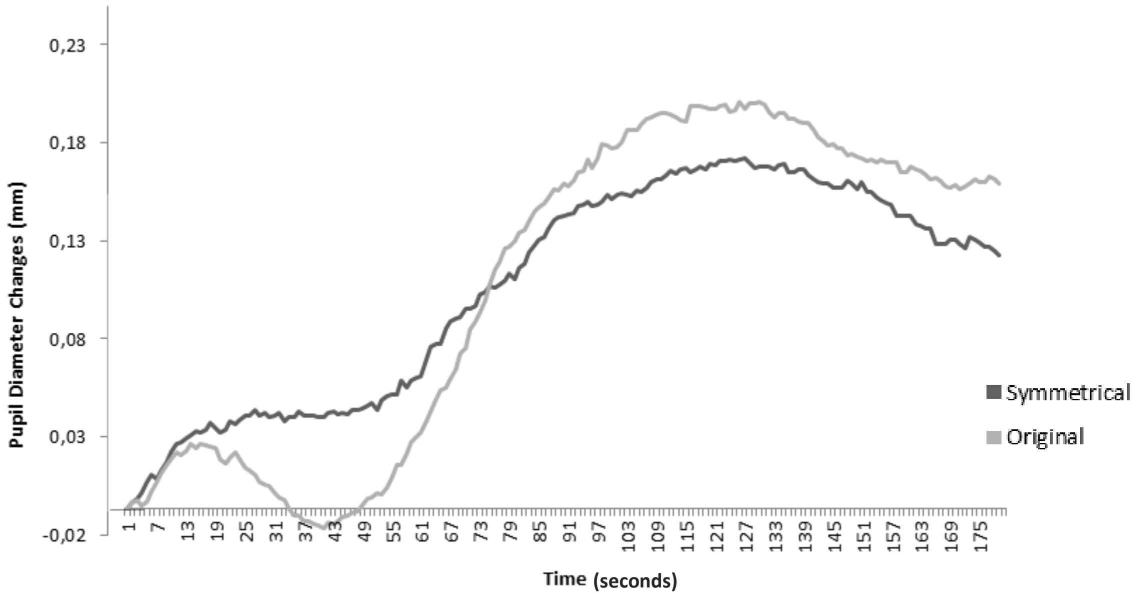

Figure 29. Pupil diameter changes of symmetrical and original images

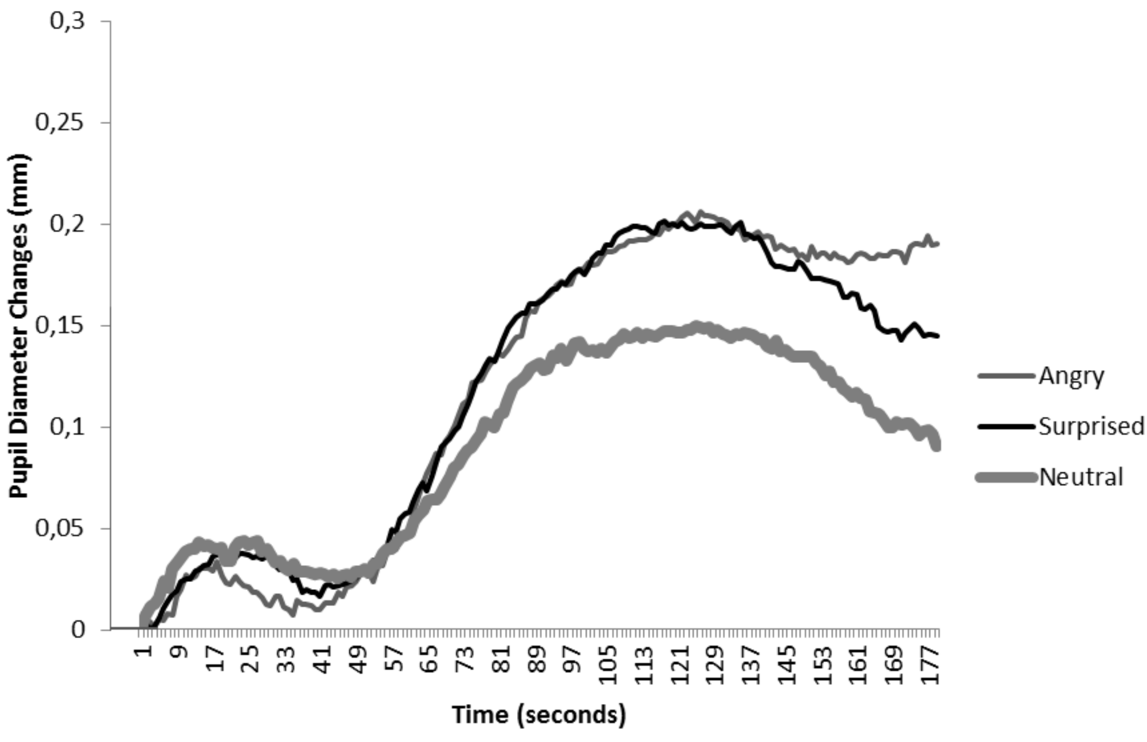

Figure 30. Pupil diameter changes of facial expressions of emotions

We conducted further analysis between pupil diameters collected during attractiveness ratings and the attractiveness ratings themselves. Correlation analysis revealed that attractiveness ratings are negatively correlated with pupil diameter changes (r = -.460, p <.031).

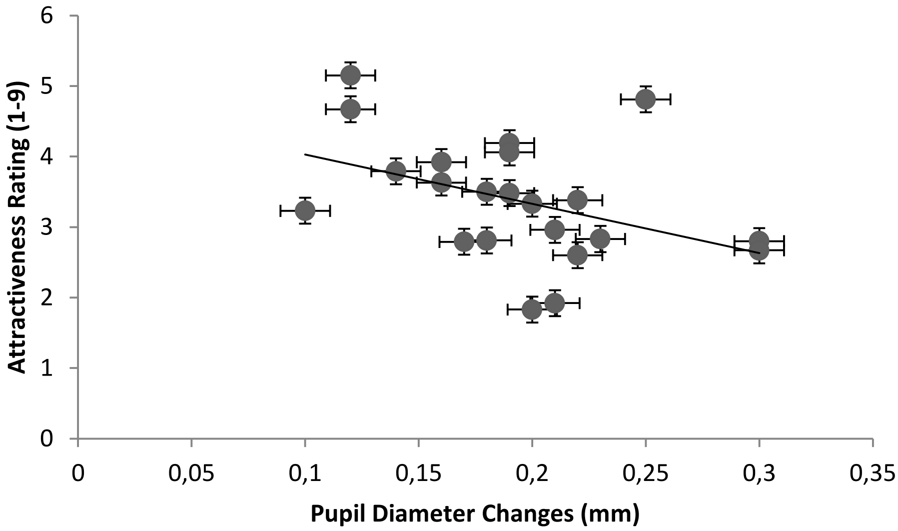

Figure 31. Scatterplot of attractiveness ratings and pupil diameter changes (*Error bars represent standard error*)

When pupil diameters are analysed while judging perceived symmetry, main effects of symmetry condition ($F_{(1, 19)}$ =0.335, p=.126) and emotion ($F_{(2, 38)}$ =0.261, p=.348) as well as interaction ($F_{(2, 38)}$ =0.574, p=.757) between them were absent. None of the statistics revealed significant differences of pupil dilations between symmetry and emotion manipulations during symmetry perception. Figures 32 and 33 below reveal differences between experimental conditions in dilation of pupils during symmetry perception.

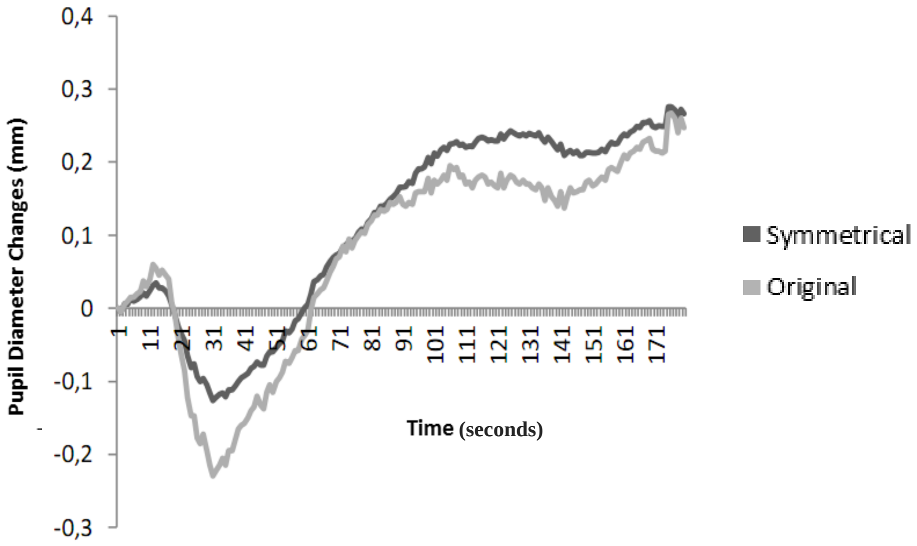

Figure 32. Pupil diameter changes of symmetrical and original images

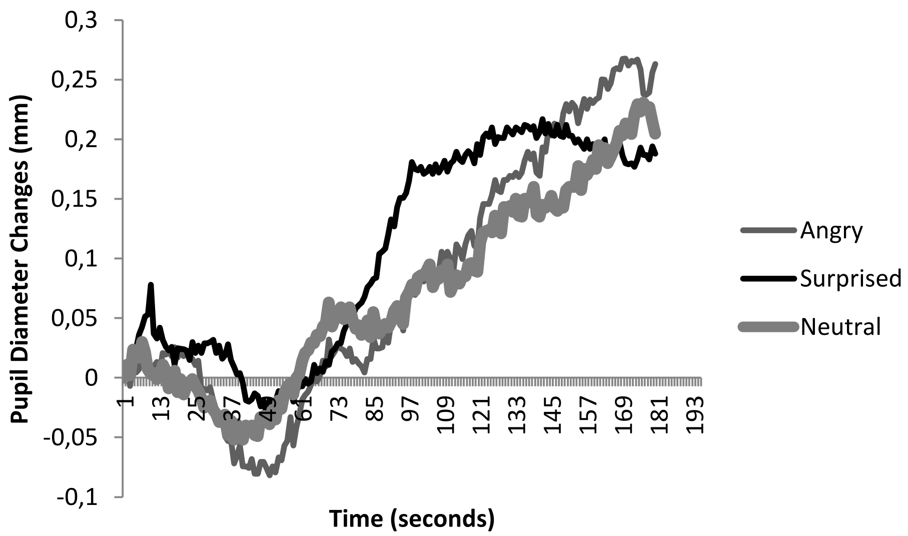

Figure 33. Pupil diameter changes of facial expressions of emotions

All of the results are summarized below in table 4 in terms of the directionality between conditions and statistical significance values as indicated by p-scores.

Table 4

Results of the Experiment (p values)

	Symmetry	*Emotion*	*Symmetry* Emotion*
ATTRACTIVENESS JUDGEMENT	**0.000*** (S>A)	**0.004*** (N>An=Su)	**0.193**
SYMMETRY JUDGEMENT	**0.000*** (S>A)	**0.000*** (N>An=Su)	**0.050***
FIXATION DURATION (ATT)	**0.041*** (S>A)	**0.011*** (An>Su>N)	**0.651**
FIXATION DURATION (SYM)	**0.876**	**0.473**	**0.670**
PUPILLARY RESPONSES (ATT)	**0.046*** (A>S)	**0.040*** (An>Su>N)	**0.884**
PUPILLARY RESPONSES (SYM)	**0.126**	**0.348**	**0.757**

(S= Symmetrical, A=Asymmetrical, N=Neutral, An= Angry, Su=Surprised)

CHAPTER 5

DISCUSSION

The aim of this thesis was to examine effects of symmetry and facial expressions in evaluation of faces while judging attractiveness and perceived symmetry. Fixation durations and pupillary responses were recorded on both phases of the experiment while judging attractiveness and perceived symmetry. In line with our aims and literature review provided on Chapter 2, we had seven hypotheses (see section 2.5). At the end of the experiment, majority of our hypotheses (1, 3, 4, 5, 7) were confirmed but few of them (2, 6) were not supported.

It is crucial to note that during attractiveness and perceived symmetry judgements, not only judgement strategies but also arousal levels of participants are observed to be different. In other words, while rating attractiveness, participants rely more on the cues of emotion and arousal derived from faces. On the other hand, while rating perceived symmetry, participants practice low-level perceptual strategies. Generally speaking, the goal of the current thesis could be extended to find any possible facilitating or inhibiting effects of symmetry and emotion on affective (i.e. attractiveness) and low-level perceptual (i.e. perceived symmetry) judgements.

In the current thesis, **while rating attractiveness**, it is found that symmetrical images were rated as more attractive than asymmetrical ones. This result verifies our hypothesis H1, and it is consistent with the literature since it has been reported by many studies that symmetry has a positive effect on the perceived attractiveness of faces (e.g. Thornhill & Gangestead, 1993; Grammer & Thornhill, 1994; Dövencioğlu, 2008; Yıldırım, 2010). On another front, contrary to our hypothesis H2, while rating attractiveness, neutral facial expressions were found more attractive compared to surprised and angry facial expressions but surprised and angry facial expressions of emotions did not differ in terms of attractiveness. One explanation of this finding is that, according to emotion overgeneralization effect, people have a predisposition to perceive emotional expressions even in the neutral faces (Zebrowitz, 1997). When participants were exposed to neutral faces they might have overgeneralized neutral faces to happy expression, which twisted our emotional expression manipulation. Mueser et al.'s (1984) study found that happy and neutral facial expressions did not differ on attractiveness, although both were more attractive than the other expressions. Therefore we may conclude that neutral facial expressions might be rated as more attractive than surprised and angry facial expressions. Moreover, in our study there were no difference between surprised and angry facial expressions on attractiveness judgements but attractiveness ratings of surprise was higher than anger. Similarly, Limbrecht et al. (2012) found that although there were no difference between surprised and angry facial expressions, attractiveness ratings of surprise was higher than anger. In addition, absence of interaction between symmetry and emotion while judging attractiveness may indicate that while judging attractiveness people rely more on arousal and emotion than symmetry cues. ,

In the second phase, **while rating perceived symmetry**, results demonstrated that symmetrical images were rated as more symmetrical than original ones like Dövencioğlu's (2008) findings. This verifies our hypothesis, H3. Since perceived symmetry rating requires a low level perceptual judgement, participants responded accurately. Interestingly, it is found that neutral facial expressions were rated as more symmetrical than surprised and angry facial expressions while surprised and angry facial expressions of emotions did not differ in terms of perceived symmetry. A review by Borod et al. (1997) suggested that left side of the face moves more widely than the right side during the generation of facial expressions, regardless of valence. A single deviation of a facial trait may become apparent while generating facial expressions of emotion. We believe that, the symmetry differences reported by the participants during emotional facial expressions are correlated with the actual movement differences of both parts of the face. An objective evaluation of this claim is left for future studies. In addition, we found an interaction between symmetry condition and emotion in which participants rated symmetrical images as more symmetrical if the images were neutral and surprised; however, they rated asymmetrical images as more asymmetrical if the images were angry and surprised. Therefore, there might be an inhibitory role of anger while judging perceived symmetry of symmetrical images resulting in lower symmetry scores. In other words, as Phelps (2006) stated in her comprehensive review that emotion influences attention and perception, during perceived symmetry task, low-level perceptual processes might be affected by emotions.

Fixation durations while judging attractiveness revealed that fixation duration for symmetrical images were longer than those for original ones, verifying our hypothesis H4. Poole and Ball (2010) stated that fixation duration of an area of interest indicates that (1) the amount of processing being applied to objects at the area of interest is higher than its counterparts, and (2) object in the area of interest is absorbing the attention. Firstly, as symmetrical images were generated by using morphing techniques, unfamiliarity with computer-generated symmetrical images may have increased the fixation duration due to more processing demands. Secondly, according to Yıldırım (2010), reaction times for symmetric images are higher than those of original images in attractiveness judgement task. As both reaction times and fixation durations have a role in attention, there might be an attention-grabbing effect of symmetric faces -perhaps due to their novelty- that increased the fixation duration. Finally, since it is reported that fixation durations to attractive faces are longer than non-attractive ones (Leder et. al, 2010) and since symmetrical faces are found more attractive, longer fixation durations for symmetrical images are supported. People look more at symmetrical images because they are more appealing than asymmetrical images.

In our study, on attractiveness judgement task, a main effect of emotion on fixation duration is observed as we hypothesized in H5. However, this effect was observed only for angry expressions, but not for the surprised ones. Fixation duration of neutral facial expressions were shorter than angry facial expressions but angry-surprised and neutral-surprise facial expressions did not differ. Similar to our findings, Bate et al. (2009) reported longer fixation durations to angry faces compared to neutral ones. On the other hand, contrary to our findings, Hunnius et al.'s (2010) findings suggest that adults fixate more on neutral and happy faces than angry and fearful ones. In evolutionary context, angry facial expressions might have a priority over neutral and the other facial expressions due to their intensity and rapid detection. Also, anger is associated with freezing response in which body motion and heart rate are reduced in order to stay in a defensive position. Thus, longer fixation durations of angry facial expressions may result from freezing response. Although attention demand of angry and surprised facial expressions are different (Palermo and Rhodes, 2006), in our study, there were no difference between angry and surprised facial expressions of emotions in terms of fixation duration. This might be related to the fact that arousal values of angry faces were nearly the same as that of surprised facial expressions.

Interestingly, while judging perceived symmetry, main effects of symmetry condition and emotion on fixation durations were absent. During perceived symmetry judgements, participants rely on perceptual and automatic strategies. Therefore, fixation duration on symmetrical and original images might be identical due to the fact that participants perform a comparison-like strategy. Additionally, participants may be focusing on only quantifying a symmetry value disregarding the facial expression backdrop in the pictures. So, the reason underlying the absence of the main effect of emotion might be related to the automaticity of symmetry processing over emotions during perceived symmetry judgement.

Pupillary responses while judging attractiveness demonstrated that original images elicited bigger pupil diameters than symmetrical ones. This does not support our hypothesis H6, because we expected symmetrical images to elicit larger pupil dilation due to their more attractive nature. Daniels et al. (2009) found that broadly spread attention results in dilation but and narrowly focused attention causes constriction of the pupils. We suspect that constriction response to symmetrical images indicates more focused attention. How does longer fixation duration co-occur with pupil constriction must be further investigated for the symmetric face images. The underlying physiological and cognitive mechanisms under this finding remain elusive at this point.

Finally, it is found that while judging attractiveness, pupil diameters were bigger for angry and surprised facial expressions than neutral ones. This observation supports H7, indicating that survival instincts rather than sexual arousal are in action while judging attractiveness. Similar to Janisse's (1984) findings we found that, pupils dilate while viewing both pleasant and unpleasant (i.e. emotional) images. Likewise, Bradley et al. (2008) reported that pupillary changes occur in reaction to both pleasant and unpleasant emotionally arousing stimuli. In the current study, since emotional arousal of the images were matched by selecting angry and surprised facial expressions of emotions, similar pupillary responses to angry and surprised facial expressions of emotions are expected if high arousal of the stimuli is the main factor deriving pupil responses during attractiveness judgement.

Limitations and Suggestions for Further Research

Although this study aims to control many variables, there are still some limitations concerning sample size, emotions and pupillary responses. Firstly, although there are various statistically significant differences, sample size is still too small to generalize the results to entire population level. While selecting subjects, different questionnaires such as Symptom Checklist 90 Revised (SCL-90-R) (Derogatis and Unger, 2010) and Toronto Alexithymia Scale (TAS) (Bagby et al., 1994) may also be used to control for psychopathological symptoms as well as identification and recognition problems of emotions. Secondly, among six basic emotions, the current thesis deals with only anger and surprise. This prohibits generalization of the results for all basic emotions.

When pupil responses are considered, although the main effects of symmetry and emotion in pupillary responses are apparent, there might be other effects that we could not observe because of excluding the data of 8 participants due to excessive interpolation. Further research should concern using regression slope, polynomial functions or mean square error instead of analysing only the peak values of pupil size as in this thesis because in normal conditions, pupillary responses have to saturate on a stable value but in our study, there exists increasing trends on pupillary responses.

In terms of fixation durations, our observations are limited to the entire face but not its sub-regions. Researchers prefer use of multiple facial ROIs to find any possible differences of fixation durations on different parts of the faces. Moreover, further studies should aim to investigate possible differences in eye gaze and fixation patterns on symmetrical and original faces.

CHAPTER 6

CONCLUSION

In this thesis we aimed to investigate the possible effects of symmetry and emotion on attractiveness and perceived symmetry judgements of faces while recording eye movements and pupillary responses.

During evaluations of attractiveness, symmetrical images were rated as more attractive replicating the literature. Fixation durations to symmetrical images were longer than their original counterparts, indicating novelty as a probable factor. We observed that pupils constricted more while exposed to symmetrical images. On the contrary, we had expected larger pupil sizes for symmetrical images since they are found to be more attractive. Constriction of pupils while judging attractiveness of symmetrical faces may indicate focused attention under symmetry manipulation. When emotion manipulation is considered, neutral facial expressions of emotions were rated as more attractive than angry and surprised facial expressions, although we had expected that positive and arousing facial expressions (i.e. surprise) would elicit larger attractiveness ratings. Additionally, both pleasant and unpleasant stimuli (i.e. angry and surprised facial expressions of emotions) caused more pupil dilation than neutral ones. This different trend between attractiveness and arousal suggests that attractiveness rating of the subjects did not rely on sexual arousal of the stimulus, but relied on their survival value. Under the emotion manipulation, fixation durations to neutral and surprised facial expressions were shorter than angry facial expressions, again indicating a survival related arrest response for negatively arousing stimuli.

During evaluations of symmetry, symmetrical images were accurately rated as more symmetrical than their original counterparts. Symmetry judgement is found to differ under the emotion manipulation: Neutral facial expressions are found to be more symmetrical by the subjects. We speculate that the subjects were able to pick up subtle differences between the left and right parts of the faces with emotional expressions. It is well known in the literature that facial expressions are not manifested equally on both parts of the face. Interestingly, fixation durations and pupillary responses under symmetry and facial expressions did not change during symmetry judgement.

At the end of the current thesis, we can conclude that symmetry and facial expressions of emotions could be considered as two of the most crucial characteristics of faces as they have an influence in our subjective emotional and perceptual judgements as well as some of our bodily reactions such as fixation durations and pupillary responses.

This thesis replicates the findings that symmetrical images are rated as more attractive. Moreover, we found that fixation durations to symmetrical images are longer. Since, longer fixation durations are related with attention, and focused attention constricts pupil, symmetrical images increase fixation durations and decrease pupil diameters. While considering emotions, neutral facial expressions were rated as more attractive and symmetrical than angry and surprised facial expressions. Furthermore, fixation durations and pupillary diameters are longer and bigger for affective stimuli. It is crucial to note that, these physiological differences observed in fixation durations and pupillary responses were evident only during attractiveness judgements which involve more cognitive processes compared to symmetry judgements which involve more automatic processes. To the best of our knowledge this is the first study that investigates subjective judgments of faces under different symmetry and facial expression conditions along with physiological responses such as eye fixation duration and pupil dilation.

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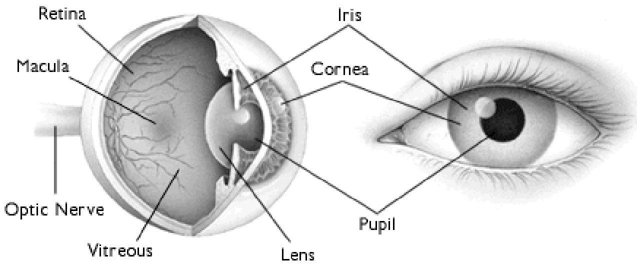
APPENDICES

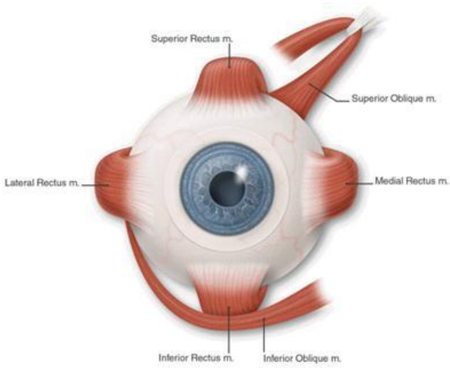
APPENDIX A: EYE ANATOMY AND EYE MOVEMENTS

Eye is the one of the five sense organs which transforms electromagnetic energy into neural energy. It helps us to see the visual environment and has various parts (see Matlin & Foley, 1997, p: 51 for explanation) (Figure 12).



Structure of the eye

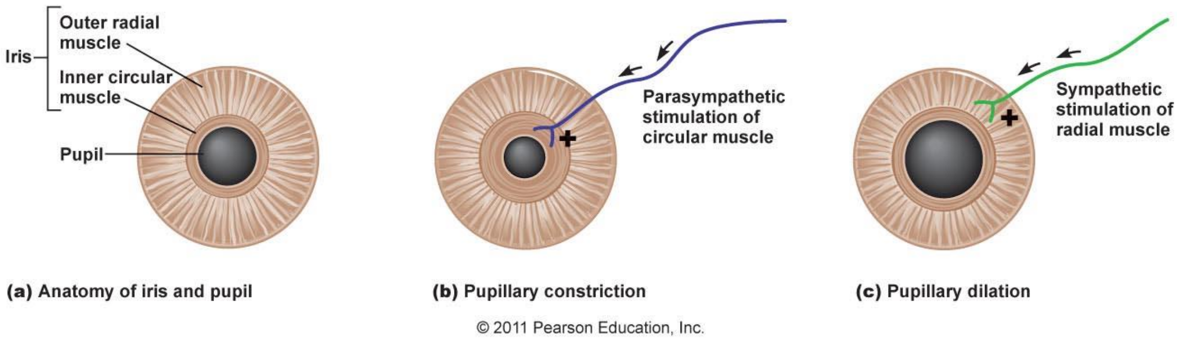
In general, the eyes move through six strong, precisely controlled extra-ocular muscles: the *medial* and *lateral recti* (sideways movements), the *superior* and *inferior recti* (up/down movements), and the *superior* and *inferior obliques* (twist) (Davson, 1980) (see Figure 13). Eye movement control signals stem from various regions of the brain. Efferents from three areas (i.e. occipital cortex, semicircular canals and superior colliculus) are transported by using mesencephalic and pontine reticular formations (Duchowski, 2007).



Extraocular muscles

APPENDIX B: PUPIL ANATOMY AND PUPILLARY RESPONSES

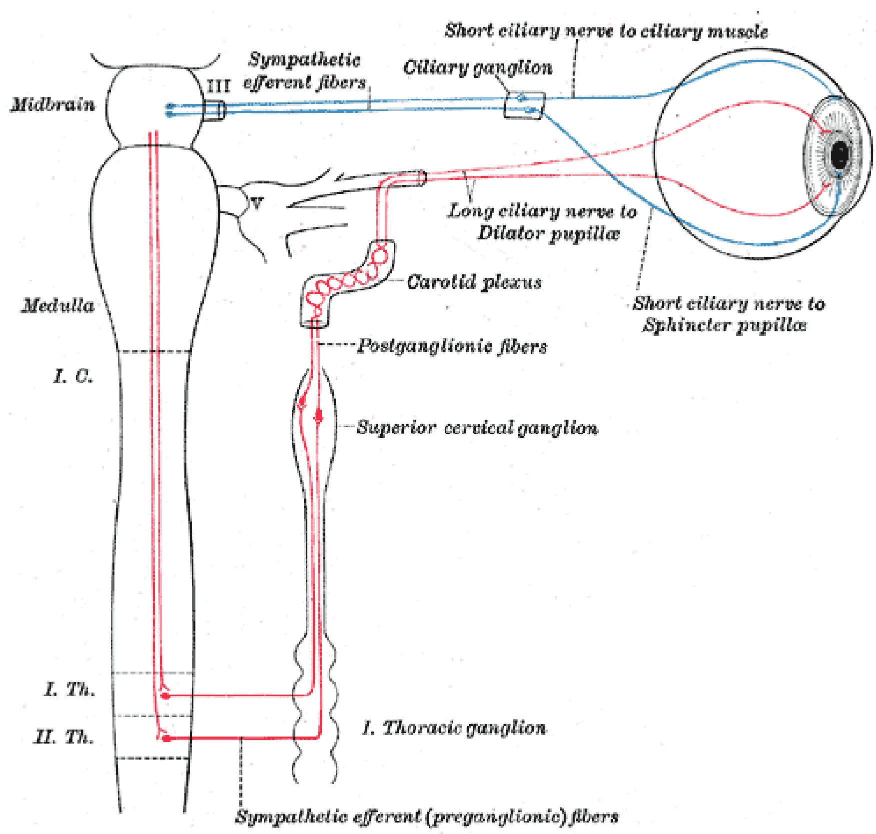
The word pupil comes from the Latin *pupilla*, the little girl, as pupil denotes the reflections of the person's image on the pupil when looking at the eyes of another. "Pupil is the hole in the middle of the iris through which light information passes" (Matlin & Foley, 1997, p.52). Iris has *sphincter pupillae* (circular) and *dilator pupillae* (radial) muscles to control the constriction (*miosis*) and the dilation (*mydriasis*) of the pupil, respectively (Figure 14). It is known that all sensory stimuli (visual, tactile, auditory, gustatory, olfactory) results in pupillary responses (Beatty & Lucero-Wagoner, 2000).



Muscles of the iris, pupil constriction and dilation

Pupillary responses are controlled by both sympathetic and parasympathetic pathways of the autonomic nervous system. Parasympathetic innervation begins in the Edinger Westphal oculomotor complex/nucleus in the midbrain, travels to oculomotor nerve (third cranial nerve), then reaches to the ciliary ganglion and finally ends in the sphincter pupillae. Sympathetic innervation begins in the hypothalamus, travels through the spinal cord, then it reaches to the superior cervical ganglion and finally ends in dilator pupillae. (see Figure 15).

Not only sympathetic system but also parasympathetic system causes pupil dilation. As sympathetic activity increases, dilator muscles activity increases. Alternatively, inhibition of parasympathetic system minimizes the activity in sphincter muscle and causes dilation. Therefore, changes in pupil diameter might occur as a response to the changes in both divisions of the autonomic nervous system.



Neural structures and pathways that control pupillary responses

APPENDIX C: POSITIVE AND NEGATIVE AFFECT SCALE (PANAS)

Bu ölçek farklı duyguları tanımlayan bir takım sözcükler içermektedir. **Şu anda** nasıl hissettiğinizi düşünüp her maddeyi okuyun. Uygun cevabı her maddenin yanında ayrılan yere işaretleyin.

	Çok az-Hiç	Biraz	Ortalama	Oldukça	Çok fazla
1. İlgili					
2. Sıkıntılı					
3. Heyecanlı					
4. Mutsuz					
5. Güçlü					
6. Suçlu					
7. Ürkmüş					
8.Düşmanca					
9. Hevesli					
10. Gururlu					
11. Asabi					
12. Uyanık					
13. Utanmış					
14. İlhamlı					
15. Sinirli					
16. Kararlı					
17. Sinirli					
18. Tedirgin					
19. Aktif					
20.Korkmuş					

APPENDIX D: LIST OF STEPS AND METHODS USED IN PREPROCESSING AND MORPHING

1. Pre-processing

a. RGB to Grayscale: (image>mode>grayscale)
b. Face Size Rescaling: (image>pixel aspect ratio>custom pixel aspect ratio)
c. Head Orientation Adjustment: (edit>transform>rotate)
d. Cropping, Masking and Make-up: Crop tool, brush tool, healing brush tool (manual)
e. Intensity Adjustment: (image>adjustments>levels)
f. Blurring: (filter>blur>Gaussian blur)

2. Morphing

a. Mirroring: (edit>transform>flip horizontal)
b. Landmarking: TPSDIG software (manual)
c. Warping: Abrosoft FantaMorph 5.2.6 software (video creation)

APPENDIX E: COORDINATES OF ANATOMICAL LANDMARKS

Image ID	ex		en		en'		ex'		na		na'		ch		ch'	
	x	*y*	*x*	*y*	*x*	*y*	*x*	*y*	*x*	*y*	*x*	*y*	*x*	*y*	*x*	*y*
F06ang	171	377	239	374	328	374	399	375	244	295	324	290	221	209	341	209
F06neut	171	372	236	369	331	370	402	376	240	293	322	294	219	220	342	217
F06surp	168	375	238	373	329	375	395	375	239	294	324	291	220	210	334	208
F09ang	174	375	239	377	326	373	392	377	246	283	322	282	228	212	339	215
F09neut	175	379	239	377	326	372	396	375	244	291	322	295	227	224	341	221
F09surp	175	380	238	375	323	373	395	378	242	292	320	288	226	217	342	213
F12ang	178	378	239	374	328	375	393	376	239	284	324	285	221	222	348	228
F12neut	182	378	242	374	329	371	392	368	241	287	320	287	219	221	338	223
F12surp	186	379	244	373	327	370	387	372	239	289	321	288	228	205	330	203
F13ang	183	378	239	377	317	373	379	370	243	294	328	295	229	226	332	228
F13neut	177	378	239	377	316	372	382	370	246	286	323	285	227	231	332	226
F13surp	176	380	242	374	317	371	384	375	245	285	321	284	227	218	330	215
F14ang	181	379	240	373	319	375	390	378	239	275	324	279	235	218	328	214
F14neut	175	372	241	371	317	373	384	379	238	286	323	292	238	212	331	216
F14surp	179	380	240	374	314	375	380	381	237	284	327	291	245	198	323	201
F19ang	184	377	239	376	318	376	377	377	245	284	321	286	242	216	325	217

F19neut	189	379	241	371	320	374	375	377	245	286	315	287	234	223	333	223
F19surp	190	379	242	376	317	373	374	378	248	292	316	292	243	212	325	214
F20ang	176	382	236	375	322	374	386	386	242	283	320	287	235	224	324	225
F20neut	171	375	237	371	325	371	391	377	243	284	320	287	227	213	338	214
F20surp	178	384	241	374	322	372	389	380	247	290	319	290	229	213	331	208
F21ang	169	378	240	369	334	368	403	370	243	275	321	275	229	211	336	207
F21neut	171	379	241	373	335	372	407	372	242	280	325	280	231	209	334	205
F21surp	164	379	237	373	329	370	402	375	240	284	324	283	225	199	335	196
F22ang	182	378	239	371	325	373	384	375	246	288	315	288	239	226	323	225
F22neut	182	376	241	371	323	371	389	377	248	287	314	291	236	223	332	223
F22surp	179	385	241	375	322	374	388	383	246	286	317	289	230	220	331	220
F25ang	174	381	236	374	325	372	389	380	246	281	324	279	224	216	324	213
F25neut	176	379	237	371	328	372	387	378	243	283	323	282	227	219	334	217
F25surp	181	381	242	376	325	375	384	381	246	291	322	292	229	215	329	213
F30ang	186	385	247	376	328	369	397	369	241	268	328	263	219	208	341	201
F30neut	177	383	246	375	322	369	391	375	244	277	324	274	226	215	337	211
F30surp	181	384	246	376	317	372	381	376	244	276	321	275	237	208	332	204
F34ang	172	381	243	377	326	373	395	371	237	276	325	277	222	215	343	213
F34neut	180	378	241	368	322	373	389	376	241	289	322	289	225	226	346	226
F34surp	177	384	243	377	325	378	393	380	239	293	322	293	225	212	340	212
M01ang	170	376	238	374	336	380	400	381	245	281	325	284	226	212	344	216
M01neut	168	374	227	373	328	376	396	382	243	284	324	288	224	218	347	221
M01surp	165	381	235	373	331	375	404	384	241	279	323	281	228	202	340	205

M05ang	172	381	236	376	329	373	402	382	237	281	328	279	219	207	331	203
M05neut	176	370	241	369	322	371	391	377	236	289	319	291	218	216	340	217
M05surp	173	376	241	371	324	373	395	383	237	286	325	289	224	181	327	185
M06ang	161	374	231	368	319	378	398	391	236	276	328	286	220	209	347	223
M06neut	171	376	233	372	325	374	393	380	236	291	324	295	213	216	335	219
M06surp	164	377	232	373	320	377	390	387	232	288	324	296	222	205	334	210
M08ang	168	380	233	374	321	374	389	379	247	269	313	270	230	200	334	200
M08neut	172	368	234	372	320	375	390	379	251	283	318	285	233	211	346	221
M08surp	171	376	233	375	322	373	388	380	248	279	319	280	238	189	333	192
M09ang	166	382	237	380	327	380	400	382	236	273	325	273	224	206	346	209
M09neut	173	373	238	375	325	377	394	376	240	272	326	278	230	209	351	209
M09surp	168	375	236	379	322	378	390	381	240	279	324	285	230	190	339	197
M13ang	177	383	239	380	325	379	396	383	243	273	324	279	223	207	340	206
M13neut	174	381	239	372	325	375	388	379	241	276	319	282	223	218	331	217
M13surp	174	379	237	372	321	381	381	390	245	279	319	286	230	209	330	210
M14ang	173	378	236	374	325	374	390	382	237	273	320	276	218	204	349	206
M14neut	180	375	245	372	324	375	393	381	238	287	321	291	226	217	340	221
M14surp	176	381	243	376	321	375	389	385	240	282	321	284	230	198	336	203
M22ang	188	380	246	375	319	373	379	377	243	287	316	287	236	214	326	215
M22neut	187	374	250	372	316	371	379	375	243	291	315	292	231	221	328	217
M22surp	189	376	251	375	319	372	377	377	247	290	319	292	239	208	328	208
M29ang	181	383	236	373	325	374	385	382	240	283	327	285	228	209	337	210
M29neut	180	380	242	374	325	375	381	376	240	298	326	298	230	22	335	218

M29surp	181	385	240	380	321	379	385	383	238	308	327	308	224	217	334	213
M31ang	175	375	237	372	334	377	398	379	239	287	331	290	232	202	354	207
M31neut	172	372	231	372	326	373	389	374	237	288	326	292	225	215	345	218
M31surp	173	379	233	375	323	376	387	379	234	292	328	291	228	204	332	201
M34ang	177	379	237	372	320	368	386	371	230	291	330	287	221	219	330	214
M34neut	175	380	237	372	322	372	390	371	236	291	323	290	217	222	339	215
M34surp	176	381	237	375	321	371	392	373	232	290	327	291	226	202	327	198
M35ang	180	379	240	377	324	374	378	377	246	286	322	286	234	220	335	221
M35neut	180	373	242	373	322	375	384	372	241	284	325	287	238	217	338	223
M35surp	171	375	239	375	317	379	385	379	243	285	322	290	243	204	334	208
MEAN	**176**	**378**	**239**	**374**	**324**	**374**	**390**	**378**	**241**	**285**	**322**	**286**	**228**	**210**	**336**	**213**
S.D	**6,3**	**3,6**	**4,2**	**2,6**	**4,7**	**2,8**	**7,3**	**4,7**	**4,2**	**7,1**	**3,8**	**7**	**6,8**	**24**	**7,1**	**8,8**

APPENDIX F: COORDINATES OF EXTREME POINTS AND AXES

Image ID	u		w		l		r		V	H
	x	*y*	*x*	*y*	*x*	*y*	*x*	*y*	axis	axis
F06ang	285	553	272	109	119	340	449	352	284	331
F06neut	283	561	279	109	119	322	455	332	287	335
F06surp	286	558	271	90	111	324	443	326	277	324
F09ang	270	553	282	121	130	335	459	339	295	337
F09neut	276	556	280	119	120	328	454	328	287	338
F09surp	276	560	281	94	117	341	460	339	289	327
F12ang	277	550	276	123	127	356	438	360	283	337
F12neut	281	558	273	127	128	319	432	316	280	343
F12surp	283	552	280	66	130	311	434	313	282	309
F13ang	270	530	276	120	131	328	425	330	278	325
F13neut	274	532	278	129	127	331	431	330	279	331
F13surp	272	523	274	89	129	320	430	315	280	306
F14ang	274	561	280	129	121	342	439	340	280	345
F14neut	269	567	282	118	122	327	436	344	279	343
F14surp	270	552	279	72	126	299	436	311	281	312
F19ang	276	531	283	138	135	330	421	336	278	335
F19neut	274	540	279	134	134	335	424	341	279	337
F19surp	278	534	282	109	141	317	415	322	278	322
F20ang	272	537	282	147	128	356	421	354	275	342
F20neut	270	553	278	125	127	327	427	331	277	339
F20surp	272	548	273	118	137	330	421	327	279	333
F21ang	278	548	282	116	132	345	435	333	284	332
F21neut	278	564	282	105	121	336	439	335	280	335
F21surp	273	566	278	82	120	309	435	308	278	324
F22ang	274	529	277	132	136	333	431	333	284	331
F22neut	276	532	280	136	137	325	435	329	286	334
F22surp	274	532	278	106	132	326	432	327	282	319
F25ang	282	547	275	127	123	329	431	323	277	337
F25neut	283	544	286	129	123	336	434	337	279	337

F25surp	284	531	280	124	135	331	429	330	282	328
F30ang	289	551	276	99	146	331	440	332	293	325
F30neut	286	550	280	101	137	302	441	328	289	326
F30surp	282	535	286	80	146	322	430	335	288	308
F34ang	277	546	277	113	117	330	445	330	281	330
F34neut	279	547	278	132	126	321	445	326	286	340
F34surp	282	533	283	107	122	326	452	332	287	320
M01ang	282	562	286	118	136	323	459	330	298	340
M01neut	273	570	285	115	127	310	439	324	283	343
M01surp	278	569	284	97	128	326	450	329	289	333
M05ang	285	574	267	120	123	330	449	337	286	347
M05neut	278	570	275	132	129	327	444	337	287	351
M05surp	276	578	271	62	124	306	445	316	285	320
M06ang	258	571	296	115	110	352	452	370	281	343
M06neut	280	576	277	114	120	325	450	327	285	345
M06surp	272	565	285	91	115	293	452	307	284	328
M08ang	278	563	277	94	119	344	435	342	277	329
M08neut	265	568	293	106	126	313	439	326	283	337
M08surp	276	569	289	68	124	304	443	313	284	319
M09ang	284	572	287	119	113	352	453	356	283	346
M09neut	276	576	290	99	116	334	459	350	288	338
M09surp	272	576	292	76	117	320	449	338	283	326
M13ang	270	591	281	109	124	351	451	365	288	350
M13neut	270	601	275	119	111	359	439	358	275	360
M13surp	267	576	282	85	111	318	436	335	274	331
M14ang	276	562	287	107	125	323	441	335	283	335
M14neut	268	558	289	117	135	326	440	326	288	338
M14surp	268	556	284	88	130	307	440	323	285	322
M22ang	279	553	279	120	153	316	422	319	288	337
M22neut	277	554	275	123	144	316	420	317	282	339
M22surp	273	554	283	106	148	316	418	321	283	330
M29ang	280	580	287	109	136	348	445	347	291	345
M29neut	282	572	286	111	135	325	449	324	292	342
M29surp	283	561	277	97	133	326	436	326	285	329
M31ang	276	558	297	99	110	302	459	317	285	329
M31neut	266	565	288	120	111	310	446	310	279	343
M31surp	270	552	280	69	107	302	444	315	276	311

M34ang	285	563	272	119	132	308	439	312	286	341
M34neut	281	576	267	120	126	344	444	344	285	348
M34surp	277	563	269	80	125	319	443	312	284	322
M35ang	280	557	278	119	126	320	444	331	285	338
M35neut	280	561	283	126	132	301	436	303	284	344
M35surp	274	548	284	90	125	301	444	311	285	319
MEAN	**276**	**557**	**280**	**109**	**127**	**325**	**440**	**330**	**283**	**333**
S.D	**5,8**	**16**	**6,2**	**19**	**9,6**	**15**	**11**	**14**	**4,7**	**11**

APPENDIX G: LOCAL AND GLOBAL ASYMMETRY SCORES

Image ID	EXv	NAv	CHv	ENv	EXh	NAh	CHh	GlobalV	GlobalH
F06ang	-2	0	6	1	-2	-5	0	5	-7
F06neut	1	12	13	7	4	1	-3	33	2
F06surp	-9	-9	0	-13	0	-3	-2	-31	-5
F09ang	23	21	22	24	2	-1	3	90	4
F09neut	3	8	6	9	-4	4	-3	26	-3
F09surp	7	15	9	16	-2	-4	-4	47	-10
F12ang	-6	2	-4	-2	-2	1	6	-10	5
F12neut	-14	-1	3	-11	-10	0	2	-23	-8
F12surp	-9	4	6	-7	-7	-1	-2	-6	-10
F13ang	-6	-15	-5	0	-8	1	2	-26	-5
F13neut	-1	-11	-1	3	-8	-1	-5	-10	-14
F13surp	-1	-7	2	0	-5	-1	-3	-6	-9
F14ang	-11	-3	-3	1	-1	4	-4	-16	-1
F14neut	-1	-3	-11	0	7	6	4	-15	17
F14surp	3	-2	-6	8	1	7	3	3	11
F19ang	-5	-10	-11	-1	0	2	1	-27	3
F19neut	-6	-2	-9	-3	-2	1	0	-20	-1
F19surp	-8	-8	-12	-3	-1	0	2	-31	1

F20ang	-13	-13	-10	-9	4	4	1	-45	9
F20neut	-8	-9	-11	-8	2	3	1	-36	6
F20surp	-9	-8	-2	-5	-4	0	-5	-24	-9
F21ang	-5	3	2	-7	-8	0	-4	-7	-12
F21neut	-18	-7	-5	-16	-7	0	-4	-46	-11
F21surp	-11	-9	-5	-11	-4	-1	-3	-36	-8
F22ang	1	6	5	3	-3	0	-1	15	-4
F22neut	1	10	4	8	1	4	0	23	5
F22surp	-3	1	3	1	-2	3	0	2	1
F25ang	-9	-16	6	-7	-1	-2	-3	-26	-6
F25neut	-6	-9	-4	-8	-1	-1	-2	-27	-4
F25surp	-1	-4	6	-3	0	1	-2	-2	-1
F30ang	3	17	26	11	-16	-5	-7	57	-28
F30neut	10	10	15	10	-8	-3	-4	45	-15
F30surp	14	11	7	13	-8	-1	-4	45	-13
F34ang	-5	0	-3	-7	-10	1	-2	-15	-11
F34neut	2	8	0	8	-2	0	0	18	-2
F34surp	4	13	9	6	-4	0	0	32	-4
M01ang	25	25	25	21	5	3	4	96	12
M01neut	2	-1	-5	11	8	4	3	7	15
M01surp	9	14	10	12	3	2	3	45	8
M05ang	-2	7	22	7	1	-2	-4	34	-5
M05neut	6	18	15	10	7	2	1	49	10

M05surp	1	7	18	4	7	3	4	30	14
M06ang	3	-2	-5	12	17	10	14	8	41
M06neut	6	10	22	12	4	4	3	50	11
M06surp	13	11	11	15	10	8	5	50	23
M08ang	-3	-6	-10	0	-1	1	0	-19	0
M08neut	3	-4	-14	11	11	2	10	-4	23
M08surp	8	0	-4	12	4	1	3	16	8
M09ang	0	5	-4	2	0	0	3	3	3
M09neut	8	9	-6	12	3	6	0	23	9
M09surp	8	2	-3	8	6	6	7	15	19
M13ang	2	8	12	11	0	6	-1	33	5
M13neut	-12	-10	-4	-14	-2	6	-1	-40	3
M13surp	-8	-17	-13	-11	11	7	1	-49	19
M14ang	3	9	-1	5	4	3	2	16	9
M14neut	2	16	9	6	6	4	4	33	14
M14surp	5	9	4	6	4	2	5	24	11
M22ang	8	16	13	10	-3	0	1	47	-2
M22neut	-2	6	5	-2	1	1	-4	7	-2
M22surp	0	0	-1	-4	1	2	0	-5	3
M29ang	15	14	16	20	-1	2	1	65	2
M29neut	23	18	19	17	-4	0	-3,5	77	-7,5
M29surp	3	4	11	8	-2	0	-4	26	-6
M31ang	-4	-1	-17	-2	4	3	5	-24	12

M31neut	-4	-6	-13	0	2	4	3	-23	9
M31surp	-9	-11	-9	-5	0	-1	-3	-34	-4
M34ang	8	11	20	14	-8	-4	-5	53	-17
M34neut	5	11	14	11	-9	-1	-7	41	-17
M34surp	0	9	15	10	-8	1	-4	34	-11
M35ang	12	2	1	6	-2	0	1	21	-1
M35neut	4	2	-8	4	-1	3	6	2	8
M35surp	13	4	-8	13	4	5	4	22	13
MEAN	**1**	**3**	**3**	**4**	**0**	**1**	**0**	**10**	**1**
S.D	**8,568713**	**9,58281**	**10,55781**	**8,9187**	**5,701943**	**3,013825**	**3,886104**	**33,36748**	**11,26833**

APPENDIX H: EQUATIONS FOR CALCULATING LOCAL AND GLOBAL ASYMMETRY SCORES

Midpoint of V-axis: (lx+rx)/2

Midpoint of H-axis: (uy+wy)/2

Distance of landmarks to V-axis: V-*ex*, *ex'*-V, V-*na*, *na'*-V, V-*ch*, *ch'*-V, V-*en*, *en'*-V

Distance of landmarks to H-axis: H-*ex*, H-*ex'*, H-*na*, H-*na'*, H-*ch*, H-*ch'*

Local asymmetry score of EX_v: (V-*ex*) - (*ex'*-V)

Local asymmetry score of NA_v: (V-*na*) - (*na'*-V)

Local asymmetry score of CH_v: (V-*ch*) – (*ch'*-V)

Local asymmetry score of EN_v: (V-*en*) – (*en'*-V)

Local asymmetry score of EX_h: (H-*ex*) – (H-*ex'*)

Local asymmetry score of NA_h: (H-*na*) – (H-*na'*)

Local asymmetry score of CH_h: (H-*ch*) – (H-*ch'*)

Global asymmetry score of V-axis: $EX_v + NA_v + CH_v + EN_v$

Global asymmetry score of H-axis: $EX_h + NA_h + CH_h$

APPENDIX I: SAMPLE PROCESSED IMAGES

APPENDIX J: EDINBURGH HANDEDNESS INVENTORY

Aşağıdaki görevleri yaparken elinizi kullanma durumunuzu işaretleyiniz.

	Her zaman Sağ	Çoğunlukla Sağ	Eşit	Çoğunlukla Sol	Her zaman Sol
Yazmak	○	○	○	○	○
Çizmek	○	○	○	○	○
Top atmak	○	○	○	○	○
Makas kullanmak	○	○	○	○	○
Bıçak kullanmak	○	○	○	○	○
Kaşık kullanmak	○	○	○	○	○
Süpürge kullanmak	○	○	○	○	○
Kibrit çakmak	○	○	○	○	○
Kutunun kapağını açmak	○	○	○	○	○
Diş Fırçası kullanmak	○	○	○	○	○

APPENDIX K: CONSENT FORM

Bu çalışma Orta Doğu Teknik Üniversitesi Enformatik Enstitüsü Bilişsel Bilimler Bölümü öğretim üyelerinden Dr. Didem Gökçay danışmanlığında yüksek lisans öğrencisi Pırıl Hepsomalı tarafından yürütülen bir tezdir. Yapılan bu çalışma, yüz algısıyla ilgilidir. Çalışmadan önce size bir anket verilecek ve bunu doldurmanız istenecektir. Çalışma insanların çeşitli yüz resimlerine verdikleri tepkinin ölçülmesini içermektedir. Ekranda siyah-beyaz ve rötuşlanmış yüz resimleri göreceksiniz. Fotoğraflar Karolinska Directed Emotional Faces (KDEF) Veritabanı'ndan alınmıştır. Sizden istediğimiz, bir resme bakarken sizde ilk uyandırdığı etkiyi derecelendirmenizdir. Çalışma esnasında göz hareketleriniz kaydedilecek fakat bu size herhangi bir zarar vermeyecektir. Çalışma yaklaşık olarak 10 dakika sürecektir.

Çalışma sürecinde size farklı duygu ifadelerini içeren fotoğraflar sunulacak ve 2 ayrı kritere göre (ör: çekicilik) değerlendirmeniz istenecektir. Çalışmada katılımcılardan elde edilen veriler isim kullanılmaksızın analizlere dahil edilecektir; yani çalışma sürecinde size bir denek numarası verilecek ve isminiz araştırma raporunda yer almayacaktır.

Çalışmaya katılmanız herhangi bir risk içermemektedir ve tamamen kendi isteğinize bağlıdır. Katılımı reddetme ya da çalışma sürecinde herhangi bir zaman diliminde devam etmeme hakkına sahipsiniz. Eğer görüşme esnasında katılımınıza ilişkin herhangi bir sorunuz olursa, araştırmacıyla iletişime geçebilirsiniz.

Çalışma ile ilgili daha fazla bilgi almak için Bilişsel Bilimler yüksek lisans öğrencisi Pırıl Hepsomalı ile iletişim kurabilirsiniz (e-mail: piril.hepsomali@ii.metu.edu.tr, tlf: 537 815 15 00).

Çalışmanın içeriğini ve amacını anlamış bulunuyorum. Herhangi bir etki altında kalmadan gönüllü olarak katılıyorum. Yukarıdaki formu okudum. Araştırmacı haklarımı ve sorumluluklarımı açıkladı ve sorularımı yanıtladı.

Katılımcının İmzası:

Katılımcının Telefon Numarası:

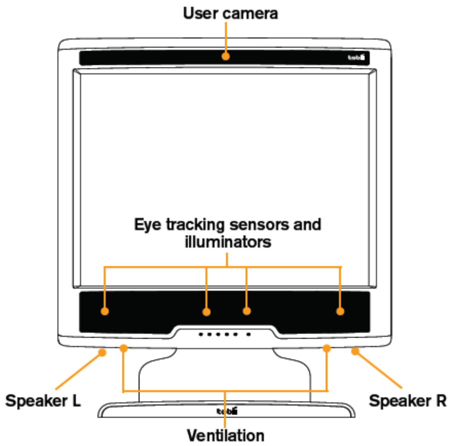
Deney personelinin imzası:

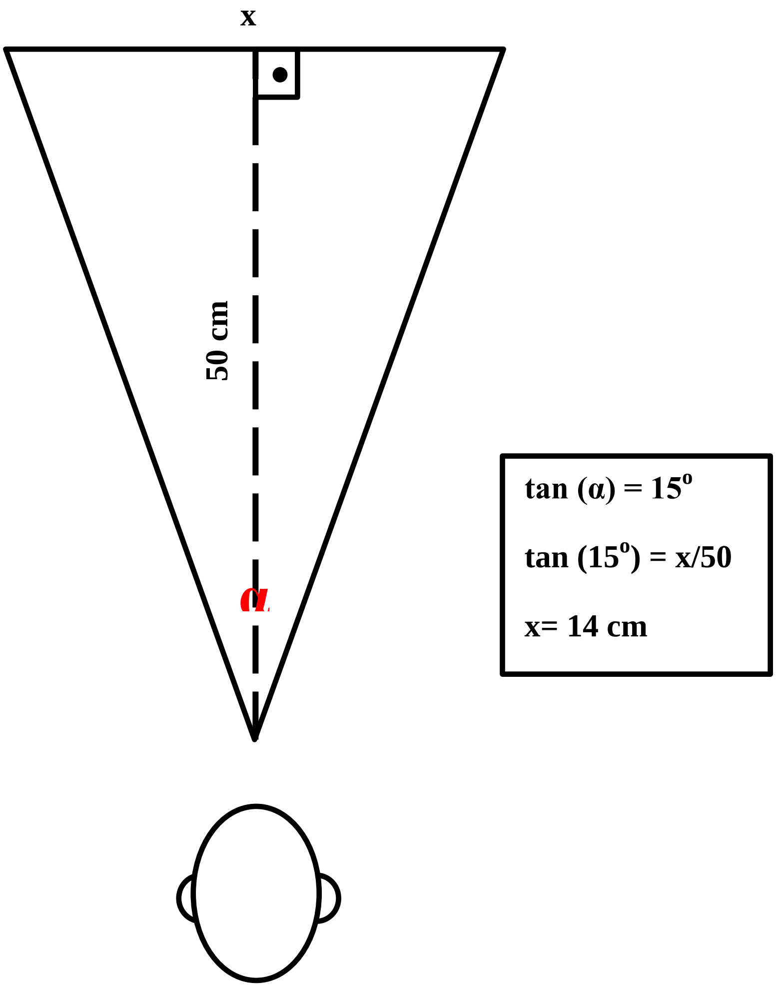
Tarih

APPENDIX L: PARTICIPANT GROUPS IMAGE DISTRIBUTON

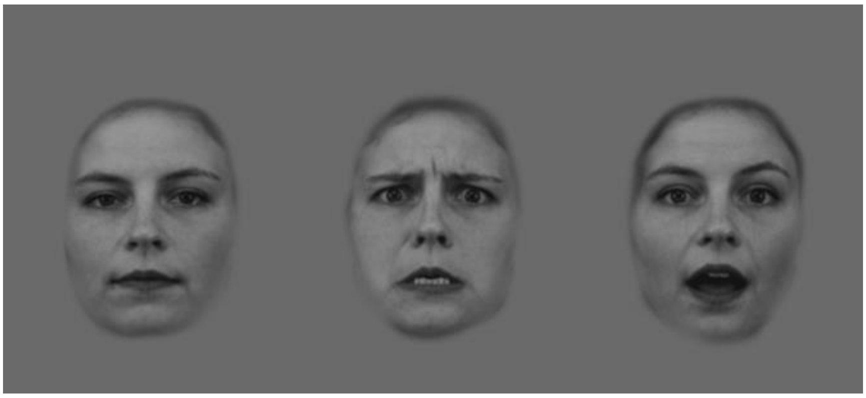
Participant Group 1		Participant Group 2		Participant Group 3	
KDEF	*KDEFs*	*KDEF*	*KDEFs*	*KDEF*	*KDEFs*
F06ANG	F06ANG	F06SUR	F06SUR	F06NEUT	F06NEUT
F09SUR	F09SUR	F09NEUT	F09NEUT	F09ANG	F09ANG
F12NEUT	F12NEUT	F12ANG	F12ANG	F12SUR	F12SUR
F13ANG	F13ANG	F13SUR	F13SUR	F13NEUT	F13NEUT
F14SUR	F14SUR	F14NEUT	F14NEUT	F14ANG	F14ANG
F19NEUT	F19NEUT	F19ANG	F19ANG	F19SUR	F19SUR
F20ANG	F20ANG	F20SUR	F20SUR	F20NEUT	F20NEUT
F21SUR	F21SUR	F21NEUT	F21NEUT	F21ANG	F21ANG
F22NEUT	F22NEUT	F22ANG	F22ANG	F22SUR	F22SUR
F25ANG	F25ANG	F25SUR	F25SUR	F25NEUT	F25NEUT
F30SURP	F30SUR	F30NEUT	F30NEUT	F30ANG	F30ANG
F34NEUT	F34NEUT	F34ANG	F34ANG	F34SUR	F34SUR
M01ANG	M01ANG	M01SUR	M01SUR	M01NEUT	M01NEUT
M05SUR	M05SUR	M05NEUT	M05NEUT	M05ANG	M05ANG
M06NEUT	M06NEUT	M06ANG	M06ANG	M06SUR	M06SUR
M08ANG	M08ANG	M08SUR	M08SUR	M08NEUT	M08NEUT
M09SUR	M09SUR	M09NEUT	M09NEUT	M09ANG	M09ANG
M13NEUT	M13NEUT	M13ANG	M13ANG	M13SUR	M13SUR
M14ANG	M14ANG	M14SUR	M14SUR	M14NEUT	M14NEUT
M22SUR	M22SUR	M22NEUT	M22NEUT	M22ANG	M22ANG
M29NEUT	M29NEUT	M29ANG	M29ANG	M29SUR	M29SUR
M31ANG	M31ANG	M31SUR	M31SUR	M31NEUT	M31NEUT
M34SURP	M34SUR	M34NEUT	M34NEUT	M34ANG	M34ANG
M35NEUT	M35NEUT	M35ANG	M35ANG	M35SUR	M35SUR

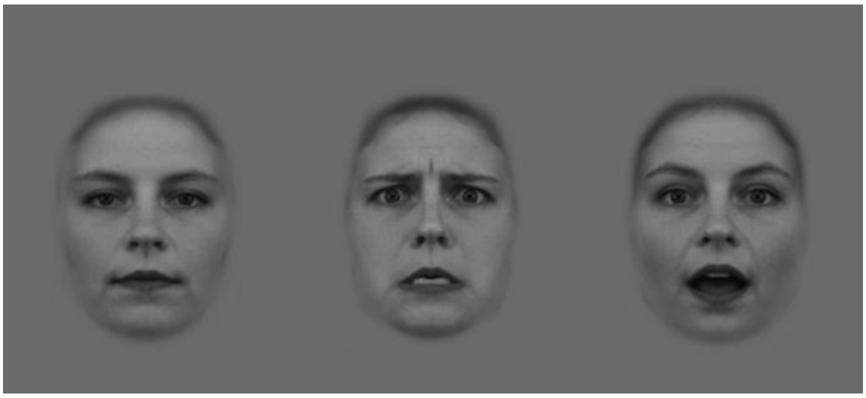
APPENDIX M: VISUAL ANGLE COMPUTATION



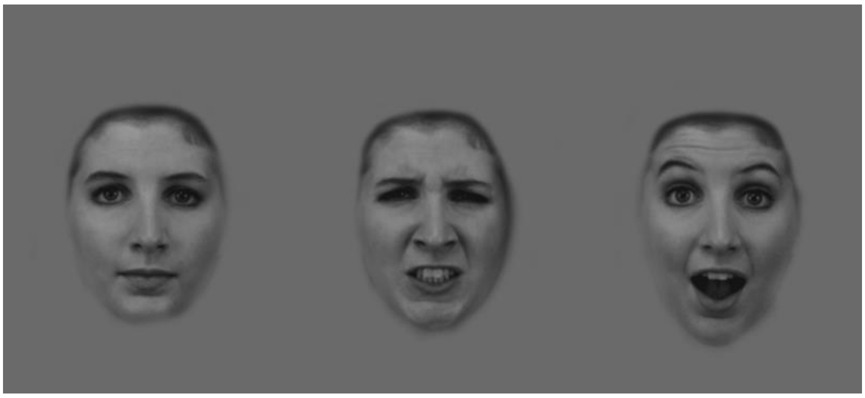
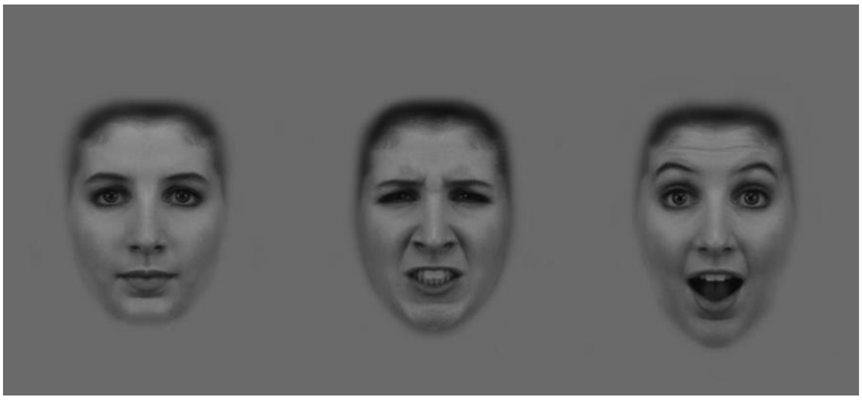


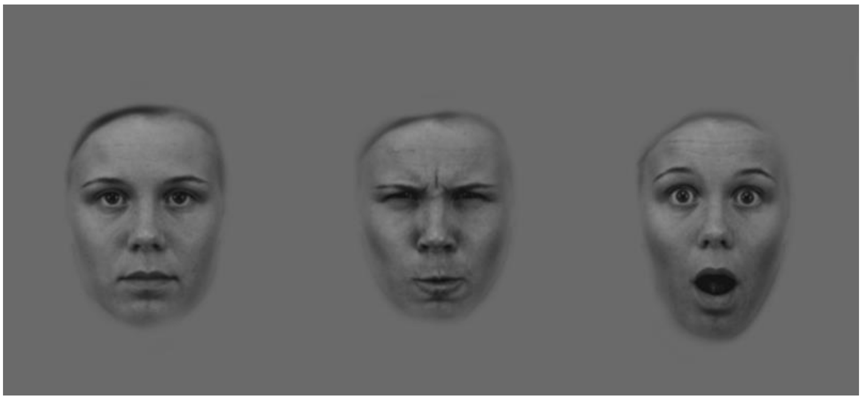
APPENDIX N: SELECTED STIMULI FROM KDEF AND KDEFs

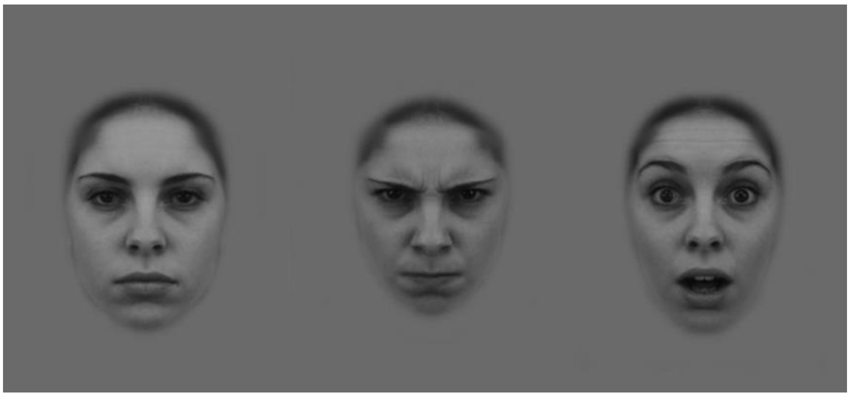


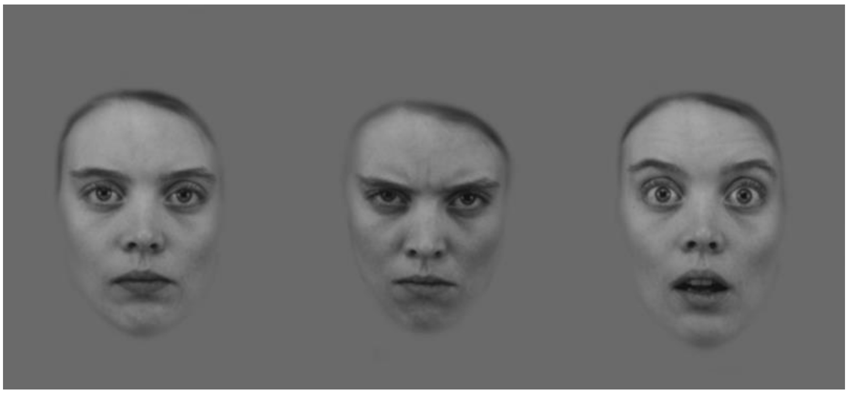






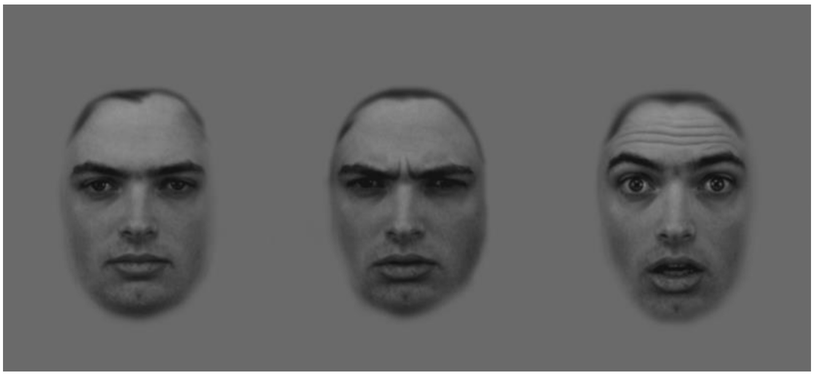


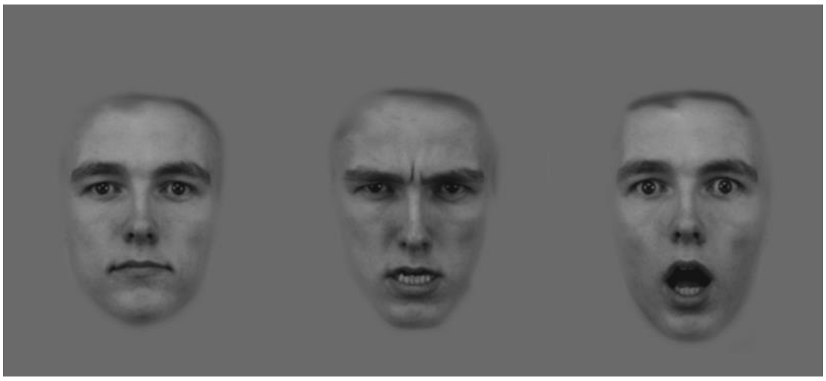


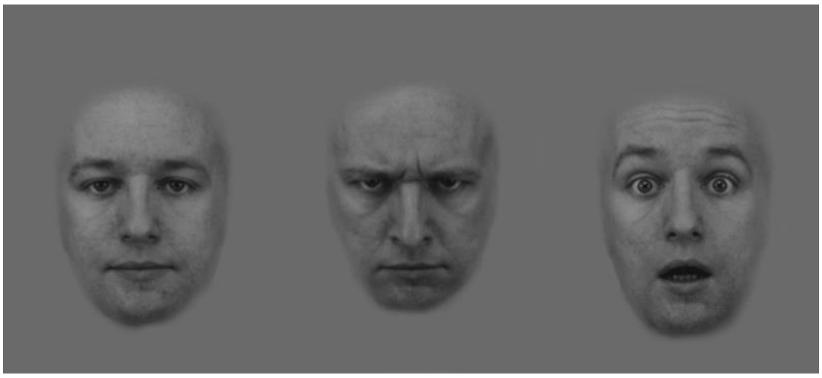


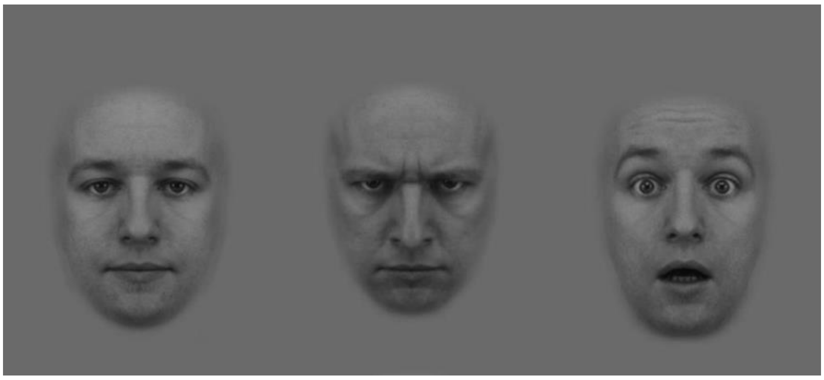


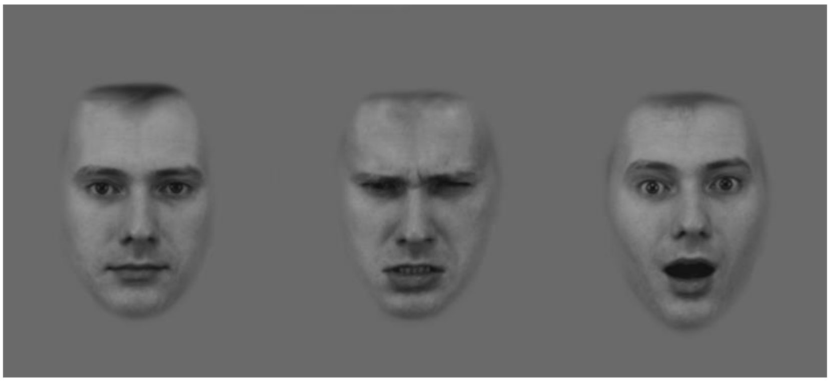


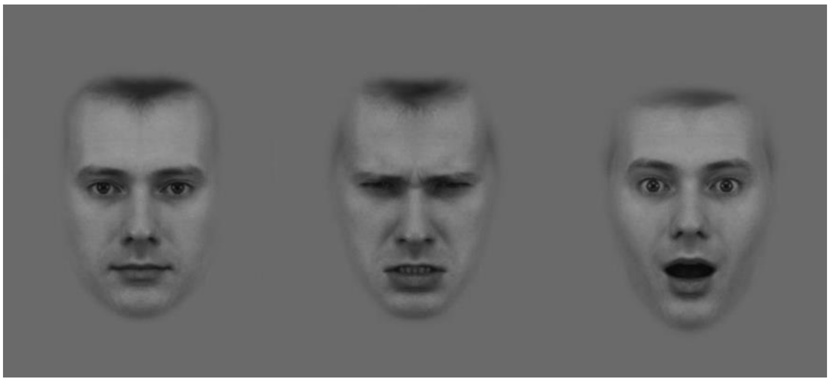


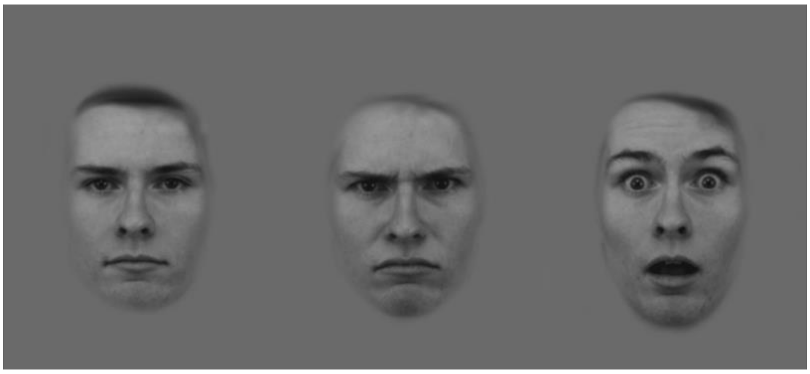


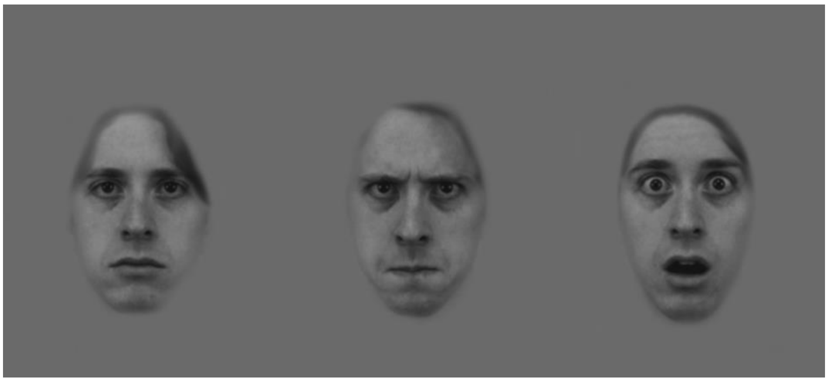


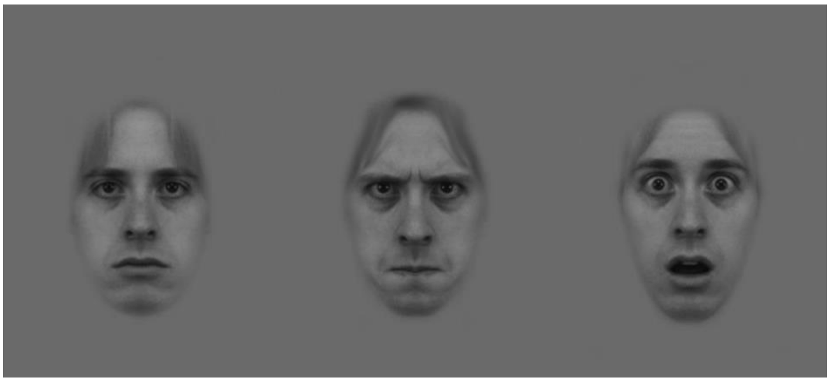


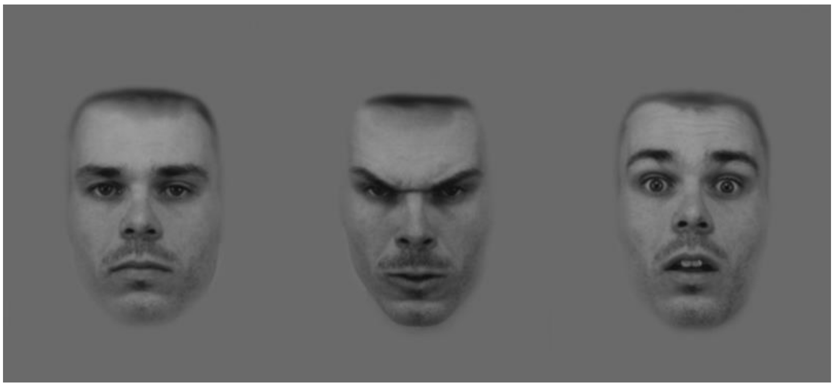


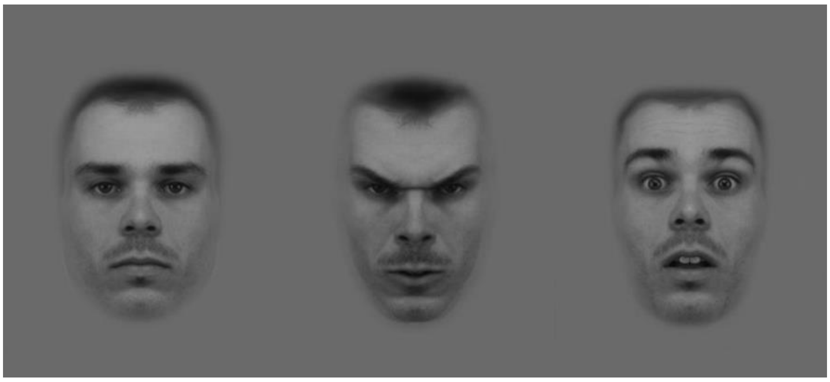


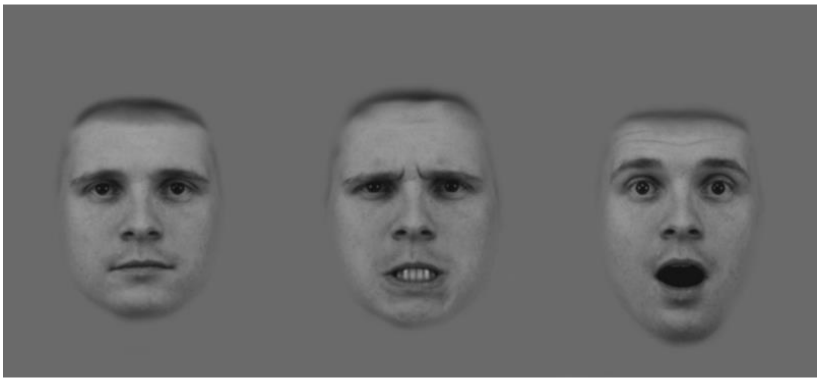


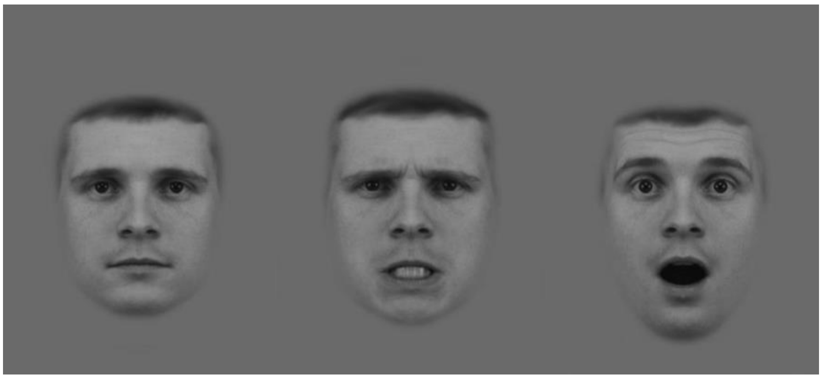




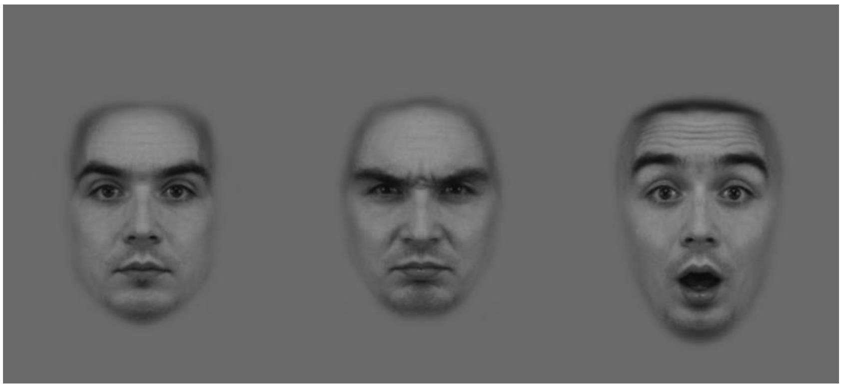










APPENDIX O: DEBRIEFING FORM

Bu çalışma daha önce de belirtildiği gibi ODTÜ Enformatik Enstitüsü Bilişsel Bilimler Bölümü öğretim üyelerinden Dr. Didem Gökçay danışmanlığında yüksek lisans öğrencisi Pırıl Hepsomalı tarafından yürütülen bir tezdir. Araştırmanın amacı, simetrik ya da orijinal (simetrik olmayan) olan yüz ifadelerine verilen çekicilik ve algılanan simetri değerinin göz izleme cihazıyla incelenmesidir.

Fiziksel görünüm, bireyin sahip olduğu genlerin kalitesi hakkında güçlü ipuçları verir. Örneğin, simetrik yüze ve vücuda sahip insanlar daha çekici olarak değerlendirilmişlerdir. Çalışmada, simetrik olan yüz ifadelerinin orijinal olanlardan çekicilik ve göz hareketleri bakımından farklı olduğunun bulunması beklenmektedir. Aynı zamanda, 2 temel duygu ve bir adet nötr fotoğrafın da çekicilik ve göz hareketleri bakımından farklı olduğunun bulunması beklenmektedir.

Bu çalışmadan alınacak ilk verilerin 2013 yazı sonunda elde edilmesi amaçlanmaktadır. Elde edilen bilgiler sadece bilimsel araştırma ve yazılarda kullanılacaktır. Çalışmanın sonuçlarını öğrenmek ya da bu araştırma hakkında daha fazla bilgi almak için aşağıdaki isimlere başvurabilirsiniz. Bu araştırmaya katıldığınız için çok teşekkür ederiz.

Yrd. Doç. Dr. Didem Gökçay (didem@ii.metu.edu.tr)

Pırıl Hepsomalı (piril.hepsomali@metu.edu.tr)

TEZ FOTOKOPİ İZİN FORMU

ENSTİTÜ

Fen Bilimleri Enstitüsü ☐

Sosyal Bilimler Enstitüsü ☐

Uygulamalı Matematik Enstitüsü ☐

Enformatik Enstitüsü ☐

Deniz Bilimleri Enstitüsü ☐

YAZARIN

Soyadı : ....

Adı : ....

Bölümü : ....

TEZİN ADI
(İngilizce) : ....

....

TEZİN TÜRÜ : Yüksek Lisans ☐ Doktora ☐

1. Tezimin tamamı dünya çapında erişime açılsın ve kaynak gösterilmek şartıyla tezimin bir kısmı veya tamamının fotokopisi alınsın. ☐

2. Tezimin tamamı yalnızca Orta Doğu Teknik Üniversitesi kullanıcılarının erişimine açılsın. (Bu seçenekle tezinizin fotokopisi ya da elektronik kopyası Kütüphane aracılığı ile ODTÜ dışına dağıtılmayacaktır.) ☐

3. Tezim bir (1) yıl süreyle erişime kapalı olsun. (Bu seçenekle tezinizin fotokopisi ya da elektronik kopyası Kütüphane aracılığı ile ODTÜ dışına dağıtılmayacaktır.) ☐

Yazarın imzası .... Tarih ....