Differential processing strategies in face perception

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This Thesis is dedicated to the beloved faces of my family.

“Our minds light on the face like butterflies on a flower, for it gives us a priceless flow of information.”

Daniel McNeill, 2000, pp.4

“The face is the soul of the body”

Ludwig Wittgenstein, (1889 –1951)

“Everything is in the face”

Marcus Tullius Cicero (106 - 43 B.C.)

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Tromsø, May, 28th, 2010

Line Sæther

LIST OF RESEARCH REPORTS

The present dissertation is based on the following empirical reports:

Report I Sæther, L., & Laeng, B. (2008). On facial expertise: Processing strategies of twins' parents. *Perception*, 37, 1227-1240.

Report II Sæther, L., Van Belle, W., Laeng, B., Brennen, T., & Øvervoll, M. (2009). Anchoring gaze when categorizing faces’ sex: Evidence from eye-movement data. *Vision Research*, 49, 2870–2880.

Report III Sæther, L., & Laeng, B. (submitted). Age versus beauty: Assessing different attributes of faces yield different oculomotor scan patterns.

SAMMENDRAG
(ABSTRACT IN NORWEGIAN)

Ansikter utgjør en unik objektklasse ved at de inkluderer omfattende informasjon om mange aspekter av menneskelig interaksjon, og likevel medfører ekspertprosessering av individuelle objekter på et underordnet/spesifikt nivå. En så grunnleggende ferdighet er det nødvendig å forstå før man kan gjøre fremskritt innen anvendt forskning. Den foreliggende avhandlingen beskriver flere eksperimentelle studier som undersøkte ulike basale egenskaper ved ansiktspersepsjon, i forhold til en rekke prosesseringsoppgaver. I Rapport I ble de ytre grensene for vår ansiktsprosesseringsekspertise undersøkt i to eksperimenter. Gjennom kategorisering og invertering av svært like tvillingansikter, ble det vist at erfaring spiller en viktig rolle for ansiktsprosessering. Resultatene indikerte at konfigurell prosessering av ekstremt like ansikter kan læres, og at denne ekspertisen bygger på typiske ansiktsprosesseringsstrategier. Dvs. dette er ikke en spesialisert form for ekspertise. Kategorisering av ukjente tvillingansikter er likevel en så vanskelig oppgave at typiske ansiktsprosesseringsstrategier blir lagt til side, spesielt for tvillingforeldre som ser ut til å ha utviklet en form for perseptuell ekspertise som er særegen for deres egne barn. Rapport II og III benyttet øyebevegelsesmetoden for å undersøke ansiktspersepsjonens bakenforliggende okulomotoriske strategier. Disse studiene viste at perseptuell skanning av ansikter er avhengig av den spesifikke prosesseringsoppgaven som blir utført. Resultatene pekte mot at ulike diagnostiske trekk blir benyttet som holdepunkter under ulike typer ansiktsvurderinger. Øyebevegelsesmønsteret ved vurdering av et ansikts kjønn eller attraktivitet besto hovedsakelig i sentral blikkforankring og kunne dermed være basert på konfigurelle strategier, mens aldersestimeringer så ut til å være mer basert på analytisk fokusering direkte på øyeregionen. Den visuelle vinkelen (VA) til det presenterte ansiktet påvirket også deltagernes øyebevegelsesmønster. Dvs. at det var større skanningsvariasjon mellom oppgavene i små enn i store ansikter selv om avstanden mellom ansikt og observatør var den samme (Rapport III). Dette var forventet i og med at hver øyefiksering gir mindre informasjon med lav oppløsning, i store enn i små ansikter. Imidlertid ble attraktivitetsvurderinger mer påvirket av endringer i visuell vinkel enn aldersestimeringer. Dette kan være forårsaket av ulik prosesseringsstrategi i de to oppgavene, og tyder på at øyebevegelsesmetoden bør variere den visuelle vinkelen som anvendes ved ansiktsprosesseringsforskning der ansiktsinformasjon med lav oppløsning er forventet å bli benyttet. Rapport II og III tilsikter i tillegg å utforske hvordan øyebevegelsesmetoden kan tilpasses ansiktsprosesseringsforskning på en best mulig måte. Generelt viser avhandlingen at prosessering av ulike egenskaper ved ansiktene kan avhenge av den perseptuelle oppgaven som blir utført.

ABSTRACT

Faces constitute a unique object class in that they include extensive information about many aspects of human interaction, and still imply expert processing of individual subordinate-level objects. It is necessary to understand such a basic skill before progress in applied research can take place. The present thesis describes several experimental studies that investigated different basic attributes of face perception, according to a number of processing tasks. In Report I, two experiments examined the upper limits of our face processing expertise. Results showed that experience plays an important role in face processing, as obtained by categorisation and inversion of similar twin faces. The findings indicated that configural processing of extremely similar faces can be learned and that such expertise is built upon typical face processing strategies. That is, it is not a specialized form of expertise. However, categorization of unfamiliar twin faces is such a difficult task that typical face processing strategies are set aside, especially for twins' parents who seem to have developed a form of perceptual expertise that is idiosyncratic to their own children. Report II and III employed the eye-tracking method to investigate the oculomotor strategies underlying face perception. These studies indicated that perceptual scanning of faces depends upon the specific processing task that is performed. The findings suggested that different diagnostic features are used as cues during diverse types of face assessments. The eyes' scan paths during assessments of facial sex or beauty mainly consisted of a central gaze anchoring and could thereby be based on configural strategies, whereas age estimations seemed to be more based upon analytical focus directly on the eye region. The visual angle (VA) subtended by the presented faces also affected participant's eye-movement patterns. That is, there was more scanning variation between tasks in small than in larger faces, although the distance between the face and the observer was the same (Report III). This was expected, as every fixation gives less low-resolution information in large than in small faces. However, beauty assessments were more affected by changes in visual angle than age estimations were. This could be caused by diverse processing strategies in the two tasks, and might indicate that the eye-tracking method should vary the visual angle employed with face processing research where elicitation of face information with low resolution is expected. Additionally, Report II and III intended to explore how the eye-tracking method could be best adapted to face processing research. Generally, the thesis shows that processing of different facial attributes could be dependent upon the perceptual task performed.

INTRODUCTION

Faces are extraordinarily rich sources of information, containing and displaying data about the identity, the race, the sex, the age, the aesthetics, and the facial expression of a person, as well as aspects concerning communication (e.g., lip movements), health quality (e.g., colour; symmetry), and personality/ social interaction (e.g., gaze direction; cf. Kanwisher & Moscovitch, 2000). Thus, faces constitute an object class including more information than most other object classes, and the kind of information they hold is of great social significance. For this reason, faces are of central importance to us in our everyday lives. The way people often interpret unidentifiable structures, like clouds and mountains, as faces, exemplifies the significance of face representations in memory (e.g., "the man in the moon"; "the face on Mars"; see also Suzuki & Cavanagh, 1995).

At the same time, faces are very similar as visual patterns which form instances of individual exemplars within a subordinate category (Peterson & Rhodes, 2003). This makes perception of faces more complicated than perception of less similar between-category objects (Tarr, 2003). This complexity is illustrated by the vast involvement of brain areas employed during perception of faces (e.g., Haxby et al., 1999). Although scientific examinations indicate that face perception is a highly complex ability, it is a naturally acquired ability which seems effortless. In fact, face perception represents a distinctive kind of object processing with which adults are experts (e.g., Gauthier & Logothesis, 2000). This expert skill is partly attributed to configural or holistic processing of faces but not non-expertise objects (Diamond & Carey, 1986; Gauthier, Curran, Curby, & Collins, 2003; Gauthier & Tarr, 1997; Maurer, Le Grand, & Mondloch, 2002; Tarr & Gauthier, 2000). Yet, some studies reveal expert face processing that is also sensitive to the local properties of the facial parts (Cabeza and Kato, 2000; Dal Martello and Maloney 2006; Leder, Candrian, Huber & Bruce, 2001; Martelli, Majaj, & Pelli, 2005). Thus, face perception might be a "multidetermined" process where both local and global attributes could contribute (Uttal, 2001).

However, the strategy employed might depend on the face processing task performed (e.g., estimation of age), as the diagnostic information varies between tasks (Gosselin & Schyns, 2001; Schyns, Bonnar, & Gosselin, 2002; Smith, Cotrell, Gosselin, & Schyns, 2005). Additionally, some tasks might depend on subtle or small features (e.g., the eye) which demand analytical processing, whereas other processing tasks might rely on comparison of facial features (e.g., to examine relative size or symmetry), or larger diagnostic areas (e.g., skin colour) which might be appreciated configurally or holistically. Yet, face processing might also depend on low level properties of the stimulus face, like borders or regions with high luminance or colour contrast, as in the eyes (Mannan, Ruddock, & Wooding, 1996; Parkhurst, Law, & Niebur, 2002). However, information acquisition seems to be more guided by the processing task than these stimulus properties (Malcolm, Lanyon, Fugard, & Barton, 2008).

A more apparent stimulus property is the pose the face is seen in. Unfortunately, most studies have investigated frontal images of faces only, but how results based on a single facial pose can be directly generalized to every viewing condition remains questionable. Indeed, in non-frontal poses some facial features might be more or less occluded or reveal more about their geometric properties than in the full face (e.g., size, shape, curvature gradients; Laeng and Rouw, 2001). Depending on the diagnostic features in the particular processing task performed, some poses might be more revealing than others (e.g., the size and shape of the nose is better appreciated in three-quarter or profile view, and these poses might therefore be preferred in tasks where the nose is a diagnostic feature).

A combination of stimulus and perceptual factors, like the distance between the face and the observer, might also affect the processing. Since most adult faces have approximately the same size (mean 22 cm, vertical measure; Farkas, Hreczko, & Katic, 1994), the distance to a typically sized face establishes the visual angle (VA) of the image, and settles its spatial frequency (Loftus & Harley, 2005; Smith & Schyns, 2009); that is, both the size of the image on the retina, and the detail resolution of the image is affected by distance. These factors influence processing, as recognition accuracy decreases with increasing distance to the observed face (e.g., Lindsay, Semmler, Weber, Brewer & Lindsay, 2008). However, varying distance between the face and the observer might affect processing strategies differently depending on the perceptual task performed. For instance, holistic processing does not seem to be possible with visual angles smaller than 0.6° or larger than 47.5° (McKone, 2009). Perceptual tasks where holistic processing is preferred might therefore be more affected by low or high visual angles than other perceptual tasks.

Several perceptual aspects might therefore depend on the face-processing task performed, and some of these complicating factors are lined up above. Additionally, the central position faces have in our lives poses scientific problems concerning adequate control stimuli, processing task confusion, and habitual social interaction even with pictures of faces. Research on face processing may be challenging, and some of the most basic questions involved in this kind of processing remains controversial (Uttal, 2001). However, it is worth the effort, as it is important to understand how the brain processes faces before progress in applied research fields (e.g., criminal investigations, biometric identification systems, development of robot vision, face animation, aiding prosopagnosic patients) can be achieved.

The present thesis investigates how our brains process faces during performance of different perceptual tasks. Research Report I discusses face recognition, Report II examines sex categorizations, and Report III compares age estimations and beauty assessments. Additionally, the studies investigated how the perceptual strategies of different tasks affected, or were affected by, various processing aspects, like the degree of expertise in observers (Report I), the eye movements during face processing (Report II and III), the visual angle subtended by a face (Report III). Report II and III also intended to explore how the eye-tracking method can be best adapted to face-processing research. These examinations are done through experimental manipulations, where velocity, accuracy and/or eye movements were measured and analysed. However, concerns regarding the eye-movement process are considered in all the experiments of the present thesis, even though the eye-tracking method is only employed in two of the Research Reports.

BACKGROUND

THE VISUAL SYSTEM UNDERLYING FACE PERCEPTION

The involvement of brain areas employed during perception of faces is vast (e.g., Haxby et al., 1999). This is partly due to the complexity of face processing, and partly due to the fact that the visual sense is the most dominating sense in humans. Almost 40% of the nerve fibres, and nearly 40% of the cortex is preoccupied with visual information (Brodal, 1995). The physical stimulus of the visual system is light between 400- 700 nm, which acts upon light-sensitive cells (photoreceptors) to produce impulses that communicate sensory information to the brain (Schiffman, 2001). The way the visual system deciphers patterns of light may have consequences for the way faces are perceived (Bruce & Young, 1998).

Basic anatomy of the eye

A short description of the eye's anatomy is included in order to provide basic background information for the subsequent eye-movement paragraph. The wall of the human eye consists of three membranes, the white sclera is the outer surface, the blood-vessel-filled choroid is in the middle, and the retina is on the inside of the eyeball (Brodal, 1995). The image that is viewed is focused on the retina. In front of the sclera, the translucent cornea is inserted. This is where the light ray initially is bent in order to be focused on to the retina. The frontal part of the choroid, beneath the cornea, is called the iris (ibid). In the middle of the iris, the opening labelled the pupil is located. The iris reduces or increases the amount of light which reach the retina, by adjusting the pupil. The lens is situated beneath the iris and the pupil. Accommodation of the lens focuses the image on the retina (Schiffman, 2001). The eye can be moved by six muscles which are attached to the sclera. These muscles cooperate extremely precisely (Brodal, 1995).

The retina covers nearly 200° of the eyeball's internal surface (Schiffman, 2001). The small central region of the retina (1.5 mm in diameter) is called the fovea. The retina is very thin at the fovea in order to easily lead the light to the photoreceptors. There are two kinds of photoreceptors in the retina: rods and cones. Cones are responsible for good resolution and colour vision, whereas rods are more light-sensitive than cones and can provide night vision (Brodal, 1995). Only cones are present in the fovea, and the retinal acuity is therefore maximal in this area, diminishing gradually with distance from the fovea (Anstis, 1974; Rayner & Pollatsek, 1989). Thus, large or close objects will only partly be perceived with good resolution unless the gaze is moved. The area surrounding the fovea is called the parafovea, and the area beyond the parafovea is called the perifovea. In the present thesis the conservative assumption that the fovea is 2° of visual angle (VA), the parafovea is 5° of VA, and the perifovea is anything beyond 5° of VA is employed (Balota & Rayner, 1991; Millodot, 2002). (For a discussion of VA, consult the paragraph: "Aspects affecting the resolution of the visual information").

Eye movements and face perception

Vision is an active process (Henderson, 2003), and eye movements are an essential part of vision, as they relocate the fovea, and thus generate high resolution processing in some visual areas but not others (Henderson & Hollingworth, 1998, 1999; Rayner, 1998; Zangemeister, Stiehl & Freksa, 1996). Despite this selective sampling, the sensation is completely and smoothly perceived, as the system compensates in several ways (Stark & Choi, 1996).

The eye can only be in one of two states: movement or fixation (Yarbus, 1967). The large eye-movements, which can shift the gaze from one fixation to another, are called saccades (from the French verb *saccader*, which means to flick; Schiffman, 2001). Saccades are primarily voluntary, but also react reflexively to suddenly appearing, flickering or moving stimuli. Still, they are ballistic movements in that they have a pre-determined destination (Schiffman, 2001). Saccades are performed extremely fast, as they occupy only 10% of the total viewing time (Schiffman, 2001). Vision during saccades is extremely poor, as the high speed of the retinal image leads to blurring. Thus, the purpose of the saccade is mainly to change the point of fixation so that another image falls into the fovea (Yarbus, 1967).

Fixations imply focus on a target or placing the image of the target within the fovea (Schiffman, 2001). The duration of a fixation is related to the difficulty of the processing task, and can vary between 100– 400 ms (Reichle, Rayner, & Pollatsek, 2003). However, stabilized fixations can not last longer than approximately 300 ms, as the image on the retina otherwise would fade away with adaption to the stimulus (Yarbus, 1967). That is, without changes in the light intensity, the cells will stop firing. This effect is the cost of a visual system which is governed by neural adaption, which makes it possible to quickly discover changes in the visual field (Martinez-Conde, Macknik, & Hubel, 2004). However, Yarbus (1967) showed that unconscious, automatic petite movements of the eyes will always accompany fixations, to prevent the image from fading away. Such movements include drift, tremor, and micro-saccades. Drifts denote relatively slow, irregular, larger eye movements, but not so large that the fixation point drifts out of the fovea. Drift maintains accurate fixation between micro-saccades (Nachmias, 1959; St Cyr & Fender, 1969). Tremor signifies tiny oscillatory movements with high frequency (90 Hz) and very small amplitude (20- 40 sec of angle; about the diameter of a cone in the fovea; Martinez-Conde et al., 2004; Yarbus, 1967). Tremor occurs during fixation, drift and saccades, and is thought to maintain activity in the early visual system (Martinez-Conde et al., 2002; 2004). Micro-saccades are fast twitchy, involuntary and parallel eye movements with small amplitude (typically 1-25 min of angle), and a duration of about 10-25 ms (Martinez-Conde et al., 2004; Yarbus, 1967). Only 3% of the movement during a fixation is occupied by micro-saccades (Yarbus, 1967). Micro-saccades occur mainly to correct a fixation point which has drifted too far from the centre of the fovea (Cornsweet, 1956; Yarbus, 1967). However, it is possible that micro-saccades also have a function in visual perception (Gur, Beylin, & Snodderly, 1997; Martinez-Conde et al., 2004). Almost no visual information is perceived during eye movements, but movement is necessary for fixations to be efficient. Yet, fixations are still perceived as completely stationary (Yarbus, 1967).

The eye-movement and fixation process is often interrupted by blinking, which typically last for 100- 400 ms and occurs about 15 times per minute (Gingsborg, 1952; Schiffman, 2001). During blinking the image disappears from the retina, the light intensity rapidly change and the size of the pupil adjust. Eyes also rotate half way as to moisten the cornea, but they return to the original position before the eyes open again (Yarbus, 1967). An inhibitory signal decreases the sensitivity for visual input during the blink, and thereby diminishes the interruptive effect (Schiffman, 2001). Perception is therefore relatively unaffected by the blink (ibid). Blinks are most likely to occur when the attention requirements are minimal (e.g., the blinking rate decreases to about 3- 4 times per minute during reading (Fogarty & Stern, 1989; Orchard & Stern, 1991).

According to Yarbus (1967) the strong connection between eye-movement control and processing of visual input is caused by the fact that saccadic eye-movements change the retinal image. Attention is therefore accompanied by eye fixations, and the human eye will fixate those parts of an object that carry or may carry essential information (Mackworth & Bruner, 1970; Yarbus, 1967). Eye movements have therefore often been studied as indicators of the brain mechanisms involved in visual perception (Guo, Robertson, Mahmoodi, Tadmor, & Young, 2003).

Yarbus (1967, pp. 196) stated that “foveal vision is reserved mainly for those elements containing essential information needed by the observer during perception”. However, even if the locus of attention often is correlated with the locus of fixation, this is not always the case (Malcolm et al., 2008). In some cases it could be advantageous to fixate a central position of the object to observe as much information as possible parafoveally in one fixation (cf. Schwarzer, Huber, & Dümmler, 2005). Positions close to the centre of gravity (COG) is typically fixated in two-dimensional (2D) objects when the task is to look at the object as a whole (e.g., He & Kowler, 1991; Vishwanath & Kowler, 2003), and the COG is preferred to fixations on features for this task (e.g., McGowan, Kowler, Sharma, & Chubb, 1998). It has been suggested that fixation positions are computed by averaging visual signals across all locations within the object (Vishwanath & Kowler, 2004). However, when objects are three-dimensional (3D) the central landing position is weighted according to implied depth (Vishwanath & Kowler, 2004). Processing of both 2D and 3D faces when the task is to categorize frontal faces according to all features, that is, to look at the face as a whole, leads to central fixations on the nose, the eye or between these features (Schwarzer et al., 2005). These are central anchored fixations, but not always close to the COG, which would be approximately on the nose bridge in frontal faces. Faces are objects composed of two quite symmetrical halves, and this might affect the computation of landing position in these objects. Additionally, faces are objects with social significance, which might lead to habitual processing of social aspects independently of the task (Vuilleumier, George, Lister, Armony, & Driver, 2005). These findings show that foveal vision is not always reserved for features containing essential information, especially not when the task demands processing of the whole object. However, perceptual tasks involving featural processing leads to feature-specific gaze behaviour in faces (Schwarzer et al., 2005). This illustrates that fixations can function as a measure of attention during analytical processing.

Both “distribution of fixations”, and “duration of fixations” function as measures of attention towards specific locations (Henderson 2003). Duration of fixation may be measured as “dwell time” and would then include fixations, series of contiguous fixations, and ocular pauses which can be defined as very brief moments between saccades, when the eye sometimes may come into focus (Manor & Gordon, 2003). The small saccades between contiguous fixations, but not larger saccades, may sometimes be included in dwell time measures (Tchalenko, 2009).

However, distribution and duration of fixations can be modulated by the cognitive demands of the task and the characteristics of the stimulus (Andrews & Coppola 1999; Guo, Mahmoodi, Robertson, & Young, 2006; Salthouse, Ellis, Diener, & Somberg, 1981), and may therefore tap into different attentional aspects. Longer fixation duration is often associated with task difficulty (Hooge & Erkelens, 1998; Pollatsek, Rayner, & Balota, 1986), whereas an increased number of fixations may be associated with complex visual patterns (Andrews & Coppola, 1999). For example, Guo et al., (2006) found that fixation distribution was similar between face and scene perception in monkeys, even though fixation duration differed, showing longer fixations on faces. Fixation duration might reflect detailed analysis of specific regions of the face, whereas distribution of fixations might specify analysis of several facial regions.

Direction and duration of fixations compare participant's fixations directed to the same area independently of where in the scanning sequence they appeared. Additionally, the order of fixations can carry information about the complexity of the perceptual process. Noton and Stark (1971) introduced the concept of "scanpath" and defined it as a consistent pattern of successive fixations. They noticed that the scanpaths diverged between participants during free viewing, but were similar between the learning and the recognition phase, indicating a top-down process. Scanpaths ought to be examined in relation to the particular perceptual task performed, and the importance of sequence effects of fixations can be illustrated by the following example. Hsiao and Cottrell (2008) noticed that additional fixations might be carried out even after maximum performance was reached, and concluded that these redundant fixations should be excluded from the analysis. This procedure could lead to a new understanding of the processing task in question. Although, the maximum number of fixations that are necessary for completion of a task is still unknown for most tasks, this exemplifies the complexity of the perceptual process and the importance of sequence effects. Thus, the scanpath seems to reflect an active information searching process.

Aspects affecting the resolution of the visual information

Face recognition becomes less accurate as distance between the face and the observer increases (Lindsay et al., 2008). This is partly caused by the diminishing size of the face on the retina, and partly by the gradual blurring of the face as it moves further away (Loftus & Harley, 2005; Smith & Schyns, 2009).

The decreasing retinal size with larger distance is a phenomenon related to a measure called visual angle (VA). Since the resolution of a face varies both with its size and its distance from the observer, a measure of acuity should take both size and distance into consideration (Schiffman, 2001). The visual angle is the size of the retinal image of the viewed object, which is a function of the size of the object and the distance to the observer (ibid). Stated differently, the VA corresponds to a degree of the visual field that corresponds to the outer edges of the image on the retina. Technically, visual angle is given in degrees, minutes or seconds of arc (1° = 60 minutes, and 1 minute = 60 seconds; Schiffman, 2001). In the case of faces, object size is approximately similar for all exemplars (mean 22 cm, vertical measure; Farkas et al., 1994), making the distance to the observer the effectual measure of VA for adult faces in real life. Thus, a face seen at a conversational distance of 90 cm will subtend a visual angle of approximately 14°. Faces subtending a large VA (by being close to the observer) may loose some fine details as only parts of the face are captured on the fovea and the rest of the face is seen para- or perifoveally, whereas faces subtending a small VA (by being further away from he observer) may be completely included in the fovea. However, faces subtending small VAs as a consequence of distance between the face and the observer may also loose fine details caused by lower resolution of the facial image.

The gradual blurring of the face with increased distance is related to the phenomenon of spatial frequency (SF). SF can be defined as "the number of variations in luminance over a given space" (Schiffman, 2001, pp. 151). The luminance varies according to number of cycles, which indicates number of sine-wave gratings over a given area; that is, cycles per degree of VA (cycles/degree; ibid). Stated differently, the highest luminance constitutes the top of the sine-wave, the lowest luminance the bottom of the sine-wave, and the amplitude settles the number of sine-waves in the given area. As such, the frequency of the patterns varies across space, and therefore the sine-waves may be referred to as having different spatial frequencies (Bruce & Young, 1998). SF of varying degree carry different kinds of information, as lower SF hold global information and higher SF bring detailed analytical information (Loftus & Harley, 2005). For instance, low SF might decompose a face so that information from its features is degraded. Faces at increasing distances are difficult to recognize partly because the visual system have limitations in representing progressively lower SFs, and therefore, according to Loftus & Harley (2005), increasingly coarser details are lost.

Previous research has indicated that our visual system filters the observed image into separate spatial frequencies, perhaps through pooling of ganglion cells with similar receptive fields (e.g., Blakemore & Campbell, 1969; Bruce, Green, & Georgeson, 1996; Graham, 1989). One purpose of these separate channels may be to simplify edge localisation of outer edges versus edges within the object/face which are only present in higher SF scales (Bruce & Young, 1998). However, information from different scales may vary according to significance for the specific object class. Previous research has indicated that the best scale for face recognition varies between 8 and 32 cycles per face which is quite coarse-scaled (Parker & Costen, 1999). The reason for this may be that the 3D clue, shading, which is important for face recognition, is only present in coarse scales (Bruce & Young, 1998). Another possible explanation is that coarse scales can give enough recognition information at a distance, and that the visual system may be adapted to the need to quickly recognize an approaching person (ibid). Nonetheless, it has been established that the preferred SF of faces varies between processing tasks (Schyns et al., 2002). The preferred scale for sex categorization is for instance coarser than that for face recognition. Similarly, anger and fear, but not surprise and happiness, are poorly recognized at a distance (Smith & Schyns, 2009). However, low spatial frequency information in faces can lead to implicit processing of emotional information (Laeng et al, in press). These studies indicate that the nature of the diagnostic information involved in the processing task controls the efficiency of the SF scale employed. Thus, the evolutionary function of face recognition may not be the best explanation of the separate SF channels.

THE PROCESSING LEVEL OF FACES

Objects can be recognized at several levels of abstraction, but most knowledge is organized at the basic level which often serves as the entry level (Tanaka, 2001). Rosch (1978) defined the basic level of abstraction as the level with the highest degree of cue validity. That is, the highest level where a visual representation is readily available, where category members share a similar shape, and where associated motor actions are homogenous (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). According to Rosch (1978), the category “dog” would be at the basic level of abstraction, the category “animal” at the superordinate level, and for instance, “Golden Retriever” at a subordinate level. Similarly, the category “human face” would be at a basic level, as a visual representation is easily derived, whereas the category “primate face” has no such representation, and would therefore be at the superordinate level. Categories like “Caucasian face”, “female face”, or “young face” would fill the subordinate level of abstraction (Tanaka, 2001). Thus, individual face exemplars would be recognized at the specific level of unique identity within a subordinate category (Tanaka, 2001).

Consequently, discrimination between a Golden Retriever and a Poodle would be at a similar level of abstraction as discrimination between an Asian and a Caucasian face. However, faces are very similar as visual patterns, with all features at approximately the same position (e.g., Peterson & Rhodes, 2003). Objects, on the other hand, may vary considerably within a basic category, especially for nonliving things (e.g., chairs; Humphreys, Riddoch, & Quinlan, 1988). Living categories seem to be more structurally similar than other objects, and therefore might require a more detailed visual analysis (Forde & Humphreys, 1999). Yet, faces are living things which may be especially structurally similar (Peterson & Rhodes, 2003). For example, different dog breeds may vary extensively, whereas Asian and Caucasian faces share the same overall structure. This makes perception of faces more complex than perception of less similar objects, and face perception should therefore be compared with discrimination within a specific level of unique identity (Tarr, 2003). Thus, discrimination between individual Golden Retrievers would be at a similar difficulty level as recognition of human faces.

However, most people would have difficulties recognizing one particular Golden retriever between other dogs of the same breed, but recognizing one individual face in a crowd seems effortless. That adults are extremely good at this skill could be caused by the fact that faces hold information of great social significance (Carey, 1992; Carey & Diamond, 1977; Gauthier & Logothesis, 2000; Tanaka & Gauthier, 1997). When face expertise is compared to visual expertise in general, similar processes are revealed. One of the hallmarks of visual expertise is an entry point of recognition at a lower level of abstraction than is the case for novices (Gauthier & Tarr, 1997; Johnson & Mervis, 1997; Tanaka & Taylor, 1991). As expected, the entry point of recognition for face identification is at the exemplar level of abstraction, indicating expert processing (e.g. adults can recognize a specific face as efficiently as when recognising a face as human; Tanaka, 2001). Thus, a downward shift in entry point recognition exists for face identification, as for non-face object expertise identification. In other words, the initial recognition occurs within the subordinate level of abstraction, at the point of unique identity, as predicted by Bruce and Young, 1986.

Object generalization from subordinate-level exemplar expertise to other exemplars within the same class seems to be based on a refinement of perceptual categorization, and a tendency to focus more on details than is the case for novices (Johnson & Mervis, 1997; Tanaka, Curran, Sheinberg, 2005). The question dealt with next is if this also is the case with face expertise.

FACE PROCESSING STRATEGIES

In colloquial speech parts of the face are identified as separate features, but the relationships between these features are not mentioned equally often. This does not necessarily imply that the visual system use such facial parts as building blocks to form a face percept (Bruce & Young, 1998). Perception of a face might be more than the sum of its features; the relations between the facial parts might be detected by the visual system and included in the face percept. Such visual descriptions of the features and the relation between them could be done through configural or holistic processing. Global/ holistic processing implies processing the whole facial image at once without analysing it into separable features. However, configural processing could imply that facial parts interact, or that spatial relation information between the parts also contributes to the processing. The span of configural processing could be small or large depending on the distance between parts and number of parts included, and large spanned configural processing might be defined as holistic processing (Peterson & Rhodes, 2003). Part-based/ piecemeal/ local or analytical processing, on the other hand, implies that the facial parts are processed independently from each other.

Some studies report that part-based processing makes important contributions to face perception (Cabeza & Kato, 2000; Dal Martello & Maloney 2006; Leder et al., 2001; Martelli et al, 2005; Rhodes, Brake & Atkinson, 1993). However, these studies employed simple tasks like categorization of familiarity (Cabeza & Kato, 2000; Dal Martello & Maloney, 2006), assessment of distance between the eyes (Leder et al., 2001), and recognition of parts in a crowding task (Martelli et al., 2005). Such tasks might be less configurally based than more complex face processing tasks like identification of a face, and such techniques may fail to incorporate that new functional configurations might be formed even though the nominal aspect is featural (Bartlett, Searcy & Abdi, 2003). Even though processing is also sensitive to facial parts, there is considerable agreement that faces are mainly processed in configural/holistic manner.

A hallmark of face perception is that it mainly seems to rely on configural or holistic processing, whereas perception of other objects relies on more part-based processing (e.g., Bartlett et al., 2003; Bruce & Humpreys, 1994; Tanaka & Farah, 1993; Young, Hellawell, & Hay, 1987). The most striking evidence indicating that faces are holistically processed comes from several techniques, including the face superiority effect, the inversion effect, the composite face paradigm, and the Thatcher illusion. In the face superiority effect, facial parts are discriminated faster if presented in the context of a face than if presented alone or in a scrambled face, although this advantage is eliminated by inversion (Tanaka & Farah, 1993; Tanaka & Sengco, 1997). This finding can be interpreted as evidence for a configural process where facial parts are perceived in a relation to other areas of the face, or the whole face. The inversion effect demonstrates that inversion of a face by 180° impairs recognition more than inversion of other objects (e.g., Farah, Tanaka, & Drain, 1995; Yin, 1969). This effect can be understood as sensitivity to the configurations of upright faces, as this is the orientation people are most experienced with. When the face is inverted, the configurations are disrupted, although the features remain the same. Thus, holistic processing might be involved in upright, but not in inverted faces. The composite face paradigm demonstrates that when upper halves of faces are aligned with lower halves of other faces it is hard to ignore one of the halves (Carey & Diamond, 1994; Hole, 1994; Young et al., 1987). Instead, these composite faces seem to form new faces which indicate that holistic processing is employed. However, the half faces are easier to recognize when the composite faces are inverted, representing a powerful inversion effect. The Thatcher illusion demonstrates that a face looking grotesque, because the eyes and the mouth have been inverted, does not look grotesque when the whole image is inverted (Stürzel & Spillmann 2000; Thompson, 1980). This finding can be explained by the configural processing hypothesis, as also faces with features that have been moved horizontally appears less grotesque when inverted (Bartlett & Searcy, 1993).

Inversion of the face is a component in all of these techniques, and the basis of the inversion effect has therefore been studied extensively. An inversion effect has not been found in face matching tasks (Bruyer & Velge, 1981; Valentine, 1988), which could indicate that faces have to be stored in memory for an inversion effect to take place. Within this theoretical frame it is not surprising that the inversion effect not has been found for unfamiliar faces (Loftus, Oberg, & Dillon, 2004; Megreya & Burton, 2006; Sekuler, Gaspar, Gold, & Bennett, 2004). The inversion effect has therefore been explained by a single processing strategy model which suggests that upright faces are processed holistically/configurally, whereas such a strategy is harder to use on inverted faces, as they first may have to be mentally rotated (Bruyer, Galvez, & Prairial, 1993; Collishaw & Hole, 2002; Rock, 1973; Valentine & Bruce, 1988).

However, an inversion-effect study that compared the encoding and the storage stage of configural and part-based information found that the inversion effect is mainly caused by the disruption of configural information at the encoding stage (Freire, Lee, & Symons, 2000). These researchers suggested that inverted faces are not necessarily mentally rotated, but that the matching task (which is also used for most studies on unfamiliar faces; e.g., Megreya & Burton, 2006; Sekuler et al., 2004) is less complex than the identification task, and that configural processing might not be necessary in the simple matching task. Other studies have also found variation in the inversion effect according to the processing task performed (e.g., Enns & Shore, 1997; Itier & Taylor, 2001; Sergent, 1984). Similarly, studies employing the composite face paradigm shows analogous results for unfamiliar and familiar faces also when the composite faces are inverted (Hole 1994; Le Grand, Mondloch, Maurer, & Brent, 2004). These studies could be interpreted as indicating that the effects are caused by a dual process where configural/holistic and part-based coding constitute different routes to face perception, but that configural coding is preferred for this object class (e.g., Carey & Diamond, 1977; Rhodes et al., 1993; Sergent , 1984).

Other previous studies have investigated if the inversion effect is caused by an abrupt qualitative shift in perception as faces are rotated away from an upright position (e.g., Lewis, 2001), or by a gradual linear quantitative decline (e.g., Collishaw & Hole, 2002). The qualitative shift could indicate a dual process, whereas the quantitative decline could indicate a single process. Mondloch and Maurer (2008) found, by inverting composite faces in seven orientations, that there was a linear decline in perception until the face was rotated by 90º. Further rotation led to an abrupt perceptual shift. These results were interpreted as indicating that beyond 90º, sensitivity to the distance between features, which is necessary for face identification, were sufficiently impaired to cause an abrupt shift in the salience of the face. This could indicate that configural and holistic processing constitute the same route, whereas part-based processing employs another route to face perception. The results also show that holistic processing precedes configural and part-based processing (cf. Le Grand et al., 2004).

There is still quite some controversy regarding the quantitative or qualitative nature of this difference, perhaps because a resolution could provide hints regarding a larger discussion; what is the reason that faces and non-face object are processed differently. Are faces treated as a special kind of object by the brain?

FACE-SPECIFIC PROCESSING?

Several differences in performance effects between face and object processing have been found. The inversion effect for faces, but not objects is one of them. Secondly, the caricature effect, showing that distinctive exemplars are more recognizable, is found for faces but not non-face objects (Benson & Perrett, 1991; Rhodes, Brennan, & Carey, 1987). Thirdly, line drawings of non-face objects are easier to identify than line drawings of faces (Bruce, Hanna, Dench, Healey & Burton, 1992). Additionally, some brain damaged patients have problems with face recognition (prosopagnosia) but not with non-face objects (Damasio, 1985), and a double dissociation has been reported (Assal, Favre, & Anderes, 1984).

The prominent social significance of faces, together with these findings, have led some researchers to conclude that face perception use other and more specialized processing mechanisms than non-face objects (e.g., Farah, 1996). Such specialized systems/modules might include the fusiform face area (FFA; mid-fusiform gyrus in the temporal lobe) which, by this account, is thought to be engaged only with face processing (e.g., Kanwisher, 2000; Kanwisher, McDermott, & Chun, 1997). Studies of single-cell recordings in monkeys support such a “faces are special” account, as cells that mostly respond to faces have been found in the temporal cortex of the monkey (Hietanen, Perrett, Oram, Benson, & Dittrich, 1992). At the bottom of this account is the assumption that two qualitatively different perceptual routes exist, and that faces only occupy one of them. If part-based and configural processing were found to be parts of the same system, this account would stagger. Yet, the account could still be incorrect if qualitative differences were found, because both faces and non-face objects could engage both routes.

However, the performance effects described above could be explained without considering unique face-processing mechanisms. The expertise account proposes that since faces constitute similar exemplars within a basic category, extensive experience is required to distinguish them. The same level of expertise performed on exemplars within another basic object class would, according to this account, lead to the same processing effects as with faces. Object expertise studies give support for this position (Carey & Diamond, 1977; Diamond & Carey, 1986; Gauthier & Tarr, 1997; Gauthier, Williams, Tarr & Tanaka, 1998; Goldstein & Chance, 1980). Other studies indicate that expertise is also driving the caricature effect (Rhodes, 1994; Rhodes & McLean, 1990), and possibly the line drawing effect (Leder, 1996; Price & Humphreys, 1989). Some studies find no similarity between processing of faces and other expertise classes (e.g., Kanwisher, 2000). However, this is explained by different categorization- or expertise levels between the object classes in the studies (Tarr & Gauthier, 2000). Neural correlates of an expertise mechanism have also been indicated, as the FFA has been found to be active during expertise object processing of birds or cars (Gauthier, Skudlaski, Gore & Anderson, 2000). Thus, the prosopagnosia studies can be understood as deficits in an expertise area, or an area for holistic/configural processing. Yet, one prosopagnosic patient did show expertise in sheep recognition (McNeil & Warrington, 1993), although the task employed was a forced choice recognition memory task, not an identification task. Such expertise might be on a lower level where configural processing is not necessarily activated.

However, in an fMRI study, Haxby et al. (2001) showed that face and object processing lead to overlapping patterns of activity in the cortex. These patterns, not only the most responding area, could identify the stimulus class that was processed. Thus, the role played by the FFA in face processing might be exaggerated in the literature.

The reason for the differential processing of faces and objects is not settled yet, but the expertise account is supported by a growing research literature. The present thesis is therefore anchored within the expertise account.

FACE-PROCESSING TASKS

The rich information found in faces can be used to answer different questions regarding a specific face. Such questions are referred to as processing tasks. The tasks studied in the present thesis include face identification, sex categorization, age estimation, and beauty assessment. Physical differences between the groups categorized in a specific task (e.g., skin smoothness differences in young and old faces), could be expected to constitute diagnostic features or patterns. However, the visual expertise connected with faces could instead lead to a more configural strategy signifying that the physical differences might not be the most attended perceptual difference for a specific task (Hsiao & Cottrell, 2008). Yet, both the perceptual strategy generally employed, and the pattern of information that is typically used might depend on the processing task performed (e.g., Malcolm et al., 2008; Smith et al., 2005). The debate can be divided into two themes: 1.What is the objective anatomical differences between face categories (e.g., young and old faces)? 2. Which pattern of facial information is sufficient and spontaneously attended by participants during performance of a specific perceptual task?

Face identification

A face is one of the most reliable keys to a person's identity (Bruce, 1989). Yet, the face identification task place heavy demands on the visual system as discriminations of face exemplars have to be performed across different poses, expressions, facial ages, gender and so forth. Individual exemplars resemble each other, as the basic featural pattern is the same across faces (with eyes above the nose etc.). However, the overall shape, the surface, the colours, the facial parts and the configurations may differ between exemplar faces in subtle ways. All of these features might potentially differ physically between two faces, and the complexity of possible subtle featural differences is overwhelming (Gombrich, 1976). The identification task is therefore a very complex processing task. Still, it is normally performed seemingly without much effort as a result of the expertise acquired by adults on this object class.

Both familiar and unfamiliar faces may be identified, or categorized, according to familiarity, although there are several levels of familiarity, and the complexity level of the processing might vary according to the familiarity level of the face (Stacey, Walker & Underwood, 2005). For example, face matching of unfamiliar faces is not as demanding as identification of familiar faces, and the strategies involved might therefore differ. Recognition processing of familiar faces might also be heavily influenced by facial memories, resulting in a different information gathering than for unfamiliar faces (Althoff & Cohen, 1999; Barton, Radcliffe, Cherkasova, Edelman, & Intriligator, 2006; O'Toole, Abdi, Deffenbacher, & Valentin, 1993). An example of the role of experience in face recognition comes from studies showing that people are more accurate when recognizing faces of their own race (Levin, 2000; Malpass, 1981; Meissner & Brigham, 2001) or their own age (Anastasi & Rhodes, 2005, Fulton & Bartlett, 1991; Memon, Bartlett, Rose, & Gray, 2003).

Familiar faces seem to be identified mainly through holistic or configural strategies (e.g., Young et al., 1987), although processing is also sensitive to analytical cues (Cabeza & Kato, 2000; Dal Martello & Malooney, 2006).This might be the case for unfamiliar faces as well, but only when the task demands are complex enough (c.f., Le Grand et al., 2004; Megreya & Burton, 2006). The part-based identification kit system, Photofit, generates poor recognition performance of unfamiliar faces (Ellis, Davies, & Sheperd, 1978) indicating that also unfamiliar faces are generally recognized by means of configural cues. However, this could also be an effect of the lack of external cues in the Photofit system (Ellis, 1986), as some studies indicate hairstyle and head shape dominance in the memory for unfamiliar faces (O'Toole et al., 1993). The E-fit system which is improved according to global cues generates much better recognition performance (Sheperd, 1986).

For familiar faces, there seems to be a consensus that the whole internal facial region (brows, eyes, nose and mouth) is diagnostic to the identification task (e.g., DeAngelus & Pelz, 2009; Henderson, Falk, Minut, Dyer, & Mahadevan, 2001). Additionally, a study using the Bubbles technique found that the eyes, compared to the rest of the diagnostic internal region, were especially in need of high resolution focus (Schyns et al., 2002). Such eye attention might be an indication of particularly important diagnostic information in this area, but could also indicate either a need for high resolution on small features, or habitual processing of social aspects, including eye contact (Vuilleumier et al., 2005). An eye-tracking study by Hsiao and Cottrell (2008) showed that people anchor their gaze slightly to the left of the nose during face recognition, and that fixations on the eyes occur only after maximum performance is reached. However, in a recognition study where morphing increased ambiguity between face stimuli, the eye region was more attended than without morphing, suggesting that diagnostic information in this area may be particularly valuable for face recognition of familiar faces after all (Barton et al., 2006).

Age estimation

The accuracy of age estimations of adult faces is quite good, showing only minor deviations between the estimated and the actual age of the person (2- 4 years; Burt & Perrett, 1995; George & Hole, 2000; Sörqvist & Eriksson, 2007). Older adult faces seem to be more distinctive and therefore more memorable than younger adult faces (Deffenbacher, Vetter, Johanson, & O'Toole, 1998). However, the estimation of a person's age might be even easier when he/she is a child, as the most dramatic facial ageing effects take place during the first 20 years of a person's life (Enlow, 1982). During this period of growth, the nasal and jaw regions enlarge much more than the *neocranium*, which initially was more developed than the rest of the head in order to house such a large brain. The lower face of children, including the nose and the jaw, is therefore smaller than in adult faces, relative to the cranium, and the developed eyes in children seems large in comparison to the small face (Berry & Mc Arthur, 1986; Enlow, 1982). The period of growth leads to an upwards "movement" of the inner facial features (Rhodes, 2009).

However, the face continues to change after adulthood is reached. Nose and ear cartilage never cease growing, and the eyebrows gradually become thicker. Both these changes affect the relative perceived size of the eyes, which are gradually perceived as smaller than before. Hair also gradually becomes thinner and loose colour.

Nonetheless, perhaps the most apparent changes in adult faces are the ones that concern the skin, the soft tissue, and the skeletal support structures of the human face (Sadick, Karcher & Palmisano, 2009). First, the connective structures, which anchor the skin to the skeleton, start to change by the middle age. Such changes, together with the effect of gravity, lead to sagging of the skin which is more visible in the face than on the rest of the body (Cole, 1998). Such skin drooping is especially visible on the upper eyelids, and near the jaw and chin (Sadick et al., 2009). Secondly, the changes in the soft tissue, including loss of elasticity and loss/gain of adipose tissue, exacerbate this sagging of the skin and expose the underlying bone structure (e.g., zygomatic bone). Some facial areas loose adipose tissue (e.g., lips) whereas other areas (e.g., jaw) gain adipose tissue with age (Sadick et al., 2009). The eye region has a particularly high disposition to loose adipose tissue, giving a more sunken eye appearance with age (e.g., Rhodes, 2009). Finally, the facial skin is changed in several ways with aging, predominantly leading to the onset of wrinkling by the age of 30 or 40 (Rhodes, 2009). The age factors which influence the skin includes: repeated contractions in several facial areas, dermal atrophy (flattening of the skin), and degradation of dermal elastic tissue (Mark et al., (1980); Sadick et al., 2009). These processes are typically coordinated, and do not occur independently of each other (Enlow, 1968). Wrinkling of the skin is particularly visible on the forehead, in the eye area, on the *glabella* (the area between the eyes), and around the mouth (Bruce & Young, 1998; Burt & Perrett, 1995; Sadick et al., 2009).

The changes according to age are therefore numerous and continuous, making age assessments a complex task (c.f. George & Hole, 2000). However, several kinds of age-related changes are found in the eye region (e.g., information concerning changes in the skin, the soft tissue, the skeletal support structures, the thickness of the brows, and the relative size of the eyes; Enlow, 1982; Sadick et al., 2009). This area may therefore be a likely candidate for receiving perceptual attention during age estimation of a face.

However, perceptual studies have shown that a variety of cues contribute to age estimations (see Rhodes, 2009 for a review). George & Hole (1998) substituted facial parts in individual faces from different age groups, and showed that age estimations can be influenced by local features. Similarly, it has been shown that age estimations does not suffer when faces are inverted, indicating analytical processing (George & Hole, 1995). Yet, global features, like skin texture, skin colour, and head shape have also been shown to contribute to age estimations of adult faces (Burt & Perrett, 1995; George & Hole, 2000; Mark et al., 1980; Montepare & McArthur, 1986). Of these global features, skin texture (revealing wrinkles) has been reported to have a stronger influence on age estimations (Burt & Perrett, 1995; George & Hole, 1995; 2000; Mark et al, 1980).

In studies where the influence of particular facial features on age estimations are compared the eye region have been found to be diagnostic to this task (Jones & Smith, 1984; Lanitis, 2002; Rexbye & Povlsen, 2007). Eye-tracking studies are in agreement with this conclusion as participants' attention predominantly is anchored on the eye region during age estimation performance (Firestone, Turk-Browne, & Ryan, 2007; Nguyen, Isaacowitz, & Rubin, 2009). Such findings might reflect the numerous sources of age information in the eye region, also including skin texture and colour information.

Sex categorization

Normally, a person's sex can be correctly and rapidly determined simply by looking at someone's face. This is accurately accomplished even in the absence of culturally defined sex-cues like clothing attires, make-up, and hairstyles (Bruce & Young, 1998). Apparently, sex categorisation on the sole basis of facial structure in adult faces can be almost perfectly achieved by adults (Wild et al., 2000). Additionally, such a task can be more efficiently performed than other processing tasks (i.e., 613 ms; as opposed to 897 ms for familiarity decisions: Bruce, Ellis, Gibling, & Young, 1987). ERP studies have shown that the brain potential's latency related to sex categorizations of faces is remarkably fast (i.e., 150 ms; Schendan, Ganis, & Kutas, 1998). Even with very fast and peripherally located exposures (26-75 ms) accuracy of sex decisions is remarkably good (O'Toole, Peterson & Deffenbacher, 1996; Reddy, Wilken, & Koch, 2004; Sergent & Hellige, 1986). In addition, neuroimaging studies reveal that areas of the brain activated by sex categorizations of faces are more posterior than those activated by identifying the same faces (Sergent, Ohta, & MacDonald, 1992), which in turn suggests that such information may be processed early within the visual pathways. The ease with which the sex categorization task is carried out suggests that the faces of males and females do differ distinctively in physical appearance and in a manner that can be easily picked up in a cursory glance.

Human faces are noticeably sexually dimorphic (Zebrowitz, 1997) even at young ages (Nute & Moss, 2000; Wild et al., 2000). However, puberty intensifies the dimorphism in faces both because of increases in sex steroid levels, and divergent puberty onsets. The vertical elongation of facial structures that generally occurs during growth (Behrents, 1990) continues for a longer time in boys, since they commonly begin and end puberty at older ages than girls (Enlow, 1982; Hennesy, Kinsella, & Waddington, 2002). Thus, males tend to have larger skulls (about 14% larger according to Ferrario, Sforza, Schmitz, Miani, & Taroni, 1995), more prominent areas for muscle attachment and relative lengthier facial shape than females (Burton, Bruce, & Dench, 1993; Nute & Moss, 2000). Accordingly, all parts of the skull and cartilage are larger in males (e.g., the zygomatic bone, chin and mandible; Ferrario, Sforza, Pizzini, Vogel, & Miani, 1993; Henneberg, Simpson, & Stephan, 2003), and most parts are also dimorphic according to shape (Enlow, 1982). The orthodontist, Enlow (1982; 1990) links these relative differences to the males' greater need for oxygen exchange, due to his larger body mass and lungs. This would require larger breathing passages/ noses (*nasopharynx*), with larger flaring nostrils and a straight to convex nasal shape to allow a sizeable stream of air to pass. The convex shape leads to a more downwards turned tip, whereas the more concave female nose has a more upwards turned tip. The nasal dimorphism also leads to other collateral dimorphic differences, like a more protuberant male vs. female brow ridge (Genecov, Sinclair, & Dechow, 1990), and a backward sloping male, vs. bulbous female forehead (Enlow, 1982). The protrusive male brow ridge also shortens the distance between eyes and brows (Campbell, Brooks, de Haan, & Roberts, 1996) and leads to a narrower eye shape in males (Enlow, 1982). However, the interpupillary distance is greater in males than females (MacLachlan & Howland, 2002). Thus, with the exception of eyes' size, the larger skull generally leads to larger facial areas in males than in females (e.g., the mouth: Liggett, 1974; the angel bow: Burton et al., 1993).

Another source of sexual dimorphism is linked to secondary effects of the female sex hormones on physical traits. In general, females have twice as much hypodermic fat and adipose tissue as males (Grammer, Fink, Juette, Ronzal, & Thornhill, 2002). This generally leads to rounder and less bony shapes (e.g., rounder jaw, fleshier chin and larger zygomatic protrusion; Ikeda, Nakamura, & Itoh, 1999; Merow & Broadbent, 1990; Nakdimen, 1984; Shepherd, 1989). Some of these oestrogen-mediated traits can also change in relation to levels of circulating hormones (Roberts et al., 2004). Facial hair is another obvious indicator of biologically-based changes in puberty, as both beard follicles and eyebrows appear heavier in males. Likewise, the female skin is generally of lighter pigmentation and has a smoother texture (Laidman, 1979; O'Toole, Vetter, Troje, & Bülthoff, 1997; Shepherd, 1989); although such sex differences in skin lightness may be inexistent among northern Europeans (Ritgers-Aris, 1973; Van den Berghe & Frost, 1986). All of the above-described, average differences contribute to the anatomical sexual dimorphism in faces, but perhaps not to the same degree. Burton and colleagues (1993, study 5), and Bruce and Young (1998), proposed that the largest anatomical sexual dimorphism in the human face is represented by the protuberance of the nose, followed by the cheeks, as observed in 3-D (see also O'Toole et al., 1997).

Intuitively, one would expect that the most dimorphic anatomical difference between the sexes would correspond to the most attended part during face categorizing. However, experiments based on the data-limited and part-transformation approaches have predominantly suggested that the eye region, especially the brows, and the eyes and brows as a composite region, may be most diagnostic for sex categorizations of frontally viewed faces (e.g., Brown & Perrett, 1993; Bruce, et al., 1993, Exp. 2; Campbell et al., 1996; Campbell, Benson, Wallace, Doesbergh, & Coleman, 1999; Schyns et al., 2002; Smith, Gosselin, & Schyns, 2004). However, studies using part substitutions have additionally indicated that the jaw is one of the more diagnostic frontal parts (Brown & Perrett, 1993; Yamaguchi, Hirukawa, & Kanazawa, 1995). Several masking studies have also stressed the importance of the nose in addition to the eye region in frontally viewed faces (e.g. Bruce et al., 1993, exp. 2; Roberts & Bruce, 1988, exp. 1), but it has been suggested that relevant nasal information may need to be evaluated within the context of the face. The inconsistencies between these findings could be due to the ambiguous patterns produced by the part-substitution approach, or artificial patterns in data-limited studies. The approaches thereby might show different aspects of the same process and may not necessarily reveal the strategy one would spontaneously use in ecological situations.

However, a more sophisticated segmenting approach, called the Bubbles technique, indicates that the nose could be the more diagnostic frontally viewed part when seen in coarser scales (corresponding to information between 5.62 and 22.5 cycles per face), whereas the diagnostic value of the eye depends on high spatial frequencies only (cut-off of scale: 90 cycles per face; Schyns et al., 2002). These coarser scales also elicited faster responses than the finer scales, indicating that nasal information may be sufficient for full-view sex categorisations (c.f. Chronicle et al., 1995). But, the question of how we accomplish this simple judgment is still debated and, essentially, unresolved.

Beauty assessment

A person's facial beauty might be based on much more than aesthetics (e.g., clues revealing aspects of personality or resourcefulness; c.f. Cunningham, 1986). One class of information that increase the rated beauty of a face includes clues signalling positive emotions or interest (e.g., a smile, raised eyebrows, dilated pupils or a direct gaze; Eibl-Eibesfeldt, 1970; Kampe, Frith, Dolan, & Frith, 2001). A neutral face, which diminishes such clues, is still assessed very efficiently (Olson & Marshuetz, 2005). Actually, it seems to be difficult <u>not</u> to assess beauty (Sui & Liu, 2009). This effortless assessment suggests that there might be anatomical differences between beautiful and less beautiful faces, and that such differences can easily be perceived. However in the case of beauty assessment, anatomical differences are still unknown. There have been several early attempts to measure the anatomical differences between more or less beautiful faces. For example, Leonardo da Vinci used Plato's golden ratio (1.618) to create facial beauty in his drawings (e.g., length of a beautiful face / width of a beautiful face = the golden ratio). However, consensus concerning measurable beauty has never been reached. This could of course be caused by lack of consistency between individual judgments of aesthetics; that is, too small rater samples. Yet, several studies have found no relation between beauty and the golden ratio (Baker & Woods, 2001; Moss, Linney, & Lowey, 1995).

Conversely, the subjectivist account suggests that there are no anatomical differences between more or less beautiful faces, as beauty may be a construct of the observer and the culture in which he/she lives (Kubovy, 2000; Tatarkiewicz, 1970). In line with this account it has been established that the facial beauty ideal does change over time (Pogrel, 1991). Specifically, a trend of increasing lip protrusion has been found in face models during the twentieth century (Auger & Turley, 1994; Nguyen & Turley, 1998). Familiarity also seems to affect beauty assessments of faces (Bornstein, 1989), indicating that the observer's experience influence perceived beauty. Familiarity is indicated as an explanation of the finding that faces are perceived as better looking the closer they are to an average face (e.g., Langlois & Roggman, 1990; Potter, 2008; c.f. Rhodes & Tremewan, 1996). Similarly, it has also been indicated that people prefer faces that resemble their own or their parent's faces (DeBruine, Jones, & Perrett, 2005; Penton-Voak, Perrett, & Peirce, 1999; Wilson & Barrett, 1987; Zei, Astofli, & Jayakar, 1981).

However, a familiarity effect is only one possible explanation of the crucial average effect. This finding could also be explained by mate value. That is, people might prefer average faces as they may signal healthy genes (Buss, 2004; Gangestad & Scheyd, 2005; Langlois & Roggman, 1990; Symons, 1979). This explanation belongs to the objectivist account, which describes beauty as a trait of the face (c.f. Chen, German, Zaidel, 1997). In recent years it has been found that the average beauty judgments are consistent between cultures (Langlois & Roggman, 1990), and that infants, as young as 9 months of age, prefer faces judged as beautiful by adults (Hönekopp, Rudolph, Beier, Liebert, & Müller, 2007; Langlois et al., 1987). This might indicate anatomical similarities between beautiful faces which also are perceptually informative for beauty assessments. Such beauty clues could be based on averageness, but Perrett, May, and Yoshikawa (1994) showed, by comparing morphed average faces to beautiful faces, that averageness is not the only clue to beauty assessments. Another possible clue could be the symmetry across a vertical midline in a face, as enhanced symmetry increases the perceived beauty (Gangestad & Thornhill, 1998; Little, Penton-Voak, Burt, & Perrett, 2002; Perrett et al., 1998). This finding could also be explained by mate value, as DNA is sensitive to stressors that can influence symmetry during development (Kowner, 2001). When averageness and symmetry are compared, both seem to be important beauty assessment aspects (Komori, Kawamura, & Ishihara, 2009). However, these aspects may also be partially explained by fluency, as symmetric and average faces are closer to a prototypical face which is processed fluently and therefore more favorable, as fluency is accompanied with positive emotions (Winkielman, Halberstadt, Fazendeiro, & Catty, 2006).

Another proposed clue to beauty assessments is youthfulness, as it has been indicated that older faces are less attractive than younger adult faces (Deffenbacher et al., 1998; Furnham, Mistry, McClelland, 2004). This may again be explained by mate value, as it advertises fertility, especially in women who have a shorter fertile period than males (Symons, 1979). The distinguishing features signalling youthfulness and beauty are for instance lifted eye appearance, full lips and smooth skin (Johnston & Franklin, 1993; consult the paragraph: "age estimation").

Facial features associated with beauty may differ between the sexes, as enhanced femininity in female faces, and to a lesser degree, enhanced masculinity in male faces might increase beauty assessments (Komori et al, 2009; Rennels & Langlois, 2008; Rhodes, 2006; Russel, 2003; Smith, Jones, DeBruine, & Little, 2009; Swami, Furnham, & Joshi, 2008). This may be explained by high oestrogenic levels in feminine females, and high testosterone levels in masculine males, indicating fertility (Buss, 2004; Mazur, 1994). However, the smaller effect of masculine faces on beauty assessments may be explained by stereotypical personality attributions to faces (Penton-Voak, & Perrett, 2001; c.f. Perrett et al, 1998).

Features associated with femininity in females are, among others, large eyes and high cheekbones, and features associated with masculinity are large noses and jaws (e.g., Baudouin & Tiberghien, 2004; Edler, 2001; Scheib, Gangestad, & Thornhill, 1999: consult the paragraph: "Sex Categorization"). However, when the question concerns attractivity and not mere aesthetics, women prefer less masculine looking men (Perrett et al., 1998), although only between ovulations in their menstrual cycles (Little et al, 2002; c.f. Gangestad & Thornhill, 1998).

Generally, the most distinguishing features during beauty assessments seem to be the eyes, the mouth and the nose (Hassebrauck, 1998; Tatarunaite, Playle, Hood, Shaw, & Richmond, 2005).

However, beauty assessments have been found to be holistically performed (Abbas & Duchaine, 2008; Baudouin & Humphreys, 2006), indicating that distinguishing features may not have to be inspected directly, or that featural distances also play an important role for this perceptual task. This could also indicate that averageness and symmetry may be important clues to beauty assessments, as these clues can be appreciated holistically.

Independently of which features that are the most diagnostic for this task, it seems obvious that these possible anatomical differences between more or less beautiful faces must be interpreted when perceived by an observer. This point is recognized by the interactionist account, which states that beauty is an interaction between the anatomical clues in a face, and the observer's cognitive and affective processes (Hönn & Göz, 2007; Reber, Schwarz, & Winkielman, 2004). Thus, this account marries the two other accounts, as it argues that beauty is both within the information held by a face, and in the eye of the beholder.

COMPONENTS OF THE FACE PERCEPTION SYSTEM

The diversity of information conveyed by a face might be expected to be handled by a system with multiple components (Bruce & Young, 1986). The face recognition model of Bruce & Young (1986) suggests a possible relationship between diverse facial information (Figure 1). The model proposes that different processing modules are linked in sequence or in parallel, and that processing of facial expressions, lip reading, identification, and unfamiliar faces follow independent routes. Processing of unfamiliar faces is proposed to follow a route which also allows basic processing of familiar faces without accessing identity (e.g., sex categorization, age estimation, and beauty assessment). According to the model, identification of familiar faces starts with structural encoding (SE) in which faces are described in accordance with the available diagnostic information. These descriptions are then compared with stored representations (Face Recognition Units: FRUs). If a match is found, information about the person's identity (Person Identity Nodes: PINs) may be obtained, and subsequently the person's name could be generated (Name Generation: NG). During the whole process information from the cognitive system is assumed to be available.

Some support for the model has been found. A double dissociation between recognition of facial expression and identification of faces has been indicated (e.g., Bruyer et al., 1983; Kurucz & Feldmar, 1979; Kurucz, Feldmar & Werner, 1979; Shuttleworth, Syring, & Allen, 1982), and a double dissociation between lip reading and identification of faces has also been found (e.g., Campbell, 1992; Campbell, Landis, & Regard, 1986). These differences have also been confirmed by other methodologies (e.g., Campbell et al., 1996; Young, McWeeny, Hay, & Ellis, 1986). However, although the routes seems to be parallel, information about identity may to a certain degree influence the processing of facial expression (Haxby, Hoffmann, & Gobbini, 2000; Martens & Leuthold, 2010), and the processing of lip reading (Schweinberger & Soukup, 1998). Parallel processing of identification and other basic processing tasks is not equally well examined and no double dissociation has been reported. Some support for independence of face identification and sex categorization has, however, been indicated (Bruce, 1986; Mouchetant-Rostaing, Giard, Bentin, Aguera, & Pernier, 2000). Yet, other studies show that sex categorizations are influenced by face identification (Rossion, 2002).

The most massive critique the model has met comes from prosopagnosia studies where patients show covert recognition and associative priming (Bauer, 1984; De Haan, Young, &

Newcombe, 1987; Young, Hellawell, & De Haan, 1988). The model can not explain how a prosopagnosic patient can obtain information from a deeper level (NG) in the system without having obtained information from an earlier level (PINs).

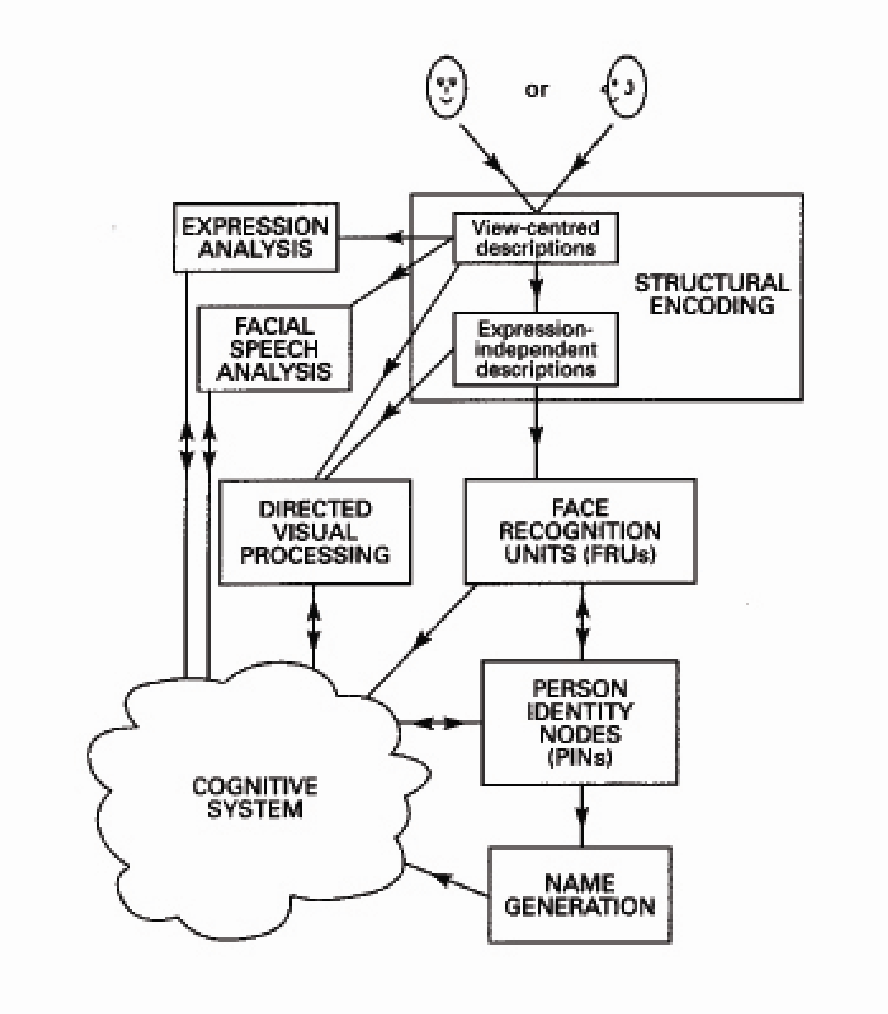

Figure 1. The Bruce and Young (1986, pp. 312) model of face recognition.

However, Burton, Bruce, and Johnston (1990) suggested, and implemented, a connectionist version of Bruce & Young (1986) model, called the IAC model (interactive activation and competition model). The architecture is similar to the McClelland (1981) model. The model suggests that identification is obtained at the PIN level where all information is available from the other storages. Activation of a FRU code will lead to activation of the equivalent PIN code, the name unit and the semantic information units. Other units will be inhibited, according to the model. However, some activation of units sharing the same information will occur due to feedback. Thus, the model is able to explain covert recognition in prosopagnosia patients.

Nonetheless, some prosopagnosia patients do not show covert recognition (Young et al., 1994). This finding may be explained through the Disconnection Hypothesis, indicating that a large brain damage might block information exchange between a consciousness system and two recognition systems where one is more dependent upon consciousness than the other (Young & de Haan, 1992). Alternatively, the finding may be explained through the System Damage Hypothesis, indicating that the brain damage is within one recognition system (Farah, O'Reilly, & Vecera, 1993). Schweinberger and Burton (2003) suggested a model which showed that covert and overt recognition may be produced by the same system. Damage between FRUs and PINs will lead to recognition deficits, but covert recognition is less influenced by the damage because the tests employed are more sensitive than the tests for overt recognition. These studies are not conclusive regarding the nature of the components in the face recognition system, and the Bruce and Young (1986) model, although refined and improved in several studies, still generate research.

METHODOLOGICAL CONSIDERATIONS

THE EYE-TRACKING METHOD

The eye-tracking method generates a large amount of information, and the challenge lies in the analysis method. Special considerations have to be taken in relation to facial stimuli as these are very similar visual patterns which must be compared at the exemplar level (Peterson & Rhodes, 2003). The diagnostic differences between them might be tiny, and eye-movement analysis must therefore be very precise. The most obvious pitfall concerns the parsing method.

When the eye-tracking method was initially introduced with face stimuli, the face was typically coarsely parsed into its main features. For example, Luria & Strauss (1978) parsed the face into large squares or triangles containing the eyes, the nose, the mouth and the ears. The rest of the face was not further divided. Such parsing is too arbitrary, as for instance fixations on the cheek would be analyzed as eye attention. Even if the facial features are simply parsed following the anatomy of the face, the parsing is too coarse (Figure 2, left face; see Research Report II). This parsing does not inform about the distribution of fixations within each facial feature, or on the borders between features (illustrated by green dots in Figure 2). For example, an infraorbital fixation (between the eye and the nose) would be analysed as a cheek fixation, although perceptual information from the eye and the nose would be closer and therefore be seen with higher resolution, than the zeugmatic protrusion.

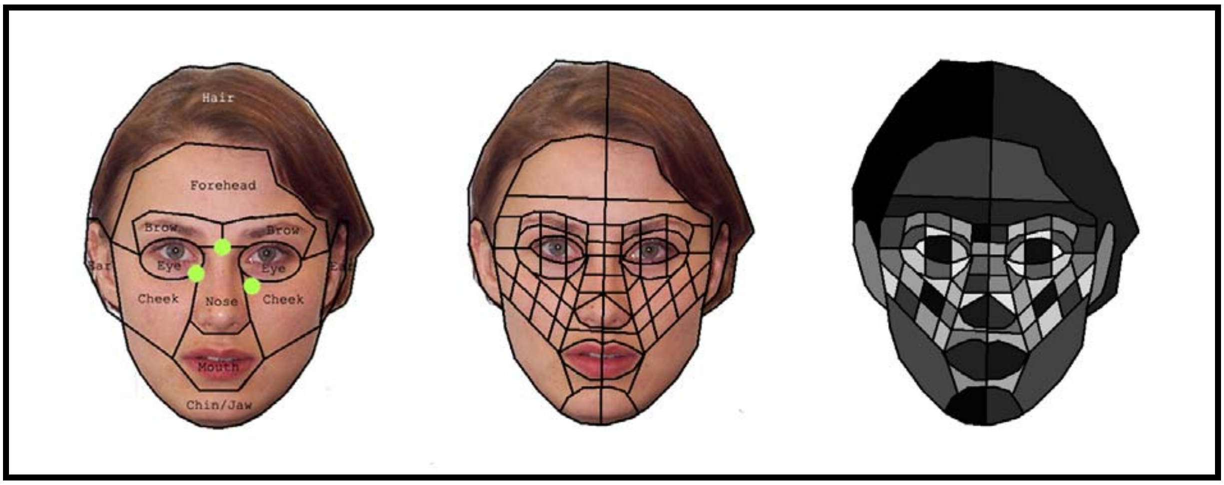

Figure 2. Examples of different parsing methods. To the left: a natural parsing based on the anatomy of the face. Middle: an elaborated parsing based on the natural parsing. Right: Matlab readable elaborated parsing. The green dots indicate problematic border fixations.

However, a more elaborated parsing based on the natural parsing (Fig. 2, middle face), which divides the inner mask of the face into sufficiently small segments, was shown to give approximately the same results as an *a posteriori* parsing in Research Report II. Only the inner mask of the face was finely parsed, as eye movements tend to be directed predominantly to internal facial features (Groner, Walder, & Groner, 1984; Henderson, Williams, & Falk, 2005; Walker-Smith, Gale, & Findlay, 1977). Problems regarding the position of fixations within large inner facial features would be avoided with the use of such a parsing method. Yet, a problem with fixations on the borders between segments could still lead to arbitrary analysis effects. This problem could be solved by using dwell time as a measure, as the time spent on this fixation point could be divided between the segments instead of arbitrarily being assigned to one of the segment as a fixation. A MATLAB program can read the segments by assigning an individual grey-level nuance to every single segment. Percent dwell time in each segment should then be divided by segment area to avoid effects of larger or smaller segments.

The issue of analytical and configural processing should be handled with care in relation to eye movements. Although a previous study has indicated that holistic processing of faces elicits central fixations on the nose, the eye and the infraorbital area (Schwarzer et al., 2005), such fixations might also indicate analytical processing. Another study suggested that holistic processing could be independent of oculomotor behaviour (De Heering, Rossion, Turati & Simion, 2008). It is too early to conclude anything regarding this issue. Even fixations between parts should not automatically be assigned to configural processing, as the best resolution for the task may be lower than achieved with fixations exactly on the feature (Schyns et al., 2002). However, the visual angle (VA) subtended by the distance from the fixation point to the feature, and the VA subtended by the feature itself can tell us what is seen foveally, and parafoveally. Such measures, in relation to better future knowledge of preferred SF for different processing tasks, may give valuable information regarding configural or analytic processing strategies measured with eye movements. At the moment, only speculations regarding this question can be derived from the eye-tracking method.

Another limitation of the eye-tracking system employed in the present thesis is that it does not allow participants to move within the natural environment and interact with real faces/persons. Mobile eye-tracking systems does exist, although they tend to be less accurate and produce data which are harder to analyze than is the case for stationary systems (Senior, Russell & Gazzaniga, 2006).This constraint might affect processing, and oculomotor behaviour during processing of faces more than during processing of non-face objects, as social aspects may be more pronounced during natural interaction with other persons than with objects. On the other hand processing of faces may be automated, and habitual social interaction may also occur with still-images of faces (Vuilleumier et al., 2005).

Eye blinks could potentially constitute a difficulty for the eye-tracking method. Unless blinks are removed from the data, missing values might affect the fixation duration analyses. Eye-tracking studies take care of this difficulty by different analysis techniques. However this could particularly constitute a problem for RT measures in visual tasks (Johns, Crowley, Chapman, Tucker, & Hocking, 2009). The dwell time analysis program employed in the eye-tracking experiments of the present thesis, automatically remove eye blinks. Still, some noise will be present, as blink suppression begins before, and ends after the blink itself (Volkmann et al., 1980). This might be a larger problem when attention requirements are minimal, as blinking is less frequent during tasks requiring attention, like the tasks in the present research (Fogarty & Stern, 1989; Orchard & Stern, 1991).

An advantage of the eye-tracking method is that it does allow measurements of covert attention of natural images of faces (Henderson, Williams, & Falk, 2005; Yarbus, 1967). Data-limited face processing studies include facial images which are masked or manipulated in other ways in order to investigate normal face processing strategies (e.g. to assess the significance of features on face processing). Such masking might produce artificial stimuli with a novel perceptual meaning to the perceiver (for an example see Figure 3). The eye-tracking technique does not introduce artificial cues or external elements to the stimuli during the task. Thus, it may contribute to clarifying what the normally-used strategy in a specific perceptual task might be.

Figure 3. The left image is an example of a facial image which might be perceived as artificial due to masking, as compared to the right original picture.

AIMS OF THE THESIS

The general aim of the present thesis was to explore the perceptual strategies of several face processing tasks, and to indicate the relationship between the perceptual strategies employed in the tasks and various specific processing aspects. One of the main concerns was to compare perceptual tasks in order to investigate if processing is dependent upon the task performed, and if this possibly can be exposed through eye-movement measures (Report II and III). The method of measuring eye movements during face processing is relatively new, with one of the first experiments being reported by Yarbus in 1967. However, methodological difficulties have resulted in few face-processing studies using eye-movement measures. Therefore, Report II and III intended to explore how the eye-tracking method could be best adapted to face processing research.

The specific aims of the thesis were as follows:

1. To examine the upper limits of face expertise.

    a. To explore if a specialised form of face expertise, which could able us to solve particular hard face discrimination tasks, exists (Report I).
    b. To study if the difficult task of distinguishing between monozygotic twin faces requires a shift in strategy compared to general face processing (Report I).
    c. To investigate if twin’s parents and parents of siblings process unfamiliar twin faces similarly.

2. To study the relationship between face processing and oculomotor behaviour.

    a. To explore how the eye-tracking method can best be adapted to face processing research (Reports II and III).
    b. To examine if and how the diagnostic information in a face varies between processing tasks and if this is reflected in oculomotor behaviour (Reports II and III).
    c. To investigate if processing strategy and oculomotor behaviour can be generalized to other facial poses than the frontal (Reports II and III).
    d. To examine if face processing and oculomotor behaviour during different perceptual tasks depend upon the visual angle subtended by the face (Report III).

SUMMARY OF METHODS

The experiments of the present thesis diverge considerably in terms of methodological approach. Some similarities exist, and some major differences are interesting to compare. These are outlined below. For further methodological details the reader is referred to the method sections of the individual Research Reports.

Participants

Participants in the experiments were generally students at the University of Tromsø. However, parents of twins or siblings participated in Research Report I. Both male and female participants contributed, and a reasonable balance between the sexes was achieved. All participants had normal or corrected to normal vision.

Stimuli

Photographs of Caucasian faces were used as stimuli in all experiments. Young adult models were used in Research Report II, adult models between 20 – 80 years of age were used in Report III, whereas twin children's faces constituted the stimuli in Research Report I. The photographs were presented in colour.

The models of all the experiments in the Research Reports of the present thesis were recruited and photographed especially for the present research. Models were asked to resume a neutral expression during the photographic session. The distance to the models and the lighting in the room were kept constant. Models were photographed in four poses (frontal= 00, intermediate = 22.5, three-quarter = 45 and profile =90 angles as seen from the viewer). All poses were used in Research Report II, three poses were used in Research Report I, whereas only frontal and profile angles of view was used in Research Report III to keep the number of trials tolerable. The photographs were kept natural, except some editing of cloths and hair, although in the second experiment in Report I the images were inverted by 180º.

The visual angle (VA) of the face stimuli varied between Research Reports. In Report I the faces subtended a VA of 9.8º (vertical dimension) with hair cropped, which would correspond to approximately 17º including hair. The remaining face stimuli (including hair) subtended an average VA of 14 º in Report II, and varied between 9º, 16º, and 23º in Report III.

Apparatus

In Research Report III the experimental editor was E-Prime®, whereas SuperLab© was the editor of all the other experiments in the thesis. In Report II and III eye movements were registered by different versions of systems built by SensoMotoric Instruments® (SMI, Teltow, Germany), and the initial analysis of the eye-movement recordings was computed by the software iView from SMI. Both system versions employ the contrast technique, which determines the centre between two coordinates, by tracking the position of the pupil and the reflection of the cornea.

Designs

Whenever appropriate, within-subjects designs were used, as this design is both efficient and sensitive (Keppel, 1991). In Report II and III, pure within-subjects designs were used. The experiments of Report I used mixed designs, although the theoretically most interesting manipulations were within-subject factors.

Procedures

The thesis explored several face processing tasks; face recognition, sex categorization, beauty assessment, and age estimation. The specific performance tasks employed, differed between processing tasks. In Research Report I, face recognition of familiar and unfamiliar twins was explored through a same/different task. Facial sex, beauty and age were assessed through categorization tasks in Report II and III.

Report II and III involved eye-tracking while participants performed the processing tasks. In both Reports a calibration procedure on a 3 x 3 regularly spaced matrix was performed for each participant and a fixation point was presented before each trial, to control the eye movements' starting position. This position was placed externally to the face, 1.7° away from one of the screen's corners (or 7.85° away from the stimulus' centre) in both Reports.

Analysis procedures

The main analysis method used to examine the data for effects in all the Research Reports was Analysis of Variance (ANOVA). Additionally, probability density functions were used to analyze eye-movement data in Report II.

Extremely deviant responses (> 3 standard deviations above condition mean) were discarded when response times were used as dependent variables (c.f. Miller, 1991). When percentage of dwell time was used as a dependent variable, focus outside the face was either not included, or a cut-off value of 5% was used to remove insignificant areas.

RESULTS:
SUMMARY OF RESEARCH REPORTS I – III

REPORT I

Sæther, L., & Laeng, B. (2008). On facial expertise: Processing strategies of twins' parents. *Perception*, 37, 1227-1240.

The preliminary aim of this Report was to bring support to the idea that parents of monozygotic twins are experts in the recognition of each of their own twin children. With this assertion confirmed, the main aims of the experiments in this Report were two-fold. First, the upper limits of the face identification system were examined by exploring if a specialised form of face expertise, which could able us to solve particular hard face discrimination tasks, exists. Specifically, the Report investigated if twins' parents' expertise on their own monozygotic twin children's faces can lead to a generalized expertise in discrimination between extremely similar unfamiliar faces: other twin pair's faces. Secondly, the Report studied if the task of distinguishing between monozygotic twin faces requires a shift in strategy compared to general face processing. In other words: does such a challenging task require more part-based processing than general face discrimination does?

Two experiments were completed, in which parents of monozygotic twins and parents of non-twin siblings performed a same/different task, with familiar and unfamiliar monozygotic twin faces presented in three poses (frontal, three-quarter and profile view) as stimuli. In Experiment 1 the faces were presented upright, whereas in Experiment 2, a smaller set from the same stimulus base was presented both upright and inverted by 180°.

Results:

In the upright condition, results showed that twins' parents are experts in a very challenging Face-discrimination task, as they were faster than other parents in distinguishing their own monozygotic twin children. However, twins' parents were worse (slower) than other parents at distinguishing between unfamiliar monozygotic twin faces. This implies that twins' parents' expertise on two specific similar faces may interfere with an efficient processing of unfamiliar similar faces in general, possibly due to a generalization of a habitual perceptual strategy that is efficient only with the specific familiar twin faces.

In the inverted condition, a typical inversion effect for familiar twin faces was found, indicating that twins' parents use a regular face expertise strategy on extremely similar faces. However, twins' parents also demonstrated an "inverted inversion effect" for unfamiliar twin faces. That is, unfamiliar twins' faces were recognized better when they were inverted than when upright. This effect could be caused partly by the high similarity of the face pairs which might be processed as non-face objects, and partly by the experience with familiar faces of equally high similarity. For this reason twins' parents might be particularly poor at this task.

It was concluded that the facial expertise of twins' parents was not based on a superior general facial expertise, but on an enhanced expertise on two similar face exemplars .

REPORT II

Sæther, L., Van Belle, W., Laeng, B., Brennen, T., & Øvervoll, M. (2009). Anchoring gaze when categorizing faces' sex: Evidence from eye-movement data. *Vision Research*, 49, 2870–2880.

The main objective of this Report was to examine if the preferred landing position of eye fixations was similar for a facial sex categorization task as previously reported for face recognition, and if the results could be generalized to other facial poses than the most investigated one, the frontal view. The choice of landing position could also indicate if sexually diagnostic facial parts were foveally attended, or if the gaze were anchored at a central position, possibly favouring holistic processing. A secondary aim was to compare fixational analysis methods, to guide future eye-tracking investigations of face stimuli. Specifically, *a priori* and *a posteriori* parsing methods were compared.

An eye-tracking experiment, investigating categorization of the sex of faces was performed, and stimuli consisted of photographs of faces presented in four poses (frontal, intermediate, three-quarter and profile view). Eye-movement results were analysed according to the centre of gravity of the face, according to natural and coordinate grid *a priori* parsing, and according to *a posteriori* parsing of facial parts.

Results:

Results revealed a strategy which was preferred in all poses. The strategy consisted of anchoring the gaze on a central infraorbital area of the face (between the eyes, nose and cheek), especially in the first fixation. This area was closer to the centre of gravity in frontal faces but gradually less as the head turned. The anchoring is between diagnostic parts and might possibly favor a holistic strategy, as in most other face processing tasks.

Males seemed to employ such a centered strategy to a higher degree than females, who attended more towards the eyes. This might possibly reflect a greater social interest in females than in males, but the finding shows that both strategies are useful.

Finally, the present analysis suggests that an *a posteriori* analysis method is to be preferred to a coarse *a priori* parsing of eye-movement data, although a sufficiently fine-grained *a priori* parsing method might suffice.

REPORT III

Sæther, L., & Laeng, B. (submitted). Age versus beauty: Judging different attributes of faces yield different oculomotor scan patterns.

The aim of Report III was to investigate if the observer's specific scan patterns during face processing are task-dependent, and if so, if the task-dependency is affected by the image size. Variations in the image size could indirectly indicate varying distances between the face and the observer. Like in Report II, the scan pattern could also indicate if diagnostic facial parts were foveally attended, or if the gaze were anchored onto a central position, possibly favouring holistic processing. However, in the present Report two processing tasks were compared to uncover potential differences, and to show if the eye-tracking method is sensitive enough to reveal possible differences.

An eye-tracking experiment during face processing was performed, in which an age estimation task and a beauty assessment task were compared. Stimuli consisted of photographs of faces presented in two poses (frontal and profile view), and subtending one of three visual angles (VA; 9°, 16°, or 23°, indirectly indicating identificational, conversational and intimate distances). The models' age ranged from 20 to 80 years, and the faces were rated and balanced according to beauty and age prior to the experiment. Eye-movement results were analysed according to coordinate grid *a priori* parsing of facial parts.

Results:

The main findings indicated that scan patterns during face processing of frontal views are dependent upon the task performed and the facial size presented. However, the eye-movement behavior in the beauty assessment task was more affected by the image size compared to the scan patterns of the age estimation task. With presentations of small face images, beauty assessments revealed peripheral gaze anchoring, whereas fixations were positioned more centrally (infraorbitally) with large face images.

Generally, the age estimation task relied on higher resolution information (derived from the eye region) than the beauty assessment task did. This could be interpreted as reflecting strategies employing peripheral vision for beauty assessments versus foveal vision for age estimations.

A possible interpretation is that the difference between the tasks could be caused by a lack of one single diagnostic feature in the beauty assessment task, as opposed to a strong diagnostic part (the eye) in the age estimation task. However, further research is needed before a conclusion can be reached.

GENERAL DISCUSSION

The findings in relation to the specific aims of the thesis were as follows:

1. The upper limits of face expertise:

    a. A specialized form of face expertise was not found, as superior performance on a particular hard face discrimination task seemed to be based on enhanced expertise on the specific face exemplars involved in the task (Report I).
    b. A typical inversion effect for familiar twin faces was found, indicating that the difficult task of distinguishing between monozygotic twin faces does not require a shift in strategy compared to general face processing (Report I).
    c. Both parents of siblings and twin's parents demonstrated an "inverted inversion effect" for unfamiliar twin faces.

2. The relationship between face processing and oculomotor behaviour:

    a. The findings of Report II suggested that an *a posteriori* analysis method or a sufficiently fine-grained *a priori* parsing method is to be preferred to a coarse *a priori* parsing of eye-movement data during face processing.
    b. The main finding of Report III indicated that the oculomotor behaviour during processing of frontally viewed faces is dependent upon the task performed. Overall results from Report II and III showed that the diagnostic information in sex categorizations and beauty assessments of faces seemed to be depending on peripheral vision with infraorbital anchoring, whereas age estimations seemed to rely more on foveal eye region information.
    c. For sex categorizations, results revealed a strategy which was preferred in all four poses, but results for beauty assessments and age estimations differed between frontal and profile view (Report II and III).
    d. The processing and oculomotor behaviour seems to be dependent upon the visual angle subtended by the face, although this was more prominent in the beauty assessment task than in the age estimation task (Report III).

In addition to the specific findings that could be drawn from the results of the experiments included in the present thesis, several overall findings could also be suggested. First of all, these results indicate that diverse face processing tasks are processed differently from each other, and that this is reflected in oculomotor behaviour. Only Research Report III provides a clear test of this question, by comparing two processing tasks, age estimation and beauty assessment while eye-movements were recorded. However, the eye-movement results from the sex categorisation task in Research Report II resemble the results of the beauty assessment task in Report III. Although these experiments can not be compared directly, it is plausible that sex categorisation and beauty assessments are processed differently from age estimations of faces.

Such a comparison is particularly plausible when only medium sized faces are compared, as three different facial sizes were employed as stimuli in Report III, whereas only one medium facial size was used in Report II. Since the oculomotor behaviour depended upon the visual angle subtended by the face during beauty assessments, comparisons between the sex and beauty tasks may only be done on medium sized faces, which was present in both studies. In medium sized faces results between these two tasks resembled each other, although gaze during beauty assessments seemed to be a bit more centrally anchored than during sex categorizations.

However, the oculomotor behaviour in the sex categorization task could be generalized to four facial poses (Report II), whereas in the beauty assessment task, and also in the age estimation task, results differed between frontal and profile views of faces (Report III). One possible explanation of these differences between the studies is that age and beauty assessments become harder to perform as the head turns, whereas sex categorisation is such a basic task that the pose may not matter. However, the presence of several facial sizes in Report III might have made the tasks more difficult than they typically are.

Another overall comparison concerns the general strategy of the processing tasks. Suggestions concerning configural and part-based processing are made in several of the experiments. In Report I it was concluded that an especially hard recognition task was performed by experts in the same manner as face recognition typically is performed, which might include configural processing. However, a similarly hard recognition task performed by non-experts led to an inverted inversion effect, indicating that faces were processed like non-face objects, possibly in a part-based manner. In Report II it was suggested that the infraorbital gaze anchoring might bring the dimorphic internal region into parafoveal vision, which may be cautiously considered as configural or holistic processing. In Report III the oculomotor behaviour of the beauty assessment task revealed peripheral anchoring with small faces and more central anchoring with larger facial sizes. These strategies cold be interpreted as employing peripheral vision, which again might be understood as possibly reflecting configural or holistic processing. Conversely, the age estimation task of Report III showed uniform fixations towards the eye region, which indicates foveal vision and analytical processing. However, as discussed in the paragraph “methodological considerations”, conclusions concerning configural or part-based processing in faces based on the eye-tracking method should be considered with some caution. At the moment it is only possible to suggest that it is plausible that expert recognition, sex categorizations and beauty assessments of faces is based upon configural processing, whereas age estimations and non-expert face recognition might be more analytically processed.

Finally, the overall concern of aiding future eye-tracking research on face perception was particularly examined in Research Report II, but also in Report III. The main findings were that the acuity of an *a posteriori* analysis method could be compared to a sufficiently fine-grained *a priori* parsing method, but that a coarse *a priori* parsing of eye-movement data was not sufficiently precise. Additionally, the finding that the VA subtended by the face affects the oculomotor behaviour (Report III) could guide future eye-tracking research with faces.

For a discussion of the specific findings initially listed in the discussion, the reader is referred to the relevant discussion sections of the Research Reports.

OVERALL CONCLUSIONS

The overall findings suggest that diverse face perception tasks are processed differently from each other, and that this is reflected in oculomotor behaviour. It is plausible that sex categorisation and beauty assessments are processed differently from age estimations of faces. It may also be suggested that expert recognition, sex categorizations and beauty assessments of faces is based upon configural processing, whereas age estimations and non-expert face recognition might be more analytically processed, although such suggestions should be treated with caution. Finally, the comparison of analysis methods of eye movements, and the finding that the visual angle subtended by the face affects the oculomotor behaviour could guide future eye-tracking research with faces.

GLOSSARY

Centre of gravity (COG)	The theoretical point at which the object's weight is assumed to be concentrated, or the point at which the object can be balanced. In a uniform gravitational field, it coincides with the object's center of mass.
Configural processing	Processing of more than one facial feature and the spatial relations between the features.
Face perception	The process by which the human brain understands and interprets the human face.
Face processing	The processing of facial information in the visual system of the brain.
Fovea	The area of the retina with the highest resolving capacity for spatial detail (Malcolm et al., 2008) including 2° of vision (Balota & Rayner, 1991).
Holistic processing	Processing of the whole facial image without analysing it into separable features.
Oculomotor	**-** which involves eye movements.
Parafovea	The area of the retina out to 5° beyond the foveal region (Balota & Rayner, 1991).
Part-based processing	Processing of the facial features.
Perifovea	The area of the retina beyond 5° from the fixation (Balota & Rayner, 1991).
Processing task	The type of specific perceptual question asked about the face (e.g., age estimation of a face).
Prosopagnosia	A brain damage which causes loss of the ability to recognize faces even though the visual system is intact. The patient might be able to recognize a person through cues like voice or names.
Spatial frequency (SF)	"The rate of alternation of the luminance in a visual stimulus as a function of length, usually expressed in cycles per degree" (Millodot, 2002).
Visual angle (VA)	**"**The angle subtended by the extremities of an object at the anterior nodal point of the eye" (Millodot, 2002).

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Report III

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