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Face Recognition in Human: The Roles of Featural and Configurational Processing

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1. Introduction

During the last few decades, face perception has emerged as a prevailing issue in social research. Face recognition is a fundamental and crucial skill for communicating and understanding in human society. Fortunately, most adults are able to recognize faces to identify a particular face and to discriminate among faces at a glance, begging questions of the nature of the mechanisms that underlie such face recognition. It has been established that the processing involved in face recognition likely differs qualitatively from that involved in recognizing other objects. Indeed, responses to faces are more affected by inversion than are those to non-face objects. When faces are presented upside down, it is much harder to identify them accurately. Configurational properties are disrupted by presenting visual objects upside down or by laterally offsetting the top and bottom halves of objects, and greater disruption has been found when those objects are faces than when they are other types of objects (Maurer et al., 2002). Clinical studies have provided additional evidence of the special nature of face processing. Individuals with prosopagnosia experience difficulties with discriminating among human faces. They are able to perceive a face as face, but are unable to distinguish among different persons (Banich, 2004). Their deficit is specific to faces and derives neither from problems with visual perception nor from memory impairment. Neuroimaging studies have also indicated that the neural correlates involved in face recognition are distinct from those involved in the recognition of other objects.

Face processing can be divided into two types: configurational and featural (Maurer et al., 2007). Configurational processing refers to perceptions of the internal relationships among features. This approach contrasts with featural, analytic, piecemeal, or parts-based processing, which refers to perceptions of the shapes of individual features. The relative contributions of the two types of processing to face recognition and the interaction between them remain controversial. Although researchers have proposed different hypotheses about the mechanisms by which faces are processed on the basis of experimental findings, this issue is unresolved. In the context of the remarkable progress in brain imaging technology, recent studies have investigated the neural correlates of featural and configurational face processing, offering biological evidence related to behavioral phenomena. Consistent with these findings, this chapter addresses how humans recognize faces by reviewing the relevant findings from several research areas. In particular, the chapter focuses on the

contributions of configurational and featural processing to face recognition. Based on behavioral and biological evidence, we will discuss how these two types of facial information are processed. For this purpose, we will discuss both aberrant and healthy approaches to recognizing faces, including psychiatric disorders other than prosopagnosia that are characterized by problems with recognizing faces. For example, patients with schizophrenia who suffer from psychotic symptoms such as hallucinations and delusions have shown impairments in their ability to perceive faces (Shin et al., 2008). Observations of individuals who suffer from impaired face recognition can provide important clues to the ways in which faces are processed.

2. Healthy processes underlying face recognition

2.1 Configurational and featural processing

Human faces share basic individual features including eyes, noses, and mouths as well as consistencies in the arrangement of these features (i.e., eyes above the nose and mouth below the nose). These common basic relationships among facial parts is known as a first-order configurational relationship (Diamond & Carey, 1986). First-order information is important for face detection (i.e., recognition of a stimulus as a face) (Kanwisher et al., 1998; Moscovitch et al., 1997). Even newborn infants have visual preferences for face or face-like stimuli that have first-order relationships (Johnson et al., 1991; Mondloch et al., 1999). On the other hand, the shapes of the features and the spatial distances between the features differ among individuals. Thus, to identify a particular person's face accurately, information about both the facial features and the spatial relationships among features must be encoded. The spatial distances among facial parts are referred to second-order configurational information, which is crucial for face identification and differentiation among faces (Diamond & Carey, 1986). Sensitivity to first-order relationships is important for face detection, whereas sensitivity to second-order relationships is crucial for the identification of particular individuals. According to developmental studies, configurational processing is available later in life (Brace et al., 2001; Carey & Diamond, 1977, 1994; Tanaka et al., 1998). Although several researchers have argued that even newborn infants were able to encode configurational information (Simion et al., 2007), access to second-order information seems to be unavailable until 4 years of age (Pellicano & Rhodes, 2003; Pellicano et al., 2006). Previous findings have suggested that young children recognize faces in ways that differ qualitatively from the ways in which adults recognize faces.

2.2 Measures of face recognition

Various manipulations of faces have been employed to elucidate the mechanisms underlying face recognition. In 1969, Yin compared the abilities of healthy subjects to recognize face and non-face objects presented in upright and inverted orientations (Yin, 1969). According to that study, the recognition of inverted faces was significantly more disrupted than that of inverted non-face objects such as houses and airplanes. Indeed, discrimination accuracy was reduced and reaction time was increased when faces were presented in an inverted position (Bartlett & Searcy, 1993). Inverting stimuli rendered objects more difficult to recognize, but the disruption was greater in response to faces than to other objects. This phenomenon, which has been termed the "inversion effect," has

provided evidence that faces are distinct from other objects and that configurational information plays an important role in recognizing faces. Other frequently used manipulations of facial information have involved modifications of faces themselves (Leder & Bruce, 1998). As shown as Figure 1, featural information can be altered by modifying the shapes of specific features (a). Similarly, second-order configurational information can be manipulated by changing the distances between specific features but maintaining the shapes of features as unchanged (b). Other alterations in facial information can involve the gradual blurring of faces (Fig. 1c) (Sergent, 1986). The blurred faces degraded featural information more severely than configurational information. When blurred faces were inverted, both featural and configurational information were disrupted, resulting in severe impairments in recognition (Collishaw & Hole, 2000).

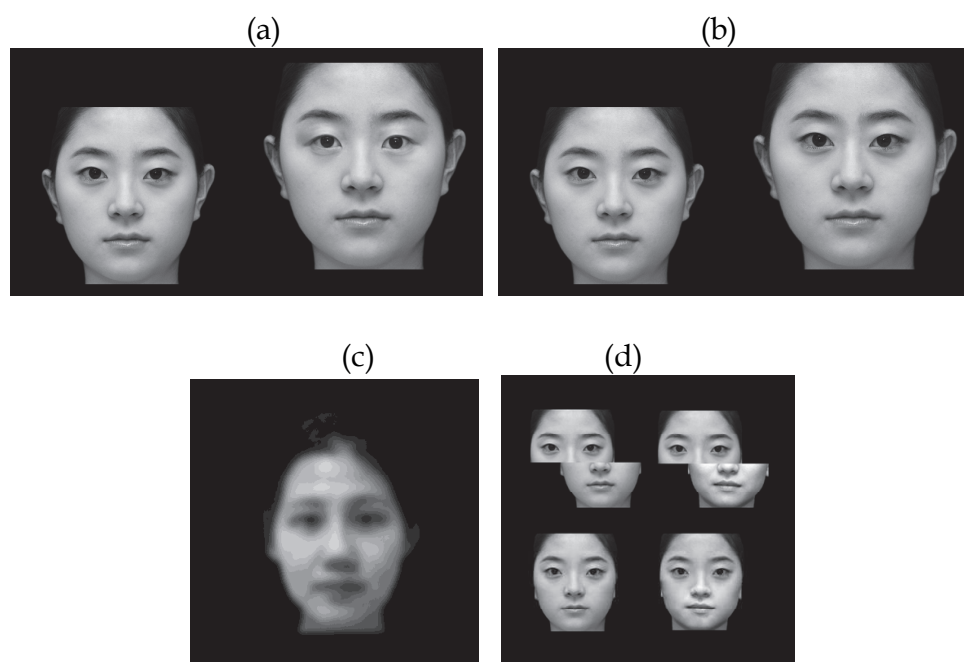


Fig. 1. Examples of the manipulation of facial information. (a) an alteration of featural information by replacing eyes with other female of the same race. (b) an alteration of configurational information by modifying distance between eyes. (c) a blurred face (d) composite faces

Another frequently employed technique is a composite face (Fig. 1d), in which the top half of one face is paired with the bottom half of another face and presented as a whole face or is offset laterally. When adults were asked to discriminate the top halves of a pair of faces, their discrimination performance was slower and less accurate under the whole-face condition than under the offset condition, indicating the holistic processing of face recognition (Young et al., 1987). This phenomenon is known as the “composite-face effect.” Various techniques have facilitated progress in research on face recognition. Measures have been modified, and new techniques have been created to examine how featural and configurational information affected face recognition. In the next section, we will focus on the role of featural and configurational processing in face recognition, on the relationship between two types of processing, and finally on whether the two types of information rest on differentiated or shared biological mechanisms.

2.3 Hypotheses about face-recognition processing

Although it has been established that both configurational and featural processing are involved in face recognition, the contribution of each type of processing to the recognition of faces remains controversial. Traditionally, three kinds of hypotheses about how facial information is processed have been advanced: (a) the holistic-processing hypothesis, which emphasizes holistic processing in the recognition of faces; (b) the featural-processing hypothesis, which argues that featural processing can account for face recognition; and (c) the dual-coding hypothesis, which asserts that featural and configurational information are processed independently. Beyond these traditional approaches, an alternative view integrating these hypotheses has been recently introduced.

2.3.1 The holistic processing hypothesis

One group of researchers has argued that holistic processing, in which featural information is combined with configurational information, dominates the processes underlying the recognition of faces (Tanaka & Sengco, 1997). Tanaka and Farah (1993) compared the performance of participants under conditions in which learned face parts were presented in isolation and under conditions in which they were presented in context. They found that subjects identified the face parts under the whole-face condition better than under the isolation condition, underscoring the role of configurational processing in face recognition. This was not the case when scrambled faces and house parts were presented. The composite effect reported by Young et al. (1987) supported this hypothesis. People performed worse when faces composed of top and bottom halves from different individuals were presented as a whole face than when they were offset laterally. This phenomenon reflected the reliance of face processing on holistic representation. To examine how facial features were processed during facial recognition, Tanaka and Sengco (1997) examined the effect of configurational information on featural information. Faces were altered only with respect to the distance between the eyes. Subjects were asked to recognize features such as the nose and mouth under three conditions: the learned-configuration condition, the unlearned-configuration condition, and the isolated-feature condition. The results showed that subjects recognized noses or mouths better under the learned upright-configuration condition than under the unlearned-condition or the isolated-feature condition. In other words, altered configurational information affected the recognition of facial features. The above observations implicated the dominant role of configurational information in face recognition. The configurational hypothesis entails interdependence between featural and configurational information, whereas interactions between them would rely on a holistic representation.

2.3.2 Featural processing hypothesis

Disagreeing with the configurational hypothesis, another group of researchers have posited that the processing of featural information is crucial for face recognition (Rakover & Teucher, 1997). They assert that the inversion effect results from factors other than disruptions in configurational information. Accordingly, the delayed development of configurational processing is argued by these researchers to reflect children's use of a featural strategy for face recognition. Alternatively, they also argue that mental rotation causes the inversion effect for faces (Valentine & Bruce, 1988), and this explains the finding that when the degree to which upright faces were rotated was increased, reaction times

followed a linear path. Another explanation, based on feature saliency, argues that facial features themselves have no configurational information; hence, visual information about features, including their saliency, is key to facial recognition. These views differ from the configurational hypothesis in that they demote the role of configurational information in face recognition. In its most extreme incarnation, this perspective holds that configurational information is less important than featural information. For example, Rokover and Teucher (1997) argued that isolated features can account for 91% of the variance in the recognition of upright face.

2.3.3 Dual-coding hypothesis

The dual-coding hypothesis has been proposed as an intermediate account of facial recognition (Bartlett & Searcy, 1993; Searcy & Bartlett, 1996). This hypothesis maintains that both sources of information are important and that they are processed simultaneously and independently (Ingvalson & Wenger, 2005). Accordingly, two modes are specialized for face recognition: one mode for encoding spatial information and the other mode for encoding featural information. According to this perspective, both modes would operate in response to upright faces, but the featural mode would be dominant in the recognition of inverted faces. To test this hypothesis, Cabeza and Kato (2000) conducted research using the prototyping effect. The prototyping effect refers to the tendency to misidentify a new face (prototype) as a face that had been seen before when it is composed of a series of faces that had already been presented. When prototypes were presented in an upright orientation, subjects incorrectly identified unlearned prototypes, and this tendency was equal in response to both featural and configurational prototypes. However, when prototypes were presented in an inverted orientation, this effect disappeared for the configurational prototype. The authors concluded that both featural and configurational information played important roles in recognizing faces and that their effects were independent.

2.3.4 Alternative views

Recently, Amishav and Kimchi (2010) offered interesting experimental data on how featural and configurational information interacted in the recognition of faces. Employing Garner's (1974) speeded-classification method, they asked participants to classify faces on a relevant dimension (e.g., configurational information) while ignoring an irrelevant dimension (e.g., featural information). Under the control condition, only the relevant dimension was altered, and under the filtering condition, both relevant and irrelevant dimensions were altered. Equivalent performances under both conditions would indicate that featural and configurational information did not interfere with each other, whereas poorer performance under the filtering condition would indicate that one source of information affected another source of information. The findings showed that reaction times were slower under the filtering condition, indicating that judgments about featural changes interfered with those about configurational changes and vice versa. The authors concluded that both featural and configurational data were integral to the processing of upright faces. This evidence contradicted the dual-mode hypothesis, which assumes the independent processing of featural and configurational information. This evidence was also inconsistent with the holistic processing hypothesis, which argues that holistic processing plays the dominant role in the recognition of upright faces.

2.4 Biological evidence

Although a substantial body of evidence has shown how faces are processed behaviorally, these data have been limited to confirming the contributions of featural and configurational information to face recognition. Recent neuroimaging studies have used various techniques such as event-related potentials (ERPs), magnetoencephalography (MEG), and functional magnetic resonance imaging (fMRI) to provide evidence about the brain correlates of face perception. More recently, researchers have attempted to find the distinct neural mechanisms underlying each featural and configurational process. Biological evidence may help us to understand the way in which faces are processed, even though the neural mechanisms underpinning face recognition have not been fully elucidated due to the small number of studies.

2.4.1 Evidence from neurophysiology

ERP studies investigating face processing have reported the involvement of various electrophysiological components including P100 (P1), N170, and P200 (P2), primarily in the posterior cortex (Bentin & Deouell, 2000; Boutsen et al., 2006; Pesciarelli et al., in press; Rossion et al., 2000). In particular, the N170 component, with a negative peak at about 170 ms after stimulus onset, appeared to reflect face-specific processing. The amplitude of N170 is greater in response to faces than to objects (Boutsen et al., 2006) and is sensitive to the inversion effect (Bentin et al., 1996; Eimer, 2000; Rossion et al., 1999). Inversion of faces induces increased and delayed activity in N170 of the right hemisphere, indicating that this component may be involved with the configurational processing related to face recognition (Rossion et al., 1999). However, the aspects of face processing to which N170 is sensitive remain uncertain. Scott and Nelson (2006) observed that activity in the right hemisphere N170 was greater for configurational processing, whereas activity in the left hemisphere N170 was greater for featural processing. Mercure et al. (2008) examined ERPs using a similar task but did not find that featural and configurational alterations affected N170. Instead, that study found that the amplitude of P2 was greater in response to configurational modification. Although the particular ERP components that modulated the two types of facial information remain uncertain, limited neurophysiological evidence has implied that featural and configurational processing are likely mediated by differential neural correlates.

2.4.2 Evidence from functional neuroimaging

Many previous studies have detected a face-specific brain area, the so-called “face area.” The fusiform face area (FFA), which is located in the region of the occipito-temporal cortex, has shown increased activity during the viewing of faces (Downing et al., 2006; Grill-Spector et al., 2006; J. V. Haxby et al., 2000; J.V. Haxby et al., 1994; Kanwisher et al., 1997). However, the neural activity in this brain region did not seem to selectively respond to specific types of face processing (Aguirre et al., 1999; R. Epstein et al., 2006; J. V. Haxby et al., 1999; Kanwisher et al., 1998; Mazard et al., 2006; Schiltz & Rossion, 2006). Yovel and Kanwisher (2004) investigated neural activity while subjects discriminated whether pairs of faces were the same or different. Stimuli were modified in terms of either the shapes of facial features or the distances between features. The central finding was that FFA activity did not differ under featural and configurational conditions, indicating the absence of face-processing activity specific to the FFA. Indeed, many neuroimaging

studies have sought to associate FFA activity with an inversion effect, but most could not find increased activity in this area (J. V. Haxby et al., 1999; Kanwisher et al., 1998; Schiltz & Rossion, 2006). In this context, the brain regions specific to each type of face processing remain unidentified. Maurer et al. (2007) investigated the neural mechanism underpinning featural and configurational processing using featurally or configurationally altered face stimuli. They reported that the right fusiform area, which is adjacent to the FFA, exhibited more activity in response to spacing than to features (Fig. 2). In addition to the right fusiform area, multiple regions in the right frontal cortex also showed increased activity during configurational processing, whereas left prefrontal activity increased during featural processing. These findings suggest that the neural correlates involved in the processing of second-order information are likely to differ from those involved in featural processing. Another similar study from Switzerland supported this notion by showing dissociated neural pathways associated with featural and configurational processing during face recognition (Lobmaier et al., 2008). Although no consensus on what brain regions are associated with each type of face processing has been reached thus far, speculation favoring separate neural networks for featural and configurational processing appears plausible.

3. Aberrant face-recognition processing

Close examination of patients who suffer from impaired face recognition should provide important insights into the mechanisms underlying face processing. Similar to studies focusing on healthy face processing, recent studies examining abnormal face recognition have attempted to identify the aspects of face processing that are impaired in disorders of face recognition. Interestingly, visual agnosia, which refers to the inability to recognize visual stimuli, is domain-specific. Indeed, damage to various brain areas caused various types of agnosia. For example, topographical agnosia, which results from damage to the parahippocampal area, is characterized by impairment in scene recognition despite intact object recognition, (R. Epstein et al., 2001). Prosopagnosia is a kind of face-specific agnosia in which patients experience difficulty in indentifying the faces even in the absence of other kinds of visual agnosia. Some patients have suffered from deficits after damage to specific brain areas such as the occipito-temporal cortex (acquired prosopagnosia), whereas others have suffered from these deficits in the absence of neurological damage (developmental or congenital prosopagnosia). Due to the specificity of deficits in face recognition, the mechanism underlying prosopagnosia has been extensively studied in research addressing face recognition. Patients with psychiatric disorders such as schizophrenia also experience problems with face recognition, but their deficits derive primarily from neurodevelopmental alterations in the brain rather than from invasive brain damage (Cornblatt et al., 2003). Patients with schizophrenia have shown dysfunction in various cognitive domains including working memory, executive functioning (Antonova et al., 2004), and social perception (Marwick & Hall, 2008). Difficulties with the perception of social objects and the interpretation of social contexts have been identified as especially critical contributors to the outcomes of the illness, although the question of whether social dysfunction in schizophrenia is associated with other sorts of cognitive deficits remains debatable.

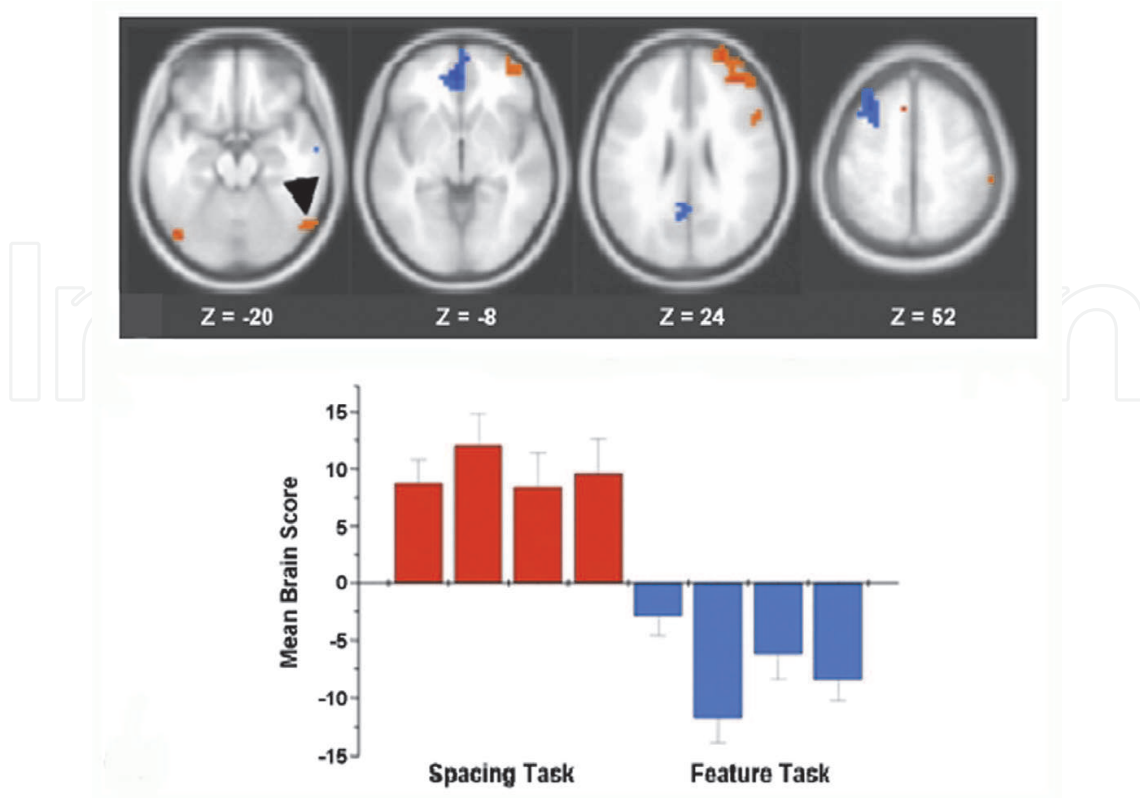


Fig. 2. Neural correlates of face recognition. Brain regions (upper panel) and the pattern of activity (lower panel) involved with the featural (blue) and configurational processing (red). Adapted from Maurer et al. (2007)

3.1 Prosopagnosia

Prosopagnosia is a rare deficit characterized by impaired face identification. Patients with this neurological disorder experience difficulties with face recognition but function in an intact manner in tasks involving the visual recognition of non-face objects. Many studies have reported findings from single cases (Ariel & Sadeh, 1996; Bentin et al., 1999; Busigny & Rossion, in press; de Gelder & Rouw, 2000; Duchaine, 2000; Duchaine et al., 2003; McConachie, 1976; Saumier et al., 2001; Steeves et al., 2006; Wilkinson et al., 2009). Although several studies have compared the performances of groups, individual differences, even within the patient group, have been prominent, especially in the case of developmental prosopagnosia (Le Grand et al., 2006). The core question raised by these studies involves the nature of the face-recognition impairment in prosopagnosia. One influential early view held that these patients experienced difficulties with recognizing faces holistically (Levine & Calvanio, 1989). According to this assumption, patients failed to integrate featural information into a whole representation. This view appeared to be compelling for patients with acquired prosopagnosia who showed damage to the brain areas primarily linked to the occipito-temporal cortex. However, findings regarding developmental prosopagnosia have varied in that patients have shown individual differences on the same task due to the heterogeneity of this disorder. For example, of the eight patients with developmental prosopagnosia studied by Le Grand et al. (2006), seven showed normal abilities to discriminate the top halves of faces under the misaligned condition; indeed, their performance under the misaligned condition was better than that under the aligned

condition, indicating intact holistic processing. Additionally, two patients showed specific deficits in the discrimination either of featurally or of configurationally modified faces, whereas one patient showed abnormalities in the ability to process both types of facial information. Another case study compared two patients, one with prosopagnosia and the other with object agnosia, to examine interactions between featural and configurational processing (Rivest et al., 2009). The main finding of this study was that the patient with prosopagnosia showed impairment in processing featural and configurational facial information, whereas the patient with object agnosia exhibited deficits in only featural processing despite normal face-recognition ability. The authors noted that configurational processing is required for face recognition and that therefore featural processing cannot proceed without configurational processing. Taken together, and despite the remaining controversy about the nature of face processing, the deficits found in studies related to prosopagnosia have implicated differentiated mechanisms underlying configurational and featural processing as well as their interactions.

3.2 Schizophrenia

Schizophrenia is a neuropsychiatric disorder characterized by social dysfunction as well as abnormal mental processes such as hallucinations and delusions. Patients with schizophrenia have difficulty identifying social objects such as faces (Joshua & Rossell, 2009; Shin et al., 2008) and bodies (Takahashi et al., 2010), recognizing facial expressions (Aleman & Kahn, 2005; Doop & Park, 2009; Morris et al., 2009; Pinkham et al., 2007), and understanding the mental states of others (Brüne & Brüne-Cohrs, 2006; Chung et al., 2008; Corcoran et al., 1995; Pinkham et al., 2003). Recent studies have investigated the basic mechanisms underlying impaired face recognition in this disorder. Shin et al. (2008) compared patients with schizophrenia with healthy control subjects without psychiatric histories in their ability to discriminate modified faces. This study found that patients with schizophrenia were less accurate in discriminating faces that differed with respect to configurational or featural facial information, whereas their ability to recognize modified non-face objects such as chairs was normal. Interestingly, the impairment in the ability to recognize configurational information was much greater than that in the ability to discriminate featural information. Additionally, the inversion effect was reduced among those with schizophrenia compared with those in the control group, indicating disrupted configurational processing among those with this disorder (Fig. 3).

However, because both configurational and featural processing were abnormal in the patients in this study, the specific aspects of face processing that contributed to aberrant face recognition remain unclear. A recent study investigated the face-recognition abilities of individuals at risk for the development of schizophrenia (Kim et al., 2010). The results indicated that subjects at risk showed alterations only in their ability to discriminate configurational, not featural, information. This observation suggested the possibility that the impairments involved in configurational processing in the service of face recognition begin earlier than do those involved in featural processing and that featural processing gradually deteriorates prior to the onset of the illness. Another study from Australia reported similar findings in patients with schizophrenia (Joshua & Rossell, 2009). Patients with schizophrenia did not rely as heavily on configurational information as did control subjects, indicating less use of configurational processing. In this context, the difficulties with face recognition experienced by patients with schizophrenia can probably be attributed to impairment in

configurational processing. Deficient configurational processing may force patients to rely on featural information to recognize faces, resulting in imperfect face recognition.

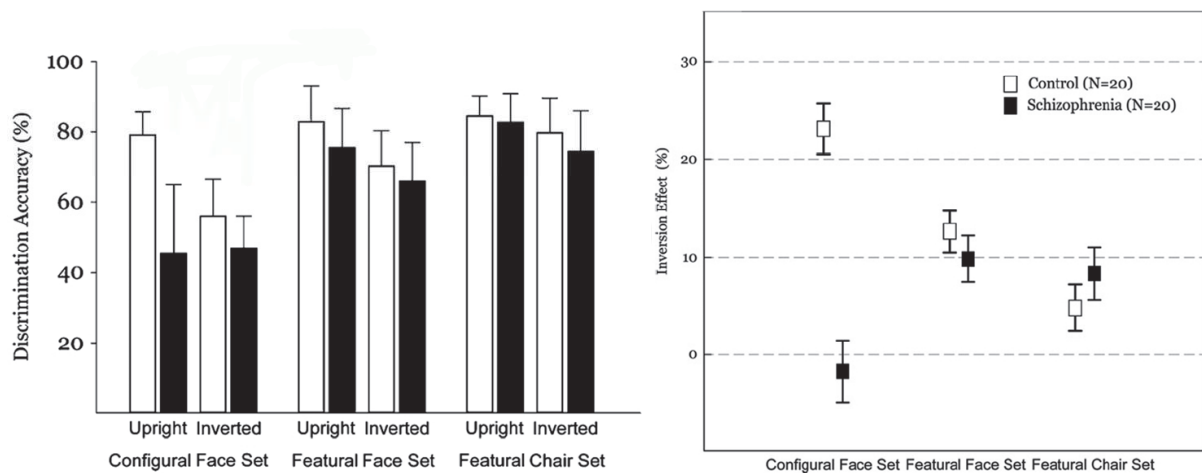


Fig. 3. Comparison of face discrimination performance between patients with schizophrenia and healthy controls. Adapted from Shin et al. (2008)

4. Conclusion

The ability to recognize faces is crucial for social communication and adaptation in human societies. Although several research approaches have sought to provide a clear answer to how and on what basis faces are recognized, this questions remain unanswered at this point. Relatively confirmatory long-standing evidence has suggested that face processing is distinct from the processing of non-face objects; this evidence has included behavioral phenomena such as the inversion effect, the existence of a face-specific disorder such as prosopagnosia, and neural correlates (e.g., the FFA) that have exhibited relative selectivity in their responses to faces. The first line of behavioral studies has provided various effective tasks or techniques to enable differentiation between featural and configurational processing, establishing a foundation for identifying the mechanisms underlying face recognition. Observations from behavioral studies have served as a basis for ideas and assumptions about how featural and configurational processing contribute to face recognition. Nonetheless, behavioral data do not consistently and clearly explain whether one type of processing plays a dominant role in face recognition or whether both types of facial processing interact or act independently. An extreme view has argued that holistic processing, in interaction with featural information, dominates face recognition. At the other extreme, arguments that featural information is processed independently and is critical for face recognition have been advanced. A neutral view holds that both featural and configurational data are important and that they interact in the accurate and efficient recognition of faces. According to limited recent evidence, the last assumption appears to be the most plausible. Some patients with prosopagnosia were unable to utilize configurational information, but others failed to recognize featural information, although all showed difficulties in the identification of faces. This evidence raises questions about whether people would fail to recognize faces if one type of process were disrupted. In other words, do both types of processing make essential contributions to accurate face recognition? Recent evidence has implicated the operation of separate neural mechanisms for featural and configurational processing. If featural and configurational processing interact during

face recognition, it can be presumed that the two types of information, processed in separate brain regions, would be connected through neural networks that function in an interactive way. Future studies investigating neural connectivity will help our understanding of the nature of the interplay between featural and configurational face processing and will clarify how faces are processed. Indeed, studies conducted from within different domains—including neuropsychology, neurophysiology, neuroimaging, neurology, and psychiatry—should be synthesized. The data collected thus far are insufficient for determining the processes underlying face recognition. Future research using effective tasks is needed to elucidate the neuropsychological mechanisms and neural correlates involved in healthy and abnormal face processing.

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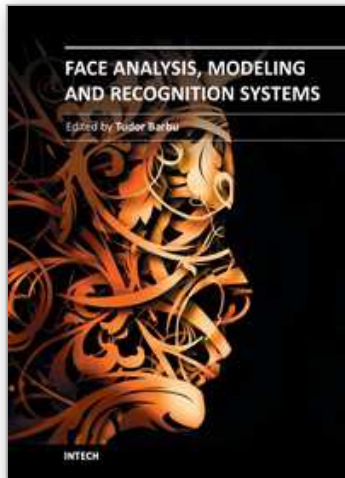
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The purpose of this book, entitled Face Analysis, Modeling and Recognition Systems is to provide a concise and comprehensive coverage of artificial face recognition domain across four major areas of interest: biometrics, robotics, image databases and cognitive models. Our book aims to provide the reader with current state-of-the-art in these domains. The book is composed of 12 chapters which are grouped in four sections. The chapters in this book describe numerous novel face analysis techniques and approach many unsolved issues. The authors who contributed to this book work as professors and researchers at important institutions across the globe, and are recognized experts in the scientific fields approached here. The topics in this book cover a wide range of issues related to face analysis and here are offered many solutions to open issues. We anticipate that this book will be of special interest to researchers and academics interested in computer vision, biometrics, image processing, pattern recognition and medical diagnosis.

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