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CONTROVERSIES IN THE FACIAL INVERSION EFFECT: FACE SPECIFICITY AND EXPERTISE

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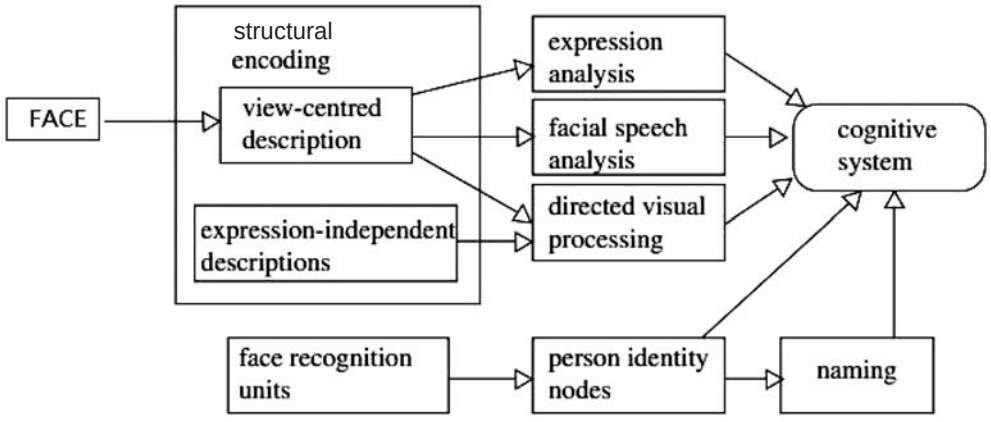
This paper reviews studies on the face inversion effect and expertise. It is suggested that the inversion effect be considered as evidence of specific processing in face recognition or expertise of the objects, which meet three prerequisites. Some disputes are also pointed out in the review. It is proposed that further studies should be addressed to the visual differences, physiological basis of cognitive modules, and anatomical and functional location of the respective networks.

Keywords: face recognition, inversion effect, face specificity, expertise.

Face recognition is currently one of the important domains in cognitive neuroscience; this topic is attracting more and more attention from many neurologists and cognitive psychologists. As the facial inversion effect (FIE) has been found to be evidence of face-specific processing [1], it became one of the important approaches in studies of face recognition and it is still a hot topic in the field of cognition, because it remains a great challenge in understanding the nature of FIE [2] .

THE FIE AND FACE-SPECIFIC PROCESSING

Over 40 years ago, it was observed in behavioral studies that face recognition is impaired disproportionally by inversion of the view or image, which was reported in Yin's landmark paper and called the *face inversion effect* (FIE) [1]. Yin suggested that the FIE may be considered as evidence of specific processing in face recognition. More importantly, studies of the facial processing mechanisms were promoted by the FIE [2].



F i g. 1. Scheme of the face processing model proposed by Bruce and Young [3].

Р и с. 1. Схема моделі обробки інформації щодо обличчя, запропонована Брюсом та Йогном [3].

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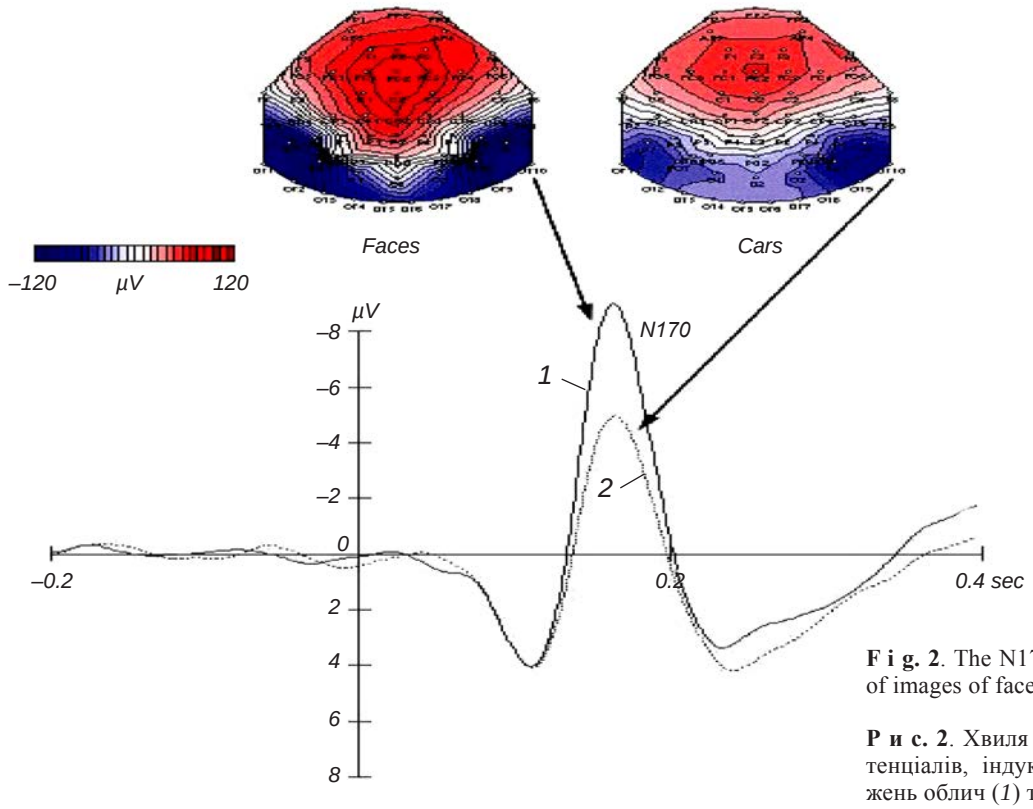


F i g. 2. The N170 wave induced by presentation of images of faces (*1*) and cars (*2*) [4].

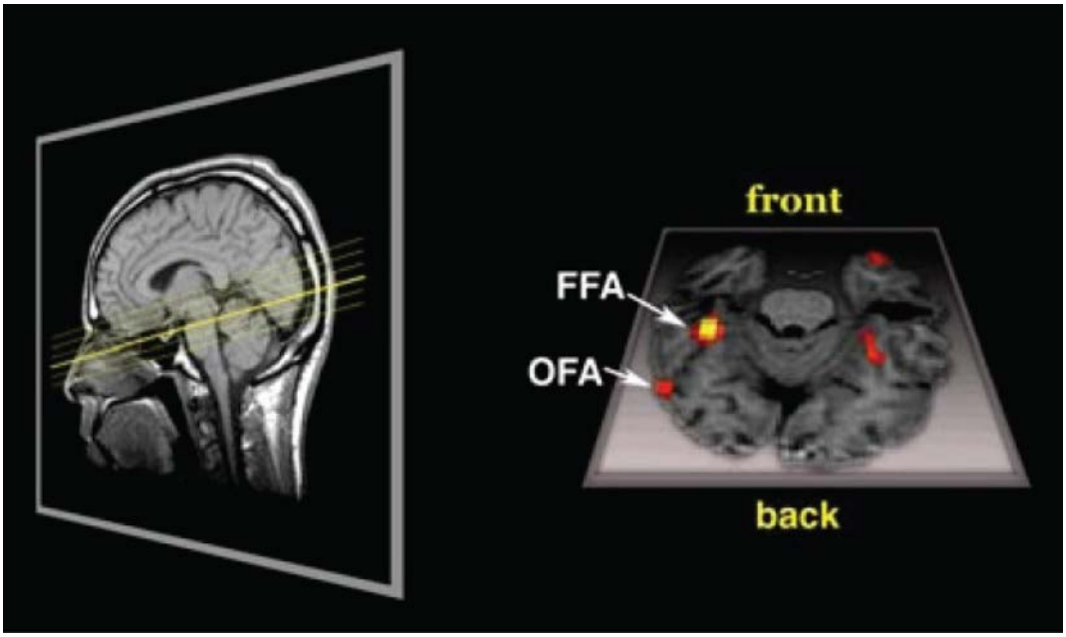
Р и с. 2. Хвиля N170 у складі викликаних потенціалів, індукованих пред'явленням зображень облич (*1*) та автомобілів (*2*) [4].

Among them, the most famous and classic cognitive model has been proposed by Bruce-Young, in which the first stage of facial processing is the configural coding [3] (Fig. 1).

With the development of the technique of event-related potentials (ERPs), this technology gradually began to play an important role in cognitive neuroscience, known as the "observing window of the advanced functions of the brain." ERP researchers found a negative wave with a latency of approximately 172 msec, called N170. This is the most significant negative deflection in the composition of ERPs, related to face recognition and observed in the bilateral temporal occipital regions [4] (Fig. 2). The N170 component, related to configural analysis of the facial features, is considered a significant argument for face specific processing independent of sex, age, or race, which reflects the configural coding in the cognitive model of Bruce and Young. It was reported that the latency of N170 is often prolonged by face inversion, while the amplitude of N170 is increased after such operation [5]. These effects can also be observed in the parietal region. A different wave of positive polarity is simultaneously recorded in this location, and this component is known as the vertex positive potential (VPP). This effect is observed not only in adults but also in pre-school children (3 to 5 years old) [6]. Some magnetoencephalographic (MEG) studies reported a weak but significant delay of the P1 component before N170, which might demonstrate that FIE may occur earlier, even at the level of P1 [7].

Kanwisher et al. [8] studied the cerebral cortex in the course of face identification by means of fMRI and found that the right fusiform gyrus is strongly activated by face images compared with non-face objects. Therefore, the fusiform gyrus is considered to play an important role in face identification, and this region was called the fusiform face area (FFA). There are three bilateral visual cortices mainly involved in face-specific activation and processing; these are the occipital face area (OFA), fusiform face area (FFA), and superior temporal sulcus (STS) [9] (Fig. 3). The FFA is the most important area, and Kanwisher's study indicated that the main function of the FFA is general detection of faces rather than identification of faces at an individual level [10].

There is a very interesting and controversial study on prosopagnosia in which patients, when confronted



F i g. 3. Location of the FFA and OFA in an fMRI image [4].

Р и с. 3. Локалізація зон FFA та OFA при функціональному магніто-резонансному скануванні (fMRI) [4]

with a face image composed of many non-face objects, could figure out each object but failed to perceive the entire face, while patients suffering from pragmatagnosia could realize that the entire visual stimulus is a face but could not identify the objects that make up the faces [11]. In theory, the FIE would not occur in patients with prosopagnosia; however, different studies came to dissimilar conclusions. It was reported that the FIE appears in patients with face agnosia [12]. In contrast, Delvenne et al. failed to find the FIE [13]. Furthermore, de Gelder and Rouw [14] observed that patients with prosopagnosia recognized inverted faces better than upright faces, which was considered the FIE reversal [15]. The core question of face recognition is: Is there a unique face processing module, or are there separate neural mechanisms of face processing? Although researchers found specific activation in some brain regions with respect to faces (e.g., the FFA), other researchers insisted that there is no difference between face recognition and non-face object recognition (with expertise). Both such processes are characteristic of classification of a subcategory in a relatively homogeneous category, and mankind is the expert to complete the classification.

THE FIE AND EXPERTISE

In 1986, when Diamond and Carey [3] examined FIE on images of human faces and dog "faces," they predicted that if the factor of class familiarity makes sense, canine experts would recognize upright dog images more effectively than inverted ones. In other words, the dog "FIE" would occur only in canine experts other than "normal" subjects. The above findings proved the hypothesis that not only the FIE but also the dog "FIE" occur in the canine experts. Diamond and Carey explained that when canine experts identify the dogs using configural information, they possess the ability to distinguish subtle differences, while novices must rely on the separate features of dogs. The usage of configural information in experts is impaired by inversion; therefore, both experts and novices have no choice but discriminate the inverted stimuli relying on separate features. Diamond and Carey put forward three prerequisites for the FIE: (i) in certain types of complex visual stimuli, all stimuli have a common structure; (ii) some kinds of stimuli can be discriminated from others by the relationship between the components of these stimuli. These components determine a common structure, which is also

known as a second sequence between features; (iii) participants possess the expertise to use these characteristics of the relationship. The cited study demonstrated that the FIE can appear in the recognition of any stimuli with common configuration with which participants are very familiar. The FIE should not be perceived as evidence of face-specific processing because this effect was found in the recognition of other non-face stimuli, e.g., a scene IE or a body IE [16]. In addition, it was reported that acquired learning has a great impact on the FIE, which also corroborates the expertise hypothesis to some extent [17].

The findings made in ERP studies showed that the N170 component can also be incurred by some non-face objects, including cars, chairs, glasses, houses, dogs, birds, flowers, butterflies, or palms [18]. Different types of expertise studied, e.g., birds and cars [19], which were of the same cognitive characteristics, such as the experts' advantage of visual short-term memory over novices, were insignificant [20].There is a very special novel type of the stimuli, called "greebles," which is a series of artificial objects manufactured by some regulations [21]. Researchers observed no difference of the N170 in novices between inverted "greebles" and upright "greebles." At the same time, the N170 latency of the experts of "greebles" was impaired by inversion, which implies that prolongation of the N170 latency might be induced by the deterioration of relational or holistic information (precisely such information is the goal of experts to obtain). In short, the IE is a symbol of destruction in cognitive processing [22].

However, some researchers even think that there is no difference in the cognitive mechanisms between upright and inverted faces, as well as between face images and non-face objects. Participants can obtain such expertise of novel "greebles" by continuous training, and they can process the upright "greebles" configurally, while they recognize inverted "greebles" featurally [23].

Thus, first, it is difficult to find an ideal paradigm to avoid the influence of visual differences among various visual stimuli.

The "face-specific processing" proponents insist that behavioral and electrophysiological studies of the FIE provide convincing evidence for face-specific processing. When participants are presented with face images, the N170 and VPP are often induced simultaneously, which is considered an early sign of face processing. By contrast, some researchers believe that, compared with other objects, the so-called face-specific component N170 is not enough to support face-specific processing, because this wave may simply reflect a low-level visual difference (such as spatial frequency) between faces and other non-face objects [24]. Meanwhile, the "expertise" supporters believe that the N170 (N1) is an index of expertise for certain types of objects, including the perception of language [25]. In addition, other studies suggest that processing of the face may begin at about 100-120 msec. The P1 wave is often observed within this period, and this component is more sensitive to the faces [26]. On the contrary, it is also proposed that the P1 might only reflect a low-level visual difference, like the N170 component [27]. A more subtle study demonstrated that the P1 reflects rough face processing, while the N170 reflects more sophisticated face recognition [28]. Further, many studies have shown that the spatial relationship between local features of faces is mainly influenced by the FIE [29], but which one is more influenced by this effect, features or configuration? There is no consensus whether a visual difference between dissimilar stimuli always constitutes the problem (such as color contrast) [30]. Thus, the problem of visual difference is one of the bottlenecks that hinder the development of visual recognition studies.

Second, it is rather difficult to find ideal visual stimuli to compare with faces.

"Expertise" proponents suggest that the IE can occur in recognition of any types of visual stimuli, which meet the three prerequisites of Diamond and Carey. However, opponents point out that the so-called appearance of the IE with respect to "non-face objects" arises only because the latter have similar changes of facial characteristics (facelike). So, face-specific processing regions are activated by those facelike stimuli that are only indicative of special face processing [31]. In addition, although people possess the expertise to recognize dogs, birds, or "greebles" by training (training time is, naturally, limited), these types of expertise cannot be compared with face recognition, as Farah's study [32] showed that a face-specific innate neural mechanism seems to exist.

Third, the findings of the IE in patients with prosopagnosia are inconsistent.

The reason why there are such different findings of the IE scope about face agnosia is that the reaction time is insufficient for correct measurements in many experiments. Although some studies showed that patients with prosopagnosia could recognize upright and inverted faces, they failed to report the findings of

recognition of upright and inverted non-face objects simultaneously. What's more, the visual stimuli and paradigms varied in different studies. In other studies, most patients suffered from impairment of recognition of general visual objects; thus, they might even be unable to identify an extensive set of objects.

Fourth, the relationship between FFA and its functional location is still unclear. For the role of the FFA, there are still different opinions. Does it represent the face-specific recognition module, or is it merely a part of the networks involving general object processing nets [33]? Compared with the demonstration of the role of the right hemisphere in face processing (both in adults and infants), there is a left-hemisphere advantage of word processing. Word processing itself is a special expertise, which seems to imply that even if there are active regions of expertise, it is likely to be multi-regional in distribution rather than a single location. Therefore, further studies are needed to address to the visual differences, physiological basis of cognitive modules, and anatomical and functional location of the respective networks.

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ПРОТИРІЧЧЯ ЩОДО ЕФЕКТУ ІНВЕРСІЇ ЗОБРАЖЕННЯ ОБЛИЧЧЯ: СПЕЦИФІКА ОБЛИЧЧЯ АБО ЕКСПЕРТНИЙ ПІДХІД?

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Р е з ю м е

Надано огляд робіт, у котрих обговорюються ефект інверсії зображення обличчя та експертний підхід у процесі його аналізу. Вважається, що ефект інверсії має розглядатись як свідоцтво специфічної обробки інформації при розпізнанні обличчя або базуватися на експертній оцінці об'єктів з наявністю трьох передумов. В огляді виділені декілька аспектів, що викликають дискусії. Пропонується, щоб наступні дослідження були спрямовані на з'ясування візуальних відмінностей, фізіологічного базису когнітивних модулів та анатомічної та функціональної локалізації відповідних нейронних мереж.

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