

A Review on the fMRI Studies of Facial Expression Recognition: Brain Regions, Developments and Abnormalities

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Abstract: This review article congregated the fMRI studies of facial expression recognition in recent years. Firstly, we introduced the brain regions of facial expression recognition including amygdala and some other brain regions. Secondly, developmental changes of the brain regions among ages were summarized. Finally, we focused on the abnormalities in facial expression recognition. In the end of this article, drawbacks of previous research and requirements of future studies were discussed.

Key words: Facial Expression Recognition • fMRI • Amygdala • Emotion

INTRODUCTION

Facial expression, as one of the most important human nonverbal signal can deliver emotions to others in social communication. Whether individuals could easily understand others' emotion or attitude is affected by the accuracy of recognizing the facial expression. The normal 6 months old infants can notice their mother's facial expression [1]. One-year old infants can understand some basic facial expressions. The ability of social judgement and communication according to facial expression develops with age. Researchers found this ability positively associates with IQ and EQ [2]. With the development of brain cognitive technology and functional magnetic resonance imaging (fMRI), which provides stable evidence [3, 4], the research of facial expression recognition has aroused great interest of researchers. This review article congregated the fMRI studies of facial expression recognition in three aspects: brain regions, developments and Abnormalities. The brain regions explained the physiological fundament of facial expression recognition and how human brain processes the facial information. The developments help us figure out how human get the recognition ability. Besides, the abnormalities of facial expression recognition associate with some mental disease. The aims of this review are to show what have been studied in past decades, such as: which and how do brain regions work in facial expression recognition, what's the pattern of development of facial expression recognition and what is wrong with

abnormalities. Besides, we try to figure out several imperfections in current studies and some study directions in the future.

Brain Regions Location of Facial Expression Recognition: Most studies on facial expression focused on the limbic system as the limbic system strongly associates with emotion process, especially the amygdala, hippocampus and insula. Early researchers believed that the recognition of each expression had a corresponding functional area of the brain to participate in processing, but this view has been gradually challenged. Nowadays, scholars believe that facial expression recognition needs several brain regions to cooperate rather than independently work [5, 6]. The processing of different facial expression has common nervous basis and unique integration characteristics, such as the prefrontal lobe amygdala cingulate gyrus and basal ganglia.

The fMRI studies on normal adults' brains show that amygdala plays an important role in facial expression recognition [7]. Amygdala is obviously activated when people are recognizing a scared expression. In addition, it is also activated when it comes to happy and sad expression [8-10]. Williams *et al.* [11] conducted a research under the conditions of binocular rivalry. They selected six persons (including three males and three females) and asked them to express happiness, fearful and neutrality individually. And then, they processed the photo with grey background and carefully controlled some other irrelevant details, such as size, length and so

on. During the binocular rivalry task, they requested the subjects to pay attention to the stimulus from the overlapping semitransparent faces or buildings, which were in green and red. The faces or buildings showed up in turns and the subjects were asked to recognize the colors. The result showed that whether it was the face or the building that was recognized by the participants, the amygdala was activated anyway. When reacting to fearful faces, the activity of amygdala is much similar to visual cortex, which provides precise evidence that amygdala plays an important role in facial expression recognition. Amygdala can process fast-changing emotional stimulus automatically and acquire emotional information in the early phase of stimuli processing. Then it enhances perceptual coding of emotional event through feedback, so as to influence the attention processing of emotional stimuli.

Not only does amygdala play an essential part in the process of facial expression recognition, but also other brain regions are equally important. Sato *et al.* [12] used dynamic facial expression stimulus to explore humans' neuron mechanism to process facial emotion in an fMRI research. The researchers set three conditions. One was dynamic facial expressions, every set of whose stimulus materials were pictures gradually changing from neutrality to standard horror (or happiness), received from standard facial expression pictures through computing, 26 of them in total and then they were played continuously to form a dynamic effect. Another control condition was to display only the standard scare (or happiness) pictures and lasted the same length of time as the dynamic ones. The third one is dynamic mosaic, which was regrouped by pictures created in experimental condition, with the same displaying order as the experimental condition. During the experiment the subject was lying in the fMRI instrument. The only thing he or she needed to do was to focus on the images displayed on the screen, without any response. The experimental result showed that, compared with static pictures and dynamic mosaic, a quite different active region was shown under the dynamic emotional picture condition. In the condition of scaring pictures, the subjects' left amygdala, right occipital lobe and temporal lobe including inferior occipital gyri, middle temporal gyrus, fusiform gyrus and right ventral premotor cortex were shown to be highly activated. While with the happiness pictures, except that amygdala was not activated, it shared almost the same activated encephalic regions with the scaring one. This study showed that, compared with the previous knowledge, our facial expression recognition system probably has further and

closer connection with emotional processing system and mirror-neuron system. What's more, it can be seen from the experiment method that, the static pictures are probably difficult to show the vitality of facial expressions people have when they have social connections in daily lives, while the movement on the face may help facial expressions to deliver more realistic and precise emotional information.

In a study of disgusting expressions by Philips *et al.* [13] it was found that consciousness of facial expressions triggers the activation of the limbic system (insula) associated with the processing emotion. The insula is part of the cerebral cortex, which connects to the frontal, temporal and parietal lobes. Early evidences that insula is involved in disgusting processing come from a study in the neural basis for identifying disgusting expressions and researchers found that disgusting expressions activate the anterior insula. The anterior insula involves in the processing of the unpleasant taste stimulus. It is reasonable that disgusting expression activates insula, because disgust arises from refusing to have the obnoxious taste stimulus. This study validated the previous results of electronic scanning using the fMRI technique. The uniqueness in the research on facial expressions lied in the comparison of different percentages of emotions, which ultimately demonstrated that 150% emotion expressed faster than 75% one, with more activated parts and complex ways.

Some researchers suggested that the choice of experimental materials and its design would affect the brain activated areas of facial expression recognition. In a study by Gorno-Tempini *et al.* [14], the author used two different experimental tasks to explore how a specific task effect on activation of encephalic regions in performing facial recognition to individuals. The experiment used design of 2 (task: to determine the emotion in the picture vs to identify the gender in the picture) * 2 (expression: disgust vs happiness) and the control group is a mosaic picture made by a computer. It has been requested to react under the cue words of each task. The results showed, for all experimental conditions that are relative to the control group, there are significant activation signs in the posterior temporal gyrus, left amygdala, anterior hippocampus, superior temporal gyrus and parietal temporal lobe junction in the left hemisphere, posterior and inferior temporal gyrus in the right hemisphere. For the main effect of emotion and its interaction analysis with experimental task, there is no significant difference in brain areas activated under the conditions of disgust and happiness, but activation of

some encephalic regions are more intense in the tasks of emotional determination. In the disgusting facial expression conditions, the right caudate nucleus, right thalamus and left amygdala have been more activated than in the happy expression conditions, while the bilateral prefrontal cortex is the opposite. In the analysis of the main effects of the task, it is found that there is a significant activation degree in the right precentral sulcus, the right prefrontal cortex, frontal lobe central and lateral gyrus, the front of the insula, as well as right fusiform gyrus, in relative to the task of gender identifying. These results demonstrated that the inconsistencies in previous studies are probably due to different experimental tasks and activated areas previously co-existing in different tasks are likely to belong to general cognitive functions such as face recognition, memory retrieval, or attentional maintenance [12].

Development Characteristics of Facial Expression Recognition:

Although studies of adults prove that amygdala plays an important role in facial expression recognition, some research findings or inferences on adults may not be applicable for children and adolescents, since their nervous systems differ from that of adults. Currently, only a few studies have investigated the development characteristics of amygdala, all of which are the research on the responses to the fear expression. Baird *et al.* [15] found that for teenagers aged 12-17, amygdala was significantly activated when identifying fear expression, however no differences on age and gender. Thomas *et al.* [16] further explored age differences. They compared the activation of the amygdala when children and adults identify fear and neutral expressions. The results showed that adults had more amygdala activation degree than children when they identified fear expressions, whereas children had higher levels of amygdala activation than adults when they identified neutral expressions. The authors elaborated that the neutral expression is ambiguous for children, which leads to the activation of the amygdala. Killgore *et al.* [17] compared the activation degree of amygdala for children and adolescents when recognizing fear expression. The results indicated gender differences: The left amygdala was significantly activated when identifying fear expression in children group, but in the adolescent group, it showed decreasing activation degree in women while no change in males. Besides, in the adolescent group, there was significant activation of dorsolateral prefrontal cortex of female, while no changes in male. The experts demonstrated that as women grow

older, the activation of the amygdala decreases gradually while the activation of the dorsolateral prefrontal cortex gradually increases indicating greater emotion management ability of them.

Except for the distinctive differences in brain activation when recognizing facial expressions for adults and children, the aged cognitive competence with age increase can also result in activation differences. Plenty of studies have proved ability deterioration in different degrees for the elderly with the increase of age, such as deterioration in working memory, attention and central executive system. The preliminary results showed that in the processing of emotional expressions, the encephalic regions activated by the elderly is more than that of the young people, with higher activation level in prefrontal cortex and parietal lobe, while it showed higher activation level in visual zone and the limbic system for young man. Gunning-Dixon *et al.* [18] illustrated that the elderly relied on frontal lobes while young men rely on amygdala and temporal lobe for facial expression processing. The prefrontal cortex activation indicated that the prefrontal cortex rational processing would make up for limbic system debility for the elderly. The researchers deduced that changes with aging did not only reflect on cognitive competence, when compared with teenagers, there are also distinctive brain activation differences in different and same areas for social-information processing.

Iidaka *et al.* [19] found that amygdala did not only play an important role in fear expression recognition. The left amygdala of the participants in all ages was activated for gender judgment on anger and disgust expressions. It showed significant age differences in left amygdala activation level for the youth group at the age of 25 years and the elderly group at the age of 65 years, with higher activation level for the young man. Meanwhile, the possibility of activation as well as age differences caused by pure human face was excluded, the amygdala was not activated when recognizing expressions without emotion.

The other encephalic regions also have their own development features in facial expression recognition. For positive emotions, the posterior Para-hippocampal gyrus is the major activation region and shows significant age difference, with the lack of activation level for the elderly and a higher level of activation for the young man. Besides, it shows lower level of lingual gyrus activation in active and neutral situation. To sum up, the facial expression sensitivity of the elderly is significantly lower than those of the young man [20].

The Abnormity of Facial Expression Recognition: The abnormity of facial expression recognition has a negative effect on social behavior, poor social functioning can be a core factor in many mental illnesses, as this function may be the cause of impaired or inappropriate emotional management [21, 22]. In a study by Stevens *et al.* [23] it was found that children with specific mental disorders were incapable of recognizing sad and fear expressions, however able to recognize happy and angry expressions. It may be related to the loss of the prefrontal cortex structure, including the orbital frontal lobe [9].

Besides, gender-related differences in brain development also have critical influences for different neuropsychiatric disorders. Durston *et al.* [24] highlighted the effect of the caudate nucleus on ADHD and Tourette's syndrome. Caudate nucleus is relatively small in men, ADHD and Tourette's syndrome occurs more commonly for them. The amygdala is relatively small in female brain, which may cause anxiety and depression emotions and female are tend to get these diseases. Besides, basal ganglia and prefrontal cortex of normal human brain have many structural and functional links. By fMRI it was found that prefrontal cortex activities of ADHD children are weak with the identification of facial expression and for certain cognitive facial expression recognition, lower frontal and prefrontal cortex is not that active for adolescents with ADHD [25].

Sparks *et al.* [26] selected 3 or 4-year-old children with autism, retarded children and normal children as participants. Using of nuclear magnetic resonance (MRI) measured volume of brain cerebellum, hippocampus and amygdala, found that children with autism in these regions were larger than the other two groups of children, especially the amygdala. Other researchers found that the children with autism had lopsided proportion of left and right amygdala. Children with autism own larger right amygdala in ages of 3 or 4, had worse social adaptation and communication in ages of 6 [27].

Researchers had also conducted many studies on the emotional processing mechanism of panic patients. Pillay *et al.* [28] investigated the activation of the anterior cingulate cortex and amygdala when panic patients saw happy face pictures by fMRI. The experiment measured the blood oxygen level dependency of 8 panic patients and 8 normal people of the same age when they were activated by both happy face and neutral face. The results showed that all subjects were able to accurately identify the happy emotions, but the activation level of the anterior cingulate cortex in patient with panic disorder was more active than that of the control group. The

activation level of control group was higher than that of the panic patients only in partial voxel in the anterior cingulate cortex.

However, for neutral pictures, the panic group's activation level of the anterior cingulate cortex was not that distinctive. It showed no significant differences in the activation level of amygdala in patient group and control group. For neutral faces, the activation level of left amygdala in the panic group was slightly higher than that of control group, however no significant differences. The increased anterior cingulate cortex activation level may represent a cognitive disorder caused by increased conflict monitoring, which was due to the increased focus on them [29-32]. Alternatively, some researchers deduced that the change in the anterior cingulate cortex may not be just a matter of reactionary attention, but also reflected the special emotional connection between a happy face and an anxious person. Related evidence proved that anterior cingulate cortex plays an important role in assessing the emotional relevance of tasks and stimuli [33]. In addition, there are many studies on the relationship between developmental psychopathology, childhood abuse experience and face recognition, however hard to reach consensus. The study remains to be improved of the relevance between anomalism of facial expression recognition and mental disorders, as well as their neural relevance.

CONCLUSIONS

To sum up, we can figure out that: firstly, not only different brain regions have prominent effects on different facial expressions, but also several brain regions cooperate to process complex facial expression. Secondly, activated brain regions of facial expression recognition and activation degrees have been changed with age. Thirdly, abnormalities of facial expression recognition are always associated with brain damage of specifically regions.

From the above study of brain regions, it can be proved that the limbic system plays an important role in the facial expression recognition: the amygdala, hippocampus, insula and orbital gyrus are critical. Because the limbic system plays an important role in emotional processing and the brain regions activated in the emotional processing have different degrees of activation in facial expression recognition. Besides, there are other encephalic regions with varying activation degrees, such as inferior occipital gyrus, middle temporal gyrus, fusiform gyrus, right ventral prefrontal cortex,

dorsolateral prefrontal cortex and so on. It can be manifested that facial expression, as a complex social behavior, commands a wide range of encephalic regions, different expressions need different brain regions for identification and processing. Studies by Sato [12] have shown that the identification of facial expressions may also have a deeper connection with the MNs (mirror-neuron system).

Facial expression recognition has a continuous development process from development angle. There would be different activated brain regions in different stages with different activation degrees, from children to adolescents and even to the elderly. The elderly has decreased facial expression recognition ability as well as activation degrees of brain regions. The underlying cause may be the degradation of emotion-processing ability. What's more, part of the development of brain regions could be affected to gender factors.

The studies on the abnormalities of facial expression recognition manifested that the abnormality of a certain brain region could result in failure of facial expression recognition, however no influence on other facial expressions. It could be served as evidence to the function of that brain region to facial expression recognition, on the other hand, it also suggests the independence of that brain region on facial expression processing.

Although Functional Magnetic Resonance Imaging (fMRI) facilitates the analysis of facial expression processing of brain, there are still some limitations of current research status. Firstly, the absence of adult control group in studying face recognition of children and adolescents has limited the results to a specific age with no enough developmental significance. Secondly, the repetitive stimuli of the same category materials under fMRI may result in decrease of brain response level due to the habitual reaction. Thirdly, the lack of comparison between emotional face with neutral face in studying face emotion for many studies, would make the conclusion unreliable. Meanwhile, currently most researches focus on the role of amygdala in face recognition, with few studies on other encephalic regions. Therefore, the research coverage is not comprehensive enough.

Further study could be conducted in the three aspects: Firstly, it's critical to increase facial expression diversity, the current research still concentrated on the amygdala, as well as fear expression, with a lack of study on other encephalic regions. Secondly, further research could focus on some confounding variables and gender differences in a broader age range, which will not only

help understanding physiological mechanisms of facial expression processing, but also prevent facial expression recognition barriers for mentally disabled children. Finally, facial expressions need to be examines in specific context such as decision making [34], social dilemma and so on. In our daily life, specific context should be combined for accurately identifying the meaning of expression. For example, different laughter can express different emotions, such as a broad smile, louder smile and forced smile and so on. Crying may refer to cry sadly or moved to tears. It's effective to separate the facial expression from the emotion, discussing whether there is any difference in encephalic region activation when recognizing a more complex expression.

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