

## Modulation of the Infant Face Schema Effect by Facial Expression and Its Underlying Mechanisms

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### Abstract

The infant face schema effect is an innate instinctive response that facilitates the formation of early parent-child relationships, and this effect has long been considered to be primarily influenced by the structural features of infant faces. However, in recent years, the influence of facial expressions on this effect has begun to receive attention. Under conditions using adult faces as a baseline, the magnitude of the infant face schema effect varies with different expressions, exhibiting a phenomenon where the effect is strongest for neutral infant faces. Given that the causes of this phenomenon and its underlying neural mechanisms are currently poorly understood, this project aims to first establish a multi-expression image system featuring the same identities for infants and adults; then, based on this system, to examine whether facial expression uncertainty modulates adults' preference and attentional bias toward infant faces with different expressions, and to explore the corresponding neural mechanisms, thereby promoting the development of parental brain research in China.

### Full Text

#### Moderating Effects of Facial Expression on the Babyface Schema and Its Neural Mechanism

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**Abstract:** The babyface schema effect is an innate instinctive response that promotes the formation of early parent-child relationships, and this effect has

long been considered to be primarily influenced by infant facial structure. However, in recent years, the influence of facial expression on this effect has begun to receive attention. When using adult faces as a baseline, the magnitude of the babyface schema effect varies with different expressions, showing that the neutral babyface schema effect is the strongest. Given that little is currently known about the causes of this phenomenon and its neural mechanisms, this project first aims to establish a set of multi-expression picture systems for infant and adult faces with identical identities. Based on this foundation, we will respectively examine whether facial expression uncertainty moderates adults' preferences and attentional biases toward infants with different facial expressions, and explore the corresponding neural mechanisms to promote the development of parental brain research in China.

**Keywords:** babyface schema; facial expression; facial expression uncertainty; parent-child relationship; parental brain

## 1.1 Research Background

The concept of baby schema (Kindchenschema) was an important notion proposed by the renowned ethologist Konrad Lorenz in 1943. It refers to a set of typical features found in the appearance of human infants or animal young that readily evoke caregiving responses from adult individuals, thereby facilitating offspring survival (Lorenz, 1943). As an innate releasing mechanism, the baby schema universally induces positive emotions in adults and constitutes an important foundation for human caregiving behavior and parent-child relationship formation (Kringelbach, Stark, Alexander, Bornstein, & Stein, 2016; Parsons, Young, Murray, Stein, & Kringelbach, 2010).

Since the concept was proposed, researchers have extensively studied the baby schema. Studies have found that typical characteristics such as infant appearance, vocalizations, and smell can effectively evoke adults' perception of "cuteness" (Kringelbach et al., 2016). Among these, the infant facial schema effect is the most pronounced, and its influence can even generalize to adults, other species, or non-living objects, producing the so-called "babyface effect" (Dou, Liu, & Zhang, 2014). Current research on the infant facial schema effect has revealed that it not only evokes positive emotions in adults but also triggers attentional bias toward infants (Brosch, Sander, Pourtois, & Scherer, 2008; Charles, Alexander, & Saenz, 2013; Shi & Luo, 2016), leads to refined motor actions and responses (Nittono, Fukushima, Yano, & Moriya, 2012), enhances parenting motivation and caregiving behavior (Cheng, Zhang, Sun, Jia, & Ta, 2015), reduces aggression, and increases prosocial behavior (Kringelbach et al., 2016).

Given that the infant facial schema effect is a social instinct formed through evolutionary processes, scholars have also explored its neural mechanisms. Results show that compared to adult faces, infant faces produce stronger activation in specific brain regions, including the fusiform face area associated with face recognition and processing, the dopaminergic reward system closely related to reward-

ing stimuli such as the nucleus accumbens, and the prefrontal cortex associated with social cognition and emotional responses (Glocker et al., 2009b; Strathearn, Li, Fonagy, & Montague, 2008). Based on existing research findings, scholars currently agree that the infant facial schema effect has specific neurobiological underpinnings (Parsons et al., 2010). Moreover, recent researchers have begun to propose and construct hypotheses about the human parental brain and have conducted validation studies from various perspectives (Feldman, 2015; Swain, 2011).

## 1.2 Research Significance

As a species with an exceptionally long infancy period, humans require good parent-child relationships for offspring survival and development. The baby schema effect is a special psychological mechanism that evolved to promote the formation of good parent-child relationships. Research on this topic has important theoretical and practical significance.

From a theoretical perspective, studying the infant facial schema effect and its influencing factors can deepen our understanding of the mechanisms underlying early parent-child relationship formation and advance research in social cognitive neuroscience. Existing research shows that the infant facial schema effect is influenced by numerous factors, and its magnitude directly affects adults' emotional and behavioral responses to infants (Kringelbach et al., 2016). Therefore, renowned parental brain researcher Swain has repeatedly pointed out that to understand the formation mechanisms of early parent-child relationships, systematic research is needed on factors influencing the baby schema effect (Swain, 2011; Swain et al., 2014). Additionally, because the baby schema effect facilitates offspring reproduction and survival, it exists cross-culturally and even cross-species. In humans, research has found that the baby schema effect actually involves a series of brain network structures including the empathy network, mirror neuron system, and mentalizing network (Feldman, 2015; Kringelbach et al., 2016). Therefore, studying the neural mechanisms of the infant facial schema effect and its influencing factors can promote the development of social cognitive neuroscience.

From a practical perspective, research on the infant facial schema effect and its influencing factors can provide new treatment and preventive measures for parents who have difficulty forming early parent-child relationships and improve their parenting quality. Good parent-child relationships are extremely important for the healthy growth of infants and young children. However, many people in real life cannot establish good parent-child relationships. For instance, special populations such as postpartum depression patients (with an incidence rate of 13.1-16.3% among Chinese mothers) and drug addicts often show insufficient positive responses to infants and may even commit acts of infant abuse or infanticide. Effective treatment and intervention for these patients would benefit the healthy development of their children. Currently, based on research findings and paradigms on the baby schema effect and its influencing factors,

foreign researchers have developed new cognitive-behavioral intervention strategies such as the “baby-social-reward-task” (Bhandari et al., 2014; Parsons et al., 2014a) and sensitivity training for sad infants (Parsons et al., 2014b; Young, Parsons, Stein, & Kringelbach, 2012), which have achieved good results. Therefore, conducting related research in China will also help develop new treatment and preventive measures to improve parenting quality in these populations.

## 2.1 The Infant Facial Schema Effect and Its Neural Mechanism

When Lorenz proposed the concept of baby schema, he defined it as common features in the appearance of human infants and animal young that particularly evoke positive responses from adult individuals and facilitate offspring survival. In humans, the baby schema is mainly manifested as a round face, a disproportionately large head relative to the body, and short, thick limbs (Lorenz, 1943). Since this concept was proposed, researchers have systematically studied which bodily features might constitute the baby schema and found that these features are concentrated in the facial region (Alley, 1981; Glocker et al., 2009a). Consequently, subsequent research on the baby schema has mostly focused on the infant facial schema effect.

Based on existing research on the infant facial schema effect, infant faces can evoke numerous responses in adults, such as enhanced attention and caregiving behavior, positive emotion induction, reduced aggression, increased prosocial behavior, and influences on fine motor responses (Charles et al., 2013; Cheng et al., 2015; Kringelbach et al., 2016; Nittono et al., 2012). However, the most typical manifestations of the infant facial schema effect are the following responses:

First, adults show clear preferences for infant faces, which evoke positive emotions and approach behavior. Numerous studies have found that the infant facial schema, as an innate releasing mechanism, universally evokes cuteness perception in adults (Glocker et al., 2009a; Glocker et al., 2009b; Luo, Luo, Ju, Ma, & Li, 2011). Adults also rate infants with more pronounced baby schema features as more friendly, healthy, and competitive (Ritter, Casey, & Langlois, 1991) and express stronger willingness to adopt and care for them (Volk & Quinsey, 2002). Moreover, in recent motivational behavior measurement paradigms, when infant and adult faces are presented together, adults show stronger viewing motivation and longer viewing times for infant faces (Charles et al., 2013; Cheng et al., 2015; Ding, Zhang, & Cheng, 2016; Parsons, Young, Kumari, Stein, & Kringelbach, 2011). These findings consistently indicate that infant faces serve as rewarding stimuli that effectively evoke positive emotions and approach behavior in adults, which plays an important role in promoting the establishment of early parent-child relationships.

Second, adults exhibit significant attentional bias toward infant faces. Since infant survival is closely related to human reproduction, researchers believe that after evolutionary selection, human cognitive processing systems tend to priori-

tize stimuli related to infants. Accordingly, Brosch, Sander, and Scherer (2007) first discovered adult attentional bias toward infant faces using a dot-probe paradigm. Subsequently, Brosch et al. (2008) further explored this phenomenon using ERP technology and found that infant faces and angry adult faces evoked the same P1 component, which was primarily located in the striate and extrastriate visual cortex, suggesting that adult attentional bias toward infant faces also has a corresponding neurobiological basis. Later researchers used eye-tracking technology to further confirm the existence of attentional bias toward infant faces (Cárdenas, Harris, & Becker, 2013; Charles et al., 2013; Jia et al., 2017). Additionally, researchers have found that this bias has cross-cultural consistency (Hodsoll, Quinn, & Hodsoll, 2010; Shi & Luo, 2016).

Since its discovery, attentional bias toward infant faces has received widespread attention from scholars. The reasons are twofold: First, it powerfully demonstrates that the infant facial schema effect is an innate releasing mechanism in humans that occupies a priority position in the cognitive processing system, similar to threatening stimuli. Studying it can expand our understanding of human attentional processing systems (Kringelbach et al., 2016). Second, researchers have found that the absence of attentional bias toward infant faces may affect parent-child relationship formation. For example, postpartum depressed women have been found to differ from normal women in their attentional bias toward infant faces (Pearson, Cooper, Pentonvoak, Lightman, & Evans, 2010). Research in this area can provide new treatment and preventive measures for parents who have difficulty forming early parent-child relationships and improve their parenting quality.

Finally, adult preferences for infant faces produce a generalization effect. As a social instinct formed through evolutionary processes, the infant facial schema effect is not limited to responses to infants themselves but also generalizes to adults, other species, and non-living objects, producing the so-called “babyface effect” (Dou et al., 2014). As a biased cognition of facial feature information, the babyface effect causes people to produce similar responses when facing adults with infant facial features as when facing infants, such as positive emotions, protection and caregiving, and reduced aggression (Berry & McArthur, 1985; Kringelbach et al., 2016). Even when inferring the personality traits of these adults, people perceive them as innocent, kind, and trustworthy like infants (Maoz, 2012; Zebrowitz & Montepare, 2008). Moreover, researchers have found that people’s affection for small animals and cartoon characters (such as Mickey Mouse) is also due to the babyface effect (Gould, 1979).

Given the important role of the infant facial schema effect in human evolution, researchers have conducted numerous studies on its neural mechanisms in recent years. Current findings show that infant faces have widespread activating effects on the human brain, involving both cortical and/or paralimbic networks such as the mirror neuron system, empathy system, mentalizing system, and emotion regulation network, as well as subcortical networks such as arousal and alertness systems and motivation and reward circuits (Feldman, 2015; Kringelbach et al.,

2016; Swain, 2011). Specifically, infant faces first activate primary visual regions such as the fusiform face area. However, infant faces additionally activate other brain regions such as the orbitofrontal cortex (Noriuchi, Kikuchi, & Senoo, 2008). Furthermore, the nucleus accumbens, prefrontal cortex, substantia nigra, insula, cingulate cortex, cingulated gyrus, and striatum also show significant activation (Glocker et al., 2009b; Strathearn, Fonagy, Amico, & Montague, 2009). Although these studies have used different methods and their results are not yet sufficient to fully elucidate the activation patterns of these brain regions (Parsons et al., 2010), it is currently certain that the infant facial schema effect, as a product of long-term human evolution, has specific neurobiological underpinnings.

## 2.2 The Influence of Facial Structure on the Infant Facial Schema Effect

Since the concept of baby schema was proposed, researchers first focused on how the baby schema effect changes with physical appearance features. Initially, researchers used phrenological measurement methods to measure infants' physical characteristics and found that faces with eyes positioned at the midline of the face vertically (Brooks & Hochberg, 1960), large pupils, short and narrow noses and mouths (Hildebrandt & Fitzgerald, 1979), large and prominent foreheads (Alley, 1981), and large eyes with small chins (Berry & McArthur, 1985) evoked more pronounced baby schema effects. Based on these studies, it is evident that the physical features constituting the baby schema are concentrated in the facial region, so subsequent research on the baby schema has mostly focused on infant facial features.

Later, with advances in computer graphics processing technology, some researchers began using image processing software to more deeply explore the relationship between facial structure and the infant facial schema effect by fine-tuning infant facial structures. For example, in Glocker et al.'s (2009a) study, after adjusting real infant faces, they found that people had stronger caregiving intentions toward infants with rounder faces and higher foreheads, which better conform to the characteristics of baby schema composition. In Bressan, Bertamini, Nalli, and Zanutto's (2009) study, they used face morphing technology to blend infant and adult facial features and examined the attractiveness and adoption willingness for faces with different blending ratios, finding that adults preferred faces with higher proportions of infant features.

Additionally, some researchers have examined the influence of natural variations in infant facial structure on the baby schema effect. Among these, cleft lip has been studied more frequently due to its relatively high incidence in newborns. Results show that although cleft lip does not significantly alter infant facial structure, it noticeably reduces maternal caregiving responses and interferes with parent-infant interaction (Murray et al., 2008). Meanwhile, childless adults rate cleft lip infant faces as less cute, and their orbitofrontal cortex responses disappear when viewing cleft lip infant faces compared to normal infant faces

(Parsons et al., 2011; Parsons et al., 2013). Furthermore, Chinese researchers Luo, Li, and Lee (2011) examined the influence of infant age on the baby schema effect and found that as infants grow older, the baby schema effect weakens, with baby schema features and their effects disappearing around four and a half years old.

Based on the above research findings, we can conclude: First, the baby schema is mainly manifested in infant faces. Second, adults are very sensitive to infant facial schemas, and even subtle changes in facial structure can directly and significantly affect the infant facial schema effect. Finally, the infant facial schema effect may influence the formation of early parent-child relationships.

### **2.3 The Influence of Facial Expression on the Infant Facial Schema Effect**

In recent years, as research on the infant facial schema effect has deepened, some researchers have argued that focusing solely on the influence of facial structure is insufficient (Sparko & Zebrowitz, 2011). In interpersonal communication, especially during early parent-infant interactions, adults often judge infants' needs through their facial expressions (Ekman & Fridlund, 1987; Fridlund, 1997). However, most research on the infant facial schema effect has used only neutral infant face pictures as stimuli (Charles et al., 2013; Cheng et al., 2015; Parsons et al., 2011), which greatly limits the ecological validity of such studies.

In fact, Sparko and Zebrowitz (2011) found in their research on the adult babyface effect that facial expression type and movement can moderate the babyface effect, with neutral static faces showing a stronger babyface effect, making them appear warmer and less dominant. Additionally, studies have found that when adults evaluate infant faces, they perceive smiling or neutral infant faces as cuter than sad infant faces and express stronger adoption intentions (Aradhya, Vonk, & Arida, 2015). Neuroimaging studies have also found that compared to neutral faces, infant smiling faces activate reward-related brain regions more strongly, including the ventral striatum, caudate nucleus, ventromedial prefrontal cortex, and orbitofrontal cortex. In contrast, sad infant faces primarily activate regions related to empathy processing, specifically the precuneus, cuneus, and posterior cingulate cortex (Montoya et al., 2012). Beyond comparing different infant facial expressions, researchers have used ERP technology to examine differences in responses to infant and adult faces with different expressions in women who have given birth. They found that the stronger the emotional intensity of infant faces, the stronger the N1 component, representing faster emotional perception. Additionally, negative infant facial expressions further evoked stronger early posterior negativity (EPN) waveforms, while these phenomena were not observed when viewing adult facial expression pictures (Peltola et al., 2014). Furthermore, researchers using near-infrared spectroscopy found that when discriminating infant facial expressions, oxygenated hemoglobin content in the right prefrontal cortex of women who have given birth increased, while this phenomenon did not occur when distinguishing adult facial expressions (Nishitani, Doi, Koyama, &

Shinohara, 2011).

Based on the above research findings, it is clear that adults' responses to infant faces differ depending on expression type. However, these studies still face an urgent problem: humans inherently respond differently to adult faces with different expressions (Fridlund, 1997; Zebrowitz & Montepare, 2008). So does the differential response to infant faces with different expressions represent a continuation of the general human response to facial expressions, or does it have its own particularity? This has become a question worth exploring. To address this issue, our team has conducted a series of preliminary studies in recent years and achieved some initial results.

First, to examine the influence of expression on the infant facial schema effect, our team developed the Chinese Infant Affective Face Picture System (CIAFPS), which contains 317 pictures, including 117 happy, 92 neutral, and 108 sad faces. The system's pictures were taken from frontal face photos of 211 normal infants aged 3-6 months and have good representativeness of infant facial features in this age range (Cheng, Zhang, Guan, & Chen, 2015).

Subsequently, our team used the CIAFPS and the Chinese Affective Face Picture System (CAFPS) (Gong, Huang, Wang, & Luo, 2011) as experimental materials to examine whether infant facial expressions affect adults' emotional responses and viewing motivation toward the infant facial schema (Ding et al., 2016) and adults' attentional bias toward the infant facial schema (Jia et al., 2017). In both studies, we used participants' responses to adult faces as a baseline to calculate a purified infant facial schema effect size (infant facial schema effect size = response value to infant faces - response value to adult faces), and then examined the influence of expression on the infant facial schema effect size.

Finally, the results showed that in emotional and motivational behavior tests, both infant and adult faces with happy or sad expressions differed significantly from neutral faces in emotional arousal and viewing motivation. However, in terms of infant facial schema effect size, the effect size for neutral faces was significantly greater than for the other two expressions (Ding et al., 2016). Meanwhile, in attentional bias toward the infant facial schema, we also found through eye-tracking technology that participants' attentional bias values toward infant faces under neutral face conditions were significantly higher than for the other two expressions (Jia et al., 2017).

Based on the results of these two studies, combined with Sparko and Zebrowitz's (2011) previous finding that the adult babyface effect is more pronounced under neutral face conditions, our team proposed the phenomenon that the infant facial schema effect is strongest under neutral face conditions. Additionally, our team used fMRI technology to conduct a preliminary exploration of the neural mechanisms underlying the influence of expression on the infant facial schema effect. The results showed that regardless of expression type, infant faces produced significantly stronger activation in bilateral fusiform gyrus and right lingual gyrus than adult faces. Beyond these two common brain regions, specific

to different expressions, sad infant faces showed significantly stronger activation than sad adult faces in the precentral gyrus, postcentral gyrus, posterior cingulate gyrus of the thalamus, and precuneus. Happy infant faces, compared to adult faces, widely activated regions related to emotion and reward processing. When comparing neutral infant faces to neutral adult faces, activation in bilateral fusiform gyrus was significantly increased, and the activation increment in left fusiform gyrus for infant faces compared to adult faces under neutral conditions was significantly higher than for the other two expressions (Li et al., 2016). Based on these results, combined with current researchers' findings that the fusiform gyrus is a specialized face-processing region in visual cortex, where the right fusiform gyrus is mainly responsible for human face category perception while the left fusiform gyrus is related to perception of fine facial features (Sun & Zhang, 2016), we further proposed the hypothesis that the expression uncertainty of neutral faces is an important reason for the strongest infant facial schema effect under neutral conditions.

## 2.4 Existing Research Gaps and Future Directions

Given the crucial role of the infant facial schema effect in early parent-child relationship formation, it has attracted attention from numerous domestic and international researchers in recent years, yielding many valuable research findings (Feldman, 2015; Kringelbach et al., 2016; Parsons et al., 2010; Swain, 2011; Dou et al., 2014; Luo et al., 2011). However, as research has deepened, several urgent problems have emerged.

First, most current studies on the infant facial schema effect have used only neutral infant face pictures as research materials (Brosch et al., 2007; Charles et al., 2013; Glocker et al., 2009b; Kringelbach et al., 2016; Parsons et al., 2011; Shi & Luo, 2016), which greatly limits the external validity of such research. In fact, when adults interact with infants, they often judge their physical and mental states through infants' expressions. Therefore, it is necessary to examine the influence of facial expression in studies of the infant facial schema effect. Based on Sparko and Zebrowitz's (2011) research on the babyface effect and our team's preliminary research results (Ding et al., 2016; Jia et al., 2017; Li et al., 2016), expression significantly influences the infant facial schema effect. Therefore, further exploration of the role and mechanisms of expression is necessary in infant facial schema effect research.

Second, the phenomenon that the neutral infant facial schema effect is the strongest needs to be re-verified under conditions where facial structure is strictly controlled. Based on Sparko and Zebrowitz (2011) and our team's research findings (Ding et al., 2016; Jia et al., 2017), the infant facial schema effect appears strongest under neutral face conditions. However, in our team's previous studies, both the Chinese Infant Affective Face Picture System (CIAFPS) and the Chinese Affective Face Picture System (CAFPS) lack multiple expression pictures of the same face. Although using multiple face pictures under three expression conditions can balance the influence of facial

structure to some extent, such designs cannot ensure that facial structures across the three expression picture groups are completely identical. According to the aforementioned research findings on how facial structure influences the infant facial schema effect, even minor facial structure changes can significantly affect the infant facial schema effect (Bressan et al., 2009; Glocker et al., 2009b; Kringelbach et al., 2016). Therefore, to exclude potential interference from facial structure, it is necessary to develop a multi-expression picture system with identical faces to re-verify the phenomenon that the neutral infant facial schema effect is the strongest.

Finally, the mechanisms and reasons underlying the phenomenon that the neutral infant facial schema effect is the strongest are currently unclear. The hypothesis proposed by our team that “the expression uncertainty of neutral faces is an important reason for the strongest infant facial schema effect” (Ding et al., 2016; Jia et al., 2017) still requires experimental verification.

### 3.1 Research Plan

The purpose of this project is first to verify whether the phenomenon of “the neutral infant facial schema effect is the strongest” discovered by our team is stable, and second to test whether the hypothesis that “the expression uncertainty of neutral faces is an important reason for the strongest infant facial schema effect” holds true (Ding et al., 2016; Jia et al., 2017). Based on this research purpose and previous findings that the infant facial schema effect is mainly manifested as adults’ preference and attentional bias toward infant faces (Charles et al., 2013; Luo et al., 2011) and that infant facial structure directly affects the infant facial schema effect (Bressan et al., 2009; Glocker et al., 2009a; Kringelbach et al., 2016), this project plans to conduct research in the following three aspects: (1) Establish a standardized multi-expression picture system for infant and adult faces with identical identities, and based on this, verify the phenomenon that the neutral infant facial schema effect is the strongest under conditions where facial structural features are strictly controlled; (2) Use motivational behavior measurement paradigms to examine whether the degree of facial expression uncertainty can predict adults’ enhanced preference for neutral infant faces and use fMRI technology to explore the corresponding neurophysiological mechanisms; (3) Use eye-tracking technology and dot-probe paradigms to jointly examine whether the degree of facial expression uncertainty can predict adults’ enhanced attentional bias toward neutral infant faces and use ERP technology to explore the corresponding neurophysiological mechanisms.

**Study 1:** Development and validation of a standardized multi-expression picture system for infant and adult faces with identical identities

**Study 2:** The influence of facial expression uncertainty on adults’ preferences for infant faces with different expressions and its neural mechanisms

**Study 3:** The influence of facial expression uncertainty on adults’ attentional bias toward infant faces with different expressions and its neural mechanisms

Specifically, this project will systematically investigate the phenomenon and mechanisms of the strongest neutral infant facial schema effect through 3 studies comprising 7 experiments.

[Figure 1: see original paper] Schematic diagram of research content

### **3.1.1 Study 1: Development and Validation of a Standardized Multi-Expression Picture System for Infant and Adult Faces with Identical Identities**

To examine the influence of expression on the infant facial schema effect, the interference of facial structure must first be strictly controlled. Only under conditions where facial structure remains consistent can the role of expression be accurately isolated. However, currently used picture systems in domestic research, including the Chinese Affective Face Picture System (CAFPS) (Gong et al., 2011) and the Chinese Infant Affective Face Picture System (CIAFPS) (Cheng et al., 2015), both lack multiple expression pictures of the same face and therefore cannot meet the needs of this study. Therefore, the goal of Study 1 is to first develop a high-quality standardized multi-expression picture system for infant and adult faces with identical identities to serve as experimental materials for subsequent research. This picture system can also become a useful supplement to the CIAFPS and CAFPS and be widely used in parental brain or other related research.

Given that there are certain differences in acquisition methods and evaluation indicators between infant and adult facial expression pictures, the establishment of the multi-expression picture system for infant and adult faces with identical identities needs to be divided into two experiments.

**Experiment 1** primarily follows the development process of the Chinese Infant Affective Face Picture System (CIAFPS) (Cheng et al., 2015) and is conducted in three phases. Phase 1 involves collaborating with professional photography agencies to collect spontaneous happy, sad, and neutral facial photos of 100 infants aged 3–6 months (half male and half female), with each infant having at least one photo for each expression. Subsequently, batch processing standardizes the brightness, contrast, and size of the collected pictures. Phase 2 involves evaluating the emotional intensity, recognition rate, and cuteness of the processed facial expression pictures, eliminating pictures with recognition rates below 60% to form the formal picture database. Phase 3 uses three indicators—pleasure, arousal, and dominance—to evaluate the emotional activation effect of the formal picture database, ultimately forming a standardized multi-expression picture system for infants with six indicators.

**Experiment 2** primarily follows the Chinese Affective Face Picture System (CAFPS) (Gong et al., 2011) and O’ Toole et al.’ s (2005) dynamic expression creation methods. Phase 1 recruits 100 adults aged 18 and above with acting abilities (half male and half female) as facial expression performers. Under the priming of emotional videos and following infant face photography techni-

cal standards, their happy, sad, and neutral facial photos are collected, with at least one photo for each expression. The same standards used for the infant face database are then applied to batch process the brightness, contrast, and size of the collected pictures. Phase 2 involves evaluating the emotional intensity, recognition rate, and attractiveness of the processed facial expression pictures, eliminating pictures with recognition rates below 60% to form the formal picture database. Phase 3 uses pleasure, arousal, and dominance indicators to evaluate the emotional activation effect of the formal picture database, ultimately forming a standardized multi-expression picture system for adults with six indicators.

### **3.1.2 Study 2: The Influence of Facial Expression Uncertainty on Adults' Preferences for Infant Faces with Different Expressions and Its Neural Mechanisms**

Our team's preliminary research found that adults show enhanced preference for neutral infant faces (Ding et al., 2016), and this enhancement may be related to increased activation in the left fusiform gyrus (Li et al., 2016). However, due to material limitations, these studies could not strictly control facial structure, meaning that the phenomenon of "adults' strongest preference for neutral infant faces" and the hypothesis that "expression uncertainty of neutral faces is an important reason for the strongest neutral infant face preference effect" require further verification. Therefore, Study 2 will use the standardized multi-expression picture system for infant and adult faces with identical identities developed in Study 1 to test the above findings and hypotheses. Specifically, the research content of this part is as follows:

**Experiment 3** First, 180 face pictures will be selected from the standardized multi-expression picture system for infant and adult faces with identical identities developed in Study 1. These 180 pictures come from 30 infants and 30 adults, with each identity having one happy, one sad, and one neutral expression, with half being male infants and male adults and half being female infants and female adults. When selecting the face photos, infant and adult face photos will be extracted from high to low recognition rates, with recognition rates matched during extraction to ensure no significant differences between the two groups. Additionally, expression intensity of the two groups of photos should be matched to ensure no significant differences. Subsequently, these 180 photos will be used as experimental materials to modify the motivational behavior test procedure previously used by our team (Cheng et al., 2015; Ding et al., 2016), adding an evaluation index for expression uncertainty degree. This motivational behavior test paradigm has been used and validated in numerous experiments and has good reliability and validity (Charles et al., 2013; Parsons et al., 2011). Through this experimental procedure, participants' evaluation of expression uncertainty degree and liking degree, anticipatory craving, and consummatory craving for infant faces can be tested separately. Finally, multilevel linear modeling will be used to process the experimental results to verify again whether the phe-

nomenon of adults' strongest preference for neutral infant faces exists and to test whether participants' uncertainty about infant facial expressions can predict the infant facial schema effect size under neutral face conditions.

**Experiment 4** The 180 face pictures selected in Experiment 3 will be used as experimental materials, and the research protocol used in our team' s previous fMRI study (Li et al., 2016) will be referenced, with participants' evaluation of expression uncertainty degree for test faces added under conditions where faces are strictly identical. The specific experiment consists of two rounds. In the first round, participants are required to carefully watch infant and adult face pictures, judge the facial expressions, rate their uncertainty about the expression judgment on a 9-point scale, and finally rate their liking of the face pictures on a 9-point scale. Each picture is presented for 2 seconds, with inter-picture intervals randomly being 2, 4, or 6 seconds, and pictures are presented in random order. The second round' s procedure is basically the same as the first round. Participants first lie still for structural image data collection, after which the program runs, but each picture appears twice. Throughout the process, the head and body must remain still. Before the fMRI experiment begins, participants practice to master the experimental procedure. To control for practice effects, the experiment uses a counterbalanced design. The collected fMRI data will be statistically analyzed using the SPM8 software system. On the one hand, our team' s previous research results (Li et al., 2016) will be retested; on the other hand, we will further examine whether participants' uncertainty about infant facial expressions can predict the specific enhanced activation in the left fusiform gyrus under neutral face conditions.

### **3.1.3 Study 3: The Influence of Facial Expression Uncertainty on Adults' Attentional Bias Toward Infant Faces with Different Expressions and Its Neural Mechanisms**

In addition to preference responses to infant faces, another important manifestation of the infant facial schema effect is adults' significant attentional bias toward infant faces. Regarding this attentional bias, our team preliminarily examined in previous research whether facial expression type influences it using eye-tracking technology and found that adults' attentional bias toward infant faces is greatest under neutral face conditions (Jia et al., 2017). However, due to the same limitation of research materials, facial structure could not be strictly controlled, so this research conclusion also requires further verification.

To thoroughly verify whether the phenomenon of "the strongest neutral infant facial schema effect" exists and whether the hypothesis that "expression uncertainty of neutral faces is an important reason for the strongest neutral infant facial schema effect" holds true, Study 3 will conduct corresponding research on adults' attentional bias toward infant faces. Specifically: First, we will replicate our team' s previous eye-tracking study and examine the role of facial expression uncertainty; second, we will use the dot-probe paradigm to cross-validate the results obtained through eye-tracking studies, thereby examining whether the

effect size of adults' attentional bias toward infant faces discovered by Brosch et al. (2007) is also the largest under neutral face conditions and whether this effect can also be predicted by infant facial expression uncertainty; finally, we will use ERP technology to examine whether the P1 component evoked by infant faces discovered by Brosch et al. (2008) differs across facial expressions and whether this component is influenced by infant facial expression uncertainty.

This part of the research specifically includes the following three experiments:

**Experiment 5** The 180 face pictures selected in Experiment 3 will be used as experimental materials. Under conditions where faces are strictly identical, the eye-tracking test procedure for infant face attentional bias previously used by our team (Jia et al., 2017) will be adopted, with evaluation of expression uncertainty degree added, to retest whether the effect of strongest attentional bias under neutral infant face conditions is stable. The experiment consists of two parts: The first part is expression uncertainty evaluation, with the specific procedure being the same as the first round in Experiment 4. The second part uses the eye-tracking test procedure for infant face attentional bias (Jia et al., 2017), in which infant and adult faces are paired vertically and presented for 6000 milliseconds, after which participants are allowed to watch freely while their eye movement trajectories are recorded. To control for practice effects, these two parts use a counterbalanced design. In this study, three eye-tracking indicators representing attentional bias are mainly examined: the location of the first fixation, total fixation duration on the same face within the area of interest, and total number of fixations on the same face within the area of interest. For the experimental results, random intercept multilevel linear regression will be used to test the contribution of facial expression uncertainty in predicting adults' attentional bias toward infant faces.

**Experiment 6** Like Experiment 5, this experiment also consists of two parts. The first part is compiled with reference to the dot-probe paradigm used by Brosch et al. (2007) and Shi and Luo (2016). The stimulus materials used in the program are consistent with Experiment 3, using 90 groups of face pictures, with 30 groups each for happy, sad, and neutral faces. The 30 groups of pictures are paired by 30 infant and adult faces according to expression type and emotional intensity. The entire experiment includes 4 modules, with the first module being a practice module containing 12 trials. The subsequent 3 modules are distinguished by expression, with each module containing 150 trials. The 3 formal test modules use a counterbalanced design across participants. The second part is expression uncertainty degree evaluation, with the specific procedure being the same as the first round in Experiment 4. The two parts of the experiment also use a counterbalanced design. For dot-probe data processing, consistent with Brosch et al.'s (2007) study, discrimination  $d'$  is used as the attentional bias effect value for infant faces. Random intercept multilevel linear regression is then used to test the moderating effect of expression on attentional bias and examine the unique contribution of facial expression uncertainty in predicting adults' attentional bias toward infant faces.

**Experiment 7** Based on Brosch et al.' s (2008) experimental method, ERP technology is combined with the dot-probe paradigm from Experiment 6 to examine the neural mechanisms underlying adults' enhanced attentional bias toward neutral infant faces. Expression uncertainty degree evaluation is also conducted, with the specific test procedure consistent with Experiment 6. For EEG data processing, following Brosch et al.' s (2008) processing standards, we focus on examining whether the P1 component (120-170 ms) in the striate and extrastriate visual cortex differs significantly across different facial expression conditions. Additionally, random intercept multilevel linear regression is used to test whether facial expression uncertainty can predict the P1 component in the striate and extrastriate visual cortex.

### 3.2 Research Objectives

**Study 1:** Develop a high-quality standardized multi-expression picture system for infant and adult faces with identical identities to provide experimental materials for subsequent research in this project. This picture system can also serve as a useful supplement to the Chinese Affective Face Picture System (CAFPS) (Gong et al., 2011) and the Chinese Infant Affective Face Picture System (CIAFPS) (Cheng et al., 2015), becoming a reliable tool for parental brain or other domain research.

**Study 2:** Using the picture system developed in Study 1 and under conditions where facial structure is controlled, first verify whether the phenomenon of adults' strongest preference for infant faces under neutral expression conditions still exists, and simultaneously examine the relationship between neutral facial expression uncertainty and adults' enhanced preference for neutral infant faces and its neural mechanisms.

**Study 3:** Using the picture system developed in Study 1 and under conditions where facial structure is controlled, use dot-probe paradigm, eye-tracking, and ERP technology to first test whether the phenomenon of adults' strongest attentional bias toward infant faces under neutral expression conditions still exists, and simultaneously examine the relationship between neutral facial expression uncertainty and adults' enhanced attentional bias toward neutral infant faces and its neural mechanisms.

### 3.3 Key Scientific Questions

Based on the current status of infant facial schema effect research, this project aims to address the following three key scientific questions:

First, address the deficiency that both the Chinese Infant Affective Face Picture System (CIAFPS) and the Chinese Affective Face Picture System (CAFPS) lack multiple expression pictures of the same face, providing essential research materials for further expanding research on the influence of expression on the infant facial schema effect and for parental brain and other domain research.

Second, after strictly controlling facial structure, test whether the phenomenon of the strongest neutral infant facial schema effect still exists, thereby enhancing understanding of the infant facial schema effect.

Finally, verify whether the hypothesis that “expression uncertainty of neutral faces is an important reason for the strongest neutral infant facial schema effect” holds true, and reveal the corresponding neurophysiological mechanisms using fMRI and ERP technologies.

#### 4 Theoretical Construction and Innovation

As an innate releasing mechanism formed through evolutionary processes, the infant facial schema effect has important influences on human caregiving behavior and parent-child relationship formation (Kringelbach et al., 2016; Parsons et al., 2010). Therefore, researchers have been striving to identify factors that influence the manifestation of the infant facial schema effect, while research on its corresponding neural mechanisms is considered an important component of human parental brain research (Swain, 2011; Swain et al., 2014). Regarding this issue, existing research has found that facial structure significantly influences the infant facial schema effect (Bressan et al., 2009; Glocker et al., 2009a; Kringelbach et al., 2016), and other studies have found that facial expression also affects adults’ responses to infant faces (Aradhye et al., 2015; Montoya et al., 2012; Peltola et al., 2014).

Given that adults’ responses to infant faces differ by expression type, our team previously discovered, using adult faces as a baseline, that adults show enhanced preference (Ding et al., 2016) and attentional bias (Jia et al., 2017) for neutral infant faces. Regarding this phenomenon, we believe that when humans face neutral infant faces, to avoid missing important signals from infants, they allocate more cognitive processing resources to identify the infant’ s current state, thus showing the strongest neutral infant facial schema effect. However, since facial structure interference could not be controlled in previous studies, whether the phenomenon of the strongest neutral infant facial schema effect holds true remains to be further verified. Moreover, the hypothesis we proposed based on brain imaging research—that expression uncertainty of neutral faces is an important reason for the strongest neutral infant facial schema effect—has not yet been experimentally validated.

To address these two issues, we specifically designed this research project. Through its implementation, we hope to achieve the following advances in infant facial schema effect research:

First, this study will develop a high-quality standardized multi-expression picture system for infant and adult faces with identical identities. The establishment of this system can compensate for the insufficient number of multiple expression pictures of the same face in the Chinese Affective Face Picture System (CAFPS) (Gong et al., 2011) and the Chinese Infant Affective Face Picture System (CIAFPS) (Cheng et al., 2015). Solving this problem can compensate

for the defect in previous research that could not purify the unique influence of expression on the infant facial schema effect due to inability to strictly match facial structures. This means that future research on the infant facial schema effect can simultaneously and comprehensively examine the roles of facial structure and expression, rather than examining only single aspects as before.

Second, through behavioral experiments in Studies 2 and 3, we can first demonstrate whether the phenomenon of the strongest neutral infant facial schema effect still holds under conditions where facial structure is controlled, and also test whether expression uncertainty of neutral faces is the cause of this phenomenon. Verifying these two hypotheses can, on the one hand, help support the explanations currently made by researchers from an evolutionary psychology perspective for the infant facial schema effect (Brosch et al., 2007; Kringelbach et al., 2016)—that human information processing resources are limited, and after evolutionary selection, human information processing systems prioritize resource allocation to things closely related to survival and reproduction, with preference and attentional bias toward infant faces being important manifestations of this resource allocation strategy. On the other hand, our results can also help reveal how expression influences the infant facial schema effect. As is well known, facial expression is an important means for humans to transmit information. Different types of facial expressions have different levels of clarity and importance. Typically, expressions like happiness or sadness have clearer and more understandable signal content, while neutral faces often have ambiguous and difficult-to-judge signal content (Fridlund, 1997; Zebrowitz & Montepare, 2008). The demonstration of the strongest neutral infant facial schema effect can, to some extent, indicate that adults are highly sensitive to infants' emotional states, which is beneficial for human reproduction and survival. In-depth research on this phenomenon and its influencing factors will help deepen our understanding of human caregiving behavior and the formation mechanisms of early parent-child relationships.

Finally, in Studies 2 and 3, we will also conduct corresponding brain mechanism research on the enhanced preference and attentional bias for neutral infant faces. In recent years, with advances in cognitive neuroscience and brain imaging technology, researchers have gained preliminary understanding of the cognitive neural mechanisms underlying parent-child relationship formation (Parsons et al., 2010). Some researchers have proposed and constructed working models of the human parental brain system (Feldman, 2015; Swain, 2011). Among these, preference and attentional bias toward infant faces are considered important manifestations of the functioning of the parent-infant orienting system. The parent-infant orienting system refers to the tendency for parents and infants to immediately attract each other and seek communication from birth, on the basis of which parent-infant interaction occurs and close relationships are established. It is considered the starting point for parent-child relationship formation (Parsons et al., 2010). In Swain's (2011) parental brain model, it mainly involves brain regions such as the striatum, ventral tegmental area, amygdala, orbitofrontal cortex, cingulate, and insula. Parental brain research is currently

in an emerging stage. Research on the influence of facial structure and expression on the infant facial schema effect and its neural mechanisms can help deepen understanding of the parent-infant orienting system and ultimately help expand knowledge of the human parental brain.

In summary, this project will use a combination of multiple research techniques and methods to explore the influence of expression on the infant facial schema effect and its neural mechanisms under conditions where facial structure is strictly controlled. This research can, on the one hand, deepen understanding of the infant facial schema effect, and on the other hand, expand our knowledge and development of the human parental brain, thereby providing suggestions for improving parenting quality and promoting the formation of good early parent-child relationships.

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