



OPEN Development and validation of the Korean Child Emotional Face Database for research in developmental neuroscience

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Facial recognition plays a crucial role in identifying emotional states and understanding human responses. Research indicates that emotional processing varies based on factors such as race and age, underscoring the importance of diverse face databases. We developed the Korean Child Emotional Face Database (KCEFD), comprising facial stimuli representing seven emotions—happiness, surprise, neutral, fear, anger, disgust, and sadness—and validated it in both children and adults. The validation process involved gathering accuracy, clarity, and valence scores. Overall emotion recognition accuracy was 70%; however, while happiness (95%) and surprise (94%) showed high accuracy, fear was recognized at only 18%, which is near chance level. Happiness was rated as the most positive emotion, while anger was perceived as the most negative. Clarity scores were consistently high. To assess the effectiveness of the KCEFD as emotional stimuli, we conducted a face-in-the-crowd task using happiness, surprise, anger, and sadness expressions. By analyzing both behavioral responses and eye movements in children and adults, we confirmed the previously established anger superiority effect. The KCEFD is the first validated emotional face database specifically for Korean children, making it a valuable resource for research on children's emotional processing.

Keywords Basic emotion, Child face, Facial recognition, Face in the crowd, Eye movement

The recognition of facial expressions holds significant importance in both social and biological contexts¹. Facial expressions are the most effective and powerful nonverbal communication signals of human emotion, sometimes conveying an individual's feelings and intentions more accurately than verbal communication. Recognizing facial expressions is essential for navigating social interactions and plays a central role in emotional understanding, empathy, and interpersonal relationships².

Over the past few decades, facial expressions have been utilized in behavioral and neuroscientific studies to investigate emotional processing, including emotional recognition and regulation^{3–5}; emotional and cognitive information processing across attention, memory, learning, reasoning, and decision making^{6–9}; and comparing emotional processing to facial expressions in individuals with psychiatric disorders^{3,10–14}.

To investigate emotional processing with facial expression, many researchers have developed and validated facial expression databases, which often contain photo stimuli of faces depicting the six basic emotions (happiness, surprise, fear, anger, disgust, and sadness) and neutral expressions that Paul Ekman proposed to be universal and innately recognizable across cultures¹⁵. These facial expressions are mainly based on emotional definitions and combinations of facial muscle movements (known as action units, AU) provided by the Facial Action Coding System (FACS)¹⁶.

Since the development of various facial expression databases, researchers have made significant progress in the field of emotional face processing. However, despite the cultural universality of basic emotions highlighted in Ekman's theory of basic emotions, many subsequent studies have reported that perception and recognition of emotional facial expressions can vary by many factors, including culture, race, gender, age, and other factors^{17–26}.

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For instance, people tend to recognize facial expressions of their own group more quickly and accurately than those of other groups^{18,20}. Regarding cultural differences, Asians were less accurate than Americans in recognizing emotions such as anger, disgust, sadness, and fear, regardless of the model's race^{23,25}. Some studies suggest that while Westerners categorize facial expressions into six distinct groups, Asians tend to have overlapping representations of surprise, fear, anger, and disgust. This implies that a six-category classification may not be suitable for Asians, who instead have three or four categories of latent expression patterns^{21,22}. In addition, differences in the ratings of emotion intensity across cultures have also been observed²⁷. This suggests that the categorical recognition and intensity of emotional facial expressions may be influenced by race or culture.

Similarly, age influences the recognition of emotional facial expressions. The biological and social significance of the face allows us to distinguish between positive and negative facial expressions from the earliest days of life^{28,29}, but despite this, children are still significantly less capable of recognizing emotions than adults, and the differentiation of emotional categories follows a significantly slower developmental process^{30–34}. However, it is important to note that most developmental research on emotional face recognition in children relies heavily on data from adult facial expressions^{30,34–36}. This reliance overlooks the own-age bias, which indicates that children are more accurate at recognizing peers of their own age³⁷. This bias reflects the richer and more recent experiences children have with their own age group³⁸. Consequently, this raises questions about the validity of studies on children's face recognition that rely solely on adult facial stimuli.

Many studies highlight the necessity for relevant face databases tailored to diverse ethnicities and age groups^{35,39–41}. Nevertheless, there is still a considerable lack of facial expression databases for Asian children. Recent efforts have led to the development of facial expression databases of East Asian children⁴². While these databases provide valuable resources, their validation has typically been conducted using only adult raters, with limited or no validation involving child raters. Moreover, databases specifically involving Korean children remain scarce.

In this study, we developed the Korean Child Emotional Face Database (KCEFD), a novel database of Asian children's emotional facial expressions, and assessed its suitability and utility. Notably, we conducted rating and utility assessments of the database with both child and adult participants. In Study 1, we developed a database and conducted a forced-choice recognition task and a clarity/valence rating task on emotional facial photographs for both child and adult raters. This study collected data on recognition accuracy, clarity, and valence ratings. We further explored potential differences in emotion recognition by age.

We further evaluated the suitability of a newly developed database as an experimental stimulus for research in emotional and cognitive psychology. To achieve this, Study 2 utilized the well-established face-in-the-crowd task, a modified version of the traditional visual search task. In this task, participants were required to rapidly identify a target face within a crowd of faces exhibiting a specific emotional expression. This method enables the investigation of attentional biases toward or away from particular emotional faces. A growing body of research suggests that angry face, in particular, tend to “pop-out” in a crowd—a phenomenon known as the anger superiority effect^{43–46}. Study 2 compared attentional biases to emotional face stimuli across age group in both children and adults to assess the appropriateness of these stimuli for emotion research. Notably, in addition to behavioral measures, we collected eye-tracking data to address the limitation of children's slow response times. Eye-tracking is an ecologically valid method for assessing real-time attention to emotional facial stimuli, as it provides multiple parameters, such as where a participant's gaze is currently fixed⁴⁷.

Accordingly, the KCEFD extends prior work in several important ways. First, it addresses the relative scarcity of facial expression databases of East Asian children—particularly Korean children—by developing a dataset of Korean child faces and validating it using both adult and child raters. This approach provides a broader set of measures and enables the examination of developmental differences in emotion recognition. Second, by integrating eye-tracking data, the KCEFD offers additional validation of the database and allows for the investigation of attentional processes underlying emotion perception. This multimodal approach further supports the utility of the database for research in emotion and cognitive psychology.

Study 1: development and validation of Korean Child Emotional Face Database Results

Recognition accuracy

The overall accuracy of the facial stimuli, as rated by both child and adult raters, was 70%. The accuracy rates for emotions were as follows: 95% for happiness, 94% for surprise, 86% for neutral, 18% for fear, 89% for anger, 52% for disgust, and 61% for sadness. For children, the accuracy rates were 94% for happiness, 94% for surprise, 86% for neutral, 16% for fear, 89% for anger, 55% for disgust, and 57% for sadness. For adults, the accuracy rates were 98% for happiness, 95% for surprise, 88% for neutral, 23% for fear, 89% for anger, 47% for disgust, and 70% for sadness (Table 1).

Among the seven emotions, the happy and surprised expressions were recognized most accurately, while fear was recognized most inaccurately. Happiness, neutral, and surprise were very accurately perceived as target emotions. Fear was primarily perceived as surprise (both 29.9%, child 30.3%, adult 29%) and disgust (both 20.5%, child 23.4%, adult 14.1%) and was often confused with anger (both 12.5%, child 10.8%, adult 16.5%). There was also a slight tendency to confuse disgust with anger (both 14.4%, child 13.4%, adult 16.5%) and sadness (both 17.3%, child 15.4%, adult 21.6%), and sadness with disgust (both 14.4%, child 18.3%, adult 5.5%) and fear (both 14.2%, child 13.9%, adult 14.9%). Anger was perceived accurately but was sometimes mistaken for disgust (both 7.7%, child 7.3%, adult 8.7%).

Clarity

The mean clarity for the facial expression is summarized in Table 1. The clarity was generally higher across the board, with relatively higher clarity for happiness, surprise and anger, and lower clarity for fear (both: mean

	Emotions	Accuracy (%)	Clarity (point)	Valence (point)
Overall	Happiness	95 (21)	5.63 (1.69)	6.18 (1.28)
	Surprise	94 (23)	5.52 (1.60)	4.14 (1.32)
	Neutral	86 (34)	5.04 (1.73)	3.64 (1.16)
	Fear	18 (39)	4.64 (1.65)	2.95 (1.35)
	Anger	89 (32)	5.81 (1.49)	1.93 (1.53)
	Disgust	52 (50)	4.87 (1.68)	2.52 (1.46)
	Sadness	61 (48)	4.92 (1.64)	2.66 (1.42)
Children	Happiness	94 (10)	5.44 (1.02)	6.14 (0.64)
	Surprise	94 (10)	5.35 (1.08)	4.15 (0.72)
	Neutral	86 (17)	5.01 (1.06)	3.65 (0.69)
	Fear	16 (16)	4.72 (1.01)	3.04 (0.69)
	Anger	89 (14)	5.77 (0.89)	1.97 (0.83)
	Disgust	55 (23)	4.93 (0.97)	2.61 (0.82)
	Sadness	57 (22)	4.92 (0.96)	2.75 (0.81)
Adults	Happiness	98 (15)	6.04 (1.32)	6.26 (1.16)
	Surprise	95 (22)	5.89 (1.30)	4.12 (1.30)
	Neutral	88 (32)	5.12 (1.70)	3.61 (1.05)
	Fear	23 (42)	4.47 (1.56)	2.75 (1.16)
	Anger	89 (31)	5.91 (1.36)	1.82 (1.28)
	Disgust	47 (50)	4.72 (1.57)	2.31 (1.24)
	Sadness	70 (46)	4.91 (1.55)	2.43 (1.19)

Table 1. Recognition accuracy, clarity, and valence of each facial expression. For clarity and valence, scores range from 1 to 7. For clarity, a higher score indicates a clearer sentiment, while for valence, lower scores indicate more negative and higher scores indicate more positive. In parentheses is the standard deviation.

clarity = 5.2, happiness = 5.63, surprise = 5.52, neutral = 5.04, fear = 4.64, anger = 5.81, disgust = 4.87, sadness = 4.92; child: mean clarity = 5.16, happiness = 5.44, surprise = 5.35, neutral = 5.01, fear = 4.72, anger = 5.77, disgust = 4.93, sadness = 4.92; adult: mean clarity = 5.28, happiness = 6.04, surprise = 5.89, neutral = 5.12, fear = 4.47, anger = 5.91, disgust = 4.72, sadness = 4.91).

Valence

The valence varied across emotions, with happiness rated as the most positive and anger rated as the most negative (both: mean valence = 3.42, happiness = 6.18, surprise = 4.14, neutral = 3.64, fear = 2.95, anger = 1.93, disgust = 2.52, sadness = 2.66; child: mean valence = 3.47, happiness = 6.14, surprise = 4.15, neutral = 3.65, fear = 3.04, anger = 1.97, disgust = 2.61, sadness = 2.75; adult: mean valence = 3.32, happiness = 6.26, surprise = 4.12, neutral = 3.61, fear = 2.75, anger = 1.82, disgust = 2.31, sadness = 2.43).

Age effects

To investigate age differences in emotion recognition, we first conducted a two-way mixed ANCOVA to examine the overarching effects across all emotion categories and age groups, while statistically controlling for rater gender. The analysis revealed significant interaction effects between emotion and age group for all dependent variables: accuracy [F(6, 1440) = 5.511, $p < .001$, $\eta^2 = 0.022$], clarity [F(6, 1440) = 8.096, $p < .001$, $\eta^2 = 0.033$], and valence [F(6, 1440) = 3.276, $p = .003$, $\eta^2 = 0.013$]. To further elucidate which specific emotions drove these interactions and to identify where discrete differences lay between the child and adult groups, we conducted subsequent univariate analyses of covariance (ANCOVAs) for each of the seven emotions, while statistically controlling for rater gender. First, our analysis revealed that adults recognized sadness [F(1, 240) = 10.352, $p = .001$, $\eta^2 = 0.041$] more accurately. For clarity ratings of each emotion, adult rated happiness [F(1, 240) = 13.210, $p < .001$, $\eta^2 = 0.052$] and surprise [F(1, 240) = 8.624, $p = .004$, $\eta^2 = 0.035$] significantly higher than children. Lastly, we found that adults rated disgust [F(1, 240) = 7.424, $p = .007$, $\eta^2 = 0.030$], and sadness [F(1, 240) = 8.178, $p = .005$, $\eta^2 = 0.033$] more negatively than children. A table of results for age group comparison is shown in Supplementary Table 2. In addition, rater gender did not confound these findings: the only nominal gender difference was for anger recognition accuracy in children ($t = 2.509$, $p = .013$), which did not survive the Bonferroni-corrected threshold ($p < .0071$), and no other comparison approached significance in either age group (Supplementary Table 4).

To further investigate developmental effects, we analyzed the association of age with accuracy, clarity, and valence within each age group. For children, only disgust was observed to be more accurate in recognizing emotions with increasing age ($r = .387$, $p = .001$). We also observed that clarity ratings for neutral expressions significantly increased with age ($r = .246$, $p = .001$). Finally, the three negative emotional expressions, with the exception of anger, were more negatively-valenced as age increased (fear: $r = -.250$, $p = .001$; disgust: $r = -.228$, $p = .003$; sadness: $r = -.285$, $p < .001$). For adults, there was no increase in accuracy or clarity ratings across the emotion categories as age increased. In contrast to children, adults rated negative emotions more positively as

age increased (anger: $r = .432$, $p < .001$; sadness: $r = .432$, $p < .001$). A table of the correlation results for age and accuracy, clarity, and valence is presented in Supplementary Table 3.

Study 2: utilization of Korean Child Emotional Face Database Results

Search (reaction) times based on target emotions

The reaction time for children to detect the target varied significantly based on the emotion presented as the target [$F(3, 273) = 24.732$, $p < .001$, $\eta^2 = 0.214$]. Specifically, search efficiency was slower when the target was a sad face, compared to the other emotions. In adults, target search efficiency followed the order: anger, sadness, happiness, and surprise [$F(3, 162) = 21.337$, $p < .001$, $\eta^2 = 0.283$]. Significant pairwise differences were found among all emotions, except for the comparisons between sadness and happiness, and between anger and sadness (Supplementary Table 5).

Search (reaction) times based on distractor emotions

Reaction times for detecting the target were influenced by the emotion of the distractor in both children and adults. For children, reaction times were significantly faster when the distractor was a sad face compared to other emotional faces [$F(3, 273) = 5.747$, $p = .001$, $\eta^2 = 0.059$]. However, no significant differences were found between the emotions of happiness, surprise, and anger. For adults, significantly faster reaction times were observed for negative faces compared to the other two emotions [$F(3, 162) = 36.833$, $p < .001$, $\eta^2 = 0.406$].

Eye movements based on target emotions

The total duration of fixations while the child participants were looking at the target AOI did not differ significantly by emotion [$F(3, 273) = 2.162$, $p = .093$]. However, both the number of fixations and saccades varied by emotion, with sadness eliciting the fewest and surprise the most [fixations: $F(3, 273) = 6.945$, $p < .001$, $\eta^2 = 0.071$; saccades: $F(3, 273) = 6.880$, $p < .001$, $\eta^2 = 0.070$]. For adult participants, there was a significant difference in the total duration of fixations for each emotional target [$F(3, 162) = 21.906$, $p < .001$, $\eta^2 = 0.289$]. Specifically, fixation duration for the anger target was significantly longer than those for all other emotional targets. Consistent with this pattern, anger also elicited a significantly higher number of fixations [$F(3, 162) = 7.869$, $p < .001$, $\eta^2 = 0.127$] and saccades [$F(3, 162) = 6.722$, $p < .001$, $\eta^2 = 0.111$] within the target AOI compared to happiness, surprise, and sadness.

The statistics for each dependent variable (i.e., reaction time and three eye movement parameters) in the target condition, along with the results of the pairwise comparison, are presented in Fig. 1A and Supplementary Table 5.

Eye movements based on distractor emotions

Children had the longest total fixation duration when anger appeared as a distractor, followed by happiness, while fixation durations for surprise and sadness were shorter [$F(3, 273) = 50.077$, $p < .001$, $\eta^2 = 0.355$]. The number of fixations and saccades were highest for anger, followed by happiness, surprise, and sadness [fixations: $F(3, 273) = 51.824$, $p < .001$, $\eta^2 = 0.363$; saccades: $F(3, 273) = 16.250$, $p < .001$, $\eta^2 = 0.152$]. Pairwise comparisons showed significant differences in the number of fixations across all emotions ($ps < 0.005$). For saccades, most between-emotion comparisons were significant ($ps < 0.005$), except for the comparisons between surprise and sadness, as well as between happiness and surprise.

For adults, significant differences were also found in the total duration of fixations on distractor AOIs based on emotion [$F(3, 162) = 7.321$, $p < .001$, $\eta^2 = 0.119$]. The longest fixation durations were for the anger distractor, with no differences between the other three emotions. Additionally, the anger distractor elicited the highest number of fixations [$F(3, 162) = 4.768$, $p = .003$, $\eta^2 = 0.081$]. More specifically, anger differed significantly from sadness in terms of fixation count [sadness: $t(54) = 3.582$, $p = .001$]. Figure 1B and Supplementary Table 6 provide the statistics for each dependent variable in the distractor condition, along with the results of the pairwise comparisons.

Discussion

To develop and validate Korean children's emotional facial expressions, Study 1 used 20 child models to validate a set of 151 photo stimuli consisting of six basic emotions and a neutral facial expression, which were rated by 169 children and 74 adults for recognition accuracy, clarity, and valence of emotional expression in Study 1. Until now, the emotions expressed by child models have often been validated by adults and/or experts^{48–51}, and rarely by peer raters^{52,53}. However, to better understand children's emotional face processing and development, it is essential to have validated databases from both child and adult perspectives. Our KCEFD can be utilized in a variety of fields related to the processing and development of emotional faces in Asian children and can contribute to the advancement of these fields.

In validation in Study 1, we observed that raters correctly recognized emotions around 70% of the time on average, but the accuracy rates between emotions were very different. Our result showed the highest accuracy (95%) in happy facial expression, which is consistent with previous databases. In fact, happiness shows a ceiling effect in almost all databases^{34,35,39–41,51–56}. In our study, we observed very high accuracy rates of 98% in adults and 94% in children. This is because happy facial expression is the only one emotion using the zygomaticus major muscle (corresponds to action unit (AU) 12 in Ekman's FACS), which is used to raise the corners of the mouth, is primarily used in situations of laughing or smiling¹⁶. Happiness is also the emotion that is most frequently observed in our daily lives⁵⁷. Thus, happy facial expressions tend to be recognized more easily than other emotions, accuracy in general.

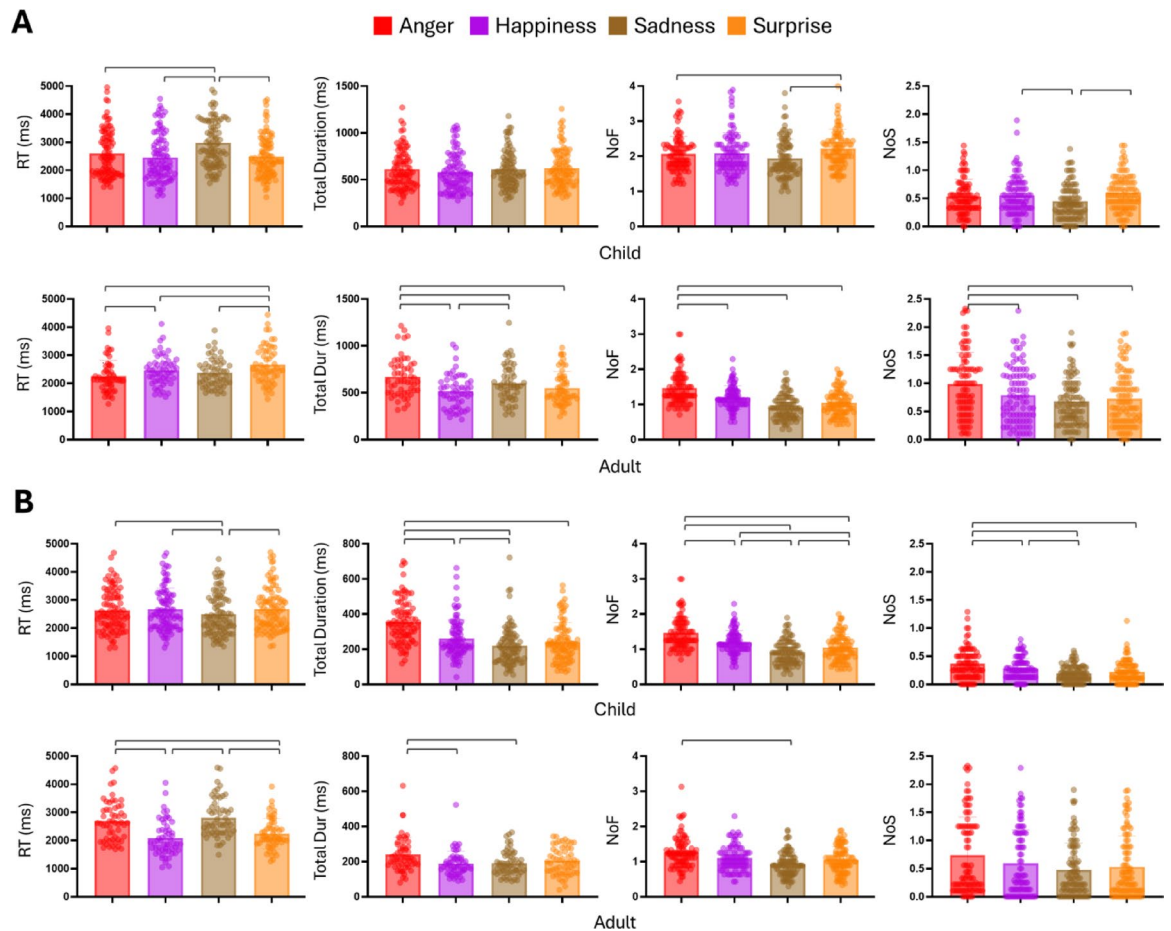


Fig. 1. Behavioral and eye-tracking results across emotional conditions for target and distractor. Mean values and individual data points are presented for each dependent variable—reaction time (RT), total duration of fixations (Total Dur), number of fixations (NoF), and number of saccades (NoS)—in the target condition (**A**) and the distractor condition (**B**). In both panels, data from children are shown in the top row and data from adults in the bottom row. Colored bars indicate emotional conditions (red: anger, purple: happiness, brown: sadness, orange: fear). Horizontal lines indicate significant differences after Bonferroni correction for multiple comparisons.

However, there is significant overlap in the facial muscles used to express various emotions, particularly negative ones, which can make distinguishing between them challenging. Disgust and fear, in particular, have relatively low accuracy compared to other facial expressions^{34,35,39–41,51–53,56}. For example, a database of child faces validated by children showed the following recognition accuracy for negative emotions: CAFÉ fear 26%, anger 65% disgust 47%, and sadness 49%⁵²; RaFD-C: fear 63%, anger 77%, disgust 68%, and sadness 75%⁵³. Not only children but also adults often struggle to differentiate these two emotions: Extended ChaeLee: fear 49%, anger 87.6%, disgust 69.1%, and sadness 89.2%⁴¹; KUEFC-II: fear 49.76%, anger 87.33%, disgust 63.46%, and sadness 84.38%⁴⁰; Y-face: mouth-closed fear 30.47%, mouth-closed anger 87.23%, mouth-open disgust 58.4%, and mouth-closed sadness 82.53%³⁹. These findings indicate that negative emotions share common features in facial expressions, making emotional face recognition difficult. Notably, it has been suggested that unlike Westerners who emphasize distinguishing between AUs and engage in analytical neuronal processing of face, Asians engage in holistic neuronal processing, grouping emotions based on common facial muscle movements without conceptualizing them into distinct emotional categories^{58–60}. In fact, Asians are reported to have significantly lower accuracy for fear and disgust than Westerners^{17,25}.

Previous research with Asians has specifically noted that fear is often mistaken for surprise and disgust for anger or sadness due to morphological similarities between the emotions^{39,40}. Surprised and fearful faces share a lot of muscle use, such as AUs 1 (inner brow raiser), 2 (outer brow raiser), 5 (upper lid raiser), and 26 (jaw drop). Also, in everyday life, surprise and fear can often occur together. For example, while watching a horror movie, people often react to scary scenes in a startled way. Given that surprised expressions are more commonly experienced than fearful expressions, it may be reasonable that fear is perceived primarily as surprise. In fact, the frequency with which each facial expression occurs in everyday life increases recognition accuracy⁶¹. The low recognition accuracy for fear warrants careful consideration regarding the practical utility of the KCEFD in future experimental designs. Specifically, researchers should exercise caution when using fear stimuli for

paradigms requiring discrete categorical identification; these images may be better suited for research focusing on general negative valence or arousal, such as affective priming or physiological arousal research.

We also evaluated the clarity and valence for each emotion. Overall, clarity was high for all emotions, but those with higher accuracy were perceived as clearer. For valence, happiness had the highest and anger the lowest. Confusing emotions, such as fear, were more difficult for participants to identify accurately, suggesting that they may have experienced confusion in their judgment process, resulting in less clarity. Fear also had a relatively high value among negative emotions, possibly because it was more often confusing with surprise.

Meanwhile, our findings did not provide evidence of an own-age bias. Following the stringent Bonferroni correction across the emotion categories, significant age-related differences in recognition accuracy disappeared for most emotions. Sadness was the sole emotion category that retained a statistically significant age difference; crucially, even here adult raters were significantly more accurate than child raters—the opposite of what an own-age bias would predict, since such a bias would instead favor child raters for these child faces. This adult advantage likely reflects adults' greater cognitive maturity and broader social experience, which appear to override any own-age advantage when evaluating children's facial expressions and thereby enable a more accurate interpretation of children's emotional signals.

Interestingly, as children aged, they tended to rate negative faces more negatively, whereas adults showed the opposite trend, rating negative faces less negatively with age. One possible explanation is that younger children may have less exposure to negative stimuli, as they receive more care and protection from their caregivers compared to older children. A widespread negativity bias has been reported in younger people, where negative information is given more weight than positive information⁶². However, this bias tends to shift toward a positivity bias in mid-to-late life^{62,63}. Our finding that middle-aged adults rated negative stimuli less negatively as they aged may reflect this positivity bias. Importantly, the evaluation of negative stimuli can change over the life cycle.

However, the shift toward more positive evaluations with age in middle-aged adults may not necessarily correspond to a change in attentional bias toward positive stimuli. In Study 2, we examined attentional biases to emotional stimuli by using eye-tracking in a face-in-the-crowd task with both children and adults. We found that, overall, anger was observed to be fixated longer, more often, and to saccade more than other emotions. Angry facial expressions may signal potential hostility or threat. From an evolutionary perspective, the human visual system may have evolved to process such cues more efficiently. Supporting this idea, numerous studies using the face-in-the-crowd paradigm have suggested that angry facial expressions capture attention more than other facial expressions^{43–46}.

Is an angry face more attention-grabbing due to its negative valence or is it because of its evolutionary significance as a threat? There are two explanations for this: The negativity bias hypothesis proposes that negative stimuli are more important to survival or decision-making than neutral or positive stimuli, regardless of whether they are associated with a direct threat and therefore tend to capture attention more effectively^{64,65}. The evolutionary threat hypothesis, on the other hand, suggests that the ability to quickly detect stimuli threatening survival has significant adaptive value. As a result, specific detection mechanisms have evolved throughout human history to prioritize threatening stimuli over non-threatening ones^{45,46,66}.

The results of the present study suggest potential age-related differences in these two hypotheses. Specifically, we found that in adults, sadness and anger were similar in behavioral responses (i.e., reaction times), whereas in children, sad faces were the least attention-grabbing compared to other emotions. Previous research has shown that negative faces (i.e., anger, sadness, and fear) are detected more quickly than happy faces in both children and adults. Additionally, anger and fear, which are associated with evolutionary threats, were found to be identified faster than non-threatening negative sadness. This finding partially supports the negativity bias hypothesis—where negative stimuli attract more attention than positive ones—while also suggesting a heightened sensitivity to stimuli signaling greater threat⁴³.

However, in the present study, children demonstrated the poorest performance in searching for sad facial expressions, which may be attributed to the relatively slower developmental trajectory of sad face processing. Prior research has indicated that children frequently misidentify sad faces even beyond the age of 10⁶⁷, a finding that aligns with the results of Study 1, where sadness recognition accuracy was 70% in adults but only 57% in children. These developmental differences are likely associated with broader changes in attentional and memory processes related to facial expression recognition. The development of attentional mechanisms may influence the specific facial features that children extract, particularly their ability to detect subtle variations in emotional expressions compared to neutral faces⁶⁷. Notably, sad facial expressions tend to be less perceptually salient than other emotions; while anger, happiness, and surprise are often characterized by open mouth, sadness is typically expressed with a closed or only slightly open mouth⁶⁸. Given that the ability to discriminate subtle visual cues associated with emotions develops relatively late⁶⁷, this ability may affect search efficiency by modulating attentional allocation.

Our study does have some limitations that should be taken into consideration. Firstly, our database does not contain many models and thus does not provide a sufficiently large number of stimuli. Secondly, compared to previous studies, the database was less accurate for some emotions, possibly because the child models are not mature enough to express these emotions clearly. The adult participants in this study consisted primarily of the primary caregivers (predominantly mothers) of the child participants, which may limit the generalizability of the findings due to gender and age imbalance. Future research should aim for a more gender-balanced sample, including fathers and non-parental adults—ranging from those who regularly interact with children to those with little to no daily contact—to determine whether these findings extend to a broader population. Furthermore, although the face-in-the-crowd paradigm employed to validate the emotional effects in this study's database is a well-established paradigm, ongoing debate persists regarding the anger superiority effect. A substantial body of research has instead reported evidence supporting a happy superiority effect^{9,69–73}. Several factors may contribute to these conflicting findings, including the relative frequency of each emotional expression in social

interactions^{61,74,75}, the visual salience of specific facial features associated with emotion (e.g., visibility of teeth)⁶⁸, and developmental factors such as age. Therefore, it is essential for studies utilizing emotional facial stimuli to account for a range of potential confounding variables. However, the present database was not explicitly designed to control the numerous factors that may serve as confounders in emotion research. Finally, it should be noted that our statistical approach relied on ANCOVA-based analyses. While this is standard for establishing normative data, it does not fully account for the nested variability within raters and stimuli. Future research employing a larger number of stimuli per category could benefit from mixed-effects modeling to more precisely disentangle rater-specific and stimulus-specific variances.

By providing recognition accuracy, clarity, and valence for the seven emotions, the KCEFD allows researchers to select pictures based on criteria appropriate to their research topic. Importantly, given that recognition performance can vary across individual stimuli, researchers are encouraged to consider stimulus-level accuracy when selecting images, particularly in paradigms requiring clear and unambiguous emotional expressions. For instance, in Study 2, one sad stimulus was excluded because its relatively low recognition accuracy in Study 1 was associated with prolonged response times, illustrating how individual item characteristics can affect task performance. Accordingly, we recommend that researchers consult the normative accuracy rates for each stimulus to ensure alignment with their experimental aims. Thus, our KCEFD can be used as a useful tool in a variety of fields related to emotional face processing and development in Asian children, contributing to the advancement of these fields.

Methods

Study 1: development and validation of Korean Child Emotional Face Database

Development of Korean Child Emotional Face Database

Model A total of 20 Korean child models (10 boys, 10 girls, aged from 7 to 11 years) participated in the photo shoot with both parent/guardian consent. For all child participants involved in the development of the child facial expression database, written and informed consent was obtained from a legal guardian prior to participation. In addition, specific consent was obtained for the publication and open-access dissemination of any potentially identifying images or information online. All procedures were approved by the Ethics Committee of the Korea Brain Research Institute (KBRI-202103-HR-002) and conducted in accordance with ethical guidelines for research involving minors.

Development procedure The photo shoot took place in a photo studio in Daegu, South Korea. The models were seated on chairs in front of a white background screen, with a distance of 235 cm between the chair and the camera (Fig. 2A). The camera was a Canon EOS R6 and the lights were Godox SL60W. All models were instructed to wear a black T-shirt and remove any extraneous elements such as hairpins, makeup, glasses, or bangs. Prior to the photo shoot, models were provided with detailed, age-appropriate descriptions of facial expressions for each emotion, informed by principle of the FACS¹⁶. To avoid overly artificial or exaggerated expressions, explicit Action Unit (AU) instructions were not given. Instead, we provided intuitive physical cues based on the principles of FACS. To further facilitate emotional elicitation, brief age-appropriate scenarios were provided alongside visual reference stimuli from Ekman's database, which were displayed on a prompt monitor situated below the camera lens.

Models were encouraged to make their facial expressions as intense and clear as possible to effectively convey the target emotion. The professional photographer captured multiple shots for each emotion, allowing ample training time for the model to express each emotion clearly and distinctly.

The stimuli selection procedure To ensure the selection of suitable stimuli for inclusion in the database, we followed a specific procedure: Initially, four research assistants identified and excluded stimuli containing photographic defects, such as out-of-focus images, or inappropriate angles. In the subsequent step, stimulus selection was conducted by 12 research assistants, consisting of graduate students and research interns who either specialized in psychology or possessed prior experience in facial expression research. The research assistants

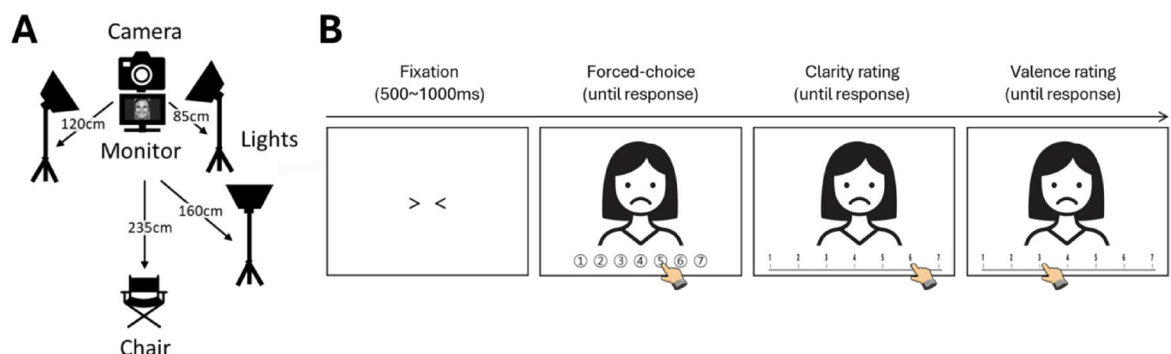


Fig. 2. Validation process for the Korean Child Emotional Face Database. (A) Organizing the setup for the photo shoot. (B) Procedure of validation task.

were trained in the basic principles of the FACS and used these as guidelines for evaluation. They evaluated each image based on whether it was consistent with the prototypical features of the target emotion. Images were rejected if the expression was ambiguous or insufficiently intense. During the selection process, priority was given to images that reached a high level of consensus among the assistants. In cases of tied or low levels agreement, both images were included in the final stimulus set to provide a broader range of high-quality exemplars for future research.

In the final, 151 stimuli (77 boy and 74 girl model photos) were selected. Selected raw photographs were preprocessed and standardized using Adobe Photoshop. Standardization proceeded in the following ordered steps. (1) Alignment: each image was rotated, when necessary, so that the inter-pupillary line was horizontal; the midpoint between the eyes was used as the geometric anchor. (2) Cropping: images were cropped to a fixed aspect ratio centered on the face, with the chin, ears, and the top of the forehead included in the frame, so that all final stimuli displayed the head and upper neck only. (3) Resizing: all static stimuli were resampled to a uniform resolution of 800 × 900 pixels (72 dpi). (4) White-balance correction: residual color casts were corrected by sampling the white background and neutralizing it using the Photoshop “gray-point” dropper, ensuring consistent skin-tone reproduction across stimuli. (5) Luminance normalization: mean luminance of the face region (defined by an oval mask covering forehead, cheeks, and chin) was equalized across stimuli using the Photoshop “Exposure” and “Curves” tools so that the face-region mean fell within ± 2 cd/m² of the dataset mean. (6) Contrast normalization: a histogram-based contrast adjustment was applied so that the inter-quartile range of pixel intensities within the face region was matched across stimuli. (7) Color/saturation: hue and saturation were standardized using the Photoshop “Hue/Saturation” tool with all sliders held within ± 5 of the dataset mean. No facial features (e.g., eye shape, mouth contour, skin texture) were edited, retouched, or smoothed; standardization affected only global image properties.

Validation of Korean Child Emotional Face Database

Participants A total of 188 elementary school children (106 boys, 82 girls, mean age [SD]: 9.03 [1.59], range 6–12) and 81 middle-aged adults (4 males, 77 females, mean age [SD]: 41.57 [3.80], range 33–50) participated in the database validation study. The adult participants were the primary caregivers of the child participants. Notably, none of the participants had any prior familiarity with the child models. First, eight of the children were excluded because their forced-choice recognition task accuracy was less than 50%, a threshold representing scores more than two standard deviations below the mean ($z < -2$). This statistical cutoff was applied to ensure the data reflected participants who adequately understood the task instructions. Second, 11 children and 7 adults were excluded due to insincere responding, operationalized as invariant or near-invariant response patterns across trials (e.g., repeatedly selecting the same response option regardless of the emotional category). Hence, 169 children (93 boys, 77 girls, mean age [SD]: 9.19 [1.54]) and 74 adults (4 males, 70 females, mean age [SD]: 41.46 [3.74]) remained as raters for our database validation.

Demographic information for 169 children and 74 middle-aged adults is presented in Supplementary Table 1. All procedures involving child and adult participants were approved by the Ethics Committee of the Korea Brain Research Institute (KBRI-202103-HR-002) conducted in accordance with relevant institutional guidelines and the Declaration of Helsinki. Written informed consent was obtained from all adult participants and from both child participants and their legal guardians.

Validation procedure The experiment for validation was created using E-prime 3.0. Experiment was conducted in a soundproof booth under controlled laboratory using an IBM compatible computer and a 24” LED monitor. To avoid the fatigue effects in child raters, the total of 151 stimuli were divided into three picture sets, so that the number of stimuli rated per person was 50 or 51. Each set was pseudo-randomized across raters, and within each set the picture stimuli were presented randomly. Before starting the validation procedure, raters were given one practice trial with a detailed explanation of the validation criteria. The emotion labels used in the validation procedure were selected to be age-appropriate and easily comprehensible for the child raters. The specific Korean labels used in the study were: ‘기쁨’ (Happiness), ‘놀람’ (Surprise), ‘무표정’ (Neutral), ‘슬픔’ (Sadness), ‘두려움’ (Fear), ‘역겨움’ (Disgust), and ‘화남’ (Anger). Notably, no child raters reported difficulties in understanding these terms for performing the task.

Raters were instructed to answer three questions per facial stimulus: first, in a forced-choice recognition task, raters viewed a picture of a facial expression and responded to the question “Which emotion is this model expressing?” by pressing the keyboard button mapped to each emotion. Second, in a subsequent rating task, raters responded to the question “How clear do you find this emotion?” on a 7-point Likert scale (1 = not very clear, 7 = very clear). Finally, they responded to “How positive or negative is this facial expression?” (1 = very negative, 7 = very positive). Figure 2B indicates a schematic drawing of the validation procedure.

Statistical analysis

We utilized SPSS 21 software (IBM-SPSS Inc, Chicago, IL, USA) for statistical analyses. In our study, we focused on recognition accuracy in a forced-choice procedure, and the rated points of clarity and valence as dependent variables. Initially, descriptive statistics were computed to determine the mean and standard deviation of accuracy, clarity, and valence for each emotion. Additionally, to examine developmental effects, we first employed a two-way mixed ANCOVA, followed by subsequent univariate ANCOVAs to compare the child and adult groups. Within each age group, we also performed partial correlations between each dependent variable (i.e., accuracy, clarity, and valence) and age, controlling for rater gender in both analyses. To control for Type I error inflation due to multiple comparisons, a Bonferroni correction was applied, setting the statistical significance threshold at $p < .0071$ (0.05/7). In addition, to confirm that rater gender did not confound these findings, we compared

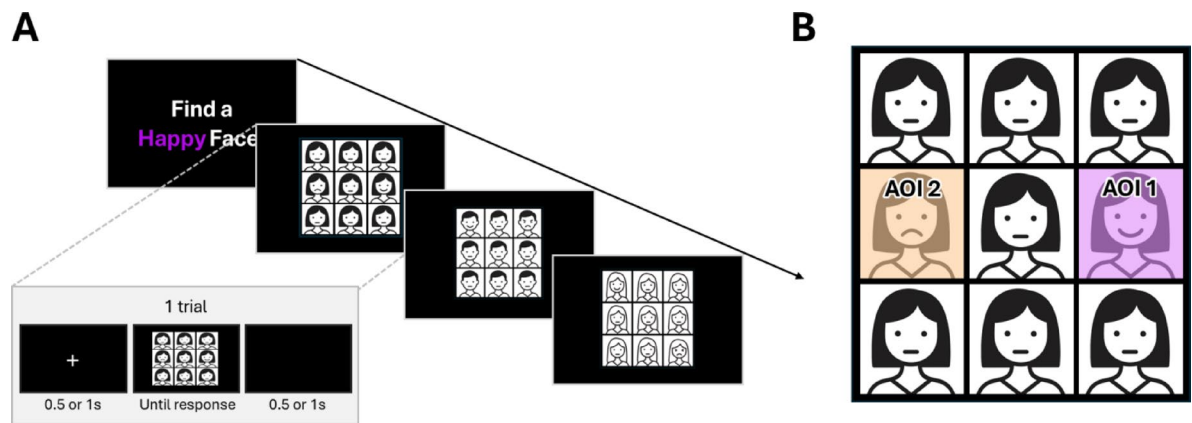


Fig. 3. Emotional face-in-the-crowd paradigm. **(A)** Each stimulus display consists of a 3×3 grid containing one emotional target, one emotional distractor, and seven neutral distractors. Participants are instructed to identify the emotional target as quickly and accurately as possible by pressing the corresponding button. Each trial begins with a fixation cross (0.5–1 s), followed by the stimulus display, which remains on screen until a response is made. A blank screen is then shown for 0.5–1 s. **(B)** Schematic depiction of area of interest (AOI) used in the eye-tracking data analysis.

male and female raters on each dependent variable within each age group using independent-samples t-tests (Supplementary Table 4).

Study 2: utilization of Korean Child Emotional Face Database

Participants

Study 2 included 147 participants, 92 of whom were children (47 boys, 45 girls, mean age [SD]: 9.98 [2.35], range 6–15) and 55 middle-aged adults (3 males, 52 females, mean age [SD]: 41.84 [3.74], range 33–49). Supplementary Table 1 presents demographic information for 92 children and 55 middle-aged adults. All participants provided written informed consent, approved by the Institutional Review Board of the Korea Brain Research Institute (KBRI-202103-HR-002). For children, consent was obtained from their legal representatives.

Design and procedure

The emotional facial expression stimuli developed in Study 1 were used as experimental stimuli. These stimuli were arranged into 3×3 matrices, each containing 1 emotional target, 1 emotional distractor and 7 neutral distractors. For instance, if a happy face is presented as the target, one of the remaining emotional expressions will be displayed in the crowd. The emotional target or distractor faces featured one of the following: happiness, surprise, anger, and sadness. To control for potential perceptual differences arising from face identity and to ensure that participants' judgments were based solely on emotional expressions, the target and distractor stimuli were always selected from the same model.

To ensure internal validity and minimize potential confounds arising from stimulus ambiguity, fear and disgust were excluded from Study 2. These emotions showed substantially lower recognition accuracy in Study 1, suggesting that their inclusion could introduce excessive variability. For example, when both the target and distractor belong to the same negative valence category, prolonged response times or altered gaze patterns toward negative target stimuli may be observed, reflecting increased cognitive load due to competition or ambiguity. To maintain rigorous experimental control and enhance the interpretability of the findings, we therefore restricted the stimulus set to four emotion categories—happiness, surprise, anger, and sadness—that were most reliably and consistently identified by participants. Within the 3×3 matrix, the target and distractor were pseudo-randomly arranged such that each appeared in every position once, ensuring that spatial positions were counterbalanced across trials. This procedure minimized location-based biases and ensured that search performance was not driven by predictable spatial configurations.

All participants performed the experiment in the soundproofed and controlled laboratory environment, consistent with the procedure in Study 1. The experiment commenced with a practice phase, consisting of one practice trial per target emotion, resulting in a total of four practice trials prior to the main experimental trials. Participants were instructed to fixate on the center of the screen, where a white fixation cross was displayed for either 0.5–1 s before the presentation of the matrix stimulus. Upon the appearance of the matrix stimulus, participants were required to identify the predetermined target as quickly and accurately as possible. Response keys were mapped to the 3×3 positions of the numeric keypad (keys 1–9). For instance, if the target appeared in the top-left corner of the matrix, participants were expected to press key 7. Following each response, a black screen was displayed for either 500ms–1s before the onset of the next trial. Feedback was provided exclusively during the practice trials and was not included in the experimental trials. The target emotions were divided into blocks, each of which were randomized in order. A schematic representation of the experimental procedure is provided in Fig. 3A.

Eye-tracking measures

While the participants were performing the experiment, gaze data from both eyes were recorded using a Tobii Pro Spark eye-tracker, operating at a sampling rate of 60 Hz. Gaze data were filtered using the Tobii I-VT (velocity-threshold identification) fixation filter. A velocity threshold of 30°/s was used to classify fixations and saccades, with a velocity calculator window length of 20 ms.

The E-prime extension for Tobii Pro 3.2 version was employed to synchronize the gaze recordings with the experiment stimuli. Before starting the experiment, a series of target points were sequentially presented on the screen for calibration, and participants were instructed to fixate on each point without moving their head. If the calibration was deemed inaccurate, the procedure was repeated until an acceptable level of precision was achieved.

The area of interest (AOI) was defined as two rectangular regions corresponding to the emotional target and a distractor, respectively (Fig. 3B). We measured three parameters as dependent variables to measure the differences in gaze behavior for each emotion: (1) the total duration of fixations that occurred within the AOI, (2) the number of fixations was detected within the AOI, and (3) the number of saccades occurring within the AOI.

Statistical analysis

We compared the influences of the four emotions as targets and as distractors, respectively. In the behavioral analysis, reaction time—measured from target detection to response keypress—was examined as the dependent variable. For the eye-tracking analysis, three parameters were assessed as dependent variables: total duration of fixations, number of fixations, and number of saccades. One stimulus (i.e., sad target with happiness distractor) was excluded from the analysis due to excessively slow reaction times across the board in both children and adults. Notably, this specific sad target had exhibited lower recognition accuracy compared to other sad faces in Study 1, suggesting that its inherent perceptual ambiguity may have hindered efficient processing.

Reaction times exceeding two standard deviations above the mean were identified as outliers based on the children's criteria, with a threshold of 6.5 s, and subsequently excluded from the analysis. We also excluded cases in which the total fixation duration on the target was 0 ms, as these likely indicate that participants responded without visually attending to the target. This resulted in the exclusion of data from 4.2% of child trials and 3.2% of adult trials. To control for the family-wise error rate in pairwise comparisons among the four emotional categories, a Bonferroni correction was applied. Consequently, the statistical significance threshold was set at $p < .0083$ ($0.05/6$).

Data availability

Data are available upon reasonable request to corresponding author.

Received: 2 August 2025; Accepted: 9 June 2026



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Acknowledgements

The authors would like to express their sincere gratitude to the participants and their families. The first author would also like to extend special thanks to the members of the Brain Development Imaging Lab at the Korea Brain Research Institute. Additionally, we would like to thank Ji Hyun Bae for their technical and administrative support during the early stages of this study.

Author contributions

S.L. and M.J. designed the experiments; S.L., Y.C., J.R., Y.J.C., and M.J. performed database development and validation; S.L. analyzed the data; and S.L., Y.C., J.R., Y.J.C., and M.J. wrote the paper.

Funding

This work was supported by the KBRI Basic Research Programs (26-BR-03-01, 26-BR-02-13), the National Center for Mental Health (MHER25C02), and Korean NRF grants (RS-2025-00517752, RS-2024-00397737) funded by the Ministry of Science and ICT.

Declarations

Ethics approval and consent to participate

The Institutional Board of the Korea Brain Research Institute granted ethical approval for this study (KBRI-202103-HR-002). Written consent and verbal agreements were obtained from all participants, and their consent included approval from their legal representatives.

Competing interests

The authors declare no competing interests.

Additional information

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1038/s41598-026-57755-0>.

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