Innovations

A Study of Reconstructing Cartoon Expressions in Picture Books-A Study on Children's Expression Recognition

Chen Menglin[1], Yu-CheHuang[2]

1KrirkUniversity,International College(IC), Art major（DFA）,10220 ,Bangkok, Thailand

2Chaoyang University of Technology, Dapartment of Industrial Design 400,Taichung,China;

Abstract

Real human facial recognition has been studied to derive facial specific expression intensity and category recognition, however, these results are based on real human facial expressions, and less has been done on cartoon expression materials. In this study, AUC facial motion coding system was used firstly to reconstruct the facial expression parts of cartoon characters in picture books and the strength of expressions were classified based on flat cartoon reconstructions. The results of experiment with children aged 4-7 showed that there were no significant cognitive differences in subtle processing of tears and lower eyelid shadows in cartoon expressions; children aged 5-6 recognized anger and sadness more strongly than those aged 6-7, and 4-5 and 5-6 year olds felt fear and sadness more than those aged 6-7.

Keywords: *Picture books, cartoon expressions, image reconstruction, children cognition*

1 Introduction

In paper-based picture books, facial expressions are predominantly portrayed through cartoon-like images. Various emoticons represent different emotions. Within the context of shared reading, picture books serve as an important medium. Yu (2009) points out that picture books are frequently used as educational resources to discuss

emotions with children and provide a platform for emotional understanding. Garner (2010) suggests that they can address the emotional characteristics of characters, and through reading picture books and interacting with more knowledgeable adults, children can develop an understanding of emotions. Research by Iordanou and Mattock (2022) indicates that if children benefit from the ability to depict emotions such as anger from picture books, parents and educators can potentially utilize them to help children identify anger and understand contextual backgrounds, thus promoting children's social competence to some extent. They also suggest that future research could investigate how emotion-based picture books can be combined with emotional discussions among co-readers such as parents or teachers to enhance children's cognitive understanding of emotions. Landau (2006) proposes that emotion-based picture books can elicit both negative and positive emotions equally. When the story characters in the picture books are not personally experienced by the children, they exhibit a strong interest in the circumstances of characters depicted as mean, bad, or mischievous, particularly in stories associated with negative emotions, which appear more vivid and captivating. A significant portion of these negative emotions is conveyed through facial expressions. However, in reality, emotional expressions in picture books have not been adequately emphasized. In paper-based picture books, they are predominantly presented through cartoon-like images, and the limited research on emotional recognition focuses not on characters in picture books but rather on images resembling simple drawings, often serving

Research on the recognition of real human and cartoon facial expressions suggests that cartoon faces maintain low-level metric parameters and facial proportions but lack advanced facial information such as skin texture, skeletal structure, and anatomical features. Compared to other types of non-realistic facial images, cartoon faces are not highly simplified like schematic diagrams and iconic faces, which use minimal pencil strokes to represent facial expressions (Fujiwara et al., 2002; Breazeal, 2003), nor are they highly realistic like comics and portraits. Several computational models have been developed to automatically transform real faces into art-stylized cartoon faces. However, these algorithms face challenges in using parameter techniques and physical models, which generate facial expressions by exaggerating the size of facial features (eyes, eyebrows, lips, and mouth) and deforming their shapes (Zaharia et al., 2008). Garner (1976) and Geldart (1999) argue

that the overall structure of cartoon faces remains consistent with real faces, and the differences mainly lie in specific local details such as the size of facial features. Cartoon faces are presented in a simplistic linear manner, characterized by strong simplification and abstraction of details.

Nijhof and Jeurissen (2006) argue that in the field of aesthetics, reconstruction is linked to deconstruction. Deconstruction, in particular, refers to the "decomposition of the structure," specifically breaking down the original structure into basic primitive units of each component. On the other hand, reconstruction represents the process of reassembling the disassembled components of the original structure into a completely new and different object or structure. Sheng You, NingYou, and Pan (2019) proposed the quantification of various factors that require reconstruction using computer technology. The use of computer media for image reconstruction is currently a common method. In the separate study of cartoon facial expressions, Zhao Lun, Zhao Kun, Liu Chang, and Chen (2006); Yang Yuankui, Wang Cai, and Zhou Jianzhong (2005) conducted experiments using black and white simple line drawings of faces, wherein external features such as ears and hair were hidden. However, this experimental material was based on cartoon images and the patterns were overly simplistic. The visual presentation of images in paper-based picture books is often in the form of cartoons. In their experiment, Masuda, Gosselin, and Nomura (2018) included cartoon facial units as experimental materials. These facial units were made of cardboard and represented a diagrammatic representation of facial actions based on the Facial Action Coding System (FACS) units or combinations of units distinguished in FACS (Ekman et al., 2002). They ensured that these units adequately represented 14 facial action units or combinations of units. In most cases, each cardboard piece represented a single action unit. However, some cardboard pieces represented shared actions of two units: raised eyebrows (inner brow + outer brow) and furrowed eyebrows (inner brow + brow). Through this experiment, they validated children's knowledge of the facial components of basic emotions and suggested that future researchers could expand such forms by selecting more facial components, as shown in the following diagram:

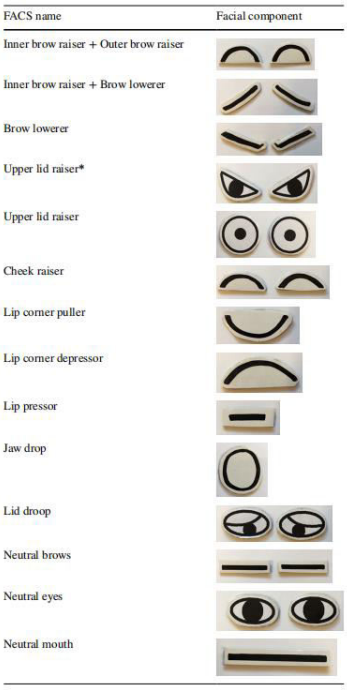


Figure 1 Facet components and their FACS names

Source: Masuda, Gosselin, & Nomura (2018)

Wang Rui (2013) conducted a relevant exploration on the categories and intensities of facial expressions in cartoon characters based on cartoon images. She compared real-life and cartoon pictures and found that the facial units in cartoon characters are simpler, with less muscular movement compared to real human faces. However, she did not dismantle and reconstruct the AU units of cartoon characters, as shown in the figure above, to test the efficacy of their expressions in facial recognition. The material below illustrates the different intensity of "joy" portrayed in the face of a cartoon boy.

Figure 2 Happy expressions of cartoon characters

Source: selected fromWang Rui(2013)

Shu Zhang. et.al. (2021) investigated how key facial features (mouth, eyes and eyebrows) affect emotion recognition based on the recognition process of cartoon

expressions (joy, sad and neutral). Three conditions were used throughout the experiment: (1) full face; (2) single feature only (hiding the other two); and (3) one feature hidden and the other two presented. The cartoon faces used were converted from the real faces of a group of Chinese performers. The intensity differences between real and cartoon expressions were compared, but the experimental materials were not differentiated.

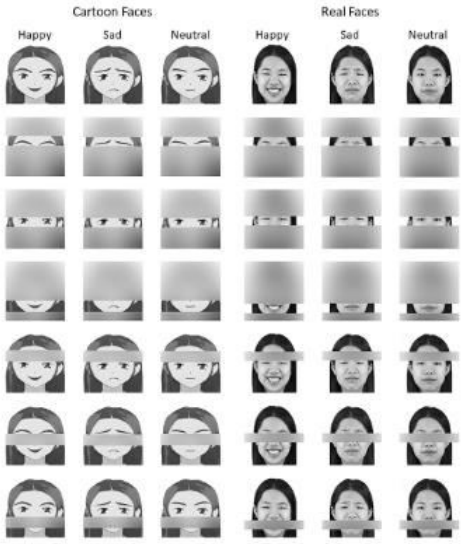


Figure 3 Cartoon character expressions

Source: Shu Zhang.et.al.(2021)

Thus cartoon expressions are deficient in both the use category and material processing, but it can be seen that current facial units are mostly processed for recognizing children's or adults' expressions.

1.2 Facial component recognition

Ekman (1986) proposed the AUC facial action coding system (FACS), which not only describes facial expressions, but also defines the classification of facial expressions accurately, and specifies the recognition target for all methods. Foreign mainstream recognition databases JAFFE and Cohn-Kanade (2000); Real-world Affective Faces Action Unit (2019,2020), etc. provide the corresponding AU calibrations, as exemplified in the following figure, which gives the basic AU of frontal face images in FACS:

Table 1 Basic AU of frontal face images in FACS
Adapted from Ouyang Yan (2013)

AU	Description	Faces	AU	Description	Faces
1	Inner eyebrows upturned		2	Outer eyebrows raised	
4	Eyebrows lowered		5	Upper eyelid raised	
6	Cheeks raised		7	Eyelids tightened	
9	Nose wrinkled		10	Upper lip raised	
11	Nasolabial folds deepened		12	Corners of mouth pulled up	
13	Cheeks stretched		14	Dimples appear	
15	Mouth corners lowered		16	Lower lip lowered	
17	Jaw rises		18	Lips wrinkled	
20	Lips stretch		22	Lips become funnel-shaped	
23	Lips tighten		24	Lips contract	
25	Lips parted		26	Chin lowered	

After defining the above facial movement units, the FACS system gives the expression templates, and the AU combinations of the four basic expressions were extracted in this study, as shown in the following table:

Table 2 Four basic expressions AU combination

Expressions	Creation of prototypes
Happiness	AU6+AU12+AU25
Anger	AU4+AU5+AU7+AU15+AU24
Sadness	AU1+AU4+AU7+AU15+AU17
Fear	AU1+AU2+AU4+AU5+AU7+AU20+AU25

Source: Adapted from Ouyang Yan (2013)

Furthermore, AU as a facial detachable recognition tool can be used for partial & whole recognition experiments (Masuda, Gosselin, & Nomura, 2018; Arterberry, Perry, Price & Steimel, 2019 ; Gagnon, Gosselin, Buhs, Larocque & Milliard, 2010 ; Gagnona , Gosselin, & Maassarani, 2014), only Guarnera, Hichy, Cascio, Carrubba, & Buccheri (2017) distinguished the intensity of specific expression categories to derive corresponding face region motion features. Some experiments did not use the specific facial muscle movements specified in FACS (Gao & Maurer, 2009, 2010; Herba, Landau, Russell, Ecker, & Phillips, 2006) but rather made the specific expressions needed and processed by computer for intensity, and the facial units driven by different intensity expression muscles are more subtle.Gagnona, Gosselin, & Maassarani (2014) conducted experiments on fear, surprise, anger, and disgust, using image software that separated specific AU combinations (with each AU primary appearance variation) involving cropped rectangles that contained the appropriate combination.

In summary, both real-life and cartoon facial units were used to process recognition material, examining component perception, category and intensity perception in these expressions for adults and children. However, for cartoon images, although this material is used but not combined with the narrative carrier of picture books to analyze expressions in depth, or process cartoon expression images based on AUC tools, therefore, it starts with picture book cartoons in our first study, reconstructs expression images based on AUCto construct the emotional intensity and facial component perceptions of four basic emotions: joy, anger, sadness and fear, in order to achieve educational significance of expression recognition in picture books co-reading. It aims to explore the perception of reconstructed images in Study 1 with children in the second study.

2 Study 1

2.1 Methods

The questionnaire was done on these expression images. We first extracted four basic emotions from explicit emotion-based picture books combined with textual

descriptions, and did not use these books and expression images directly according to experience, but obtained the four expression images to be reconstructed through experiments with children and adults. AUC was used to reconstruct these four expression images and questionnaires were given to children to examine their emotional perceptions.

2.1.1 Subjects

Fifty were tested, 10 adults and 20 children, with the children being from the same kindergarten. The average age of the adults was 30 and the children were 40 aged 3-7, with balanced participants in each age group. Parents signed a consent form to ensure that their child's intelligence and vision were normal.

2.1.2 Materials

The books have been published, won awards, and are used in emotion-related research.

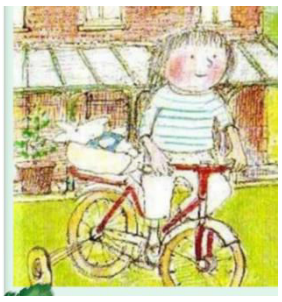
We invited 20 experienced experts, including teachers, early childhood teachers, preschool researchers, and kindergarten directors, to rate the suitability of the picture books in terms of origin, outline and content, and the reliability of the rating was 0.952, as shown in the table.

Table 3 Item statistics

Book Name	Mean	Standard Deviation	N
When Sophie Gets Angry	6.65	0.489	20
Grandpa	6.45	0.745	20
Mom is Mad	6.55	0.686	20
The Zoo	6,45	1.146	20
No, David	6.65	0.489	20
The Color Monster	6.40	0.754	20
The World’s Worst Dad	4.40	1.231	20
Owen	4.15	1.137	20
Sharing	6.40	0.821	20
Zog and the Flying Doctors	5.95	1.124	20
A Bad Case of Stripes	5.55	1.099	20
Where the Wild Things Are	4.25	1.209	20
Willy the Wizard	5.59	1.124	20
Anger	6.40	0.823	20
Why I Hate Eating Milk	5.55	1.099	20

According to the mean value and selection criteria, there were five picture books matched with each emotion at last, each with the expression of the main character as the recognition target, and the expression recognition images of four emotions were initially selected, totaling six images. The following table:

Table 4 Emotion recognition picture books

No.	Book\character	Emotion	
1	Mom is Mad: Mom	Sad	
2	Mom is Mad: Xiao Shan	Fear	
3	The Zoo:Dad	Joy 1	
4	When Sophie Gets Angry:Sophie	Angry1	
5	No, David:David	Angry 2	
6	Grandpa: Main character	Angry 2	

Researchers presented 10 adults and 20 children with pictures that depicted expressions of the four basic emotions, fear, anger, sadness and happiness. Each emotional image was displayed with other environmental information obscured to avoid pictures activating situational memory as memory cues (Tulving, 2002), trying to make the material fit the purpose of the study and reducing other factors (e.g., color, character dynamics, appendages, etc.).Photographs with the highest correct response scores among the four emotions.

The four colors of stickers corresponded to the different emotions being tested: yellow-green for sadness; pink for fear; orange for happiness; yellow for anger; and purple was also prepared to represent other emotions. The stickers were applied by the testers while the children were being tested. It should be noted that the colors used and the mood of the stickers do not have any color-emotion significance but are only used as a tool for the emotion category experiment.

2.3 Questionnaire

In the objective part of the questions 2 independent variables were designed for children based on the literature review: age and gender. For the subjective section, 16 reconstructed emoticons were designed in the questionnaire using a five-point Likert scale. For example, “happy” was set as: “very happy”, “happy”, “normal”, “unhappy”, “unhappy” and “very unhappy”. It was distributed in advance to adults by the researchers and to parents by kindergarten teachers. The information sheet specified that participants should not sign a consent form if they were familiar with the book. During shooting, the questions were asked in the same order as the pictures were presented (i.e., angry, sad, happy, and scared). Each task took about 10 min, and each participant responded with an expression corresponding to the emotion and attached the corresponding sticker.

Participants’ scores were determined based on the correct identification of emotions and accuracy was calculated as a percentage of correct answers. Based on previous studies (Ekman, 2004; Widen & Russell, 2003; Iord- anou & Mattock, 2022), a broader coding scheme was applied to the freely chosen book image labels, a second coder was consulted regarding the classification of responses, and the first coder was agreed upon. Answers such as “angry”, “frustrated”, “furious”, “wild”, “mad”, “irritated” and “grumpy” represent anger while “sad”, “lonely”, “regretful”, “depressed” and

"disappointed" represent sadness. Some words represent states (e.g., loneliness) rather than emotions and are classified according to the most relevant emotions (e.g., loneliness induces sadness) (Ekman , 2004). The expressions of negative emotions such as "dread" and "panic" are categorized as "fear" according to previous studies. In this study, the four emotions are defined as "angry, sad, happy and fearful". If a child answers "he/she is angry", then further explore: "Where do you see that?" or "Why?" and record.

2.4 Results

The correct choice scores 1 and the incorrect0. Pearson chi-square test (cross-tabulation) and Fisher's exact concept rate were used to study the difference relationship, as seen in the table above: different samples showed 0.01 level of significance (chi=21.253, p=0.001<0.01) for joy or not in the paintings, implying that different samples showed differences in the paintings, which can be combined with the percentages in brackets later for difference comparison. The following percentages are shown:

Table 5 Results of the perception of the four expressions

Expression	Name	Correct or not (%)		N
		0	1	
Sad	1	3(6.00)	47(94.00)	50
Fear	2c	8(16.00)	42(84.00)	50
Joy1	3	20(40.00)	30(60.00)	50
Anger1	4	9(18.00)	41(82.00)	50
Joy2	5	4(8.00)	46(92.00)	50
Joy2	6	9(18.00)	41(82.00)	50

Note: Percentages are in parentheses, N=50

Surprisingly, the expression of No. 5 Sophie was chosen as angry by children of almost all ages, but the choice of adults varied widely, with half choosing mute, unreadable or vicious but angry. Number 2 was incorrectly identified as "surprised", 3 was incorrectly identified as "complicated", "crying", and 4 was incorrectly identified as "vicious", "angry" or "expressionless".

According to the final results of the experiment, it should be noted that the classic picture book "When Sophie Gets Angry" expression No. 5 was selected for a

large discrepancy between adults and children (who were not familiar with the book), so David in David's Not OK was adopted as a reconstructed material for this study.

This result eventually served as the basis for the follow-up questionnaire and also provided realistic material for the reconstruction of the second expression images in this study.

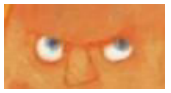
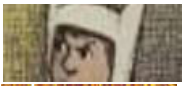
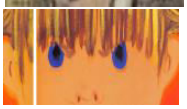
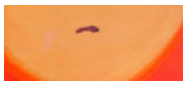
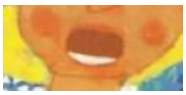
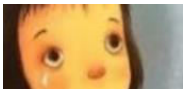
2.3 AU Image Conversion and Reconstruction

This subsection will reconstruct the four images based on the four expression emotions measured in advance, analyze the variable part of AU, the intensity of AU combination, and finally reconstruct the four images to lay the foundation for the questionnaire.

The model built from the real face AUC was reproduced by cartoon image transformation. Previous studies have generally divided the face into upper and lower parts, Based on the AU of expressions in different parts of the upper and lower face analyzed from previous studies, the AU of joy,angry and sadness in picture books were analyzed(Ekman.et.al., 2002; Masuda, Gosselin, & Nomura, 2018; Arterberry, Perry, Price &. Steimel, 2019; Gagnon, Gosselin, Buhs, Larocque **&** Milliard, 2009; Gagnon, Gosselin, & Maassarani, 2014; Guarnera, Hichy, Cascio, Carrubba, & Buccheri, 2017; Shu Zhang.et.al., 2021; WangLei, MengZhaolan,1986; Calder et al., 2003; Isaacowitz et al., 2007), and the AU used in the table are from images in the first 20 picture books, except for the six mentioned above, the rest are from: Sharing (Jokey Burkett, 2015), The Color Monster (Anna Yenas, 2016), Angry (Katelyn Dolto, 2010), Where the Wild Things Are (Maurice Sendak, 2010), Owen (Kevin Henkes, 2007), and Willy the Wizard (Anthony Brown, 2013). Except for ambiguous, animal and anthropomorphic expressions, the rest were classified according to emotional naming.According to Masuda, Gosselin, & Nomura (2018), Gagnona , Gosselin, & Maassarani (2014) facial unit segmentation method, and the combined form of AU in Table 2, all four emotions were divided into the upper and lower half of the face for AU analysis, and in the rightmost column of the table the part of the expression movement change was summarized (e.g., the corners of the mouth curved upward

when happy and the eyes do not change much), it is summarized that this emotion focuses on the lower half of the face. The following table shows:

Table 7 Analysis Table of AU Unit of Picture Books

Emotion	Upper face	Lower face	Comparison with matching table
Happy	   	   	①mainly in the lower face (mouth) ②Morphology: more variation in the corners of the mouth curved upward; or in a triangular shape wide open
Angry	    	    	① mainly in the upper face (eyebrows and eyes); frown; the lower face also has obvious unit morphological changes ③Morphology: eyebrows close to the eyes, inverted; mouth downward skewed and curved, or open in a square shape, or slightly clenched teeth
Sad	 	 No lower face	①Upper face (eye brow) ②Morphology: eyebrows change a lot, downward or upside down; mouth downward curved or not
Fear	 	 	①upper and lower face are important ②Morphology: eyes rounded, pupils constricted or wide; mouth pursed as a slit or open mouth

Note: These AUs are all from the images of expressions in the 10 published picture books, and we have segmented the complete faces

Based on the previously measured data, it was not colored and processed to remove variables such as background, pose, etc. This material processing method has

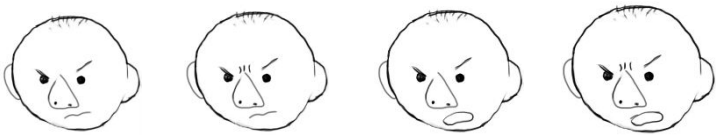
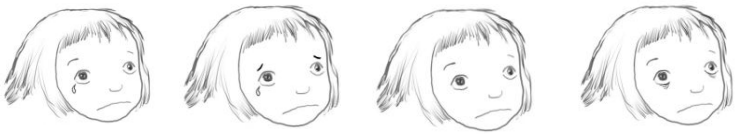
been employed and validated in the experiments of Zhao Lun, Zhao Kun, Liu Chang, and Chen (2006). The layers in the software were further used to reconstruct the basic expressions, removing redundant variables and retaining all organs of the original face, including the ears (if any), the basic form of hair, etc., which preserved more of the basic structure of the original image of the illustrated book than in (Zhao Lun, Zhao Kun, Liu Chang, and Chen, 2006), removing only the coloration and other minor variables. It is important to note that we did not include neutral expressions in the reconstruction, and according to the results of the experiment, the subjects recognized these expressions as the reconstructed basic images. We expect to examine the recognition of the categories and intensities of these new images constructed as basic images by children and adults. The following figure shows the example of "sad" (Figure 5) and the reconstruction process:

Figure 4 Image reconstruction process of "sadness"

The following four expressions are reconstructed, each based on a base expression reconstructed to form four consecutive images, with each reconstruction referring to changing or adding an facial unit or symbol.

Based on the intensity diffraction analysis of cartoon images by (Wang Rui, 2013), and the comparison between real-life and cartoon characters in the variable part of the face, this study changed each expression from the base expression to only one place per image. The drawing software "Paint World Pro" was used for reconstruction in the following table:

Table 8 Sixteen expressions after reconstruction

No.	Image
1	 Basic image
2	 Basic image
3	 Basic image
4	 Basic image

Note: Final completed expression reconstruction, the first one in each row is basic image

In summary, these images are basically consistent with the facial unit analysis in Table 7, and the upper and lower faces have been reconstructed in “joy”, “anger” and “fear” respectively while “Sadness” has not changed in the lower half of the face.

In addition, the intensity of image emotions, real-life facial expressions, intensity and intensity threshold delineation have been studied (Gao & Maurer, 2010; Garcia & Tully, 2020; Bayet, Behrendt, Cataldo, Westerlund and Nelson, 2018), and their delineation of these intensity thresholds except for neutral (5%) in addition to every 5 or 10 or 20 value-added, and their reliability was tested experimentally, but from the analysis of the intensity of real and cartoon expressions in the table above, it can be seen that cartoon images cannot be constructed with a greater density of continuous muscle changes. Thus, expression intensity is presented by upper and lower facial changes, and combined with the analysis in Table 9, the more combinations of

reconstructed images, based on the basic image, that fit a particular expression, the higher the intensity.

1. Study 2

3.1 Method

A total of 94 children aged 4-7 in a county kindergarten in Fuyang City, Anhui Province, of whom 30 were 4-5 years old, 33 were 5-6 years old, and 31 were 6-7 years old; some of those who dropped out were considered invalid questionnaires, and 62 questionnaires were actually valid. The average agein the three groups was 47.2 months for those aged 4-5, 58.4 months for those aged 5-6, and 71.8 months for those aged 6-7. All children participated voluntarily, had no language or intellectual disabilities, had normal motor development and vision (or corrected vision), and were given small gifts at the end of the experiment for praise.

3.1.1 Experimental process

Emotional storytelling introduction: a mood (emotional) picture book (excluding all picture books used in this study) was selected for the introductory session of the formal interview experiment, where Iordanou and Mattock (2022) compared emotions in photographs of real people in a study with those of the main character, Max, in Where the Wild Things Are (Sendak, 1963), and a picture book storyline was introduced to help the children to understand the emotions. The present experimenters simply trained the subject children to recognize emotions by displaying Max's image in black and white and removing the rest of the scenario to show that his different emotions consisted of (happy, angry, sad and scared). Based on recommendations from Hadwin, Cohen, Howlin, and Hill (1996); Timler, Ph.D (2003) for training schoolchildren in emotion understanding: (1) photographic facial expression recognition; (2) schematic facial expression recognition (i.e., black-and-white drawings of cartoon faces); (3) situational emotions; (4) desire-based emotions; (5) belief-based emotions, we proceeded on the second and third. Children could either respond to selected questions or dictate them to be recorded by the researcher.

3.1.2 Data analysis methods

Each of the three age stages of the children was analysed by ANOVA with each of the 16 expression images, i.e., the relationship between a categorical variable (a fixed category or ordinal variable) and a continuous variable, where each of the 16 expression images served as an independent dimension, and we analysed the relationship between the age of the children and their gender and these 16 dimensions primarily.

3.2Results

3.2.1 Distribution of children's emotions for images

Table 9. Adult expression image frequency table

Number and image	Emotions	Frequency	Percentage
	Very happy (5 points)	15	24.6
	Unhappy (2 points)	14	23
	Very unhappy (1 points)	0	0
	Very happy (5 points)	34	55.7
	Happy (4 points)	11	18
	Normal (3 points)	16	26.2
	Unhappy (2 points)	0	0
	Very unhappy (1 points)	0	0
	Very happy (5 points)	10	16.4
	Happy (4 points)	7	11.5
	Normal (3 points)	20	32.8
	Unhappy (2 points)	18	29.5
	Very unhappy (1 points)	6	9.8
	Very happy (5 points)	47	77.0
	Happy (4 points)	3	4.9
	Normal (3 points)	7	11.5
	Unhappy (2 points)	3	4.9
	Very unhappy (1 points)	1	1.6
	Very angry (5 points)	27	44.3
	Somewhat angry (4points)	12	19.7

	Normal (3 points)	14	23.0
	Not angry (2 points)	4	6.6
	Not angry at all (1 points)	4	6.6
	Very angry (5 points)	28	45.9
	Somewhat angry (4 points)	15	24.6
	Normal (3 points)	12	19.7
	Not angry (2 points)	5	8.2
	Not angry at all (1 points)	1	1.6
	Very angry (5 points)	6	9.8
	Somewhat angry (4 points)	2	3.3
	Normal (3 points)	21	34.4
	Not angry (2 points)	22	36.1
	Not angry at all (1 points)	10	16.4
	Very angry (5 points)	13	21.3
	Somewhat angry (4 points)	13	21.3
	Normal (3 points)	22	36.1
	Not angry (2 points)	8	13.1
	Not angry at all (1 points)	5	8.2
	Very sad (5 points)	20	32.8
	Somewhat sad (4 points)	14	23.0
	Normal (3 points)	17	27.0
	Not sad (2 points)	5	8.2
	Not sad at all (1 points)	5	8.2
	Very sad (5 points)	32	52.5
	Somewhat sad (4 points)	12	19.7
	Normal (3 points)	9	14.8
	Not sad (2 points)	7	11.5
	Not sad at all (1 points)	1	1.6

	Very sad (5 points)	8	13.1
	Somewhat sad (4 points)	4	6.6
	Normal (3 points)	9	14.8
	Not sad (2 points)	17	27.9
	Not sad at all (1 points)	23	37.7
	Very sad (5 points)	6	9.8
	Somewhat sad (4 points)	7	11.5
	Normal (3 points)	19	31.1
	Not sad (2 points)	14	23.0
	Not sad at all (1 points)	15	24.6
	Very fear (5 points)	21	34.4
	Somewhat fear (4 points)	12	19.7
	Normal (3 points)	13	21.3
	Not fear (2 points)	6	9.8
	Not fear at all (1 points)	9	14.8
	Very fear (5 points)	3	4.9
	Somewhat fear (4 points)	2	3.3
	Normal (3 points)	12	19.7
	Not fear (2 points)	16	26.2
	Not fear at all (1 points)	28	45.9
	Very fear (5 points)	37	60.7
	Somewhat fear (4 points)	12	19.7
	Normal (3 points)	6	9.8
	Not fear (2 points)	4	6.6
	Not fear at all (1 points)	2	3.3
	Very fear (5 points)	46	75.4

Somewhat fear (4 points)	3	4.9
Normal (3 points)	4	6.6
Not fear (2 points)	4	6.6
Not fear at all (1 points)	4	6.6

As can be seen, in the children's cognitive recognition results, age has a greater impact on negative emotions, significant differences are presented in “sad” and “fear”, and these expressions are medium intensity. In  ,  and  , very fear accounted for the highest percentage in 34.0%, 60.7% and 75.4%. It can be seen that except  , the intensity gradient of emotion cognition has been generated while Not fear at all accounts for the most. It can be concluded that: the perception of happiness is equally important in the upper and lower face, and the lower face and mouth are important for intensity perception; anger is more important in the upper face, especially the change of eyebrow contour and features has a greater impact on the recognition of the intensity of anger; Eyebrows are the main cognitive and intensity influences of sadness, which is its typical feature variation, while tears and eye shadows do not affect it much; As for fear, the upper and lower face influences predominate, with pupil morphology having a greater impact on its intensity perception, and mouth features as above.

3.3.2 Relationship between different background variables and image emotions

- Sad Image Emotion

According to the ANOVA test (e.g., Table 76), there was a significant difference between children's age and sad image emotions, and Scheffe’s post-hoc analysis

found that children aged 5-6 had significantly higher sadness perceptions (M=4.09, SD=1.24) than children aged 6-7 (M=3.05, SD=1.13)to  .

Table 10 Summary table of children's age and sad image emotion F test

	Age	Number	*M*	*SD*	*F* value	*p*	Post hoc comparison
	4-5	16	3.81	1.17	4.587	.014*	2>3
	5-6	23	4.09	1.24			
	6-7	22	3.05	1.13			
	4-5	16	4.38	1.03	.670	.515	Not significant
	5-6	23	3.96	1.15			
	6-7	22	4.05	1.21			
	4-5	16	2.81	1.87	2.619	.081	Not significant
	5-6	23	2.39	1.23			
	6-7	22	1.82	.96			
	4-5	16	2.81	1.60			
	5-6	23	2.61	1.03			
	6-7	22	2.41	1.22			
Overall sadness Image emotions	4-5	16		1.11	3.470	.038*	Not significant
	5-6	23	3.26 09	.67			
	6-7	22	2.82 95	.51			

Note：1=4-5 岁；2=5-6 岁；3=6-7 岁*p<.05.

• Fear of image emotions

According to the ANOVA test (e.g., Table 77), there was a significant difference between children's age and fear of image emotions, and Scheffe's post-hoc analysis found that children aged 4-5 feared  significantly higher (M=3.88, SD=1.20) than children aged 6-7 (M=2.64, SD=1.40); and children aged 5-6 feared  significantly higher (M=4.04, SD=1.26)than that of children aged 6-7 (M=2.64, SD=1.40).

Table11. Summary table of children's age and sad image emotion F test

	Age	Number	*M*	*SD*	*F* value	*p*	Post hoc comparison
13. 	4-5	16	3.88	1.20	7.546**	.001	1>3
	5-6	23	4.04	1.26			2>3
	6-7	22	2.64	1.40			
14. 	4-5	16	2.25	1.34	3.708*	.031	Not significant
	5-6	23	2.22	1.17			
	6-7	22	1.45	.67			
15. 	4-5	16	4.38	1.14	.176	.839	Not significant
	5-6	23	4.17	1.30			
	6-7	22	4.32	.84			
16. 	4-5	16	4.50	1.16	.409	.667	Not significant
	5-6	23	4.17	1.44			
	6-7	22	4.45	1.14			
Overall sadness Image emotions	4-5	16	3.75	.65	3.070	.054	Not significant
	5-6	23	3.65	.84			
	6-7	22	3.22	.66			

Note: 1=4-5 years old；2=5-6 years old；3=6-7 years old

*p<.05. **p<.01.

In summary, age has a greater effect on negative emotions in children's cognitive recognition results, and significant differences were found in moderately intense “sad” and “fear”, suggesting that there are cognitive differences in pupil shrinkage and eyebrow changes in these AUs for children, while subtle treatments such as tears and lower eyelid shadows do not have significant cognitive differences for children, but a direct linear relationship between age and facial recognition differences cannot be shown. Children aged 5-6 feel anger and sadness more strongly than those aged 6-7,

as for fear and sadness, children aged 4-5and5-6feel it more strongly than those aged 6-7.

4. Discussion

The inference from the children's questionnaire results that recognition peaks around the age of 5 years is consistent with the findings of previous real-life facial expression research. Whereas age of children made a significant difference for negative expressions rather than positive ones (e.g., happiness). Few studies presented attributions for children's recognition of negative intensity emotions, such as Gao and Maurer (2010); Choudhury, Blakemore, and Charman (2006); and Barisnikov et.al. (2021), who suggested that exposure to multidimensional happy expressions in the environment is accountable for children's stable recognition of happy emotions, whereas adults' high recognition of negative emotion intensity thresholds may be due to their ability to search for other (additional) cues, which children lack. In addition, neglectful parenting also interferes with children's expression recognition. Finally, in addition to the environment, improved cognitive skills, such as perspective taking whichalso helps children to decipher the meaning of subtle facial expressions. Thus, children's age remains an important factor in cartoon expression recognition (rather than gender).

On the other hand, in terms of added emoticons, the visual perceptual tools on which subtle changes in the face are based develop longitudinally, separate from the emotion recognition and labeling processes, and that different neural networks are more adept at recognizing more complex emotional cues compared to changes in emotional categories that are responsive to the intensity of the emotion, and that gradually mature with age (Barisnikov et.al.,2021). In the present study, there was no significant difference in the recognition of subtle symbols among the three ages, somehow indicating that the peak of the 5-year-olds did not include subtle emoticons in the above cognition. Experiments with a wider range of ages need to be performed in order to discover the cognitive age peaks and variability of subtle emoticons in picture books or other cartoon images. This will provide a theoretical basis for the study of children's picture books and complex emotional images (incorporating color, gesture, etc.).

As older children (6-7 years old) develop fluid intelligence, the error rate of facial unit recognition gradually decreases, and then they acquire larger categories of

emotions as they grow (Widen, 2013), such as clearly recognizing complex emotions such as surprise, disgust, and fear, etc. Therefore, it is possible that the higher perception of "sadness" and "fear" among younger children in the present study stems from a weak ability to recognize discrete categories of emotions, especially negative emotions (Vicari.et.al., 2000; Widen, 2013; Massarani.et.al., 2011), possibly accompanied by problem of expression intensity, whereas older children may have greater expression intensity thresholds for the perception of both expressions (Markham & Adams, 1992; Gao, 2010). However, these could not be directly demonstrated in the present study, and more precise construction of AU intensity thresholds for cartoon expressions (e.g., angry mouth changes, etc.) is needed.

Finally, the differences in children's perceptions of fear and sadness are indicative of the instability of feelings about them. Thus other aspects could be incorporated by future research (e.g., emotional interventions, children's beliefs, aspirations, family upbringing, etc.) (), such as cross-sectional, studies on the relationship between cognition and social competence for cartoon expressions, which has been the focus of real-life expression recognition in recent years (Eisenberg, et al., 2011; Crivelli and Fridlund, 2018 ; Barisnikov ,Thomasson , Stutzmann & Lejeune, 2021; Garcia & Tully, 2020;), and research focusing on cartoon images, which is also crucial.

5 Conclusions

To the best of our knowledge, we are the first to specifically study the expressions of illustrated cartoon characters and the first to use AU as a tool for reconstructing images. The conclusions of this study are as follows:

1. The four cartoon expressions in the picture book were reconstructed while incorporating emoticons, which can be included in future experiments on the cognition of cartoon expressions in children or adults, as well as verifying the role of these emoticons on overall recognition.

2. In the reconstructed expressions we delineated the intensity of flat cartoon expressions in picture books, which is a new attempt.

3. In a study of children aged 4-7, it was found that, as in the case of real-life expression recognition, they valued the recognition of fearfulness from the mouth and eyes, and that in the lower face, the exaggeration of the mouth played a significant role. “Chuan” lines, eye shadows and tears were less helpful in recognizing facial

expressions, whereas eyebrow and pupil changes strongly influenced their recognition of “sadness” and “anger”.

An important implication of this study is to investigate cartoon expressions in children's books, which can also be targeted at co-reading adults in the future for their educational value. In addition, expression intensity recognition has been gradually emphasized in recent years (Durbin, Rastegar & Knight, 2020;), and we made this attempt in cartoon images to provide some theoretical support for future research on intelligent recognition and art.

References

1. *Yu, X. 2009. “Levels of Meaning and Children: An Exploratory Study of Picture Books’ Illustrations.” Library and Information Science Research 31: 240–246.*
2. *Garner, P.W. 2010. “Emotional Competence and its Inflfluences on Teaching and Learning.” Educational Psychology Review22 (3): 297–321.*
3. *Iordanou, C., & Mattock, K. (2021). Where the Wild Things Are: understanding of emotions in a picture book. Education 3-13, 50(5), 627-639.*
4. *Herba, C.M.; Landau, S.; Russell, T.; Ecker, C.; Phillips, M.L. (2006). The development of emotion-processing in children: effects of age, emotion, and intensity. J Child Psychol Psychiatry, 47(11), 1098-1106.*
5. *Fujiwara, T., Koshimizu, H., Fujimura, K., Fujita, G., Noguchi, Y., and Ishikawa, N. (2002). “A method for 3D face modeling and caricatured figure generation,” in Proceedings of the IEEE International Conference on Multimedia and Expo, (Lausanne: IEEE), 137–140.*
6. *Breazeal, C. (2003). Emotion and sociable humanoid robots. Int. J. Hum. Comput. Stud. 59, 119–155.*
7. *Zaharia, T., Marre, O., Prêteux, F., and Monjaux, P. (2008). “FaceTOON: a unified platform for feature-based cartoon expression generation,” in Proceedings of the Three-Dimensional Image Capture and Applications 2008, (San Jose, CA: International Society for Optics and Photonics), 68050S.*
8. *Sybil Geldart, Daphne Maurer, Katherine Carney. Effects of eye size on adults' aesthetic ratings of facesand 5-month-olds' looking times. Perception.*
9. *Zhao Lun,Zhao Kun,Liu Chang& Andrew CN Chen.(2006).EPP: A Late Positive Component of ERPs Associated with Expression Feature Processing. Aerospace Medicine and Medical Engineering (01), 37-40.*
10. *YangYuankui, WangCai and ZhouJianzhong (2005). ERP Research on Cartoon Face Recognition and Expression Feature Analysis. The 10th National Psychology Conference. Shanghai, China.*
11. *Masuda, M., Gosselin, P., & Nomura, M. (2018). Japanese Children’s Knowledge of the Facial Components of Basic Emotions. Journal of Nonverbal Behavior, 42(2), 253-266.*

12. *Ekman, P., Friesen, W. V., & Hager, J. C. (2002). The facial action coding system CD-ROM. Salt Lake City, UT: Research Nexus.*
13. *Wang, Rui (2013).An Eye-movement Study of Facial Expression Recognition in Children Aged 4-6. Shaanxi Model University.*
14. *Shu Zhang, Xinge Liu, Xuan Yang, Yezhi Shu, Niqi Liu, Dan Zhang&Yong-Jin Liu.The Influence of Key Facial Features on Recognition of Emotion in Cartoon.Faces.Emotion Science.*
15. *Gagnon, M., Gosselin, P., & Maassarani, R. (2014). Children's ability to recognize emotions from partial and complete facial expressions. J Genet Psychol, 175(5-6), 416-430.*
16. *Guarnera, M., Hichy, Z., Cascio, M., Carrubba, S., & Buccheri, S. L. (2017). Facial Expressions and the Ability to Recognize Emotions from the Eyes or Mouth: A Comparison Between Children and Adults. J Genet Psychol, 178(6), 309-318.*
17. *Martha E. Arterberry, Elizabeth T. Perry, Cameron M. Price & Sarah A. Steimel (2019).Emotional understanding predicts facial recognition in 3-to 5-year-old children.European Journal ofDevelopmental Psychology.*
18. *Tulving, E. 2002. "Episodic Memory: From Mind to Brain." Annual Review of Psychology 53: 1–25.*
19. *Widen, S.C., and J.A. Russell. 2003. "A Closer Look at Preschoolers' Freely Produced Labels for Facial Expressions."Developmental Psychology 39: 114–128.*
20. *Gagnon, M., Gosselin, P., Hudon-ven der Buhs, I., Larocque, K., & Milliard, K. (2009). Children's Recognition and Discrimination of Fear and Disgust Facial Expressions. Journal of Nonverbal Behavior, 34(1), 27-42.*
21. *Wang Lei, Meng Zhaolan. (1986). A Preliminary Discussion of Adult Facial Expressions and Judgment, Journal of Psychology, Vol. 4*
22. *Calder, A. J., Keane, J., Manly, T., Sprengelmeyer, R., Scott, S., Nimmo-Smith, I., & Young, A. W. (2003). Facial expression recognition across the adult life span. Neuropsychologia, 41(2), 195–202.*
23. *Isaacowitz, D. M., Lockenhoff, C. E., Lane, R. D., Wright, R., Sechrest, L., Riedel, R., & Costa, P. T. (2007). Age differences in recognition of emotion in lexical stimuli and facial expressions. Psychology and Aging, 22(1), 147–159.*
24. *Yan Xiulin (2020). The Effect of Face Abstraction on the Processing of Emotional Faces in Children with Autism. Zhejiang Normal University.*
25. *Svegar, D., Fiamengo, N., Grundler, M., & Kardum, I. (2018). The effects of facial expressions and tears on the speed of sex recognition. Int J Psychol, 53(1), 49-57.*
26. *Oleszkiewicz, A., Frackowiak, T., Sorokowska, A., & Sorokowski, P. (2017). Children can accurately recognize facial emotions from emoticons.Computersin Human Behavior,76,372-377.*
27. *Kun-An Hsiao and Pei-Ling Hsieh (2014). Age Difference in Recognition of Emoticons.Springer International Publishing Switzerland, 394–403, 2014.*
28. *Gao, X., & Maurer, D. (2010). A happy story: Developmental changes in children's sensitivity to facial expressions of varying intensities. J Exp Child Psychol, 107(2), 67-86.*
29. *Garcia, S. E., & Tully, E. C. (2020). Children's recognition of happy, sad, and angry facial expressions across emotive intensities. J Exp Child Psychol, 197, 104881.*

30. *Bayet, L., Behrendt, H. F., Cataldo, J. K., Westerlund, A., & Nelson, C. A. (2018). Recognition of facial emotions of varying intensities by three-year-olds. Dev Psychol, 54(12), 2240-2247.*
31. *Choudhury, S., Blakemore, S. J., & Charman, T. (2006). Social cognitive development during adolescence. Social Cognitive and Affective Neuroscience, 1, 165–174.*
32. *Barisnikov, K.; Thomasson, M.; Stutzmann, J.; Lejeune, F. (2021). Sensitivity to Emotion Intensity and Recognition of Emotion Expression in Neurotypical Children. Children (Basel), 8(12).*
33. *Widen, S. C. (2013). Children's Interpretation of Facial Expressions: The Long Path from Valence-Based to Specific Discrete Categories. Emotion Review, 5(1), 72-77.*
34. *Vicari, S., Reilly, J. S., Pasqualetti, P., Vizzotto, A., & Caltagirone, C. (2000). Recognition of facial expression of emotions in school-age children: The intersection of perceptual and semantic categories. Acta Paediatrica, 89, 836–845.*
35. *Massarani, R., Gosselin, P., Montembeault, P., Gagnon, M., & Suurland, A. (2011, March). French-speaking children's freely produced labels for facial expressions. Poster presented at SRCD Conference, Montreal, Canada.*
36. *Gao, X., & Maurer, D. (2009). Influence of intensity on children's sensitivity to happy, sad, and fearful facial expressions. Journal of Experimental Child Psychology, 102, 503–521.*
37. *Widen, S. C., & Russell, J. A. (2010b). Children's scripts for social emotions: Causes and consequences are more central than are facial expressions. British Journal of Developmental Psychology, 28, 565–581.*
38. *Widen, S. C., & Russell, J. A. (2010a). Differentiation in preschooler's categories for emotion. Emotion, 10, 651–661.*
39. *Eisenberg, N., Eggum, N. D., & Di Giunta, L. (2010). Empathy-related responding: Associations with prosocial behavior, aggression, and intergroup relations. Social Issues and Policy Review, 4, 143–180.*
40. *Crivelli, C., & Fridlund, A. J. (2018). Facial displays are tools for social inflfluence. Trends in Cognitive Sciences, 22, 388–399.*
41. *Bayet, L.; Behrendt, H.F.; Cataldo, J.K.; Westerlund, A.; Nelson, C.A. (2018). Recognition of facial emotions of varying intensities by three-year-olds. Dev Psychol, 54(12), 2240-2247.*
42. *Durbin, K. A., Rastegar, S., & Knight, B. G. (2020). Effects of age and mood on emotional face processing differ depending on the intensity of the facial expression. Neuropsychol Dev Cogn B Aging Neuropsychol Cogn, 27(6), 902-917.*
43. *Mienaltowski A, Lemerise EA, Greer K, & Burke L (2019). Age-related differences in emotion matching are limited to low intensity expressions. Aging, Neuropsychology, and Cognition, 26(3), 348–366.*