114

ORIGINAL

Developmental changes in facial expression recognition in Japanese school-age children

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Abstract : Purpose : Facial expressions hold abundant information and play a central part in communication. In daily life, we must construct amicable interpersonal relationships by communicating through verbal and nonverbal behaviors. While school-age is a period of rapid social growth, few studies exist that study developmental changes in facial expression recognition during this age. This study investigated developmental changes in facial expression recognition by examining observers' gaze on others' expressions. Subjects : 87 school-age children from first to sixth grade (41 boys, 46 girls). Method : The Tobii T60 Eye-tracker(Tobii Technologies, Sweden) was used to gauge eye movement during a task of matching pre-instructed emotion words and facial expressions images (neutral, angry, happy, surprised, sad, disgusted) presented on a monitor fixed at a distance of 50 cm. Results : In the task of matching the six facial expression images and emotion words, the mid- and higher-grade children answered more accurately than the lower-grade children in matching four expressions, excluding neutral and happy. For fixation time and fixation count, the lower-grade children scored lower than other grade children, gazing on all facial expressions significantly fewer times and for shorter periods. Conclusion : It is guessed that the stage from lower grades to middle grades is a turning point in facial recognition. J. Med. Invest. 60 : 114-120, February, 2013

Keywords : school-age children, facial expression recognition, eye-track

INTRODUCTION

With maturity, people become capable of distinguishing familiar faces from thousands of unfamiliar faces within a second, even when seen from different angles or with changes in light, emotion, or hair style. People continue to memorize new faces throughout their lifetime, as long as they maintain a social life. People also guess others' age and gender from their faces and speculate about their emotions and psychological state by reading their facial expressions. This enables people to communicate both verbally and non-verbally in order to construct amicable interpersonal relationships in daily lives. Within

nonverbal behaviors, facial expressions contain the most information, and it would not be an overstatement to say that it plays a central part in communication.

Recognizing emotional facial expressions is a crucial factor in communication, and although this ability develops throughout childhood, the development is not continuous (1, 2). Kolb *et al.* (3) reported that recognition accuracy develops dramatically between six to eight years of age and then gradually matures to the adult level at approximately 14 years. Contrary to these findings, one study reported low emotion recognition ability in adolescents than in adults (4). Gao *et al.* (5) investigated expressions with low emotional levels and concluded that recognition of ambiguous expressions develops slowly. Other studies reported that while facial expression recognition accuracy increases with age, it may vary between expressions.

As observed above, the ability to recognize facial expressions is believed to develop during school age. These results are understandable since school age is a period of transition from a mother- or family-centered life to an external social life with children of the same age. However, very little developmental research exists on school-age children's emotional expression recognition in Japan. The present study investigates the developmental changes of exploratory behavior of the eye while recognizing emotional expressions in school-age children in Japan.

SUBJECTS AND METHOD

A total of 106 children attending elementary school participated in this study. Data of 87 children (41 boys, 46 girls) that provided data for all 12 expressions were used for analysis. Prior to the study, the participants' guardians were informed of the study's purpose and given an overview in writing through the school's principal, and they consented to participation via a consent form. Before beginning the task, the children were given instructions and told that participation was voluntary and they could discontinue at their own will at any time. The children gave oral consent. The breakdown of their grades is shown in Table 1.

A total of 12 images from JACFEE and JACNeuF (6) were used as expression stimuli for this study. They consisted of two images each for the following six expressions : angry, happy, sad, surprised, disgusted, and neutral. The Tobii T60 Eye-tracker (Tobii Technologies, Sweden) was used to measure eye movement. The 17-inch LCD-type eye camera does not require direct contact on the head nor bodily restraint during calibration and measurement, thereby allowing measurement in a natural condition.

Distance between participants' seats and the display was fixed at 50 cm. Prior to displaying the images, participants were given verbal instructions : "People's faces will appear on the screen. Please answer whether each is a happy face, normal face, angry face, sad face, surprised face, or a disgusted face." The instructions were followed by calibrations at five points on the screen. The instruction was repeated by a display on the screen saying, "People's faces will appear on the screen. Please answer whether each is a happy face, normal face, angry face, sad face, surprised face, or a disgusted face," which was read out loud by the examiner, who requested verbal response. After confirming that each participant understood the task, the examiner began the measurement. Each expression image was displayed for five seconds.

Grades were divided into three groups for comparison : grades 1 and 2 (lower grade), grades 3 and 4 (middle grade), and grades 5 and 6 (higher grade). To analyze the points of gaze, the images presented were divided into seven features-eyes, nose, mouth and facial others (forehead, cheeks, chin), hair, body, neck-and the background. These features were used to examine the fixation gaze count and fixation gaze time for each feature with an Area of Interest (AOI) analysis tool in Tobii Studio Ver 1.5.12. The fixation point was set between saccades with 35 pixels as the threshold.

Table 1.   Age demographics

Grades	first	second	third	fourth	fifth	sixth
	n=11(m : f=3 : 8)	n=11(m : f=4 : 7)	n=18(m : f=8 : 10)	n=16(m : f=6 : 10)	n=15(m : f=9 : 6)	n=16(m : f=11 : 5)
range	6y7m~ 7y7m	7y9m~ 8y6m	8y8m~ 9y9m	9y9m~ 10y6m	10y9m~ 11y8m	11y9m~ 12y6m
average	(84.7m± 3.3)	(98.8m± 3.4)	(111.3m± 4.2)	(122.3m± 2.6)	(133.2m± 3.8)	(145.4m± 3.0)

RESULTS

To examine the relationship between grades and accuracy of expression recognition, an X^2 test for independence was conducted (Table 2). All grades scored high accuracy with neutral and happy faces, resulting in no significant difference among grades. For other expressions, the lower grades scored lower than the middle and higher grades (angry : lower grade < higher grade, $p < .01$; sad : lower grade < middle grade, higher grade, $p < .05$; disgusted : lower grade < middle grade, $p < .01$; surprised : lower grade < middle grade, higher grade, $p < .01$). Between the middle and higher grades, the higher grades were significantly more accurate in recognizing angry faces.

Furthermore, in a within-group comparison, all groups scored lower in recognizing disgusted and sad faces, whereas accuracy was above 90% for recognizing neutral, happy, and surprised faces. The accuracy for angry faces was above 90% for the higher grades but was at 70% for the lower and middle grades.

We compared the fixation time and fixation count of each 6 expression (ANOVA). From multiple comparisons, no significant differences were found for angry and happy expressions, but for the other four expressions, the lower-grade children gazed at the faces for a shorter period than did the middle- and higher-grade children (Table 3). And the lower-grade children had a lower fixation count for all expressions (Table 4).

The ANOVA between grades for each expression was conducted using the percentage of fixation time and count on the inner area of the face (inner : eye, nose, mouth as %inner) and eyes (as %eye) separately from the fixation time and count on the entire face. As a result, a significant difference (F=4.211 $p < .05$) was found for happy faces between the lower grade and middle grade for %inner fixation time. No significant difference was found for %inner count, %eye time, %eye count (Table 5, 6).

Fixation time was divided by fixation count to determine the individual fixation time, which was compared of each expression. A multiple comparison was therefore conducted, revealing significant differences for two expressions : disgust between lower and higher grades (F=3.153 $p < .05$) and anger between lower grades and middle and higher grades (F=3.81 $p < .05$). Overall, lower grades had a longer individual fixation time than did middle and higher grades (Table 7).

Table 2.   Recognition accuracy by expressions

	neutral	angry		sad		happy	disgust		surprise		
lower grade	0.932	0.727		0.409		0.955	0.068		0.818		
middle grade	1.00	0.779	**	0.603	*	1.00	0.265	**	1.00		**
higher grade	1.00	0.919	**	0.629	*	1.00	0.194		0.985	**	

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

Table 3.   Gaze Fixation time of Face

	neutral	surprise	sad	happy	disgust	anger
lower grade	3.65± 1.09	3.47± 1.01	3.62± 1.08	3.53± 1.18	3.54± 1.15	3.79± 0.94
middle grade	4.12± 0.59 **	4.01± 0.79 *	4.07± 0.71 *	3.59± 0.97	3.93± 0.79 *	4.16± 0.65
higher grade	4.05± 0.66 **	3.80± 0.91	4.05± 0.78 *	3.68± 1.01	4.00± 0.89	4.09± 0.90

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

Table 4.   Gaze Fixation count of Face

	neutral	surprise	sad	happy	disgust	anger
lower grade	8.75± 2.74	8.80± 2.16	9.18± 2.53	8.20± 2.69	8.32± 2.14	8.80± 2.58
middle grade	11.24± 3.06 ** **	11.10± 2.92 **	11.56± 2.93 **	9.90± 3.52 ** *	10.60± 3.19 ** **	11.31± 2.84 ** **
higher grade	11.34± 3.43	10.76± 3.06	11.82± 3.10	10.47± 3.21	11.48± 3.30	11.35± 3.30

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

Table 5.   %Gaze fixation time

%	neutral	surprise	sad	happy	disgust	anger
lower grade						
inner	75.8± 22.1	77.2± 21.6	84.8± 15.8	76.4± 22.4	77.3± 22.0	71.9± 20.6
eye	39.0± 25.9	46.5± 27.7	61.2± 30.1	35.0± 28.5	38.9± 28.7	42.5± 26.2
middle grade						
inner	75.5± 19.1	78.0± 19.8	84.9± 14.7	85.5± 13.0	84.1± 14.0	73.6± 20.6
eye	36.7± 30.7	48.4± 26.6	55.1± 27.6	39.4± 27.1	38.8± 30.0	38.8± 29.3
higher grade						
inner	78.6± .15.1	81.5± 16.9	80.9± 16.4	83.4± 15.1	77.0± 17.8	72.7± 16.1
eye	43.3± 31.1	48.2± 29.2	53.8± 29.1	45.5± 28.2	42.1± 33.2	39.5± 28.9

* : p< .05

Table 6.   %Gaze fixation count

%	neutral	surprise	sad	happy	disgust	anger
lower grade						
inner	73.8± 19.9	76.0± 18.6	80.3± 13.8	76.6± 18.2	75.0± 18.3	72.9± 17.5
eye	37.4± 22.4	44.2± 24.7	51.9± 25.0	36.5± 24.8	36.2± 24.6	41.2± 21.9
middle grade						
inner	73.8± 15.6	79.2± 16.2	83.5± 15.2	83.8± 17.1	81.7± 13.4	72.1± 16.2
eye	32.2± 24.3	45.4± 23.7	46.5± 24.2	39.2± 23.9	37.2± 27.3	37.1± 24.3
higher grade						
inner	74.1± .15.8	78.6± 15.7	80.1± 15.1	81.1± 15.0	78.5± 14.1	71.1± 14.1
eye	38.7± 27.2	45.0± 26.3	47.6± 27.7	43.6± 23.6	41.6± 29.2	38.4± 25.2

Table 7.   Individual Fixation time of Face

	neutral	surprise	sad	happy	disgust	anger
lower grade	0.45± 0.21	0.40± 0.12	0.41± 0.12	0.47± 0.33	0.44± 0.18	0.46± 0.16
middle grade	0.40± 0.14	0.38± 0.12	0.38± 0.12	0.39± 0.12	0.40± 0.13	0.39± 0.12
higher grade	0.39± 0.18	0.37± 0.10	0.37± 0.18	0.38± 0.17	0.37± 0.13	0.39± 0.16

* : p< .05

DISCUSSION

In this study, accuracy for disgust and sadness were significantly lower than for other expressions, followed by angry. However, the difference was not significant. In labeling task, accuracy of child for disgust is low and they cannot easily recognize disgusted and angry faces (7-9). This was congruent with the results of this study, with almost 80% answering angry for disgusted. Russell *et al.* (10) asked participants to identify similarities of displayed expressions and found that the expressions were laid out on a two-dimensional circle in the following order : happy, bored, sad, disgusted, angry, fearful,

surprised, and then happy. Similar expressions may be easily mistaken for each other. Approximately 23% of sad faces were mistaken for disgusted and approximately 5.7% for angry, which interestingly concurred with Russell *et al.*'s sequence. Hoshino (11) used sketches of expressions to examine the understanding of emotional meaning recognition and reported that the ability to decipher expressions significantly increases with age, and this ability does not increase linearly but exhibits a sharp increase in childhood and a gradual increase afterward, although this varies slightly among expressions. Although this study used photographic images and not sketches of expressions,

four expressions-anger, sadness, disgust, and surprise-were less accurately recognized by lower grades than others, and while 100% of middle- and higher-grade children could recognize happy and neutral faces, some lower-grade children made mistakes. This result may indicate a boundary in emotional understanding of expression images at approximately eight to nine years of age. School age is a period when social life expands from being with mothers and families to being with friends and teachers. First and second grade in elementary school comprise a period of dramatic social change and may also stimulate the learning process of socially recognizing expressions.

Eye contact has traditionally been considered a vital element of communication, and many researchers studying facial expressions have reported that healthy subjects use the eyes as a source of information for facial recognition and interpretation. For example, Joseph *et al.* (12) reported that, to interpret faces, healthy children and adults rely more on information retrieved from the eyes than on that from the nose and mouth. Additionally, a study on healthy adults found that approximately 70% of gazes were fixated on the center features of the face : the eyes, nose, and mouth (13). Baron-Cohen *et al.* (14) found eyes to be as a vital a source of information as the entire face for interpreting not only basic expressions such as happy, sad, and angry but also complicated expressions showing scheming, admiration, and interest. For subjects with autism who are known to have difficulty interpreting emotion, certain studies have reported that these subjects fix their gaze more on the mouth and nose than on the eyes (14), whereas Snow *et al.* (15) reported more fixation on the eyes than on the mouth, as in healthy persons. We found a surprisingly high fixation time and fixation count of 70-85% on basic facial features such as eyes, nose, and mouth, with significant difference among expressions but not among ages. It can be noted from these results that children aged six to seven primarily use basic facial features to interpret expressions as did adults (13). Reviewing the fixation rate on individual features, the difference among ages for the fixation on eyes and on nose/mouth was not significant. Although traditional research has compared eye and mouth fixation, Nomura *et al.* (16) concluded that the shape of the mouth may be perceived with peripheral vision with low frequency but peripheral perception of the eye area is difficult, thus creating two groups : (1) eyes and (2) nose/

mouth. Between expressions, the results were consistent with Eisenbarth *et al.*'s study (17), with the eyes being superior in interpreting sad and angry faces, and the nose/mouth superior in interpreting happy faces. No difference was found between eyes and nose/mouth in interpreting neutral faces. The fixation rate on the eyes was high in interpreting sad faces, which had low recognition accuracy after disgusted faces. As Baron-Cohen *et al.* (14) reported, the eyes were more vital a source of information for more ambiguous expressions. It can be suggested that difficult-to-interpret expressions attracted greater gaze on the eyes.

Next, the differences in fixation times for the four expressions other than angry and happy, and in fixation count for all six expressions were significant between lower grades and middle and higher grades. The difference between middle grades and higher grades was not significant. Additionally, expressions with significant differences in individual fixation time (fixation time divided by fixation count) were disgust and anger, but individual fixation time was longer overall for lower grades than for middle and higher grades. Baudoulh *et al.* (18) reported that during elementary school, clues for face interpretation shifted from the shape of face and features to second-order facial relations (positions on the face such as right eye and left eye, eyes and nose, eyes and mouth) with age, and the ability to recognize faces improved. Mondloch *et al.* (19) also found that children begin to use second-order relations as they get older. Additionally, Campbell *et al.* (20) concluded that the facial recognition pattern shifts from the outer shape, such as facial shape, to inner-facial relations at the age of nine years. In contrast, Ge *et al.* (21) claimed that this shift from facial shape to inner relations happens as a result of experience rather than age. Middle and higher grades had a significantly higher fixation count than lower grades had, and they tended to have shorter individual fixation times. Furthermore, no difference was found in fixation rate on the eyes and nose/mouth between grades. Therefore, children in third grade or higher may have fixated on each feature for a short duration but greater number of times to improve accuracy in facial recognition without regard to inner or "other" features (such as chin and forehead). Elementary school age is a period when social life expands from being with mothers and families to friends, teachers, and adults in the community. During this time, children build relationships with

strangers for the first time, and the ability to read emotions from other people's faces becomes an increasingly vital skill as they age. As there have been reports of vocabulary skill for facial recognition (23), various factors must be intertwined. The results of this study-differences in the accuracy in matching facial images and emotion words, and in count, duration, and individual fixation time between first/second graders and third graders and above-cannot speculate on whether these differences are due to age or experience ; however it is guessed that the stage from lower grades to middle grades is a turning point in facial recognition.

CONFLICT OF INTEREST

The authors have no conflict of interest associated with the present study.

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