Taste development in Chinese newborns

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Background: **Baby facial action coding system (FACS) is a standard instrument created by Oster and Rosenstein. Many researchers used it to study the taste development in infants of different countries. This study was undertaken to investigate the facial responses of newborns to four basic tastes as well as the gender-related taste sensitivity.**

Methods: **Sixty-two newborns (31 females and 31 males) were tested at 90 minutes after birth in response to four tastes including 25% sucrose (sweet), 5% sodium chloride (salt), 1.43% citric acid (sour), and 0.025% berberine (bitter). The mothers of the newborns had normal pregnancy and spontaneous delivery. The newborns were full-term with Apgar scores ≥8 at 1 and 5 minutes. The facial responses to the four tastes were classified into nine facial action units and expressions from A1 to C3, which also represented as the 1-9 grades of intensity. Cry was defined as intensity of grade 9 and nausea as grade 10. The expressions of the newborns were recorded by video. The chi-square test and the Wilcoxon's rank-sum test were used for statistical analyses.**

Results: **Most of the newborns showed absence of mouth action or sucking while the sucrose solution was given (P<0.01). No special expressions were seen when the salt solution was fed (P>0.01). The lip pursing with brow and middle face actions was a major response to the sour solution (citric acid) (P<0.01). The expressions responding to the bitter solution were mouth gaping with brow and middle face actions (P<0.01). Male newborns were more sensitive to the sweet and bitter solutions than female ones (P<0.01). There were no sex differences in the intensities of facial responses to the salt and sour solutions (P>0.05).**

Conclusions: **Newborns can present distinct responses to the four basic tastes (sweet, salt, sour, and bitter). Male newborns are more sensitive to sweet and bitter solutions than female newborns.**

World J Pediatr 2007;3(3):203-208

Key words: **neonates; taste; development**

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Introduction

In the past decades, a series of experiments demonstrated that fetal learning does occur.[1,2] The ability to detect sensory stimuli, such as tastes and smells, also seems to develop before birth of newborns.[3] Moreover, the environment from which the newborn comes, the amnion, contains flavors derived from compounds of foods eaten by the pregnant mother.[4,5] Such exposure to dietary transmitted flavors (eg, garlic, anise) in amniotic fluid has been shown to influence the newborn's facial, oral, and orientation responses to the flavors in a short term.[6,7] The taste response was assessed in 62 normal newborns from February to June in 2004. The results of this study provide the experimental evidence in humans that newborns could distinguish the four basic tastes (sweet, salt, sour and bitter),[8] and the taste may be different in infants with different background[9,10] and sex.[11,12]

Methods

Subjects

Sixty-two pregnant mothers who were in their last trimester of pregnancy took part in the test after informed consent was obtained. All procedures of the test were approved by the Committee on Studies Involving Human Beings at the Chongqing University of Medical Sciences, China.

The inclusion criteria for pregnant mothers were uncomplicated full-term pregnancy; uncomplicated spontaneous vaginal delivery; no anesthesia used at delivery.

The inclusion criteria for newborns were Apgar score of at least 8 at 1 and 5 minutes; the weight of newborn ≥2500 g; normal and healthy on pediatric examination; normal abilities of swallow and suck actions.

Methods

The modified Rosenstein's solutions[8] included 25% sucrose (sweet), 5% sodium chloride (salt), 1.43% citric acid (sour), and 0.025% berberine (bitter). The solutions and room temperatures were kept at 37ºC and 28ºC respectively.

Testing

The newborns were tested at 90 minutes after birth. About 0.2 ml each of the four taste solutions was dropped at the central portion of the dorsal surface of the infant's tongue. Then distilled water (0.4 ml) was used as a rinse to minimize carry-over effects from one solution to another for 90 seconds. During testing, the newborns should be held upright facing forward. All the expressions of the newborns were recorded by video. Testing sessions consisted of two consecutive 30-second presentations of each of the four solutions, separated by two 90-second water rinses. The order of the four solutions was determined by a modified Latin square design.

Fascial responses analyzed with Baby Facial Action Coding System (Baby FACS)

The newborns' facial responses videotaped were coded using the Baby FACS.[8] The Baby FACS is an objective, anatomically based system whose basic units are minimally distinguishable actions of the facial muscles. Each action unit is designated by a number and scored on the basis of precisely specified changes in the shape and position of facial features and other landmarks such as wrinkles, bulges, and contours of the face. Since the Baby FACS is a standardized instrument, results obtained in different laboratories can be compared in terms of a common descriptive language. Each tape showed 1 minute trail of each taste solution presented to each infant so that judges could observe the full range of facial responses to each stimulus, including the sequence and timing of the newborn's facial movements.

The facial responses of newborns to the four solutions were divided into nine action units in facial expressions from A1 to C3, also expressed as grades 1-9 of intensity. Expression of cry was defined as grade 9 and nausea as grade 10. A1 represents no distinct mouth action or sucking on the face of the newborns during testing; A2 is A1 with a negative expression on the mid-face; A3 is A1 with a negative expression on the mid-face and brows. Similarly, B1 represents the facial response of a pursing mouth; B2 is B1 with a negative expression on the mid-face; B3 is B1 with a negative expression on the mid-face and brows. C1 represents a mouth gaping action when the infant is given the solution; C2 is C1 with a negative expression on the mid-face; C3 is C1 with a negative expression on the mid-face and brows (Fig.).

Data analysis

The data were analyzed by the statistical analysis system 8.1. Frequency and intensity of the facial action units recorded were analyzed. The chi-square test and Wilcoxon's rank-sum test were used for statistical analysis. $P<0.01$ was considered statistically significant in all the analyses except when comparing the intensity of facial responses between male and female infants ($P<0.05$).

Results

The capability of distinguishing the four basic tastes

To the sucrose solution, 93.55% of the newborns showed the expression A1. Only 27.42% of the newborns showed expression A1 when the salt solution was given, and 24.19% of them responded as C3. There were no statistical differences in the nine facial action units between the salt and non-salt tastes ($P>0.01$). The

Fig. Nine action units in facial expression. **A1:** No distinct mouth action; **A2:** No distinct mouth action with negative midface action units; **A3:** No distinct mouth action with negative brow and midface action units; **B1:** Lip pursing; **B2:** Lip pursing with negative midface action units; **B3:** Lip pursing with negative brow and midface action units; **C1:** Mouth gaping; **C2:** Mouth gaping with negative midface action units; **C3:** Mouth gaping with negative brow and midface action units.

Table 1. The frequency and percentage of facial action units to the four basic tastes

	Sweet (%)	Salt (%)	Sour (%)	Bitter (%)
A1	*58 (93.55)	17 (27.42)	* 2 (3.23)	*13 (20.97)
A2	0	5 (8.06)	3 (4.84)	* 9 (14.52)
A3	3 (4.84)	8 (12.90)	0	*11 (17.74)
B1	0	0	* 7 (11.29)	2 (3.23)
B2	0	6 (9.68)	*11 (17.74)	3 (4.84)
B3	* 1 (1.61)	9 (14.52)	*25 (40.32)	0
C1	0	1 (1.61)	3 (4.84)	2 (3.23)
C2	0	1 (1.61)	0	* 5 (8.06)
C3	0	15 (24.19)	11 (17.74)	17 (27.42)

*: $P<0.01$.

frequency of A1 expression was lower in sour response than in other taste responses (3.23%) (P<0.01). The frequency of facial expressions to sour was higher than that to other solution responses, including B1 (11.29%), B2 (17.74%) and B3 (40.32%). Five newborns (8.06%) showed expression C2 when the bitter solution was tested. Nine (14.52%) and 11 (17.74%) newborns responded to the bitter solution as expression A2 and A3 respectively. Almost 1/5 of the newborns (20.97%) responded to bitter solution as expression A1, and the frequency was lower than those of responses to sweet and salt solutions (P<0.01) (Tables 1, 2).

Intensity of facial action units

To the sucrose solution, 58 newborns responded as grade 1 intensity, which was the lowest one among the four solutions. To salt solution, 22 newborns responded as grades 1 and 2 intensity. To the sour solution, only 5

Table 2. The frequency of facial action units to the four tastes

	Sweet and non-sweet		Salt and non-salt		Sour and non-sour		Bitter and non-bitter	
	χ^2	P	χ^2	P	χ^2	P	χ^2	P
A1	121.7455	<0.01	2.8137	>0.01	39.0894	<0.01	8.3946	<0.01
A2	-	-	0.1895	>0.01	0.5263	>0.01	7.5994	<0.01
A3	1.6626	>0.01	1.6626	>0.01	-	-	8.0472	<0.01
B1	-	-	-	-	13.8739	<0.01	0.0384	>0.01
B2	-	-	0.2901	>0.01	10.4421	<0.01	1.1602	>0.01
B3	10.6563	<0.01	0.0111	>0.01	53.3781	<0.01	-	-
C1	-	-	0.2277	>0.01	2.0496	>0.01	0.2277	>0.01
C2	-	-	0.2277	>0.01	-	-	11.1589	<0.01
C3	-	-	2.7102	>0.01	0.0094	>0.01	5.8612	>0.01

Table 3. Intensity of the facial expressions to the four tastes in the newborns

	A1 grade 1	A2 grade 2	A3 grade 3	B1 grade 4	B2 grade 5	B3 grade 6	C1 grade 7	C2 grade 8	C3 or crying nausea grade 9	Nausea grade 10
Sweet	58	0	3	0	0	1	0	0	0	0
Salt	17	5	7	0	6	5	1	1	17	3
Sour	2	3	0	5	10	16	3	0	16	7
Bitter	13	9	11	2	1	0	2	6	17	1

Table 4. The frequency of facial action units to the four tastes in male newborns

	Sweet		Salt		Sour		Bitter	
	No.	Frequency (%)	No.	Frequency (%)	No.	Frequency (%)	No.	Frequency (%)
A1	*27	87.10	8	25.81	*2	6.45	7	22.58
A2	0		1	3.23	3	9.68	1	3.23
A3	3	9.68	7	22.58	0		6	19.35
B1	0		0		2	6.45	1	3.23
B2	0		1	3.23	5	8.06	3	9.68
B3	1	3.23	7	22.58	*11	35.48	0	
C1	0		0		1	3.23	2	6.45
C2	0		0		0		*4	12.90
C3	0		7	22.58	7	22.58	7	22.58

*: P<0.01.

Table 5. The frequency of facial action units to the four tastes in male newborns

	Sweet and non-sweet		Salt and non-salt		Sour and non-sour		Bitter and non-bitter	
	χ^2	P	χ^2	P	χ^2	P	χ^2	P
A1	50.1388	<0.01	1.6909	>0.01	15.2182	<0.01	0.0158	>0.01
A2	-	-	0.0695	>0.01	3.4039	>0.01	0.0695	>0.01
A3	0.3827	>0.01	3.4444	>0.01	-	-	1.5309	>0.01
B1	-	-	-	-	2.8466	>0.01	0.1139	>0.01
B2	-	-	0.9984	>0.01	4.8322	>0.01	0.3594	>0.01
B3	4.6617	>0.01	1.6782	>0.01	15.5795	<0.01	-	-
C1	-	-	-	-	0.1139	>0.01	2.8466	>0.01
C2	-	-	-	-	-	-	12.400	<0.01
C3	-	-	0.9364	>0.01	0.9364	>0.01	0.9364	>0.01

newborns respond as grades 1 and 2 intensity. 20 and 23 newborns responded to the salt and the sour solutions as grades 9 and 10 of intensity, respectively (Table 3).

The sex differentiation in facial responses

To the sucrose solution, 27 male newborns (87.10%) showed expression A1, which was the highest frequency of expression A1 among the four tastes (P<0.01); all the 31 female newborns presented expression A1 (P<0.01).

To salt solution, 8 male newborns (25.81%) showed expression A1, and 15 (48.39%) presented expression B and C. There was no statistical difference in the frequency of expression compared to the other three taste solutions (P>0.01). Fourteen female newborns (45.16%) showed expression A, and 17 (46.78%) showed expression B and C. No statistical difference was seen in the frequency of expression compared to the other three taste solutions (P>0.01).

To the sour solution, 6.45% of the male newborns showed expression A1, which was the lowest frequency of expression A1 among the four tastes, and 75.80% showed expression B and C, including 35.48% with expression B3, which was higher than the B3 frequency compared to the non-sour solutions (P<0.01). No female newborns showed expression A1, and 72.57% showed expression B. The frequency of expression B was the highest among the four solutions (P<0.01).

To the bitter solution, 45.16% of the male newborns

Table 6. The frequency and percentage of the facial action units to the four tastes in female newborns

	Sweet		Salt		Sour		Bitter	
	No.	Frequency (%)	No.	Frequency (%)	No.	Frequency (%)	No.	Frequency (%)
A1	*31	100	9	29.03	0		*6	19.35
A2	0		4	12.90	0		*8	25.81
A3	0		1	3.23	0		5	8.06
B1	0		0		5	8.06	1	3.23
B2	0		5	8.06	6	19.35	0	
B3	0		2	6.45	*14	45.16	0	
C1	0		1	3.23	2	6.45	0	
C2	0		1	3.23	0		1	3.23
C3	0		8	25.81	4	12.90	*10	32.26

*: P<0.05.

Table 7. The frequency of the facial action units to the four tastes in the female newborns

	Sweet and non-sweet		Salt and non-salt		Sour and non-sour		Bitter and non-bitter	
	χ^2	P	χ^2	P	χ^2	P	χ^2	P
A1	72.5630	<0.01	1.9649	>0.01	-	-	5.5756	>0.01
A2	-	-	0.4921	>0.01	-	-	15.1527	<0.01
A3	-	-	0.2335	>0.01	-	-	11.4426	<0.01
B1	-	-	-	-	11.4426	<0.01	0.2335	>0.01
B2	-	-	2.6935	>0.01	5.6197	<0.01	-	-
B3	-	-	1.5309	>0.01	42.0150	<0.01	-	-
C1	-	-	0.1139	>0.01	2.8466	>0.01	-	-
C2	-	-	0.6776	>0.01	0.6776	>0.01	0.2335	>0.01
C3	-	-	1.8419	>0.01	0.6631	>0.01	5.9679	>0.01

Table 8. The frequency of the intensity to the four tastes in the male newborns

	A1 grade 1	A2 grade 2	A3 grade 3	B1 grade 4	B2 grade 5	B3 grade 6	C1 grade 7	C2 grade 8	C3 or crying grade 9	Nausea grade 10
Sweet	27	0	3	0	0	1	0	0	0	0
Salt	8	1	6	0	1	4	0	0	9	2
Sour	2	3	0	0	4	6	3	0	9	4
Bitter	7	1	6	1	1	0	2	5	7	1

Table 9. Intensity of facial action units to the four tastes in the female newborns

	A1 grade 1	A2 grade 2	A3 grade 3	B1 grade 4	B2 grade 5	B3 grade 6	C1 grade 7	C2 grade 8	C3 or crying grade 9	Nausea grade 10
Sweet	31	0	0	0	0	0	0	0	0	0
Salt	9	4	1	0	5	1	1	1	8	1
Sour	0	0	0	5	6	10	0	0	7	3
Bitter	6	8	5	1	0	0	0	1	10	0

had expression A, and 12.90% had expression C2 (P<0.01). No statistical difference was observed in the frequency of the other facial units compared to the bitter solution (P>0.01). Thirteen female newborns (33.87%) demonstrated expression A2 and A3, the frequency of expression A was higher than that of the other three solutions (P<0.01). There was no statistical difference in other facial action frequency compared between the bitter and non-bitter solutions (P>0.01) (Tables 4-7).

There were significant differences in facial action units between male and female newborns responding to sucrose and bitter solutions (u=-4.7213, P<0.01), but they presented the same intensity of facial action units responding to the salt and sour solutions (P>0.05). To the bitter solution, 19 female newborns showed 1-3 grade of intensity of the facial action units, and 14 of the male newborns showed 1-3 grade of intensity (u=-2.0522, P<0.05) (Tables 8,9).

Discussion

Taste development has been studied during the past four decades. Steiner[13] published photos recording the taste response of babies to the sweet, sour, bitter and salt solutions. Afterwards, efforts were taken to find out a system coding the taste response that could be measured quantitatively. Steiner found that newborns showed us the real and direct expressions responded to taste solutions directly,[14-18] whereas adults and older children could control their expressions. They could be influenced easily by environmental factors. The newborns' videotaped facial responses were coded using the Baby FACS (Oster & Rosenstern 1978), which is an objective, anatomical system consisting of basic units that are minimally distinguishable actions of the facial muscles. Each action unit is scored on the basis of precisely specified changes in the shape and position of facial features and other landmarks such as wrinkles, bulges, and contours of the face.[19] The Baby FACS is a standardized instrument,[20,21] and the results obtained in different laboratories can be compared in terms of a common descriptive language.[22] With this instrument, Rosenstein[8] studied the responses to the four basic taste solutions in 12 newborns. He used 9 facial actions of the Baby FACS. But his method could not analyze the distinctions of sex in taste responses.

In our studies, we divided the facial responses into nine grades of intensity. Using the grades of intensity of facial expressions, we analyzed the distinctions of sex in the taste responses. The facial responses were divided into nine facial action units and expressions from A1 to C3 which are also expressed as the 1-9 grades of intensity, cry was defined as grade 9 and nausea as grade 10 of intensity. We found that there was difference in A1 facial expression. When newborns had A1 response to the sweet solution, A1 as a delighted expression included no mouth but sucking action, illustrating that the babies accept and love the sweet taste. In response to salt, sour and bitter stimulations, some babies showed expression A1, an insensitive expression without distinctive mouth action. Through the analysis of the grades of intensity and the frequency of facial action units (Rosenstein's method), we recognized the distinction of sex in facial responses to the four taste solutions. The consistent results showed that the analysis of the grades of intensity of facial expressions is desirable for the study of taste responses in a different way.

The fetus could swallow amniotic fluid in the matrix at 24 weeks during pregnancy and 1 liter amniotic fluid at full pregnancy. The amniotic fluid is a mixture containing foods, aromatics, and drinks the mother takes. Thus the fetus could contact various tastes including sweet, sour, salt, etc. The development of the glossa could make the fetus react to various tastes.[23] Witt and Reutter[24] discovered that the basal laminae of taste buds develop at the 8th week and synapses form with poorly differentiated, elongated, epithelial cells. The taste papillae in the corium of the lingual may be formed at the 9th-11th weeks during the pregnancy, and the first shallow grooves above the taste bud primordium are found around the 10th week. Most of the taste pores develop at the 14th to 15th weeks. After the 14th week of gestation when typical taste pores are present, the taste buds possibly start to perform their gustatory function. Birch[25] found that the fetus can react to various tastes. When sweet or bitter solution was injected into the amniotic fluid, the fetus showed different swallowing actions. Ganchrow et al[26] fed sweet, salt, bitter and distilled water to rats, and discovered that the rats reacted differently to the three solutions. This indicated that the taste system starts to act gustatory function in the newborn period. Rao et al[27] discovered that when the fetus and the newborns taste sweet their swallowing actions increased whereas when they taste bitter their swallowing actions decreased. Rosenstein and Oster[8] found that newborns could distinguish the four basic tastes after birth. Our study of 62 newborns showed that 93.54% of the newborns loved sweet flavor, but 6.46% refused it. The latter ones are on follow-up investigation. Twenty-five percent of the newborns accepted salt flavor, but 25% refused it. There was no statistical difference in their responses to salt taste, which were not characteristic. Most of the newborns showed expression B in response to the sour solution. Facial responses to the bitter solution included mouth gaping, negative mid-face, and negative brow. The babies showed strongest acceptance of sweet taste and grade 1 intensity of facial expression. The ability of newborns to accept salt taste was stronger than that to accept sour, and the newborns could distinguish the four basic tastes.

Bartoshuk et al[11] found that women have more fungiform papillae and taste buds than men. Chen's[12] studies showed that 25% of men and 6.1% of women had no taste to bitter, with a statistical difference. In our study, newborns had sex difference in facial responses to sweet and bitter solutions. Expression A1 appeared in 100% of the female newborns and 87.10% of male newborns when the sweet solution was given. 53.22% of the female newborns were insensitive to bitter, and 45.16% of the male newborns had the expression A to bitter flavor. These findings suggest that male newborns are more sensitive to sweet and bitter than the female newborns. All the female newborns were more sensitive to sour than male newborns.

There are so many dietary customs around the world. Mennella[3] suggested that early flavor experiences may provide the foundation for cultural and ethnic differences in cuisine. Camras et al[10] used the Baby FACS to study European, American, Japanese and Chinese 11-month-old babies of emotion-inducing laboratory procedures. Their results suggested that Chinese infants were less expressive than European, American and Japanese infants. Given the solutions prepared by Rosenstein (25% sucrose, 43% sodium chloride, 25% citric acid, and 25% berberine), most newborns vomited except the sweet solution. This indicated that the concentrations of the solutions prepared by Rosenstein are not suitable for Chinese infants. Besides, there is difference in taste responses in different countries.

Funding: None.
Ethical approval: This study was approved by the Data Inspectorate of China and by the Committee on Studies Involving Human Beings at the Chongqing University of Medical Sciences, China.
Competing interest: None declared.
Contributors: ZL wrote the main body of the article under the supervision of LHQ.

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Received February 26, 2007
Accepted after revision April 11, 2007