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NOTE

TASTE-ELICITED CHANGES IN FACIAL SIGNS OF EMOTION AND THE ASYMMETRY OF BRAIN ELECTRICAL ACTIVITY IN HUMAN NEWBORNS*

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Abstract—Recent evidence suggests that frontal brain electrical activity reveals asymmetries in activation in response to positive vs negative affective stimuli. This study was designed to evaluate whether this asymmetry is present at birth. Newborn infants were presented with water followed by a sucrose solution and then by a citric acid solution. Facial expression was videotaped during the presentation of the liquids and EEG was recorded from the frontal and parietal scalp regions on the left and right side. Usable EEG data were obtained from 16 newborn infants in response to these taste conditions. Videotaping of facial expression in response to these stimuli indicated the presence of disgust during both water (the first taste introduced) and citric acid. EEG was Fourier Transformed and power in the 1–3, 3–6 and 6–12 Hz bands was computed. The findings revealed that the water condition produced reductions in right-hemisphere power in the two higher frequency bands in both the scalp regions compared with the other two conditions. The sucrose condition produced greater relative left-sided activation in both regions compared with the water condition. These data, in conjunction with our previous findings of asymmetries in 10-month-old infants, indicate that stimulus-elicited affective asymmetries in brain electrical activity are present at birth.

INTRODUCTION

A VARIETY of data from a number of diverse sources indicate that certain regions of the two cerebral hemispheres are asymmetrically activated during the expression of certain positive and negative emotions (see [3, 4) for reviews). This finding is based upon clinical neurological data [1, 13, 14, 19, 24, 25], psychiatric data [7, 11, 16, 22, 26], and studies on normal adults using both behavioral and electrophysiological indices of asymmetric hemispheric engagement [6, 8, 9, 23, 28]. The neuropsychological and electrophysiological findings support the view that left-sided frontal activation is observed in response to certain positive stimuli while relative right-sided frontal activation is observed in response to certain negative stimuli [3, 4, 12].

In two experiments which examined whether the frontal asymmetry observed in adults is present in infants during the first year of life, DAVIDSON and FOX [5] presented 10-month-old female infants with two videotaped segments while recording ongoing EEG activity from left and right frontal and parietal scalp leads. The two videotaped segments were of an actress either smiling and laughing or frowning and crying. The results revealed differential left vs right frontal activation. EEG asymmetry from the parietal region did not discriminate between these conditions.

A number of workers have speculated that the essential continuum along which the hemispheres are lateralized for emotion is approach/withdrawal [3, 4, 12, 18]. In an attempt to examine the pattern of brain electrical activity that is associated with both approach and withdrawal behaviors in the young infant, a series of different liquid tastes were presented to a group of human newborns. Previous research [27] had reported that newborn infants exhibit positive facial responses to a sucrose solution and negative facial affect to a solution of citric acid. We therefore expected that presentation of these tastes would elicit facial action possibly indicative of approach or withdrawal behavior. EEG was recorded from left and right frontal and parietal scalp leads during preentaion of these tastes in order to explore activation asymmery during the elicitation of approach and withdrawal behavior. We hypothesized that to the

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extent that the tastes elicited relative positive/approach or negative/withdrawal behavior this would be associated with differences in relative EEG activation asymmetry.

METHODS

Subjects

Thirty-three full term, healthy infants, 2–3 days of age were recruited from the newborn nursery of a large metropolitan hospital. All infants had 5-min Apgar scores of 9 or 10 and evidenced no congenital or neurological abnormalities. Sixteen males and 17 females were recruited. Parents of the infants were administered a handedness questionnaire (Edinburgh Handedness Inventory [21]) prior to testing. Only those infants who were born to two right-handed parents were recruited. One subject's data were excluded because of a left-handed parent.

Infants were seen soon after feedings while they were in a quiet alert state. State was coded using criteria outlined by BRAZELTON [2]. Infants were observed in the nursery or in the mother's room after feeding. When an infant was judged to be in states 3, 4 or 5 he or she was brought to the lab which was next door to the nursery. Two observers coded state at the onset of the session and prior to the presentation of each taste. Only infants who remained in states 3, 4 or 5 during the study were included. Usually, once the first tastant was presented, infants remained awake and alert for the remainder of the session. A total of seven infants who began the session in a quite alert state fell asleep or began crying and their data were not included. Another nine infants' data were excluded due to excessive movement during some part of the experiment. Sixteen infants had usable data in the water, sugar and citric acid stimulus conditions.

Procedure

The infants were tested while they were lying in a bassinet. The bassinet was placed on a small wooden stand which was placed on a table. The stand tilted the bassinet upright at a 30° angle to the table. The interior of the bassinet had foam rubber padding with a space carved out for the infant's head. In addition, towels were placed against both sides of the infant's head to prevent gross head movement and keep the infant's head in mid-line. Coding of the infant's behavior revealed no significant or systematic head turning response across taste presentations.

Illumination in the room was dim. A Sanyo low-light-level camera mounted on a tripod with a 25-mm close-up lens was placed directly in front of the infant and tilted down in a straight line at the infant's face. Infant facial behavior was recorded on 1/2 in. reel-to-reel videotape with a SONY AV 3650 videotape recorder.

EEG was recorded with a specially designed Lycra stretchable cap (Electro-cap Corporation) constructed to accommodate a normal range of head circumferences among newborns. The cap was placed on the infant's head and a small elastic band with Velcro ends was placed around the infant's chest. The sides of the cap were secured to two positions on the elastic belt with small snaps. This kept the cap snugly on the infant's head. A small amount of electrolyte solution (Omni Prep) was injected into each of the recording sites on the cap. Resistance for each of the recording sites was below 5K ohms. EEG was recorded from four sites: left and right frontal and parietal scalp regions (F3, F4, P3, P4) all referenced to a common vertex (Cz). We recorded from frontal and parietal regions to compare the infant data with previously established adult findings [6, 28] and to compare the results to our study of 10-month-old infants [5]. The EEG was amplified on a Grass Model 7 Polygraph and stored in analog form on FM tape with a Vetter Model D instrumentation recorder.

Three different stimuli were presented to the infant: a sucrose solution (25% = 0.73 M sucrose); a citric acid solution (2.5% = 0.12 M citric acid); and distilled water. Solutions were presented at room temperature with graduated, disposable, sterile glass pipettes. Four milliliters of liquid were presented on each trial. Each infant was presented with each solution only once. Distilled water was always presented first, followed by the sucrose solution and then by the citric acid solution. This order of presentation was used to maximize the possibility of elicitation of positive and negative emotions to the tastes. Solutions were presented to the infant's mid-line and anterior portion of the tongue.

Preceeding presentation of the tastes, 30 sec of baseline activity was recorded. Following this period the tastes were presented. The experimenter placed the liquid on the infant's tongue and removed the pipette. Each trial was approximately 40 sec in duration and began immediately following the removal of the pipette from the infant's mouth. At the onset of each taste presentation an independent observer depressed a switch which simultaneously placed a pulse on the FM recorder and a tone-pip on the videotape. The experimenter who presented the taste moved either to the right or the left of the infant after each presentation and was not facing the infant during the recording period. There was a 60-sec inter-trial interval following the taste trial and prior to presentation of the next taste.

EEG was low-pass filtered at 44 Hz (48 db/octave) to prevent aliasing and then digitized with a PDP 11/34 computer off-line at a sampling rate of 125 samples/sec. All epochs confounded by either movement or eye movement artifact were eliminated prior to further analysis. For the water stimulus condition, a mean of 6.59 sec (S.D. = 6.54) of artifact-free data were included. For the sugar stimulus condition the mean duration of artifact-free data was 10.23 sec (S.D. = 6.83) and for the citric acid stimulus condition the mean was 8.78 sec (S.D. = 10.01). The digitized data were then processed through a Fast Fourier Transform using a hamming window. Power density (in μV^2/Hz) was computed for all artifact-free EEG during each epoch in three frequency bands: 1–3, 3–6 and 6–12 Hz.

Coding of facial behavior

Facial behavior in response to each stimulus condition was analyzed for the entire duration of each trial using Izard's MAX [17] coding system. Preliminary analysis of the facial behavior data revealed a high incidence of the codable emotions of interest and disgust and a low incidence of other emotion expressions. We chose to analyze facial behavior for the entire 30-sec trial duration rather than only those epochs during which artifact-free EEG was present. This choice was based on our observation that the most intense and sustained changes in facial behavior were often coincident with periods of EEG artifact. The analysis of the facial behavior primarily served as an independent validation of the differential affective response produced by the eliciting conditions. The number of subjects with scorable videotape records was 11. Of these 11 infants, all had usable EEG data in the water, sugar and citric acid stimulus conditions.

Reliability of facial coding

An independent coder, trained on the MAX system but naïve to the experimental design and blind to the specific stimulus conditions coded five (randomly selected) of the 11 infant videotapes. The range of correlations between coders was 0.68–0.95, while agreement varied from 70–90% for the appearance of an emotion during a taste condition.

RESULTS

Facial data

Table 1 presents the means and standard deviations of the duration of each emotion which was observed for the water, sucrose and citric acid taste stimulus conditions. It should be noted that only discrete facial expressions of emotion were coded with the MAX system. Facial behaviors which were components of facial expressions but which did not meet criteria as specified in MAX were not included in the analysis. As can be seen from this table, the duration of interest is comparable among the three taste conditions. The duration of disgust is shorter during the sucrose stimulus condition compared with the water and citric acid stimulus conditions, both of which elicited comparable durations of facial signs of disgust. However, due to the small sample size and the variability among subjects, the differences among stimulus conditions in duration of disgust is not significant. These facial data suggest that the first introduction of the pipette into the infant's mouth might be an event associated with the elicitation of facial signs of negative affect.*

EEG data

Multivariate effects across band. Since power was computed in three different frequency bands, we first performed a multivariate analysis of variance (MANOVA) with log power† in the three bands (1–3, 3–6 and 6–12 Hz) as

Table 1. Means and standard deviations (in seconds) for the duration of facial signs of interest and disgust (the two facial expressions which occurred with the most frequency) for each of the three taste conditions

		Water	Sugar	Citric
Interest	*M*	2.41	2.65	2.65
	S.D.	2.52	3.48	3.14
Disgust	*M*	1.43	0.48	1.55
	S.D.	2.22	1.25	1.18

*In the current study, in response to each of the tastes, repeated sucking movements were observed. These sucking movements are coded in the MAX system as movement 59a in the mouth region and when they occurred in the absence of facial signs in the brow and eyes which specify emotion expressions other than interest, the movement classified the facial expression as an interest expression. Due to the highly stereotypic nature of the sucking movements which accompanied presentation of the tastes, we decided to exclude the 59a code when it occurred in the absence of brow and eye movements which specify emotions other than interest. We considered it important to differentiate between this behavior which may be affect nonspecific and other facial behaviors which accompany taste.

†Log power was chosen as the main dependent measure since power is computed as μV^2 which results in a highly skewed distribution. Most studies which use EEG in the frequency domain as a measure log transform the power values.

dependent measures and Condition (water/sugar/citric acid), Region (frontal/parietal) and Hemisphere (left/right) as repeated measures factors. This analysis revealed a significant main effect for Region [$F(1, 10) = 17.54$, $P = 0.002$]. This effect was a function of more power in the parietal compared with the frontal region (M for parietal = 1.10, S.D. = 0.82; M for frontal = 0.14, S.D. = 1.4). There were no other significant main effects A significant Condition × Hemisphere interaction was observed [$F(2, 20) = 5.36$, $P = 0.03$].* This multivariate interaction was decomposed by computing separate univariate ANOVAs on log power in each of three bands.

1–3 *Hz band.* A three-way ANOVA with Condition, Region and Hemisphere as factors revealed a significant main effect for Region [$F(1, 10) = 16.50$, $P = 0.002$] but no other main or interaction effects. The main effect was due to more power in the parietal region as compared to the frontal region across condition.

3–6 *Hz band.* A three-way ANOVA revealed a significant main effect for Region [$F(1, 9) = 17.06$, $P = 0.003$]. This effect is a function of more power in the parietal region compared with the frontal region. A significant Condition × Hemisphere interaction was also obtained [$F(2, 18) = 4.90$, $P = 0.04$]. The relevant means and standard deviations are presented in Table 2. As can be seen in Table 2, in response to the water stimulus condition, less power is present in the right hemisphere (i.e. more right-hemisphere activation) compared with the left in both regions. In response to the sugar stimulus condition, the opposite pattern was observed, i.e. less power in the left hemisphere in both regions. Little hemispheric difference was observed in response to the citric acid stimulus condition in either region. A series of ANOVAs for each pair of conditions with condition, region, and hemisphere as factors were performed on the data and confirmed the difference in hemispheric activation between the water and sucrose stimulus conditions. The ANOVA comparing these two conditions was the only one to show a significant Condition × Hemisphere interaction [$F(1, 12) = 7.69$, $P = 0.02$].

Table 2. Means and standard deviations for log power in the 3–6 Hz band separately for the left and right frontal and pareital regions, by condition

		Frontal		Parietal	
		Left	Right	Left	Right
Water	M	0.352	−0.141	1.418	1.226
	S.D.	1.418	1.545	0.956	1.009
Sugar	M	0.442	0.697	1.064	1.379
	S.D.	1.118	1.001	0.928	0.816
Citric	M	0.334	0.340	1.423	1.385
	S.D.	1.592	1.465	0.995	0.776

6–12 *Hz band.* A three-way ANOVA revealed a significant main effect for Region [$F(1, 8) = 6.66$, $P = 0.03$]. This effect indicates, as noted above, that the frontal region displays less power compared with the parietal region. A significant Condition × Hemisphere interaction was again obtained [$F(2, 16) = 4.69$, $P = 0.04$]. The relevant data are presented in Table 3. In order to specify which of the condition comparisons were contributed to this effect, we performed a series of pairwise ANOVAs on each condition pair with Condition, Region and Hemisphere as factors. The results of the water/sugar comparison revealed a main effect for Region [$F(1, 10) = 6.82$, $P = 0.03$] and a significant interaction of Condition × Hemisphere [$F(1, 10) = 10.47$, $P = 0.009$]. The data indicate that water is associated with less power (i.e. more activation) in the both the right frontal and parietal regions compared with the left, while the sugar stimulus condition elicited the opposite EEG pattern, i.e. less power in the left compared with the right frontal and parietal regions. The results of the water/citric and sugar/citric ANOVAs revealed only main effects for Region [$F(1, 8) = 7.86$, $P = 0.02$; and $F(1, 11) = 11.97$, $P = 0.005$, respectively]. These main effects for region were a function of more power in the parietal as compared to the frontal region across condition.

DISCUSSION

The findings from this study indicate that newborn infants show differences in the asymmetry of brain electrical activity in response to different taste conditions. The first tastant, water, elicited a pattern of decreased power in the right compared with the left frontal and parietal scalp regions for the 3–6 and 6–12 Hz bands. The second tastant, sugar water, elicited a pattern of decreased power in the left as compared to the right frontal and parietal scalp regions for the 3–6 and 6–12 Hz bands. The citric acid condition was associated with little difference between the

*All ANOVA effects with more than two levels have been corrected with the Greenhouse–Geisser procedure.

Table 3. Means and standard deviations for log 6–12 Hz power, separately for the left and right frontal and parietal regions, by condition

		Frontal		Parietal	
		Left	Right	Left	Right
Water	*M*	−1.219	−1.562	−0.601	−0.751
	S.D.	1.373	1.282	0.819	0.741
Sugar	*M*	−1.293	−0.925	−0.701	−0.314
	S.D.	1.747	1.343	0.923	0.813
Citric	*M*	−1.603	−1.360	−0.281	−0.601
	S.D.	1.669	1.267	0.775	0.697

hemispheres in brain electrical activity. Interestingly, these Condition × Hemisphere interactions were specific to the higher frequency bands. No task-dependent effects were observed in the 1–3 Hz band. It may be that changes in power in this band are more sensitive to state changes, as is characteristic of both the infant [10] and adult EEG [20].

There were several features of these data that differed from our initial expectations. We had predicted that the citric acid condition would elicit longer durations of facial signs of disgust compared with the other two conditons. The data revealed that the water condition, which was always presented first, elicited facial signs of disgust in amounts comparable to that observed in response to the citric acid condition. We believe that these facial data suggest that the initial introduction of the pipette into the newborn infant's mouths elicited an aversive response. The second unexpected finding was the pattern of EEG asymmetry which accompanied the water condition. In both the frontal and parietal regions, less power was observed in the right compared with the left hemisphere. We had predicted that the water condition would fall between the sugar and citric acid conditions in terms of the degree of hemispheric activation asymmetry since we viewed this condition as affectively neutral. The lack of a reliable difference in EEG asymmetry between the citric acid condition and the sucrose condition was also unexpected. This finding may be associated with the order in which the tastants were presented, since the citric acid condition was always presented last. We chose to present the tastes in a fixed order since we were concerned that if the sucrose condition followed the citric acid condition, there would be carry-over of the negative affect. It may well be that the reverse process occurred in this experiment—carry-over of the positive affect from the sucrose into the citric acid condition. Whatever the explanation for the lack of EEG asymmetry during the citric acid condition might be, the data indicate that dissociations between facial behavior and underlying brain activity can occur. It remains for future research, where order effects are counterbalanced, to explain this effect.

It is of interest to note that contrary to our previous data on 10-month-old infants as well as on adults (e.g. [5, 12]), no reliable differences were observed between activation asymmetries in the frontal and parietal scalp regions. These data raise the possibility that the brain of a newborn has not yet developed the functional specificity which has been found in the brains of older subjects. Studies on the higher non-human primates indicate that the frontal region does not participate in complex cognitive and affective processes until relatively late in ontogeny [15]. The EEG which we recorded from this scalp region in newborn infants may be generated from sources in other cortical locations. Future studies with this age group might profitably examine the coherence between the EEG recorded from anterior and posterior regions in response to specific stimuli in order to make more valid inferences about common source generators. The data which are available on intrahemispheric coherence in the EEG in this age group were not obtained in response to stimulation [29].

We wish to emphasize one feature of the overall data which is of general importance to studies of the development of lateralization. Our findings are among the first to show stimulus-elicited asymmetries in EEG power in newborn infants. In none of the comparisons which were performed on the data did we obtain a main effect for Condition. The lack of Condition main effects indicates that the different tastes did not produce differences in overall EEG power. Rather, the data we have obtained indicate that the effects of these stimuli are hemispheric-specific, although not caudality specific as we had initially expected.

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