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REPORT

How sleeping neonates smile

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Abstract

Infants over one month of age tend to produce two types of smiling during especially positive social interactions, Duchenne smiles involving cheek raising and open-mouth smiles. Little is known, however, about the prevalence, frequency, duration and organization of these smiles among neonates. Twenty-five full-term, healthy neonates (12 female) were videotaped during six minutes of sleep. Smiles were identified and analysed using an anatomically based coding system (FACS/Baby FACS). One-half of the neonates showed bilateral Duchenne smiles. One-quarter of the neonates showed bilateral Duchenne smiles at a mature level of intensity whose median duration was $1\frac{1}{3}$ *s. By contrast, open-mouth bilateral smiles occurred in less than one-tenth of the sample. The contrast between the more frequent bilateral Duchenne smiles and the less frequent open-mouth smile is discussed in terms of the early synergistic functioning of facial muscles and contrasted with the smiling patterns of older infants.*

Smiling is an early social and emotional behavior. However, smiles often first occur during sleeping states without obvious external stimulation, creating what are known as endogenous smiles. This puzzle has long attracted the attention of developmental researchers (Harmon & Emde, 1972; Fogel & Thelen, 1987; Spitz, 1946; Sroufe & Waters, 1976; Wolff, 1963). More recent research indicates that in older individuals, smiles involving raising of the upper part of the cheeks (Duchenne smiles) and smiles in which the jaw is lowered (open-mouth smiles) are more likely during positive periods of interaction than are smiles without these features (Dickson, Walker & Fogel, 1997; Ekman, Davidson & Friesen, 1990; Fogel, Nelson-Goens, Hsu & Shapiro, 2000; Fox & Davidson, 1988; Messinger, Fogel & Dickson, 1997). The current research used anatomically based coding to address whether and how frequently sleeping neonates exhibit Duchenne and open-mouth smiles, smiles that are frequently regarded as indices of positive affect in older, alert individuals.

Duchenne and non-Duchenne smiles are distinguished, respectively, by the presence or absence of cheek raising caused by the muscle circling the eye. Among adults, Duchenne smiling is associated with self-reported positive emotion, but this is not the case for non-Duchenne smiling (Ekman *et al*., 1990). Among 10-month-old infants, Duchenne smiles are associated with mother's smiling approach while non-Duchenne smiles are associated with the approach of an impassive stranger (Fox & Davidson, 1988). Among infants between one and 6 months of age, Duchenne smiling was more prevalent than non-Duchenne smiling when mother was smiling (Messinger, Fogel & Dickson, 2001).

Ekman (1992, 1994) has argued that Duchenne smiles are a unique index of positive emotion. Yet the literature now suggests that open-mouth smiles may also index positive emotion in infancy. Messinger *et al*. (2001) found that open-mouth smiling involving a lowered jaw was more likely when infants were gazing at mother's face (Messinger *et al*., 2001). Combined open-mouth Duchenne smiling was more likely both when infants were gazing at their mothers and when their mothers were smiling. These combination smiles also tended to occur during physical play with fathers (Dickson *et al*., 1997) and at the peak of tickle games with mother (Fogel *et al*., 2000). Investigation of Duchenne and open-mouth

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smiles in sleeping neonates will shed light on similarities and differences with smiles that occur during emotion-eliciting social interaction at older ages.

Researchers have also examined muscular dynamics involved in the organization of Duchenne smiles (Messinger *et al*., 1997). Duchenne smiles involve simultaneous lip corner raising (zygomatic major) and cheek raising caused by the action of the muscle circling the eye (orbicularis oculi, pars lateralis). Because the muscles have an overlapping function in raising the cheek and may operate synergistically (Williams, Warick, Dyson & Bannister, 1989), Messinger *et al*. hypothesized that stronger lip corner raising would be more likely to be associated with the presence of cheek raising than weaker lip corner raising. If the muscles function synergistically, it is also likely that stronger levels of lip corner raising should be associated with stronger levels of cheek raising when both actions occur simultaneously. Messinger *et al*. also found that smiles with cheek raising (Duchenne) had longer durations than smiles without (non-Duchenne) (Messinger, Fogel & Dickson, 1999). They suggested that cheek raising might stabilize lip corner raising, creating a longer lasting expression. If similar patterns of association and duration emerged in neonates, muscular synergies would be a possible explanation.

Although smiling in neonates has been documented, little is known about the form of the smiling. Emde and his colleagues first observed that smiling in the first days of life predominated during REM states, occurring once (Emde & Koenig, 1969) to twice (Emde, McCartney & Harmon, 1971) every 10 minutes. We are not aware of descriptions or photographs of neonates with smiles involving a dropped jaw in the literature. There is photographic evidence (Oster, 1978) and several unambiguous descriptions of the occurrence of Duchenne smiles in full-term and pre-term neonates (Emde *et al*., 1971; Wolff, 1987). However, quantitative descriptions of the prevalence, frequency and duration of Duchenne smiles are lacking. Emde and his colleagues (Emde & Koenig, 1969a; Emde *et al*., 1971), for example, measured the intensity of smiles in real-time on a 5-point descriptive scale. Unfortunately, the scale was not anatomically based and slow-motion review of smiles was impossible without video records. The researchers noted, for example, that 20% of the smiles observed involved movement of the cheeks. However, their scale did not distinguish smiles in which strong contractions of the zygomatic (lip corner raising) raised the cheeks from Duchenne smiles in which orbicularis oculi (pars lateralis) raised the cheeks. In addition, the highest rating possible on the scale involved intense contraction of the muscles responsible both for lip corner raising and cheek raising; but the rating could only be made if the smile lasted at least two seconds. Brief Duchenne smiles could not, by definition, be observed.

The overall goal of this study was to document different forms of smiling in sleeping neonates. Specifically, we investigated the prevalence, frequency, duration and organization of neonatal Duchenne and open-mouth smiles. The presence of mature open-mouth and Duchenne smiles of substantial duration in sleeping neonates would suggest continuities with the interactive smiles of older infants. If stronger lip corner raises were associated with (stronger) cheek raises, and if the resulting Duchenne smiles had longer durations than non-Duchenne smiles, this would suggest a synergistic association between the muscular constituents of Duchenne smiles. Relatively infrequent open-mouth smiling and a higher frequency of Duchenne smiling, might lend support to the view that neonatal Duchenne smiling is dependent on neuromuscular synergies specific to Duchenne smiling.

Methods

Participants

Participants were 25 (12 female) neonates (Mean age = 55 hours, Mdn. = 50; range 5–106) seen at the maternity ward of the Pediatric Clinic of the University of Padua. All neonates were found to be normal and healthy during routine pediatric examinations. They were videotaped for 6 minutes while asleep (mean = 362 s, range 357–367), midway between two mid-morning meals. Videotapes captured a full-screen image of the neonate's full face. Time accurate to the tenth of a second was inserted on to this image.

Coding

The Facial Action Coding System (FACS) is an anatomically based system for identifying the muscular contractions (Action Units, AUs) responsible for changes in facial movement (Ekman & Friesen, 1978; Ekman & Friesen, 1992). FACS certified individuals trained in Baby FACS, a version of FACS applicable to infants and neonates (Oster, 1990; Oster & Rosenstein, in press), performed all coding. Action units were identified when facial movements could be identified in both real-time and slow motion. Tapes were viewed extensively in slow motion on a video cassette recorder capable of digital slow-motion output (Panasonic AG-DS850) to distinguish the onset and offset of lip corner raising, cheek raising and mouth opening.

Coders first identified lip corner raising (AU12). This action is produced by the zygomatic major and is the basis of all smiles. It raises the lip corners and the infraorbital triangle (making the cheeks more prominent), and deepens the nasolabial furrow between the nose and cheeks. Coders took pains to distinguish lip corner raising (AU12) from lip corner tightening (dimpling lateral to the lip corners) produced by the buccinator (AU14).

When an instance of lip corner raising was identified, coders ascertained whether there was co-occurring cheek raising (AU6). This cheek raising is produced by the contraction of the muscle orbiting the eye socket (orbicularis oculi) whose fibers lie around the eye socket (pars lateralis). This action was distinguished from the movement of the inner portion of the muscle (pars palpebralis) that tightens the eyelids themselves (AU7). In infants, cheek raising that deepens and raises the furrow beneath the lower eyelid is the major criterion for AU6. Coders distinguished this orbicularis oculi contraction from cheek raising produced by the zygomatic itself (which is an index of lip corner raising). To make this distinction, they focused on the raising of tissue beneath and slightly lateral to the outer portion of the lower eyelid which is caused only by orbicularis oculi (AU6) (Oster & Rosenstein, in press).

Two levels of lip corner and cheek raising were distinguished. The weaker level was 'slight but unambiguous action' (Oster & Rosenstein, in press, p. 13) that does not meet the original FACS minimum requirements (the 'a' level, Ekman & Friesen, 1992). The stronger level involved movements that met or exceeded minimum requirements for easily observed action units (the 'b' or 'x' level). In addition to providing data relevant to the possibility of a synergistic association between lip corner raising and cheek raising, these two levels distinguished weak actions of muscles, which might be particularly likely among newborns, from stronger actions.

Using criteria established in research with older infants (Messinger *et al.*, 1997), coders also ascertained whether lip corner raising co-occurred with mouth opening (AU26c–e/AU27), in which the lower jaw is clearly dropped. Closed mouth smiling was defined as smiling without a frank jaw drop which could involve lip parting (AU25) to the degree necessary to extend the tongue between the lips (AU26a–b) (Oster & Rosenstein, in press).

Facial action segmentation

A smile was considered a non-Duchenne smile if it did not involve cheek raising at any point during its duration. A smile was considered a Duchenne smile if it involved cheek raising at any point during its duration. However, only the duration of those parts of the smile in which lip corner and cheek raising co-occurred were used to calculate the duration of Duchenne smiles (following Messinger *et al.*, 2001). The characteristics of non-Duchenne segments immediately preceding or following a Duchenne smile were reported separately and not included in the measurements of non-Duchenne or Duchenne smiles. The same rules were applied to open-mouth smiles and to analyses evaluating whether stronger lip corner raises were more likely to be associated with stronger cheek raises.

Smiles were classified according to the strength of the activation of the muscular contractions they involved in the following manner. Non-Duchenne smiles were classified according to the strength of lip corner raising involved. Duchenne smiles involving weaker levels of lip corner raising, cheek raising or both were classified at the 'a' level. They were classified at the stronger level if both action units met or exceeded the b/x requirements. There were no instances of changes in the strength of facial action units that did not also involve a transition to or from a Duchenne smile. Smiles were considered unilateral only if lip corner raising was present (at either level) on one side of the face but absent on the other.

Reliability

The reliability of coding was established through independent coding of half of the sample (13 of 25 infants) by two FACS certified coders trained in Baby FACS. Using a 2 second window, there was 86% agreement on Duchenne and 69% agreement on non-Duchenne smiles. Agreement on intensity (using the 'b/x' level criterion) was 78% for lip corner raising and 75% for cheek raising. Agreement on unilateral smiles was 82% and agreement on mouth opening was 92%. Cohen's Kappas (K, which corrects for chance agreement) could not be calculated here because this type of event coding cannot indicate the number of times coders agreed that an event did not occur.

We also examined agreement on whether or not an infant showed at least one instance of a particular type of smile during the 6-minute observations. Though these analyses do not use a time window, they provide estimates of the reliability of the prevalence measures. Kappas were calculated for these measures because there can be agreement that a given infant did or did not show a particular facial expression. There was 100% agreement for Duchenne (K = 1.0) and 92% agreement for non-Duchenne (K = 0.83) smiles. Agreement on the number of infants who smiled with lip corner raising at or above the 'b/x' level was 92% (K = 0.81); cheek raising also showed 92% agreement (K = 0.81). Agreement on the number of infants who showed unilateral smiles was 83% (K = 0.65) and agreement on the number of infants who showed open-mouth smiles was 91% (K = 0.74).

Results

Approximately half the neonates in the sample (52%) produced bilateral Duchenne smiles during the 6 minutes in which they were observed (see Table 1). Bilateral Duchenne and non-Duchenne smiles each occurred slightly more than 0.20 times per minute. There were no overall differences in the median length of the Duchenne (0.95 s) and non-Duchenne (1.00 s) smiles (only infants who produced a given smile contributed to the calculation of its duration).[1]

Approximately two-thirds of both Duchenne and non-Duchenne smiles involved action units at weaker levels of activation (the 'a' level) (see Table 1). Investigations of smiling between one and 6 months of age have used the b/x level as the criterion for identifying lip corner and cheek raising (Messinger *et al*., 1997). Approximately one-quarter (24%) of the current sample produced Duchenne smiles with this stronger level of muscular contraction (see Figure 1). The median duration of Duchenne smiles at the stronger level of activation was 1.35 s and the median duration of corresponding non-Duchenne smiles was 0.86 s. However, the small number of infants who produced both types of smiles precluded a statistical comparison.

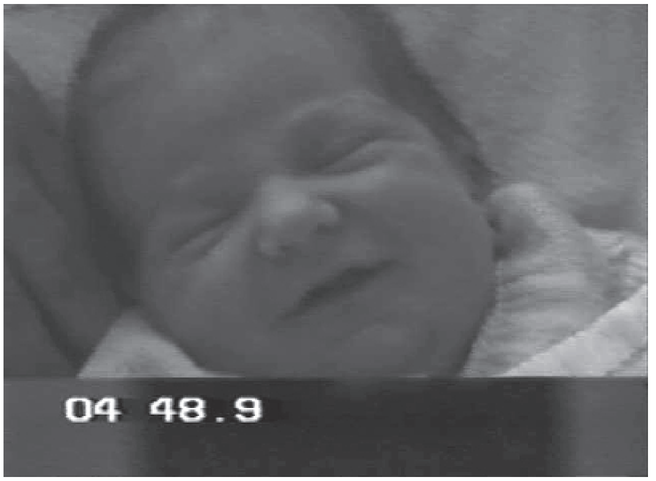

Figure 1 *The Duchenne smile of a 42-hour-old sleeping infant. Both lip corner raising and cheek raising are present at the 'b/x' level or greater and the smile does not involve jaw dropping.*

Table 1 *Neonatal smiles*

	Non-Duchenne Smiles			Duchenne Smiles		
	'a' Level	'b/x' Level	All levels	'a' Level	'b/x' Level	All levels
Bilateral						
Number of Infants (%)	14/25 (56%)	6/25 (24%)	17/25 (68%)	10/25 (40%)	6/25 (24%)	13/25 (52%)
Rate per minute (SD)	0.16 (0.19)	0.07 (0.15)	0.23 (0.23)	0.13 (0.23)	0.06 (0.14)	0.21 (0.29)
Median Duration	1.00	0.86	1.00	0.94	1.35	0.95
Mean duration (SD)	1.06 (0.67)	0.84 (0.35)	0.93 (0.39)	0.94 (0.45)	1.58 (1.27)	1.07 (0.56)
Unilateral						
Number of Infants (%)	14/25 (56%)	4/25 (16%)	15/25 (60%)	6/25 (24%)	2/25 (8%)	8/25 (32%)
Rate per minute (SD)	0.13 (0.15)	0.04 (0.10)	0.17 (0.21)	0.07 (0.14)	0.03 (0.08)	0.09 (0.15)
Median Duration	0.67	1.00	0.70	0.62	1.15	0.62
Mean duration (SD)	0.95 (0.69)	1.63 (1.60)	1.04 (0.78)	0.88 (0.70)	1.15 (0.78)	0.87 (0.55)

Notes. Mean and median durations are in seconds. For non-Duchenne smiles, the 'a' (weaker) and 'b/x' (stronger) levels refer to the strength of lip corner raising only. For Duchenne smiles, 'a' indicates that either lip corner raising, cheek raising, or both are at the weaker level; 'b/x' indicates that both actions are at the stronger level. The number of infants refers to those who produced the expression. Statistical comparisons are found in the text.

Comparisons of bilateral and unilateral smiles indicated that bilateral Duchenne smiles were more frequent than unilateral Duchenne smiles (rates of 0.21 versus 0.09 per minute, respectively), $Z\ (24) = 2.40$, $p < 0.025$.[2] Bilateral non-Duchenne smiles were not more frequent than unilateral non-Duchenne smiles. Comparisons of between-subject variables indicated that there were no significant differences between the smiles of male and female infants. There was also no pattern of significant correlations between age in hours and any smiling measure.

Chi-square tests were calculated to evaluate the synergy hypothesis. Stronger lip corner raises were 2.15 times more likely to co-occur with cheek raises (of any strength) than were weaker lip corner raises, but this association was not statistically significant, $\chi^2\ (1) = 2.14$, $p = 0.14$. Given that both actions co-occurred, stronger lip corner raises were 10.0 times more likely to be associated with stronger cheek raises than were weaker lip corner raises, $\chi^2\ (1) = 6.74$, $p = 0.009$. Analyses of unilateral facial actions indicated a similar pattern of significance.

[1] These descriptors do not cover non-Duchenne smiles (without cheek raising) that immediately preceded or followed Duchenne smiles (with cheek raising). Eight infants produced non-Duchenne smiles that immediately preceded Duchenne smiles. These occurred at an overall rate of 0.08 per minute and had a median duration of 0.48 seconds. Five infants produced non-Duchenne smiles that immediately followed Duchenne smiles. These occurred at an overall rate of 0.04 per minute and had a median duration of 0.50 seconds.

[2] All comparisons of frequency and duration were made with the nonparametric Wilcoxon Signed Ranks Test (paired *t*-tests yielded identical results).

Stronger unilateral lip corner raises were only 1.18 times more likely to co-occur with cheek raises (of any strength) than were weaker lip corner raises, χ^2 (1) = 0.42, p = 0.84. Stronger unilateral lip corner raises were more likely to occur with stronger than weaker cheek raises, χ^2 (1) = 7.22, p = 0.007. An odds ratio could not be calculated, in fact, because stronger unilateral lip corner raising *never* occurred with weaker cheek raising.

In comparison with closed mouth smiles, open-mouth smiles were rare. In all, the 25 neonates produced only three bilateral open-mouth smiles, one of which was a Duchenne smile. They produced four unilateral open-mouth smiles, none of which were Duchenne smiles. Consequently, the prevalence of bilateral open-mouth smiles was less than that of bilateral closed mouth smiles, 8% (2/25) and 84% (21/25), respectively, $p < 0.01$. The frequency of bilateral open-mouth smiles was lower than that of bilateral closed mouth smiles, 0.02 and 0.41 times per minute, respectively, Z (24) = 4.06, $p < 0.001$. Among unilateral smiles as well, open-mouth smiles were less prevalent than closed mouth smiles, 12% (3/25) and 72% (18/25), respectively, $p < 0.01$. The frequency of unilateral open-mouth smiles was lower than that of unilateral closed mouth smiles, 0.03 and 0.24 times per minute, respectively, Z (24) = 3.45, $p < 0.001$.

Discussion

The current study may be the first to have used anatomically based (FACS) coding of videotaped records of sleeping neonates' smiles. In a brief period of observation, bilateral Duchenne smiling occurred in half the sample at an overall rate of once every five minutes. In one-quarter of the sample, the strength of muscular action during Duchenne smiling fulfilled criteria typically used for coding smiling among older infants in social interactions (Messinger *et al.*, 1999). By contrast, bilateral open-mouth smiling was rare, occurring in 2 of the 25 infants observed.

The ratio of non-Duchenne and Duchenne smiles in this study (roughly equal) was similar to that found among older infants (Messinger *et al.*, 1999). Yet while older infants also produce roughly equal quantities of open and closed mouth smiling, neonates produced many more closed than open-mouth smiles. In older infants, both Duchenne and open-mouth smiling tend to occur during positive periods of interaction. There may, however, be a neuromuscular synergy active in Duchenne smiles for which there is no evidence in open-mouth smiles.

The Duchenne smile synergy is based on a similarity in function of the muscles involved. Zygomatic major pushes – while orbicularis oculi pars lateralis pulls – the cheek upward. We found evidence supportive of the possibility that these two muscles influence one another synergistically. Though the difference was not significant, stronger lip corner raises were twice as likely to occur with cheek raises as weaker lip corner raises. When both lip corner and cheek raise muscles were active in Duchenne smiles, the stronger actions were ten times more likely to occur together than the weaker actions. This may occur because the action of the zygomatic major pushes tissue over the lower muscle body of orbicularis oculi pars lateralis, making contraction of the muscles at similar intensity levels more likely (Williams *et al.*, 1989).

A possibility consonant with a muscular synergy perspective is that the dual enervation and contraction of the two muscles involved in Duchenne smiles tends to create a longer lasting display than that involved in the contraction of the zygomatic alone in non-Duchenne smiles (Messinger *et al.*, 1997). The current results suggest this may be most true when the muscles contract strongly. There were no overall differences in the durations of Duchenne and non-Duchenne smiles. At stronger levels of muscular contraction, however, Duchenne smiles had a median duration of 1.35 s, as compared to 0.86 s for non-Duchenne smiles. This increased duration is consonant with results indicating that among smiles of stronger intensity occurring in older infants, Duchenne smiles continue to have longer durations than non-Duchenne smiles (Fox & Davidson, 1988; Messinger *et al.*, 1999).

It should also be noted that the frequency of bilateral Duchenne smiling among the neonates was higher than the frequency of unilateral Duchenne smiling. No such laterality difference was evident for non-Duchenne smiles. This suggests that when both lip corner raising and cheek raising were involved in a smile, the action was likely to involve muscles on both sides of the face. Ipsilateral (same side) enervation tends to yield bilateral movement (Rinn, 1984). The tendency for smiles involving cheek raising to be bilateral is consistent with the high proportion of ipsilateral neural fibers enervating the upper face.

Conclusion

Emde's early work indicated that neonatal smiles were not related to feeding sequelae (i.e. burps, regurgitation and flatus), negating the 'gas' hypothesis (Emde & Koenig, 1969b). High rates of smiling in premature infants (Emde *et al.*, 1971) and the observation of smiling in a microcephalic infant (Harmon & Emde, 1972) led Emde *et al.* to conclude that neonatal smiling was caused by brainstem activation and had no clear relationship to positive affect (Emde & Koenig, 1969b).

Observational studies such as ours are necessarily limited in discerning the function of early smiling. Electromyographic (EMG) investigation of electrical activity produced by facial muscles would shed light on synergies involved in Duchenne smiling. Electroencephalographic (EEG) measurement of neural activity accompanying Duchenne and non-Duchenne neonatal smiles would shed light on their emotional significance. In a complementary approach to emotional significance, we are currently asking naïve observers to judge the joy expressed by neonatal Duchenne and non-Duchenne smiles involving more and less intense levels of muscular contraction.

Judgment studies are of special interest because caregivers' responses to neonatal smiling might influence the developmental significance of this behavior. In this sample, some neonates displayed Duchenne smiles while others did not. Longitudinal research examining the relationship between neonatal smiles and smiles in the first months of life could help determine whether individual differences in the form and quantity of endogenous smiling presage or are irrelevant to later differences in the quantity of social smiling. It may be that neonates who smile more during sleep are also more likely to smile when awake. Early smiles during waking states might lead to parents' visual attention, smiles and vocalizations. This may be particularly true of Duchenne smiles which typically involve stronger muscular contractions than other smiles. Positive caregiver responses to these smiles might in turn lead to early social smiling and positive interactions with the young infant. The current study indicates the need for longitudinal research investigating whether the way in which young infants smile impacts later socioemotional development.

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