What's in a Smile?

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In positive social contexts, both adults and older infants show more Duchenne smiling (which involves high cheek raising) than non-Duchenne smiling (which does not). This study compared Duchenne and non-Duchenne smiles in early infancy for clues to their emotional significance. Infants ($N = 13$) from 1 to 6 months of age were videotaped weekly for 5 min in 208 face-to-face interactions with their mothers. Levels of Duchenne and non-Duchenne smiling were correlated within interactive sessions, and the 2 smiles had similar developmental trajectories. Duchenne smiles were typically preceded by non-Duchenne smiles. The results suggest these frequently contrasted types of smiles occur in similar situations and are often different temporal phases of a continuous emotional process. In contrast to adults, infant Duchenne smiles had longer durations than non-Duchenne smiles, suggesting infant smiling does not fit adult models of emotional functioning.

Positive emotion is a central feature of social development. This study is an in-depth examination of the prototypical facial display of positive emotion, the smile. The premise is that information on how social smiles form and develop in early infancy will expand knowledge of the emotional processes that may be involved in these phenomena. Smiling is associated with self-reports of happiness in adults (Ekman, Friesen, & Ancoli, 1980) and is used as an index of enjoyment in some measures of infant facial expression (Izard, Dougherty, & Hembree, 1983). However, distinct types of smiles occur in different contexts.

Duchenne Smiling

All smiles occur when the zygomatic major contracts, lifting the lip corners up and to the sides of the face (Ekman & Friesen, 1978). The Duchenne smile is distinguished from other (non-

Duchenne) smiles because it involves the contraction of a muscle (orbicularis oculi, pars lateralis) that raises the cheeks around the eyes (Ekman, Davidson, & Friesen, 1990). The situational and experiential correlates of Duchenne smiling differ from those of non-Duchenne smiling. Ekman et al. (1990) found that adults spent more time Duchenne smiling while watching pleasant than unpleasant films. Time spent Duchenne smiling was also differentially associated with self-reports of happiness among adults (Ekman et al., 1990). Among infants, Duchenne smiles were more likely to occur than other smiles when 10-month-olds greeted their mothers (Fox & Davidson, 1988). These investigators also found that Duchenne smiles were accompanied by greater left frontal cerebral activation, which is thought to be associated with approach activation, than were non-Duchenne smiles.

Ekman's (1992, 1994) discrete emotions theory emphasizes the qualitative distinction between Duchenne and non-Duchenne smiles. In adults, Duchenne smiles are thought to be associated with enjoyment, and non-Duchenne smiles are not (Ekman et al., 1990). Does this qualitative distinction also hold for infants? Information on the association of Duchenne smiles with non-Duchenne smiles, the formation of Duchenne smiles, and the duration and development of the two smiles in infancy will help address this question.

Are Levels of Duchenne and Non-Duchenne Smiling Associated?

In Ekman's (1992, 1994) discrete view, joy is expressed by Duchenne smiling but not by non-Duchenne smiling. These smiles, then, have different putative causes in adults. This would make it noteworthy if interactive sessions high in Duchenne smiles were also high in non-Duchenne smiles. To test this association, both the frequencies and the total durations of these two smiles were correlated over interactive sessions.

Do Duchenne Smiles Typically Emerge From Non-Duchenne Smiles?

The association between Duchenne and non-Duchenne smiling can also be looked at within a given episode of smiling. Given the discrete emotion emphasis on the distinction between adult Duchenne and non-Duchenne smiling, it would be of particular interest if infant Duchenne smiles were typically preceded by non-Duchenne smiles. If Duchenne smiles typically emerged from non-Duchenne smiles, it would suggest a relatively continuous process of positive emotional activation among infants.

Do Duchenne Smiles Last Longer Than Other Smiles?

Discrete emotion theory predicts that because of their status as emotion expressions, Duchenne smiles will have shorter mean durations than non-Duchenne smiles (Ekman & Friesen, 1982). Comparisons among adults, however, either have not included statistical tests (Ekman et al., 1990; Ekman & Fridlund, 1987) or have been nonsignificant (Frank, Ekman, & Friesen, 1993). Yet, Fox and Davidson (1988) found that among older infants, Duchenne smiles had longer mean durations than non-Duchenne smiles. Not all of Fox and Davidson's infants produced each type of smile, however. This underlines the importance of the present, strictly within-subject replication of their results.

Ekman (1992, 1994) also argued that emotional expressions—that is, Duchenne smiles but not non-Duchenne smiles—are of relatively uniform duration. In support, Frank et al. (1993) found that there was less variance around the mean duration of adult Duchenne smiles than around the mean duration of adult non-Duchenne smiles. Frank et al., however, selected only one Duchenne and one non-Duchenne smile per participant and then compared variances in the durations of smiles between participants. This does not address whether, for any given individual, the durations of Duchenne smiles are less variable than the durations of non-Duchenne smiles. The present study's aim was to shed light on the temporal stability of the positive expressions of individual young infants. To do this, we compared the mean durations of their Duchenne and non-Duchenne smiles as well as the degree of variability in the duration of each type of smile.

Do Duchenne and Non-Duchenne Smiling Show Similar Associations With Age?

The development of social smiling and positive affect between 1 and 6 months of age makes this a propitious period to examine the dynamics of smiling for clues to infant emotional development. If Duchenne and non-Duchenne smiles have similar associations with age, it would suggest similarities in their developmental function. Oster and Rosenstein (in press) photographed Duchenne smiles in premature neonates. However, Duchenne smiles in full-term neonates are rare (Emde, McCartney, & Harmon, 1971), and Wolff (1987) first observed the Duchenne smile only at 3 weeks of age. These initial reports highlight the need for additional information on the development and characteristics of Duchenne smiling in social contexts.

Does Duchenne Smiling Typically Occur With Mouth Opening?

The varieties of infant smiling are not exhausted by the distinction between smiles that do and do not involve cheek raising. In open-mouth smiles, the lip corners are raised, and the jaw is dropped. Between 10 and 18 months, open-mouth smiles have been found to predominate during social games (Dedo, 1991) and during physical play with fathers (Dickson, Walker, & Fogel, 1997). They are also referred to as play smiles (e.g., Dickson et al., 1997) because a similar configuration is seen among nonhuman infant primates, typically during play involving physical contact (Plooij, 1979; Redican, 1975; van Hooff, 1972).

Ethologically oriented researchers have typically examined mouth opening and lip movements during smiling (e.g., Jones, Raag, & Collins, 1990), whereas emotion-oriented researchers have been concerned with cheek raising (e.g., Frank et al., 1993). By measuring both of these dimensions, we ask the degree to which smiles that involve cheek raising (Duchenne smiles) are also likely to involve mouth opening (producing what Dickson et al., 1997, called the "duplay smile"). As a contrast to Duchenne smiles, we also explored the formation of open-mouth smiles in real time, their typical duration, and development.

Goals

This study responds to calls for longitudinal investigation of the development of infant smiling (Jones et al., 1990; Oster & Ekman, 1977). By comparing Duchenne and non-Duchenne smiling, we sought to shed light on infant emotional experience. If both the frequency and the total duration of Duchenne and non-Duchenne smiles are associated within interactive episodes, it would suggest these smiles occur in similar circumstances. If Duchenne smiles typically emerge from non-Duchenne smiles, it would suggest these smiles can be part of a continuous emotional process. If Duchenne smiles last longer than non-Duchenne smiles, it would indicate difficulties with the view that, as positive emotional expressions, Duchenne smiles are briefer than putatively nonemotional, non-Duchenne smiles. If Duchenne and non-Duchenne smiling show similar associations with age, it would indicate these smiles have similar developmental trajectories. If Duchenne smiles typically occur with mouth opening, it would invite interest in the emotional meaning of the joint configuration. To address these issues, the organization of smiling, cheek raising, and mouth opening was examined weekly during the first 6 months of life in a relatively small sample of infants engaged in face-to-face interaction with their mothers.

Method

Participants

The mothers of 15 singletons were recruited through ads in a local newspaper to participate in a longitudinal study. Two mothers ceased participating within the 1st month of their infants' attendance. Of the 13 remaining infants, 6 were firstborn; 8 were male, and 5 were female. All infants were part of two-parent, middle-class families in a small Midwestern community. One mother was African American, and the rest were European American.

Procedure

Mothers were asked to bring their infants to the observation room weekly and were paid $150 after the completion of the first 6 months of attendance. When mothers brought their infants to the lab for the first observation session, they were asked to "play and talk to your baby as you would at home." Mothers were seated on chairs and held their infants in their laps without having access to toys.

Mother–infant dyads were videotaped in a 12.5-ft (3.81-m) square carpeted observation playroom with three video cameras mounted on the walls. The movement of each camera was remotely controlled from an observation room located behind a one-way mirror. Two cameras were focused on the infant's face and upper body. Each camera was placed in one of the corners of the room behind the mother. The camera with the best image of the infant's face comprised half of a composite split-screen video image onto which running time, accurate to the video frame, was superimposed.

Sessions lasted approximately 5 min. Sessions were terminated if the infant cried hard and continuously for more than 30 s (this occurred in nine instances). The mean session duration was 287 s (range = 80–300 s). Mothers began bringing their infants at a mean age of 4 weeks 2 days (range = 4–9 weeks), and the last lap sessions occurred when the infants were on average 23 weeks 1 day old (range = 22–24 weeks). Thirteen infants completed a total of 208 sessions. The mean number of sessions per infant was 16 (range = 9–20, mode = 18, Mdn = 16).

Facial Coding

The Facial Action Coding System (FACS; Ekman & Friesen, 1978) is an anatomically based coding system that allows for the identification of muscular contractions, termed *facial action units* (AUs), that produce unique appearance changes. In this study, the presence or absence of infant lip-corner raises (smiles), cheek raises, and mouth opening was coded continuously during each videotaped interaction. Each of these AUs was coded if its intensity met or exceeded minimum requirements (the "x" level; Ekman & Friesen, 1978). Each AU was coded independently of whether other facial actions were occurring.

Graduate students certified in FACS (Ekman & Friesen, 1978) and trained in its application to infants (Oster & Rosenstein, in press) coded lip-corner raising and cheek raising. Lip-corner raising (AU 12) is produced by the action of the zygomatic muscle and constitutes the basis of other smiles. The three minimum criteria for lip-corner raising are raising of the lip corners, raising of the infraorbital triangle (making the cheeks more prominent), and a deepening of the nasolabial furrow between the nose and the cheeks. Cheek raising (AU 6) is produced by the contraction of the muscle orbiting the eye (orbicularis oculi, pars lateralis). In infants, prominent cheek raising that deepens and raises the furrow beneath the lower eyelid is the major criterion for cheek raising.

In Ekman and Friesen's (1978) original formulation, when lip corners were raised to their maximum extent, cheek raising was also coded. To follow this decision rule (which never had to be applied arbitrarily), approximately the first third of the sessions (35%) were coded in a single pass through the videotape. With the advent of new decision rules indicating that these AUs could be coded independently (Friesen & Ekman, 1992), the AUs were coded in separate passes for the remaining sessions (65%). A comparison of codes completed in one pass and in two separate passes showed good agreement (lip-corner raising: 92% agreement, Cohen's κ = .75; cheek raising: 90% agreement, Cohen's κ = .68).

The criterion for mouth opening was that the jaw was clearly dropped (Oster & Rosenstein, in press). This facial action was relatively easily identified and was coded by coders who were trained in the relevant FACS AUs but who were not FACS-certified. Approximately half of the reliability sessions conducted on this AU were carried out between the primary uncertified coder and a FACS coder, and approximately half were carried out between uncertified coders. These yielded virtually identical estimates of intercoder agreement (88% and 87% agreement, respectively, with identical κs of .72).

During the mother–infant interactions, infants were held on their mothers' laps, and mothers were free to move their infants about as they might at home. At times, infants covered their faces with their hands, and mothers quickly lifted their infants in the air or pressed their infants to their cheeks or chests. During such episodes, a "not observable" code was used. In the coding of lip-corner raising, cheek raising, and mouth opening, codes for not observable accounted for 14%, 4%, and 14%, respectively, of the total session time. To address concerns about the total duration of not-observable codes, we conducted trial analyses in which we assumed that when a particular facial action was not observable, the prior facial action had continued until the next facial action was observed. These trial analyses yielded results identical to those reported below in which instances of not observed were deleted.

Intercoder Agreement

The order in which sessions were coded was randomized, and weekly coding meetings were held to review difficult coding decisions and disagreements stemming from reliability analyses. Intercoder agreement was calculated on random samples of approximately 15% of the sessions. At least two sessions for each infant, one before and one after 13 weeks of age, were used in these analyses. Analyses were conducted separately to ascertain whether coders agreed as to when facial actions began and to ascertain whether coders agreed on the durations of these actions.

To ascertain agreement on the beginning of facial actions, we established a 2-s time window within which each coder had to code the onset of a facial action, irrespective of its duration, for the codes to be counted as an agreement (see Bakeman & Gottman, 1986). Percentages of agreement were 79% for lip-corner raises, 79% for cheek raises, and 78% for mouth opening.[1] Having ascertained agreement, the actual mean lags between coders were 0.37 s (SD = 0.27) for lip-corner raises, 0.32 s (SD = 0.31) for cheek raises, and 0.50 s (SD = 0.57) for opening the mouth.

Although coders agreed on the onsets of facial actions, it is possible that coders may have disagreed on the duration of facial actions. To address this possibility, we calculated the percentage of agreement and Cohen's kappa (which corrects for random agreement) for time spent in each facial action. Time spent in facial actions (i.e., their duration) was calculated to 1/30th of a second (one video frame). In this analysis, the total durations of all segments of an interaction in which coders agreed that the same action was occurring at exactly the same time were summed to produce time in agreement (see Bakeman & Gottman, 1986). The durations of segments in which coders were not coding the same action were summed to produce time in disagreement. Percentages of agreement were 89% for lip-corner raising, 87% for cheek raising, and 88% for mouth opening. The respective kappas were .77, .63, and .72.

Data Summary and Analysis

For data analysis, information on the presence and absence of lip-corner raising (smiling), cheek raising, and mouth opening were combined to provide information on the onsets and offsets of Duchenne smiles (smiling and cheek raising) and open-mouth smiles (smiling and mouth opening). Because of variations in session length, frequency and total duration statistics were calculated, respectively, as frequency per minute and percentage of time (both excluding time in not observed). For analyses related to the mean duration and the total duration of Duchenne and non-Duchenne smiling, summary statistics were calculated for each infant (collapsing over

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[1] In ascertaining agreement on the onsets of events (rather than their total duration), agreement on nonevents could not occur. This prevented the calculation of agreement expected by chance and of Cohen's kappa.

weekly sessions). This strategy resulted in highly stable summary means for individual infants, each based on more than 100 instances of a particular type of smile.

To test developmental and other effects, summary statistics concerning Duchenne and non-Duchenne smiling were calculated for each weekly session. In longitudinal data, group correlations can obscure the developmental trajectories of individual infants (see Rogosa, 1995). To test hypotheses regarding the association of Duchenne and non-Duchenne smiling, correlations were conducted over developmental sessions for each infant. To test developmental increases in each type of smiling, correlations were calculated between each type of smiling and age in weeks for each infant. All correlations were converted to z scores. One-sample t tests of these z scores indicated whether associations between smiles and associations between smiles and age were due to chance. Paired t tests of the z scores indexing the correlations of Duchenne and non-Duchenne smiles with age indicated whether they were statistically different from one another.

Results

Are Levels of Duchenne and Non-Duchenne Smiling Associated?

Individual infants showed high correlations between the frequencies of their Duchenne and non-Duchenne smiles, as well as high correlations between the total durations of these smiles (see Table 1). Sessions that had high levels of one type of smiling tended to have high levels of the other type of smiling.[2]

Do Duchenne Smiles Typically Emerge From Non-Duchenne Smiles?

An average of 60% of Duchenne smiles were immediately preceded by non-Duchenne smiles (see Figure 1 for an example). A statistical comparison of observed and expected transition probabilities indicated that Duchenne smiles were also more likely to be preceded by non-Duchenne smiles than one would expect by chance, $t(12) = 4.84$, $p = .000$.[3] Nevertheless, an average of only 30% of non-Duchenne smiles were followed by Duchenne smiles. In fact, non-Duchenne smiles were more likely to relax into nonsmiles than to be followed by Duchenne smiles, $t(12) = -3.82$, $p = .002$. In sum, non-Duchenne smiles

Figure 1. An infant's non-Duchenne smile (on the left), followed approximately 2 s later by a Duchenne smile (on the right) in which the cheeks are raised more prominently.

typically ended rather than proceeding to Duchenne smiles. Yet, when a Duchenne smile formed, it was typically preceded by a non-Duchenne smile.

Do Duchenne Smiles Last Longer Than Other Smiles?

Before comparing the mean durations of non-Duchenne and Duchenne smiles, we note that their mean durations differed depending on the sequences in which they were embedded. Non-Duchenne smiles that preceded Duchenne smiles were briefer (1.21 s) than non-Duchenne smiles that preceded nonsmiles (1.54 s), $t(12) = 3.12$, $p = .009$. Duchenne smiles that followed non-Duchenne smiles were lengthier (2.50 s) than Duchenne smiles that followed nonsmiles (1.95 s), $t(12) = 4.02$, $p = .002$. To account for these differences, we first compared all Duchenne and non-Duchenne smiles, whether or not they were sequentially ad-

Table 1

Correlations Between Different Types of Smiling

Type of smile	Mean r	t(12)	No. of infants showing effect
Duchenne and non-Duchenne smiles			
Frequency	.70	7.08**	13
Mean duration	.25	2.78*	11
Total duration	.56	4.86**	13
Open- and closed-mouth smiles			
Frequency	.71	6.42**	13
Mean duration	.13	1.58	9
Total duration	.46	3.85**	12

Note. Correlations were calculated across sessions individually for each of the 13 infants. Correlations were then converted to z scores, and t tests were used to test the significance of the associations. * p < .05. ** p < .005.

[2] Levels of different types of smiles could also be summed over sessions for each infant and smiling levels correlated between infants. Those infants who showed a high frequency of Duchenne smiles also showed a high frequency of non-Duchenne smiles ($r = .88$, $p < .01$). However, the association between the total durations of these smiles was not significant ($r = .39$, $p > .05$) in this sample of 13. Nevertheless, correlations conducted within infants are most conceptually appropriate. The question of interest was whether, for each infant, Duchenne and non-Duchenne smiles tended to occur in similar situations.

[3] For these comparisons, facial configurations were divided into Duchenne smiles, non-Duchenne smiles, and periods that did not involve either type of smile (nonsmiles). The nonsmile category involved all configurations without smiling, including cheek raising in the absence of smiling. Distinguishing between nonsmile configurations with and without cheek raising had a minimal impact on unconditional transition probabilities and no impact on their significance.

To calculate significance, observed transition probabilities were compared with expected probabilities. Expected probabilities reflect the observed distribution of the relevant facial actions. (Only half of Duchenne smiles, for example, were expected to be preceded by non-Duchenne smiles. This is because Duchenne smiles could be preceded by either non-Duchenne smiles or nonsmiles, and the frequency of these configurations was approximately equal.) This comparison produced a z score for each infant that was evaluated with t tests.

Table 2
Duchenne-Smiling Comparisons

Measure	Duchenne smiling	Non-Duchenne smiling	Paired $t(12)$	p	No. of infants (out of 13) showing effect
All Duchenne and non-Duchenne smiles					
Mean duration[a] (in seconds)	2.27	1.47	4.50	.001	11
Variation in duration[b]	0.90	1.14	4.39	.001	13
Frequency (per minute)	1.95	3.60	−8.56	.000	13
Duchenne and non-Duchenne smiles following periods of nonsmiling					
Mean duration[a] (in seconds)	1.95	1.45	2.99	.011	11
Variation in duration[b]	0.91	1.15	2.94	.012	11
Frequency (per minute)	0.68	2.40	−11.75	.000	13

[a] To facilitate comparison with Frank et al.'s (1993) findings, we also conducted Wilcoxon matched-pairs signed-rank tests. These tests confirmed that infants' Duchenne smiles had longer durations than non-Duchenne smiles (all smiles: $z = 2.83, p = .005$; smiles preceded by periods of nonsmiling: $z = 2.41, p = .016$). [b] Variation in mean duration was measured for each infant with the coefficient of variation. The coefficient of variation is the standard deviation of the mean duration divided by the mean itself. Lower numbers indicate less variation in the duration of a smile.

jacent to one another. Then we compared only those non-Duchenne and Duchenne smiles that emerged from periods without smiling. Both sets of comparisons yielded equivalent results.

Duchenne smiles had longer mean durations than non-Duchenne smiles (see Table 2). The durations of the Duchenne smiles of individual infants also varied less around their means than did those of non-Duchenne smiles.[4] In sum, Duchenne smiles were maintained by infants for relatively long and relatively constant periods.

Do Duchenne and Non-Duchenne Smiling Show Similar Associations With Age?

The frequency, mean duration, and proportion of time spent in Duchenne and non-Duchenne smiling, open- and closed-mouth

Table 3
Correlations Between Different Types of Smiling and Age

Measure	Mean r	$t(12)$	No. of infants showing increase
Total smiling			
Frequency	.38	3.99	12
Total duration	.51	5.81	11
Mean duration	.41	4.34	12
Duchenne smiling (non-Duchenne smiling)			
Frequency	.34 (.43)	4.45 (3.96)	10 (12)
Total duration	.40 (.49)	5.63 (4.98)	12 (12)
Mean duration	.32 (.35)	3.50 (3.91)	11 (10)
Open-mouth smiling (closed-mouth smiling)			
Frequency	.37 (.43)	4.69 (4.37)	12 (12)
Total duration	.42 (.44)	6.07 (4.69)	12 (11)
Mean duration	.29 (.25)	4.37 (2.32)	12 (10)

Note. Correlations were calculated individually for each of the 13 infants. Correlations were then converted to z scores, and t tests were used to test the significance of the associations with age. All $ps < .005$, with the exception of the mean duration of closed-mouth smiling, $p < .05$.

smiling, and all types of smiling combined showed a linear increase with age (see Table 3 and Figure 2). Regression analyses testing quadratic and cubic terms did not yield significant effects ($ps > .10$). Paired t tests indicated no differences in the strength with which infants' Duchenne and non-Duchenne smiling, or open- and closed-mouth smiling, rose with age ($p > .10$). Likewise, the proportion of smiling that was Duchenne and open-mouth smiling did not increase with age ($ps > .10$). In sum, no differences could be detected in the strength of the developmental increases in different types of smiling over the first 6 months of life.

Does Duchenne Smiling Typically Occur With Mouth Opening?

A greater percentage of Duchenne smiling (55%) than of non-Duchenne smiling (33%) involved mouth opening, $t(12) = 7.77$, $p < .001$. Focusing on open-mouth smiling, transition probabilities indicated that when infants smiled with their mouths closed, they stopped smiling 65% of the time, rather than proceeding to an open-mouth smile. The tendency for smiling to end, in other words, was more pronounced than the tendency to open the mouth while smiling, $t(12) = 4.43, p = .001$. This pattern paralleled the Duchenne transition probabilities. There was, however, no tendency for open-mouth smiles to be preceded by closed-mouth smiles, simplifying the comparison of durations. The mean duration of open-mouth smiles was almost equivalent to the mean duration of closed-mouth smiles, and variation around these means did not differ (see Table 4).

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[4] Comparisons of variance around the means of each smile between subjects were not significant. Specifically, we followed Frank et al. (1993) in using Levene's formula, as well as variants suggested by Brown and Forsythe (1974). Practically, however, the small number of participants reduced power in finding between-subjects differences. Conceptually as well, explanations for reduced variability invoke processes that operate on individuals, making the within-subject comparison most appropriate.
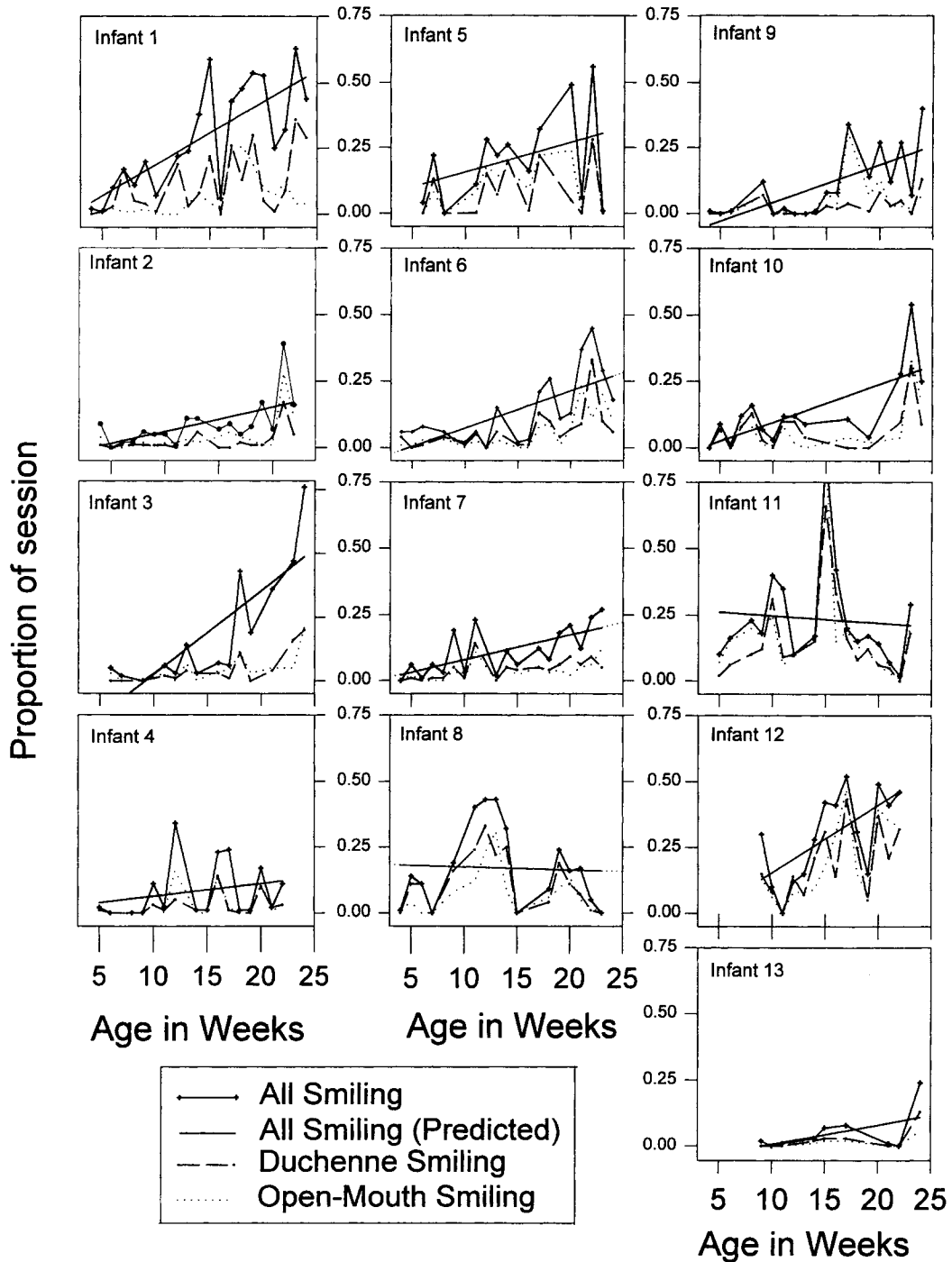
Figure 2. The duration of total smiling, Duchenne smiling, and open-mouth smiling increased with age. The solid straight line plots the predicted changes in total smiling with age. The observed proportions of all categories of smiling show a high degree of association as well as high infant-to-infant and session-to-session variability. The proportion of total smiling by Infant 11 at 15 weeks of age was .85.

Discussion

Non-Duchenne smiles have been termed *unfelt smiles* in adults (Ekman & Friesen, 1982) and are not regarded as expressions of

emotion in Ekman's discrete account (Frank et al., 1993). They have even been classified as indexes of negative emotion among older infants (e.g., Dawson, Panagiotides, Klinger, & Spieker, 1997). However, the present finding that non-Duchenne and

Table 4
Open-Mouth Smiling Comparisons

Measure	Open-mouth smiling	Closed-mouth smiling	Paired $t(12)$	p	No. of infants (out of 13) showing effect
Mean duration (in seconds)	1.60	1.50	0.55	.595	11
Variation in duration[a]	1.16	1.14	0.41	.690	6
Frequency (per minute)	2.65	3.69	−3.80	.003	12

[a] Variation in mean duration was measured for each infant with the coefficient of variation. The coefficient of variation is the standard deviation of the mean duration divided by the mean itself. Lower numbers indicate less variation in the duration of a smile.

Duchenne smiles are associated within sessions and contiguous within episodes of smiling suggests these conclusions may be premature.

Duchenne and Non-Duchenne Smiling Are Associated Within Interactive Sessions and Within Episodes of Smiling

The finding that levels of Duchenne and non-Duchenne smiling are correlated supports the supposition that Duchenne and non-Duchenne smiles have a hedonic similarity. Specifically, it may be that non-Duchenne smiles are positively toned (Izard et al., 1983). If so, this positive state would be more conducive to the transition to intense positive engagement associated with Duchenne smiling than would periods of nonsmiling. This would help explain why Duchenne smiles are typically preceded by non-Duchenne smiles. One might regard the transition from non-Duchenne to Duchenne smiling as a single smile involving a two-step increase in positive engagement. If so, this more graduated increase may set the stage for more sustained periods of enjoyment. This would explain the tendency of Duchenne smiles preceded by non-Duchenne smiles to have particularly prolonged durations.

Duchenne Smiles Last Longer and Are More Stable Than Non-Duchenne Smiles

In the first 6 months of life, Duchenne smiles lasted approximately 50% longer than non-Duchenne smiles. The greater duration of Duchenne smiles is consistent with the findings of Fox and Davidson (1988) for 10-month-olds and with Ekman et al.'s (1990) description of longer duration Duchenne smiles among adults watching positively toned films (but see also Frank et al., 1993).

Individual infants showed less variation in the durations of their Duchenne smiles than in the durations of their non-Duchenne smiles. Frank et al. (1993) also found that the durations of Duchenne smiles were more consistent than those of other smiles. The process of forming and dissolving Duchenne smiles may be relatively automated at a neural level (Frank et al., 1993). Duchenne smiles may also index a more intense and consistently longer duration process of affective involvement than non-Duchenne smiles.

Different Types of Smiling Have Similar Associations With Age

The frequently contrasted Duchenne and non-Duchenne smiles, as well as closed- and open-mouth smiles, showed similar devel-

opmental trajectories (see Table 3 and Figure 2). Despite session-to-session variability, the frequency of smiles, their mean duration, and the proportion of time spent smiling increased with age for almost all infants.

Duchenne Smiling Typically Involves Mouth Opening

We found that more than half of Duchenne smiling involved mouth opening. Multiple studies have documented the propensity of Duchenne smiles to occur in positive situations (Ekman et al., 1990; Fox & Davidson, 1988). The present results highlight the importance of investigating whether open-mouth smiles also tend to occur in positive situations. Research is also needed to determine the situations in which Duchenne and open-mouth smiling tend to occur together, a configuration that may be a precursor to laughter.

Conclusion

The present results indicate that there may not be a rigid qualitative distinction between the emotional meanings of infant Duchenne and non-Duchenne smiles that occur during interaction. The two types of smiles tended to follow one another in real time, suggesting that they can be part of a continuous emotional process. At a more global level, interactions high in one type of smiling tended to be high in the other, again suggesting a common emotional process. Finally, the developmental trajectories of the two types of smiles did not differ, suggesting common developmental functions broadly conceived.

Nevertheless, commonalities between the smiles must not be overstated. It remains to be seen, for example, whether Duchenne and non-Duchenne smiles are associated with different infant and mother actions during face-to-face interaction. More generally, Fox and Davidson (1988) found that the majority of 10-month-old infants Duchenne smiled to mothers' smiling approach and non-Duchenne smiled to an approaching, nonsmiling stranger. When elicited in different contexts, Duchenne and non-Duchenne smiles may show more qualitative differences than when observed in a single naturalistic context involving repeated interactions with mothers, caregivers with whom infants are intimately familiar. It nevertheless appears clear that infant Duchenne and non-Duchenne smiles do not fit current models of adult emotional functioning and must be investigated on their own terms.

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