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All Smiles are Not Created Equal: Morphology and Timing of Smiles Perceived as Amused, Polite, and Embarrassed/Nervous

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Abstract We investigated the correspondence between perceived meanings of smiles and their morphological and dynamic characteristics. Morphological characteristics included co-activation of *Orbicularis oculi* (AU 6), smile controls, mouth opening, amplitude, and asymmetry of amplitude. Dynamic characteristics included duration, onset and offset velocity, asymmetry of velocity, and head movements. Smile characteristics were measured using the Facial Action Coding System (Ekman et al. 2002) and Automated Facial Image Analysis (Cohn and Kanade 2007). Observers judged 122 smiles as *amused*, *embarrassed, nervous*, *polite*, or *other*. Fifty-three smiles met criteria for classification as perceived amused, embarrassed/nervous, or polite. In comparison with perceived polite, perceived amused more often included AU 6, open mouth, smile controls, larger amplitude, larger maximum onset and offset velocity, and longer duration. In comparison with perceived embarrassed/nervous, perceived amused more often included AU 6, lower maximum offset velocity, and smaller forward head pitch. In comparison with perceived polite, perceived embarrassed/nervous more often included mouth opening and smile controls, larger amplitude, and greater forward head pitch. Occurrence of the AU 6 in perceived embarrassed/nervous and polite smiles questions the assumption that AU 6 with a smile is sufficient to communicate felt enjoyment. By comparing three perceptually distinct types of smiles, we found that perceived smile meanings were related to specific variation in smile morphological and dynamic characteristics.

Keywords Dynamic characteristics · Morphological characteristics · Smile interpretation · FACS · Automatic facial image analysis

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Introduction

What does it mean *to you* when someone smiles at you? You may think that the person is happy, they like you, they want to approach, they are hiding something or they are just being polite. Often, we have strong impressions about the meaning of a smile. An emerging view is that characteristics of the smile dramatically alter a smile's perceived meaning. This paper is about characteristics of smiles that influence perception of one meaning versus another. With the many possible meanings that smiles may communicate, knowledge of the distinction among different kinds of smiles and how they influence interpretation is critical to social adaptation (Abe et al. 2002; Brannigan and Humphries 1972; Cheyne 1976; Garotti et al. 1993; Harrigan and Taing 1997; Kraut and Johnston 1979; Krull and Dill 1998; Messinger et al. 1999; Otta et al. 1996; Scharlemann et al. 2001; Vrugt et al. 2004).

Surprisingly little is known about the association between smile characteristics and their perceived meaning. Previous literature has emphasized the relation between smile characteristics and the encoder's subjective experience rather than the decoder's interpretation. Smile characteristics that map onto the encoder's subjective experience are not necessarily the same as those that influence decoder's interpretation. For example, deliberate and spontaneous smiles have been found to differ in a number of respects (Hess and Kleck 1990; Schmidt et al. 2006a), but decoders use just some or even different features to identify smiles as spontaneous or deliberate (Hess et al. 1989; Hess and Kleck 1994). Hess and Kleck (1994) asked subjects to judge whether video clips of smiles and disgust were spontaneous or deliberate. They found that subjects were relatively poor at differentiating spontaneous and deliberate smiles, and the low performance was found to be a function of the consistent use of invalid cues, such as gaze aversion. Thus, studies of the relation between smile characteristics and encoder's subjective experience provide initial leads to characteristics that influence decoder's interpretation, but they are not sufficient. For that, it is necessary to study the relation between smile characteristics and decoder's interpretation, which is the focus of this paper. The current study is on how smiles were perceived rather than how they were produced. We first review studies of smile characteristics in relation to encoder's experience and then those of smile characteristics in relation to decoder's interpretation.

Smile Characteristics and Encoders' Experience

Several types of smiles have been studied. These include amused (also called felt, Duchenne, enjoyment, genuine, humor, duplay, and broad), polite and embarrassed (also called non-Duchenne, unfelt, non-enjoyment, false, social, masking, and controlled), tickling, and pain smiles. Most studies compare one smile type with a less specific one. For example, enjoyment was compared with non-enjoyment (Frank et al. 1993). A comparison of this sort provides information on the global distinction between broad classes of smiles. It does not, however, inform differences among more specific smile types such as among amused, polite, and embarrassed. To our knowledge only three studies have compared two or more specific and well- defined smile types, such as amused versus embarrassed (Harris 2001; Keltner 1995), and amused (humor) versus tickling and pain (Harris and Alvarado 2005).

Smiles can vary in both morphological and dynamic characteristics. Morphological characteristics are those such as presence or absence of cheek raising or mouth opening. Dynamic characteristics refer to the temporal unfolding of the smile, such as the velocity with which it begins or ends. With few exceptions (Frank et al. 1993; Keltner 1995), previous studies have focused on morphological characteristics to the exclusion of dynamic ones. This neglect of dynamics is partly due to the difficulty in measuring dynamic characteristics manually from video, which was the method used in the past. Symmetry of lip corner movement between the left and right sides of the face, for example, may be extremely subtle and difficult to observe reliably. More precise measurement techniques than available until now are needed (Ekman et al. 1981; Scheff 1983). The emergence of automated facial image analysis makes it possible to quantify the dynamics of facial expressions over time (Cohn and Kanade 2007).

Overall, studies of encoder's experience and smile characteristics have found that smiles associated with self reported amusement are accompanied with activation of *Orbicularis oculi*, which raises the cheek, referred to as action unit (AU) 6 in the Facial Action Coding System (Ekman et al. 2002), and by less variable duration (Ekman and Friesen 1982; Ekman et al. 1988; Frank et al. 1993). Smiles associated with self-reports of embarrassment are marked by gaze aversion, lip press (FACS AU 24), which inhibits the upward pulling of the lip corner, head movement down and to the left, and face touch (Keltner 1995). Tickling shares some characteristics with amused smiles and includes activation of *Orbicularis oculi* (AU 6) and an open mouth (Harris and Alvarado 2005).

Smile Characteristics and Decoders' Interpretation

A few studies considered the association between smile characteristics and decoders' interpretation. Some of these studies used actual smiles (Frank et al. 1993; Keltner 1995; Miles and Johnston 2007; Otta et al. 1996), others used manipulated or synthetic smiles (Dinehart et al. 2005; Hess et al. 1989; Krumhuber and Kappas 2005). All used an experimental approach in which pre-selected smiles that vary in one or two pre-determined characteristics were shown to observers who then made judgments about the smiles' meaning.

An advantage of the experimental approach is that it allows for causal inferences about the mapping of smile characteristics and decoder's judgments. Disadvantages are that the number of characteristics that can be parametrically combined is limited in practice and the smile stimuli may fail to generalize outside the laboratory. Because the smiles are either pre-selected or digitally manipulated, they may fail to represent the heterogeneity of naturally occurring smiles. Naturally occurring smiles can vary in multiple ways, not only in the configuration of facial actions (morphological characteristics), but also in their timing (dynamic characteristics) and their relation to other expressive behavior, such as head movements (Cohn et al. 2004; Hess et al. 2007; Kappas et al. 1994; Keltner 1995; Krumhuber et al. 2007; Lyons et al. 2000; Mignault and Chaudhuri 2003).

Overall, previous studies have identified a number of characteristics that may influence decoders' interpretations. Cheek raising (AU 6) and mouth opening contribute to perceptions of enjoyment (Frank et al. 1993). Slower onsets are associated with perceptions of greater genuineness or sincerity (Krumhuber and Kappas 2005; Schmidt et al. 2005). Irregular onsets are associated with perceptions of lack of spontaneity (Hess and Kleck 1994). Decoders perceive differences between smiles associated with encoders' reports of amusement and those associated with embarrassment, although the characteristics that influence decoders' judgments are not identified (Keltner 1995). Such findings suggest that both morphological and dynamic characteristics of smiles may relate to decoders' interpretations.

The Current Study

To study the relation between smile characteristics and decoders' interpretation we began with a large sample of heterogeneous smiles. We then collected observers' judgment of their meanings and measured smile morphological and dynamic characteristics using two approaches. These were the Facial Action Coding System (Ekman et al. 2002) to identify action units, and Automated Facial Image Analysis (AFA) to assess asymmetry, smile intensity or amplitude, and smile dynamics.

We used smiles that occurred during the course of directed facial action tasks (DFAT) (Ekman 2007). These were smiles that occurred in the absence of a request to smile. Keltner (1995) used the same method, and found that some of the smiles were associated with encoders' reports of embarrassment and amusement. In our implementation of DFAT, posers were instructed to perform 23 different facial actions. The experimenter was seated in front and slightly to the side of the poser. Presence of the experimenter in the DFAT paradigm is associated with diverse smiles (Cohn et al. 2004). As expected, posers smiled during the course of the DFAT at times when no smile was requested. These smiles were the focus of the current study.

To identify their perceived meaning, we used a perceptual judgment paradigm in which decoders viewed video clips of the smiles and made judgments. Decoders were provided with response alternatives that included the types of smiles identified in past literature—*amused, embarrassed, nervous, polite,* and *other*; the latter was included so as not to force decoders to use pre-selected smile labels if they believed they did not apply (Russell 1993). The label amused was used in place of "happy." "Happy" has more often been used when comparing different emotions (e.g., happy versus sad); whereas amused or amusement has more often been used when comparing different types of smiles. We followed the latter convention.

We then measured morphological and dynamic characteristics of each smile and evaluated the mapping between smile characteristics and perceived meaning. Morphological characteristics were the presence/absence of AU 6, mouth opening (AU 25/26), smile controls, maximum amplitude, and asymmetry of maximum amplitude between left and right lip corners. Dynamic characteristics were smile duration, velocity of lip corner movement, asymmetry of lip corner velocity, and rigid head motion. This approach allowed us to investigate the morphological and dynamic characteristics of multiple smile types as perceived by decoders.

Because the smiles were not created/selected based on *a priori* criteria, they could vary in multiple characteristics. As a result, the boundaries of meanings among smile types were not necessarily as perceptually evident as those of experimentally manipulated or pre-selected smiles. Thus, the first question of interest was to what extent the smiles were perceived as one of several types that included *amused, embarrassed, nervous,* and *polite* by the majority of the observers. We then asked what morphological and dynamic characteristics were associated with each type of smile, where smile type was defined by perceptual judgment. Our focus was on characteristics that relate to the perceived meaning of diverse smiles by observers (i.e., decoders) rather than their subjective meaning or intention to the individuals smiling (i.e., encoders). Unless otherwise noted, type of smile refers to decoders' perception, or judgment, rather than encoders' subjective experience.

Based on previous findings (Keltner 1995), we predicted that some of the smiles would be perceived as amused and embarrassed. Also, given the social nature of our version of DFAT, we predicted that some of the smiles would be perceived as polite smiles.

With regard to morphological characteristics, we predicted that the occurrence of AU 6 and mouth opening would be more frequent in perceived amused than perceived embarrassed or polite. Consistent with Keltner (1995), the occurrence of smile controls would be more frequent during smiles perceived as embarrassed than during those perceived as amused and polite. Amplitude for perceived amused would be greater than for perceived embarrassed and polite smiles. We also predicted that perceived amused smiles would have greater symmetry of amplitude than perceived embarrassed and polite (Ekman and Friesen 1982; Frank et al. 1993).

For dynamic characteristics, we predicted that the duration of smiles perceived as amused would be between .5 to 4 s and those perceived as embarrassed and polite would be either shorter or longer (Ekman and Friesen 1982). The maximum velocity of the onset and offset of the smiles was predicted to vary with smile type (Krumhuber and Kappas 2005; Schmidt et al. 2005). Based on Ekman's and Friesen's (1982) proposition we predicted that perceived amused smiles would have more symmetric onset and offset velocity than perceived embarrassed or polite. Finally, following Keltner (1995), we predicted that perceived embarrassed smiles would be associated with head movements downward and to the left, more so than perceived amused and polite.

Method

Participants

Participants were 101 undergraduate students of the University of Pittsburgh (61% female, average age 19.5 years), who received class credit for their participation. The majority was Caucasian (78%), others were African-American (8%) or other ethnicity (14%). The rights of the participants were protected and applicable human research guidelines were followed.

Stimuli

Image data were smiles that occurred during the course of the recording of the Cohn-Kanade Facial Expression Database (Cohn et al. 1999; Kanade et al. 2000). One hundred subjects were video recorded while performing directed facial action tasks (Ekman 2007) during which 84 subjects smiled to the experimenter at one or more times between tasks. These smiles were not performed in response to a request. They comprised the initial pool for stimuli selection. Criteria for further inclusion were: (a) relatively neutral expression at start, (b) no indication of the requested directed facial action task, (c) absence of facial occlusion prior to smile apex, and (d) absence of image artifact (e.g., camera motion). One hundred twenty-two smiles from 66 subjects (91% female) met these criteria. Thirty-two percent were accompanied by brief utterances, which was not unexpected given the social setting and hence not a criterion for exclusion. Occlusion at some time between smile apex and offset was present in 22 cases, which resulted in missing data for analyses of smile duration and the offset parameters as described below.

Each smile was digitized from S-VHS video into 640 $\times$ 480 pixel arrays with 24-bit color resolution from one frame prior to smile onset (i.e., start of the smile) until smile offset (i.e., end of the smile) as determined by FACS (Ekman et al. 2002) criteria.

In constructing stimulus sets, video clips were created with the first neutral image shown for 1 s followed by the rest of the images presented at NTSC frame rate (29.97 f/s). An item number was presented for 1 s before and after each clip. Order of items was determined at random with the restriction that smiles from the same individual be separated by at least three smiles from different individuals. To control for possible effects of fatigue on judgments of later items, two identical sets of stimuli were created that differed only in the order of the items. Participants were randomly assigned to one or the other set.

Procedure

The current study consisted of two parts. The first was a judgment task to assess perceived meanings of the smiles. The second was to test the hypotheses about the relation between perceived meanings and specific smile characteristics.

Judgment Task

Items (i.e., smile clips) were projected one at a time onto a large viewing screen to groups of 10 to 17 participants. Participants recorded their judgments during a pause following each item. They were instructed to watch the whole clip and make judgments after seeing the item number at the end of the clip. Judgments consisted of smile type (amused, embarrassed, nervous, polite, or other), and Likert-type ratings of smile intensity (from 1 = *no emotion present* to 7 = *extreme emotion*), and confidence in smile type judgments (from 1 = *no confidence* to 7 = *extreme confidence*).

To familiarize participants with the task, three practice items (not part of the stimuli) were presented just prior to starting. A 5-min rest break was given in the middle of the procedure. At the conclusion of the judgment task, participants were debriefed.

Smile Characteristics

Morphological characteristics and smile duration were derived from manual FACS coding by certified FACS coders. Coders determined the presence or absence of AU 6, smile controls (AU 15, 17, and 23/24), and mouth opening (AU 25 or 26). Smile duration was determined by calculating the number of frames from the onset to the offset of AU 12 (lip corner puller). Comparison coding was performed for 20% of the smiles. Inter-coder agreement as measured by Cohen's Kappa coefficient was .83 for AU 6 and .65 for smile controls.

Dynamic characteristics other than duration were derived from Automated Facial Image Analysis (AFA v.3), which automatically tracks movement (pixel coordinates) of facial features in digitized face images (Cohn and Kanade 2007; Moriyama et al. 2006). Dynamic characteristics were maximum velocity of the lip corners during the onset and offset phases of the smile, asymmetry of lip corner velocity, and rigid head motion. Rigid head motion included pitch (up-down head movement), yaw (left-right head turn), and roll (left-right head tilt). Consistent with FACS, onset and offset of smiles were defined as the period from initial movement of the lip corners to maximum amplitude and from maximum amplitude to resting position, respectively. Following previous studies (Schmidt and Cohn 2001; Van Swearingen et al. 1999), lip corner motion was quantified as the displacement of the lip corner coordinates,

$$\Delta d = \sqrt{\Delta x^2 + \Delta y^2}$$

To enable comparison across individuals, each individual's Δd value was standardized on the initial width of the mouth in the first image. Maximum velocity was defined as maximum change between two consecutive frames. Asymmetry of lip corner velocity was calculated by subtracting the left from the right lip corner Δd value. This was calculated separately for onset and offset phases.

Data Analysis

Judgment Data

For each smile we calculated the percentage of participants who judged it as amused, embarrassed, nervous, polite, or other. These percentages are referred to as judgment scores. From the five judgment scores, smiles were assigned to the modal type if at least 50% of participants endorsed that type and no more than 25% endorsed another. The 50% endorsement criterion represented the minimum modal response. The 25% maximum endorsement for the rival type was used to ensure discreteness of the modal response.

Smile Characteristics

Chi-square was used for categorical data. MANOVA was used for quantitative measures. ANOVA with planned comparison followed significant MANOVA results.

Results

Judgment Data

Smile Type

Using the 50–25 criteria (described above), 19 smiles were classified as perceived amused, 23 as perceived polite, 3 as perceived embarrassed, 8 as perceived nervous, and 1 as perceived other. Smiles classified as perceived embarrassed, nervous, and other occurred infrequently. Following previous literature (Costa et al. 2001; Keltner 1995), perceived nervous smiles were pooled with perceived embarrassed smiles. The “other” smile was excluded from further analysis. Thus, the analyses focused on three types of smiles: perceived amused, polite, and embarrassed/nervous. Table 1 shows the mean judgment scores for each type. Unless otherwise noted, all results reported below are for smiles that met the 50–25 criteria. See Fig. 1 for examples of perceived amused, perceived polite, and

Table 1 Mean and standard deviation (*SD*) of the judgment scores (percent) for each smile type

	Percentage of decoders that selected each type						
Smile perceived as	*N*	Amused		Embarrassed/nervous		Polite	
		M	*SD*	*M*	*SD*	*M*	*SD*
Amused	19	74.25	14.98	8.92	5.04	5.85	7.44
Embarrassed/nervous	11	8.65	8.14	70.96	9.01	11.08	7.08
Polite	23	7.50	6.43	8.58	3.10	64.57	9.47

Note: Smile type was determined by 50–25 criterion. That is, the selected category was endorsed by 50% or more of the decoders and no other type was selected by more than 25%

Fig. 1 Examples of a perceived amused (top), perceived embarrassed/nervous (middle), and perceived polite (bottom) smile

perceived embarrassed/nervous smiles. Video clips of these smiles can be viewed at http://www.pitt.edu/~emotion/perceivedsmiles.html.

Preliminary Analyses

Confidence and Intensity Ratings

Mean confidence ratings for smiles that met the 50–25 criteria was significantly higher than those that did not meet the criteria, $F(1, 121) = 12.22$, $p < .001$. No differences were found in intensity ratings, $F(1, 121) < 1$.

Presence and Absence of Offsets

Because not all smiles had a recognizable offset, we wished to determine whether missing offsets were more or less likely for some types of smiles. The number of smiles missing offsets did not vary with smile type, $\chi^2(2, N = 53) = 1.08$, $p > .05$. Because duration and offset velocity could not be measured when offsets were missing, smiles with missing offsets were omitted from analyses of these characteristics.

Appearance of Talking

Because the smiles occurred in a social context, talking was not uncommon. The appearance of talking was present in 32% of smiles. Of these, 67% involved utterance of a single word, such as ok or yes. The appearance of talking varied with smile type, $\chi^2(2, N = 53) = 9.063$, $p < .01$. Appearance of talking was less frequent for perceived polite than for perceived amused, $\chi^2(1, N = 42) = 8.81$, $p < .005$, and perceived embarrassed/nervous, $\chi^2(1, N = 34) = 6.08$, $p < .01$. The appearance of talking did not differ between perceived amused and embarrassed/nervous, $\chi^2(1, N = 30) = .1$, $p > .05$. To evaluate whether inclusion of smiles that included talking influenced the findings, all analyses were conducted with and without smiles that included talking. The pattern of results was the same whether or not smiles with talking were included. Thus, in interests of economy of presentation, results are not reported separately for smiles with and without talking.

Morphological Characteristics

Coactivation of Orbicularis oculi

The occurrence of AU 6 varied with smile type, $\chi^2(2, N = 53) = 10.63$, $p < .005$. AU 6 occurred more during perceived amused than perceived embarrassed/nervous, $\chi^2(1, N = 30) = 4.85$, $p < .05$, and perceived polite, $\chi^2(1, N = 42) = 10.71$, $p < .001$. The occurrence of AU 6 during perceived embarrassed/nervous and polite was comparable, χ^2 $(1, N = 34) = .75$, $p = .39$.

Mouth Opening

Presence of mouth opening varied with smile type, $\chi^2(2, N = 53) = 28.65$, $p < .001$. Mouth opening was less likely to occur during perceived polite than amused, $\chi^2(1, N = 42) = 24.37$, $p < .001$, or embarrassed/nervous, $\chi^2(1, N = 34) = 15.41$, $p < .001$. The occurrence of mouth opening during perceived amused and embarrassed/nervous did not differ, $\chi^2(1, N = 30) = .35$, $p > .05$.

Smile Controls

Total number of smile controls varied with type of smile, $F(2, 50) = 3.99$, $p < .05$. Perceived polite involved fewer smile controls than perceived amused, $t(50) = -2.74$, $p < .01$. There was no difference between perceived embarrassed/nervous and amused, $t(50) = .60$, $p = .55$, or polite, $t(50) = -1.69$, $p > .05$.[1]

Amplitude

Smile amplitude varied with smile type, $F(2, 49) = 11.39$, $p < .001$. Perceived polite had smaller amplitude than perceived amused, $t(49) = -4.52$, $p < .001$, and embarrassed/nervous, $t(49) = -3.09$, $p < .005$. Perceived amused and embarrassed/nervous did not differ in amplitude, $t(49) = .59$, $p > .05$.

[1] We used a conservative measure of the number of action units as it was based on the presence/absence of AUs. Hence, each AU could have a maximum frequency of 1 per smile regardless of how many times it actually occurred during the smile.

Asymmetry of Amplitude

Although there was a trend toward more symmetric amplitude in perceived amused than polite or embarrassed/nervous, the difference was not significant, $F(2, 49) = 2.13, p > .05$.

Dynamic Characteristics

MANOVA of the dynamic characteristics, which included smile duration, maximum velocity of onset and offset, and head motion (yaw, pitch, and roll) revealed a significant effect of smile type, $F(2, 39) = 4.99$, $p < .05$.[2]

Duration

There was a significant effect of smile type on smile duration, $F(2, 40) = 6.28$, $p < .005$. Perceived polite had shorter duration than perceived amused, $t(40) = -3.55$, $p < .001$. The duration of perceived embarrassed/nervous smiles did not differ from either perceived polite, $t(40) = -1.22$, $p > .05$, or amused, $t(40) = 1.59$, $p > .05$. On average, perceived amused lasted about 4 s whereas perceived polite or embarrassed/nervous lasted for 2 s and 2.9 s respectively.

Maximum Velocity

There were significant effects of smile type on maximum velocity for both onset, $F(2, 49) = 3.63$, $p < .05$, and offset, $F(2, 39) = 7.29$, $p < .005$. Amused had higher maximum onset and offset velocity than polite, $t(49) = 2.65$, $p = .011$, and $t(39) = 3.66$, $p < .001$ for onset and offset, respectively. Perceived amused had similar maximum onset velocity, $t(49) = .73$, $p > .05$, but larger maximum offset velocity than perceived embarrassed/nervous, $t(39) = 2.54$, $p < .05$. Perceived amused increased more rapidly than perceived polite and decreased more rapidly than perceived polite and embarrassed/nervous. There was no difference in maximum velocity of onset, $t(49) = 1.42$, $p > .05$, or offset, $t(39) = .20$, $p > .05$, between perceived polite and embarrassed/nervous.

Asymmetry of Velocity

MANOVA on asymmetry scores of the maximum velocity onset and offset was not significant, $F(2, 39) = 2.67$, $p > .05$.

Head Movement

One-way ANOVA showed that maximum pitch varied with smile types, $F(2, 49) = 3.74$, $p < .05$. There were greater head movements downward during perceived embarrassed/nervous than during either perceived amused, $t(49) = 2.34$, $p < .05$, or polite, $t(49) = 2.63$, $p < .05$. Neither yaw nor roll varied with smile types, $F(2, 49) = 1.15$, $p > .05$, and $F(2, 49) = 1.14$, $p > .05$, for yaw and roll respectively.

[2] Heterogeneity of variance among the smile types was not uncommon. For this reason, data were analyzed both with and without assumptions for homogeneity. The pattern of findings remained unchanged. For consistency, the results reported are for tests that assume homogeneity of variance.

Table 2 Summary of morphological and dynamic characteristics of perceived amused, polite, and embarrassed/nervous smiles

	Smiles perceived as			
	Amused	Embarrassed/nervous	Polite	Test statistic†
Morphological characteristics				
Orbicularis oculi (AU 6)	.95[a]	.64[b]	.48[b]	10.63**
Mouth opening (AU 25/26/27)	.89[a]	.82[a]	.13[b]	28.65****
Smile controls	1.32(1.2)[a]	1.09(1.10)[a]	.45(.70)[b]	4.07*
Maximum amplitude	.61(.22)[a]	.56(.37)[a]	.30(.12)[b]	11.41****
Asymmetry of amplitude	−.0019(.04)	.13(.41)	.0007(.03)	2.13
Dynamic characteristics				
Duration (in seconds)	4.07(2.43)[a]	2.89(1.7)[ab]	2.02(.80)[b]	6.28***
Maximum velocity-onset	.07(.04)[a]	.06(.06)[ab]	.04(.02)[b]	3.48*
Maximum velocity-offset	.06(.03)[a]	.03(.02)[b]	.03(.03)[b]	7.29***
Asymmetry velocity onset	−.0019(.01)	.07(.19)	.0016(.05)	2.67
Asymmetry velocity offset	.0006(.01)	.0024(.004)	.0006(.006)	.17
Maximum pitch	−2.81(9.91)[a]	5.42(14.31)[b]	−3.54(4.07)[a]	3.74*
Maximum yaw	2.13(11.65)	−4.73(21.13)	−.56(2.77)	1.15
Maximum roll	2.56(4.88)	.18(5.44)	.99(3.44)	1.14

Note: † Entries for AU 6 and mouth opening are proportions and were analyzed using Chi-Square tests. Entries for all other measures are mean values with standard deviations shown in parentheses and were analyzed using ANOVA. Values with different superscripts significantly differ from each other by planned comparison tests. For χ^2 tests, $df = 2$. For ANOVA, $df = 2, 50$ except for duration and maximum velocity offsets, for which $df = 2, 39$ due to missing values due to occlusion ($n = 10$) and technical problems ($n = 1$)

**** $p < .001$

*** $p < .005$

** $p < .01$

* $p < .05$

Summary of morphological and dynamic characteristics of perceived amused, polite, and embarrassed/nervous smiles are shown on Table 2.

Discussion

This study addressed two questions. First, what meanings do observers assign to smiles? Second, what smile characteristics map onto different meanings? Participants viewed short video clips from which they judged each smile's meaning by choosing between one of several choices (amused, polite, embarrassed, nervous, and other). To minimize the effect of forced choice (Russell 1993), an *other* option was included. Using conservative criteria for categorizing a smile into specific types, we found that about 40% of the smiles were perceived as one of four types. The others were ambiguous and appeared to be blends of two or more types. We offer several possible explanations for the relatively low classification rate in a later section.

Of the smiles that conveyed clear meaning, most were perceived as amused or polite. The number of smiles perceived as embarrassed or nervous was relatively small. Following previous work, these two types of smiles were pooled together. The resulting three types were perceived amused, perceived polite, and perceived embarrassed/nervous.

The three types of smiles varied with respect to multiple features. Relative to perceived polite smiles, perceived amused had larger amplitude, longer duration, more abrupt onset and offset, and more often included AU 6, open mouth, and smile controls. Relative to those perceived as embarrassed/nervous, perceived amused smiles were more likely to include AU 6 and have less downward head movement. Relative to those perceived as polite, perceived embarrassed/nervous smiles had greater amplitude, longer duration, more downward head movement, and were more likely to include open mouth.

As predicted, AU 6 was present more often during smiles perceived as amused, than during smiles perceived as polite and embarrassed/nervous. This finding is consistent with previous literature (Frank et al. 1993; Keltner 1995) that suggests that AU 6 occurs more frequently with felt positive emotion. We consider this finding further below. The hypothesis about mouth opening also was confirmed, as mouth opening was observed more frequently during smiles perceived as amused than during those perceived as polite. This result is consistent with Messinger and colleagues' (Dinehart et al. 2005; Messinger et al. 2001) findings that adult observers perceive infant open-mouth smiles as conveying increased happiness relative to closed-mouth smiles. Ours is the first study that we know of to report this effect for adult smiles.

Our findings for smiles perceived as embarrassed/nervous were partly consistent with previous literature in which embarrassed/nervous smiles, as identified by self-report, more often included downward head movement and smile controls (Keltner 1995). In perceived embarrassed/nervous smiles, we found greater downward movement but not increased smile controls. The latter occurred similarly in perceived embarrassed/nervous and perceived amused. It is possible that the lack of significant findings for smile controls was due to the small sample of perceived embarrassed/nervous smiles in our data. Fewer than five percent of smiles in our study met initial criteria for perceived embarrassed type. While pooling perceived embarrassed and nervous increased the percentage, it remained well below the 56% found by Keltner (1995).

The infrequency of smiles perceived as embarrassed in our study may have been because many smiles failed to contain elements of the prototypic embarrassment display as proposed by Keltner (1995). To test this possibility we conducted an *ad hoc* analysis. We coded all smiles using Keltner's (1995) classification method (synthesis of his studies 2, 3, and 4). This method classifies each smile into one of six categories based on the number of elements resembling amused (1) or embarrassed (6). Using this method, 8 of 53 smiles had characteristics of prototypic embarrassed smiles (category 4 and above). Of these, only three were perceived as embarrassed by our participants. The hypothesized prototypic criteria, while present, failed to influence participants' judgments of smile meaning.

It is possible that had more smiles met criteria for hypothesized embarrassment display, results might have been more supportive of the hypothesis. Alternatively, the elements that make up a prototypic embarrassment display may still be in question. Several other studies have failed to support the hypothesized prototypic embarrassment display. Harris and Alvarado (2005) found that predicted gaze shifts and head movements were less instead of more common in a condition that produced high self-reports of embarrassment than in other non-embarrassing conditions. Costa et al. (2001) found a context effect on nonverbal behavior of embarrassment. In the presence of others, compared with when alone, embarrassment was marked by *fewer* elements of the proposed embarrassment display such as face touch, gaze shift, gaze down, and head down. Even when all the proposed elements of embarrassment display are present, observers may fail to associate them with embarrassment (Haidt and Keltner 1999). Together, these findings suggest that it may be premature to decide that a constellation of characteristics communicates embarrassment to observers.

The current study included detailed analysis of asymmetry between the left and right side of the face. Asymmetry of lip corner movement was analyzed for maximum amplitude and maximum velocity of onset and offset. Evidence of asymmetry by smile type was lacking. Methodological factors may in part account for the current null finding. Using automated facial image analysis, accurate assessment of asymmetry requires either a frontal view of the face or precise 3D image registration when head pose is non-frontal or rigid head motion is present. Non-frontal pose and rigid head motion were both common in our data, and indeed are likely to be common in any sample of spontaneous facial behavior recorded in an interpersonal context. The 2D normalization (affine) used here may have been inadequate to capture small differences in asymmetry. Previous work in posed facial expressions suggests that differences between the left and right side of the face are small (Liu et al. 2003) and may be easily missed if recording is not optimized for assessment of asymmetry. It is also possible that using a denser sampling of facial features (e.g., Liu et al. 2003), we may have found more evidence of asymmetry. Alternatively, recent work by Schmidt et al. (2006b) suggests that the asymmetry of facial expression identified in previous work may have resulted from baseline differences in face shape rather than in lip corner motion. In light of the hypothesized importance of asymmetry in influencing social judgment and behavior (Brown and Moore 2002; McGee and Skinner 1987; Skinner and Mullen 1991), more research on this issue is encouraged.

Our findings for smiles perceived as polite are consistent with two of Ekman's (1992) predicted characteristics of coordination smiles. These are smiles that regulate the exchange between two or more people "…to smoothly show agreement, understanding, intention to perform, or acknowledgement of another's proper performance. (They involve) a slight smile, usually asymmetrical, without the action of the muscle orbiting the eyes" (Ekman 1992, p. 157). Consistent with coordination smiles, smiles perceived as polite tended to have smaller amplitude and lack *Orbicularis oculi* (AU 6) contraction. They also were more likely to have closed mouth, brief duration, and gradual onset and offset. Unlike the proposed coordination smiles, however, perceived polite smiles were no less symmetric than other smiles.

The findings for duration were only partially consistent with another of Ekman's and Friesen's (1982) predictions. They predicted that non-amused (which they referred to as non-enjoyment) smiles are either shorter or longer than amused smiles. Consistent to this prediction, smiles perceived as polite were shorter than those perceived as amused. However, smiles perceived as embarrassed/nervous, which is also a non-amused smile, were no longer or shorter than those perceived as amused. Smiles perceived as polite also were shorter than those perceived as embarrassed/nervous. Amusement and embarrassment are emotions, whereas polite is not. These findings suggest that, from an observer's point of view, instead of signaling a specific emotion (e.g., amused), duration may signal whether an expression is related to an emotion (e.g., amused or embarrassed) or a social intention unrelated to emotion (e.g., polite).

The idea that genuine smiles include AU 6 is so well-ingrained in the literature that there is a tendency to use this single characteristic as a marker of genuine amused smiles (Bonanno et al. 2002), also labeled as the "Duchenne marker" (Ekman et al. 1990; Frank et al. 1993; Gosselin et al. 2002; Merkel et al. 2007; Nijholt 2002; Williams et al. 2001).

Our findings question this practice. The presence of AU 6 accompanying a smile was not sufficient to signify amusement. Other smile types often included AU 6, a finding also found by others. Hess et al. (2002) found AU 6 in appeasement smiles, and Keltner (1995) found 17% prevalence of AU 6 for embarrassment smiles. Messinger et al. (2001) found that Duchenne and non-Duchenne smiles may represent different temporal phases of a continuous emotional process. Harris and Alvarado (2005) found that smiles with AU 6 occurred as automatic responses to a physical stimulus (tickling) in the absence of positive affect. Messinger and colleagues (Dinehart et al. 2005; Messinger 2002) found that AU 6 was frequent during infant distress, and Prkachin (1992) found that AU 6 occurs in response to physical pain. All these highlight Ekman and Friesen's (1982) word of caution that while the *absence* of AU 6 may be evidence that a smile is not felt, the *presence* of AU 6 may indicate that a smile is either felt or not. More generally, the current findings suggest that multiple features may influence the meanings of smiles as perceived by observers.

As mentioned before, the current study found low classification rate for the meaning of the smiles. Only 40% of smiles could be classified into perceived amused, perceived embarrassed/nervous, and perceived polite. A factor may have been that the 50–25 criteria, which we used, are more conservative than those used previously in the literature. For example, Keltner (1995) used a 50% cut off with no minimum endorsement criterion. Other studies used pre-selected or synthetic smiles, which would serve to increase classification rates because ambiguous smiles would not have been included. While use of other, less stringent, criteria or possibly additional choices might have resulted in higher classification rate, it is likely that significant ambiguity would have remained. While classification rates for synthetic and posed expressions have been high, naturally occurring expressions of emotion have been found to be remarkably difficult to classify. In a study in which posed and spontaneous expressions were carefully designed to ensure comparability of the two types, Motley and Camden (1988) found that about 80% of posed facial expressions were accurately identified, while only about 26% of spontaneous ones were, a rate that is lower than ours.

Nevertheless, other factors may be involved in decreasing classification rates. Lack of consensual meaning may be related in part to individual differences in decoders' experience or bias (e.g., Pollak et al. 2000). For instance, Pollack et al. (2000) found that abused children have a lower threshold for perceiving threat in the face. They perceived anger expressions more readily than children not having a history of abuse. Another possible explanation is absence of contextual information (Carroll and Russell 1996; Fernández-Dols et al. 1991; Wallbott 1991). The smiles in the current study were judged out of context. It is likely that context can influence judgment and enable categorizations of smiles that otherwise would remain ambiguous. Future research is needed to consider the role of these additional factors.

A few limitations of the current work should be noted. One, as noted above, decoders in our study lacked information about the context in which the smiles occurred. A related issue is that the smiles were sampled from a single interpersonal context. Consequently, we cannot say to what extent smile characteristics were specific to the context chosen. Fridlund (1991) found that amused smiles had larger amplitude in social than in solitary contexts and that amplitude varied to some extent with whether social context was actual or imagined. However, Fridlund used pairs of friends, and the "audience effects" may be altered in the presence of strangers (Hess et al. 1995). It is possible that the characteristics of the smiles we sampled might have differed had we sampled from additional contexts. There are few data on this issue; it remains a research question.

In the current study, smile characteristics were investigated in relation to perceived meaning rather than encoders' self-reported emotion. There is a related issue whether the meanings that decoders' perceived is veridical; that is, to what extent it corresponds with the encoders' subjective experience or intentions. The veridicality of facial expressions is an issue that is of long standing in the emotion literature and is beyond the scope of the current study. Our focus is on how smile characteristics are associated with the kinds of meanings perceived by decoders. We cannot say whether meanings perceived by decoders agreed with the messages intended by encoders. At a glance, the lack of information regarding the intention or felt emotion of the encoders may seem a validity issue. In reality, this lack of information is not a unique situation. In everyday life, more often than not, direct information about other peoples' subjective experience or intentions is unavailable; more often than not they can only be inferred from expressive behavior. Our findings speak to what information is available in facial behavior to guide those inferences.

In summary, we found that smiles perceived as amused were more likely to include AU 6 and open mouth, have larger amplitude and more abrupt onset and offset. Smiles perceived as embarrassed/nervous were more likely to include downward head movement. Smiles perceived as polite were more likely to have closed mouth and smaller amplitude. Previous literature typically considered only two smile types, with one defined only as not the other. By comparing three perceptually distinct types of smiles, we discovered that smile perceived meaning was related to specific variation in multiple characteristics, both morphological and dynamic.

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