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Judgments of Subtle Facial Expressions of Emotion

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Most studies on judgments of facial expressions of emotion have primarily utilized prototypical, high-intensity expressions. This paper examines judgments of subtle facial expressions of emotion, including not only low-intensity versions of full-face prototypes but also variants of those prototypes. A dynamic paradigm was used in which observers were shown a neutral expression followed by the target expression to judge, and then the neutral expression again, allowing for a simulation of the emergence of the expression from and then return to a baseline. We also examined how signal and intensity clarities of the expressions (explained more fully in the Introduction) were associated with judgment agreement levels. Low-intensity, full-face prototypical expressions of emotion were judged as the intended emotion at rates significantly greater than chance. A number of the proposed variants were also judged as the intended emotions. Both signal and intensity clarities were individually associated with agreement rates; when their interrelationships were taken into account, signal clarity independently predicted agreement rates but intensity clarity did not. The presence or absence of specific muscles appeared to be more important to agreement rates than their intensity levels, with the exception of the intensity of zygomatic major, which was positively correlated with agreement rates for judgments of joy.

Keywords: facial expressions, subtle expressions, dynamic presentation paradigm, signal clarity, intensity clarity

Decades of studies on judgments of facial expressions of emotion have primarily focused on prototypical, high-intensity expressions. These are expressions that involve full-face configurations with contractions of muscles considered critical to emotional displays at relatively high-intensity levels, with no other muscle innervation. Findings from judgment studies involving such expressions serve as one of the pillars of evidence for the universal recognition of facial expressions of emotion (Elfenbein & Ambady, 2002; Matsumoto, Keltner, Shiota, O'Sullivan, & Frank, 2008), albeit one that has received its fair share of controversy (Ekman, 1994; Izard, 1994; Russell, 1994, 1995). One of the reasons for this controversy is the almost exclusive use of prototypical, high-intensity expressions (although see Matsumoto, Olide, Schug, Willingham, & Callan, 2009, for evidence involving spontaneous expressions).

One concern about an almost exclusive focus on prototypical, high-intensity expressions is that those prototypes are not the only types of emotional expression that occur in real life, and what may occur just as if not more frequently are subtle versions or variants of the prototypes. Whether or not this is true, as an ethological survey of emotional expressions occurring in everyday life is yet to appear in the literature, the fact that subtle and variant facial expressions of emotion actually occur in real life suggests a gap in knowledge about emotional displays.

The existence of subtle facial expressions of emotion was suggested over three decades ago in the original version of the *Facial Action Coding System manual* (FACS; Ekman & Friesen, 1978). FACS is an anatomically based technique for measuring any facial behavior (not just emotional expressions) that allows for the identification of each of the functionally independent muscle movements in the face (action units; AUs in FACS terminology).[1] Coders learn the anatomical bases and appearance changes for each of the 40+ AUs that are identifiable. An investigator's guide provides a listing of the proposed AU configurations for expressions of anger, disgust, fear, happiness, sadness, and surprise. These configurations include the AU combinations associated with each of the "prototypic" facial expressions of each emotion, as well as a listing of the proposed variants of each.

To date, however, no one has provided an operational definition for subtle expressions. We define "subtle" facial expressions of emotion here as emotional expressions that involve relatively low-intensity and/or few appearance changes in the face (defined here as AU C-level intensity or lower, described more fully below in the Method section). For emotional expressions that involve only a single AU considered critical to the emotional display (e.g., contempt, disgust, joy), subtle facial expressions involve expressions of the critical AUs at low intensity. For emotional expressions that involve multiple AUs in different areas of the face (e.g.,

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[1] FACS is based on functional, not structural, anatomy and uses the nomenclature AU instead of anatomical muscle names. For example, the muscle that runs across the forehead (frontalis) is a single muscle (Gray & Goss, 1966), but it can produce two independent movements—one in the inner corners of the brows and one in the outer corners. FACS identifies these as two distinct AUs (AU 1 and AU 2, respectively) despite the fact they refer to a single muscle. The muscles that bring the brows down and together are actually comprised of three muscles (the corrugator muscle group) that in adults always function together. Thus FACS identifies them as a single AU (AU 4) even though they comprise multiple anatomical muscles.

brows, eyes, nose, mouth) in a multicomponent configuration (e.g., anger, fear, sadness, surprise), subtle expressions may involve low-intensity versions of the full-face configuration, or single components (“partial” expressions) of the full-face configuration.

Two theories exist about why subtle facial expressions of emotion occur. The first is based on the notion of the existence of innate affect programs that store the full-face configurations of the expressions (Ekman, 2003). This theory suggests that individuals are born with the capacity to produce the full-face, prototypic emotions when emotions are elicited. But the theory also suggests that the innate affect programs are “open” programs (Mayr, 1974) that allow for modification of the triggers of emotion and the exact configurations of their produced expressions via learning. Subtle expressions, therefore, are produced because of learned cultural and/or individual habits or idiosyncrasies that modify the full-face, prototypic configurations.

A second theory suggests that subtle facial expressions occur because they reflect the outcome of the appraisal process of emotion elicitation (Scherer & Ellgring, 2007). This theory suggests that different components of the appraisal process evaluating emotion elicitors unfold across time in sequence, and each influences expressive behaviors and other physiological reactions. Subtle expressions, therefore, are produced as the result of a cumulative series of sequential checks in the appraisal process that can produce a wide variety of expressive configurations.

Both theories may predict the production of the same subtle facial expressions of emotion; the theories differ, however, in their claims about why those expressions are produced. On one hand, theories based on an innate affect program would posit that the full-face prototypes are stored as part of our evolutionary history, but that individuals learn to display only parts of those prototypes based on cultural or familial norms, experiences, or even idiosyncrasies. Innate affect program theories would also posit a larger role for the muscles in the lower face, especially around the lips and mouth, when people learn to control their emotions, because closing one’s mouth and pursing one’s lips may have evolutionary roots in preventing attacks (biting or even verbal attacks). On the other hand, appraisal theories link specific muscle actions with specific evaluative steps in an appraisal process and would predict that the facial components would be produced as a result of their corresponding evaluative step in that process. Raising the brows and lifting the upper eyelid, for instance, increases the visual field, and appraisal theories would predict that this facial component is linked to an evaluative step associated with novel orientation.

The goal of this paper is not to examine which claims are correct concerning the underlying reasons subtle expressions occur, but to identify which subtle expressions may have signal value as emotions. In fact a small number of studies has examined some subtle emotional expressions over the years. For example, several studies have examined judgments of facial expressions of emotion varying in intensity from low to high (Hess, Blairy, & Kleck, 1997; Matsumoto et al., 2002; Matsumoto, Kasri, & Kooken, 1999). These studies have, unsurprisingly, shown that judgment-agreement rates for the intended emotions are lower than for high-intensity prototypes, often in a linear fashion. Other studies involving subtle expressions have examined the effects of temporal dynamics in the perception of expressions (Ambadar, Schooler, & Cohn, 2005; Bould & Morris, 2008; Bould, Morris, & Wink, 2008), demonstrating that dynamic information improves the identification of emotions in subtle expressions (but see Fiorentini & Viviani, 2011, for a study with null results).[2]

Close examination of the methods used to portray subtle expressions in the studies immediately above, however, suggests some limitations to the knowledge generated from them. Earlier studies examining judgments of low- to high-intensity expressions (Hess et al., 1997; Matsumoto et al., 2002; Matsumoto et al., 1999), for instance, used morphing technologies that used full-face, high-intensity expressions and neutral expressions as anchors and produced intermediate images at fixed intervals (e.g., 10%, 25%, 75%, etc.). Although such morphing techniques can produce images at intervals of specific linear distances, those images may or may not represent expressions that are anatomically possible or likely because facial muscles may not move or produce appearance changes in a strictly linear fashion (although there are no data on this issue). The methodologies used in the more recent research examining the effects of movement on the perception of subtle expressions (Ambadar et al., 2005; Bould & Morris, 2008; Bould et al., 2008; Fiorentini & Viviani, 2011) addressed this limitation by using videos of actors portraying full-face, high-intensity expressions and truncating the videos at lower intensity levels. But this methodology introduced another potential limitation because posed expressions activate facial muscles with different timing and laterality characteristics (Ekman & Friesen, 1982; Ekman, Hager, & Friesen, 1981; Hess & Kleck, 1990); that is, different muscles are activated at different times and apex at different speeds when expressions are posed. This may be potentially problematic because spontaneous expressions innervate muscles relatively symmetrically and simultaneously (Ekman et al., 1981; Hager & Ekman, 1985). If so, truncating videos of posed expressions at certain times before expression apex may result in some AUs appearing relatively imbalanced in their expression (cf., the notion of expression irregularity, discussed in Hess & Kleck, 1990, 1994). And both techniques only sample low-intensity versions of full-face prototypes and not the variant expressions involving different AU combinations that comprise the partial expression versions of subtle expressions, such as those proposed as variants in the *FACS manual*. These variant expressions may in fact be more common in everyday life than low-intensity versions of full-face prototypes.

We addressed these limitations by examining judgments of subtle expressions of not only low-intensity versions of full-face prototypes, but also of a number of the proposed variants of those prototypes. In doing so, it was necessary to identify a list of the “critical AUs” deemed important for each emotional expression from the list of the prototypical AUs, which were the minimal AUs required in each of the prototype configurations in the *FACS manual*. From this, we also derived a listing of “also-allowed AUs,” which were those AUs that occurred in some, but not all, prototypic configurations and thus that had no influence on the predicted emotion signal. AU information for contempt was taken from sources providing initial evidence for its cross-cultural recognition (Ekman & Friesen, 1986; Ekman & Heider, 1988; Matsumoto, 1992). We recruited actors to pose expressions portraying prototypical and variant versions of the various emotions and

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[2] The use of dynamic stimuli has the added advantage of enhancing perceptions of naturalness of the expressions (Sato & Yoshikawa, 2004) and facilitating neural responsivity to the stimuli (Sato et al., 2004).

utilized the image portraying the apex of those expressions, ensuring that all intended AUs were displayed. Doing so addressed the limitations of previous techniques in producing expressions, while at the same time ensured that we sampled not only low-intensity versions of full-face, prototypic expressions, but also variants of those expressions. A dynamic paradigm was used in which observers were shown a neutral expression followed by the target expression to judge, and then the neutral expression again. This paradigm allowed a simulation of the emergence of the expression from and then a return to the baseline.

Examining partial and low-intensity versions of subtle expressions raised issues concerning the effect of signal and intensity clarity on judgments because subtle expressions vary in clarity (at least less so than full-face, high-intensity prototypes), and faces with higher signal and intensity clarity should be recognized at higher agreement rates than expressions with relatively lower clarities. In this paper, we defined signal clarity as the degree to which the qualitative content of a message in a signal is clear relative to any noise in the signal that renders that content ambiguous. Faces with higher signal clarity should be relatively less ambiguous concerning which emotion was being signaled; those faces should include more muscles associated with that emotion and fewer muscles associated with other emotions. We define intensity clarity as the degree to which the quantitative amount of a message in a signal is clear relative to the total amount that message could theoretically display. Faces with higher intensity clarity should portray more muscles related to an emotion signal with greater intensity; faces with less intensity clarity would include fewer muscles at less intensity. Including not only full-face but also partial versions of subtle expressions ensured a wide range of expressions varying substantially in both signal and intensity clarity. In this study, we utilized an adapted version of a measure of signal clarity introduced in a previous study (Matsumoto et al., 2009; more below); we also introduced here a new measure of intensity clarity and examined the relationship of both to judgment-agreement rates of subtle emotional expressions.

Method

Observers

Observers were 273 students ($N_{\text{females}} = 187$, $M_{\text{age}} = 20.58$) recruited from the San Francisco State University Psychology Department participant pool, which consists primarily of students taking introductory psychology classes, and who participated voluntarily with no compensation in partial fulfillment of course requirements. The vast majority of these students are not psychology majors (and thus have little or no proficiency in emotion theories or facial expression research). They were split into two groups, one that viewed stimulus Pool A ($N = 139$) and one that viewed stimulus Pool B ($N = 134$).

Stimuli

The expressions were obtained by asking 190 male and female expressors from six ethnic groups (European, African, Asian, South and Southeast Asian, Hispanic, and Middle Eastern) to pose specific AU combinations on their faces designed to sample prototypic and variant expressions of each emotion according to the *FACS manual*, and to test new potential variant expressions.[3] The potential pool of expressions was independently FACS-coded by both authors (reliability = .86). Expressions were selected for testing in this study according to the following criteria:

- *Prototypical expressions* were those that included the minimal set of critical AUs considered necessary for that emotion.
- *FACS-variant expressions* were those that included the AU combinations for proposed variants from the *FACS manual*.
- *Other proposed variants* were additional expressions we requested that lacked the AUs required for proposed variants (or a prototype), but for which we thought may also convey the intended emotion.[4]
- None of the anger, disgust, fear, sadness, and surprise expressions contained AU 12.[5]
- All critical AUs were at C-level intensity *or less*, with the exception of expressions of fear that included only a single AU 5 or a single AU 20.

These criteria resulted in the final selection of 110 subtle expressions that sampled prototypical expressions, FACS variants, and other proposed variants. They included a total of 21 expressions of anger, five of contempt, 14 of disgust, nine of fear, 18 of joy, 18 of sadness, and 25 of surprise (see Table 1).

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[3] All expressors were actors who answered an ad that requested individuals to produce a variety of facial expressions of emotion, and who were compensated for their time and effort. The actors were initially interviewed by a screener who was provided with pictures and verbal descriptions of the facial muscle movements required to pose each of the various universal facial expressions of emotion. Only those individuals who had relative ease of movement in voluntarily producing the expressions, especially more difficult-to-pose fear and sadness brows (AUs 1 + 4 or AUs 1 + 2 + 4), were selected for inclusion in the potential expressor pool. The actors were then scheduled for a photo session, each of which generally lasted approximately 90 min. Before the session, the actors were provided sample images of each of the universal facial expressions of emotion and verbal descriptions of their muscle movements, and were asked to practice moving their faces to produce the depicted expressions. During the photo shoot, a facilitator guided the actors to pose specific muscles in order to portray the following emotions (photos were taken in this order): neutrality, happiness, surprise, fear, sadness, anger, disgust, and contempt. The facilitator instructed the actors to voluntarily move specific muscles on their faces to portray each of the emotional expressions according to the directed facial action task (Ekman, 2007). When expressions required multiple muscle movements in multiple parts of the face (e.g., AUs 1 + 2 in the brows, AU 5 in the eyelids, and AU 26 in the mouth), the actors were asked to portray each of these components prior to the full-face configuration; shots of these partial face expressions were taken and served as the pool from which the subtle and variant expressions used in this study were obtained. Between 70 and 150 expressions were obtained from each actor.

[4] By requesting the components of the various expressions (see footnote 3), we were able to obtain a number of partial expressions that made up a component part of the full-face prototypes of an emotion, but were not included in the close reading of the FACS prototypes or variants list. For example, the AU combination 4 + 5 + 7 is the upper face component of anger, but is technically not part of the FACS-variant list. Likewise, AU combination 1 + 4 is the upper face component of sadness, but is not technically part of the FACS-variant list. Thus, we selected for testing those components that were part of the full-face configuration but were not part of the FACS-variant list.

[5] We excluded images that had any hint of AU 12 because their inclusion would have resulted in a smile being part of the expression. These expressions would have been viewed either as partial masks of another emotion, or as a blend between happiness and another emotion. In either case, they were not the signals of subtle/partial/variant expressions of single emotions, which was the purpose of the current study (although the study of such blended expressions would be interesting in its own right).

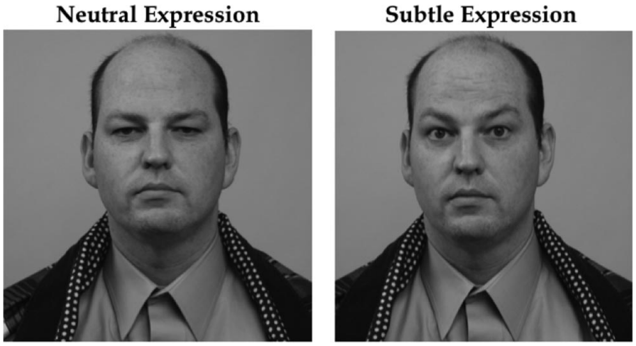
Table 1
Mean Judgment Accuracy, Signal Clarity, and Intensity Clarity for the Different Types of Facial Expressions for Each Emotion

Emotion	Expression type	Number of images	Mean judgment accuracy (%)	Mean signal clarity	Mean intensity clarity
Anger	Prototype	7	61.74	.867	.433
	FACS variants	4	70.14	.788	.281
	Other variants	10	68.53	.669	.316
Contempt	Prototype	5	31.50	.300	.227
Disgust	Prototype	14	53.32	.909	.418
Fear	Prototype	3	46.76	.944	.413
	FACS variants	1	33.33	.800	.420
	Other variants	5	24.72	.200	.200
Joy	Prototype	9	81.58	.926	.478
	FACS variants	2	74.07	.500	.300
	Other variants	7	58.10	.381	.150
Sadness	FACS variants	6	80.90	.450	.179
	Other variants	12	56.21	.225	.093
Surprise	Prototype	4	80.90	1.000	.313
	FACS variants	13	82.70	.712	.281
	Other variants	8	68.00	.457	.261
All expressions		110	59.20	.609	.285

Fourteen (of the 110) expressions were created by taking full-face expressions and covering part of the face with clothing (from the bridge of the nose and lower so that only the brows and eyes could be seen; see Figure 1 for an example of a neutral and subtle expression).

Judgment Tasks and Procedures

Because judging 110 expressions in one sitting was too cumbersome, the expressions were split evenly into two 55-expression sets (Pools A and B), ensuring that each of the intended emotions was equally distributed between the two pools, and within each emotion each expressor sex was equally distributed. Expressions were then randomly ordered within each pool. The entire experiment was administered online. Participants who signed up for the study received a link that directed them to one of the two sets, which they could access at their leisure using a computer with Internet access. Expressions were programmed in the following manner. For each expression, observers were first shown a 2-s presentation of the target expressor's neutral face, and then a 1 s presentation of the target subtle expression, followed by the same neutral face, which stayed on the screen until observers made a judgment selection.[6] Participants were instructed to judge the emotion portrayed in each target expression by selecting a single label from the following fixed-choice list that was to the right of the expression image frame: anger, contempt, disgust, fear, joy, sadness, surprise, neutral, and other. When they were done with one expression, observers clicked "Next" to proceed to the next expression on their own pace until all expressions were judged. A practice expression not included in this study was presented first so that observers could familiarize themselves with the judgment task.


Neutral Expression

Subtle Expression

Figure 1. Example of the stimuli used in this study.

Measures of Signal and Intensity Clarity

We created a measure of signal clarity in facial expressions using this formula from Matsumoto et al. (2009):

$$\frac{\text{\# of observed critical AUs}}{\text{\# of critical AUs} + \text{\# of observed noncritical AUs}}$$

For example, there are four critical AUs for anger: 4, 5, 7, and 23 or 24. All other AUs were defined as noncritical. AUs that are also allowed (e.g., AUs 10, 17, 22, 25, and 26 for anger) were not

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[6] We chose this forward and backward masking procedure (neutral–target–neutral format) because it allowed us to isolate the judgment of the target face with no contamination by other possible expressions (which is a fairly standard format in perceptual studies of faces). Spontaneous expressions in real life sometimes follows this format and sometimes not. Also, previous studies examining the timing characteristics of facial expressions of emotion have demonstrated that these typically last between 0.5 and 4 s (Ekman, 1999). Of this range, we arbitrarily chose a 1-s presentation because it was well within conscious awareness and still within the range of ecologically valid expressions, albeit on the lower end of that range. Longer presentation times may have produced higher agreement rates, as previous studies have shown with judgments of full-face prototypes (Hess et al., 1997; Matsumoto et al., 2002; Matsumoto et al., 1999). Readers are cautioned to interpret the findings presented below with these caveats.

counted among either the critical or noncritical AUs.[7] An angry expression involving AUs 4 + 5 + 7 + (23 or 24) would yield a signal clarity value of 4/(4 + 0) = 1.00. An angry expression with AUs 4, 5, 14, 17, and 24 yielded a signal clarity value of 3/(4 + 1) = .60; AUs 4, 5, and 24 are part of the critical AUs; AU 17 is allowed and not counted; AU 14 is extraneous and thus should reduce signal clarity. A signal clarity value was computed for all expressions in this manner.

Another feature of expressions germane for this study was the intensity of the critical AUs present in each expression. We created a measure of intensity clarity for each expression using the following formula:

$$\frac{\text{Sum of intensities for observed critical AUs}}{\text{Total intensity for all possible critical AUs for that emotion}}$$

The following scalar values were assigned to each of the FACS intensity codes[8]: A = 1, B = 3, C = 6, D = 8, E = 10. According to this formula, the denominator values were determined entirely by the number of critical AUs associated with each emotion. For example, the total number of critical AUs for anger was four; thus the denominator for all angry expressions was 40, and an angry expression with FACS codes 4B + 5B + 7C + 14A would yield an intensity-clarity score of (3 + 3 + 6)/40 = .30.

Results

Judgments of Prototypical, FACS-Variant, and Other Variant Expressions

We first computed overall response-classification chi-squares on each of the expressions (chance at 1/9); all were significant. We followed these with single-*df* chi squares, testing whether the percentage of judges selecting the intended emotion label for each expression was significantly greater than chance. All were statistically significant, with the exception of one prototypical and two other variant expressions of anger, three prototypical expressions of disgust, two other variant expressions of fear, two other variants of sadness, and one other variant of surprise. Mean judgment accuracies for each of the emotions and their expression subtypes are provided in Table 1. Across all images the mean judgment accuracy was 59.20%.[9]

Examination of other variant expressions that obtained significantly greater-than-chance percentage-agreement rates of the intended emotion suggested potentially new facial configurations of subtle emotional expressions. For instance, there were two types of angry expressions that were judged as anger: AUs 4 + 5 and 4 + 5 + 7, with and without AU 14. For fear, expressions containing only AU 20 at C intensity or higher or AU 5 had agreement rates higher than chance. Joy expressions with only AU 12 were all judged as joy at significantly greater than chance rates. Expressions of sadness containing only AUs 1 + 4 or only AU 15 were judged as sadness. Expressions of surprise that contained AUs 1 + 2 + (5C, 5D, or 5E) were judged as surprise.

The Influence of Signal and Intensity Clarity on Judgment Accuracies

Using expressions as cases, we computed correlations between the number of observed critical AUs, the number of observed noncritical AUs, signal clarity, and intensity clarity with judgment-accuracy rates, separately for each emotion and across all emotions (see Table 2). The number of observed critical AUs was positively correlated with judgment accuracies for all emotions (except for contempt and disgust, which could not be computed because the number of observed critical AUs for them was constant across the expressions). Thus recognition accuracy for each of the emotions increased when more of the critical AUs were included in the expression. Conversely, the number of observed noncritical AUs was negatively correlated with expressions of disgust, joy, and across all emotions, suggesting that AUs extraneous to each emotional expression reduced judgments of the intended target emotion. Consequently, signal clarity was positively correlated with all of the emotions (except contempt), indicating that the ratio of critical to extraneous AUs in each expression was associated with the degree to which observers would judge the emotions intended in each expression.

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[7] The measure of signal clarity utilized in Matsumoto et al., (2009) counted the "also-allowed AUs" in the computation of the total AUs in the expression. That study, however, was based on a comparison of the AUs that occurred in spontaneously occurring expressions with full-face prototypes of the expressions. The current study is concerned with subtle expressions, which by definition do not necessarily involve full-face prototypes. We identified the also-allowed AUs as those AUs that were sometimes listed and sometimes not in the AU configurations for the same emotion, per the *FACS manual* (Ekman & Friesen, 1978); thus, they are best considered optional AUs associated with the emotions that may also occur with the required AUs. That is, if they appear, they do not necessarily add or subtract anything to the emotion signal. When interpreted in this fashion it is clear that they should *not* be included in the count of the total number of AUs in the expression, because the latter should represent AUs that are distractors to the emotional expression and should detract from signal clarity (thus they are in the denominator). According to our understanding of also-allowed AUs, they are not counted in either the numerator or denominator.

[8] The original FACS described a 3-point intensity scale that was labeled X, Y and Z. Shortly thereafter, FACS was revised to the current 5-point system (A–E) because it was determined that sometimes AUs occurred that were below even the minimal threshold for coding described by X intensity; also it was acknowledged that the Y intensity (which corresponded to medium intensity) actually represented a larger range of absolute values than did either X or Z; that is, X referred to fairly small-intensity muscle movements that were fairly well defined, and Z referred to extremely large-intensity muscle movements that were fairly well-defined, but Y referred to a much broader range of medium-level intensity movement. Thus the determination was made to split the Y category into two levels. Coupled with the determination to add an intensity level below B, the decision was made to switch to a 5-point rating system (the current A–E designation). The A–E system, however, describes an ordinal, but not an interval or ratio, scale of measurement (because the difference between A and B is not equivalent to the difference between B and C, etc. To wit, the current *FACS manual* describes *seven* levels of intensity: trace, slight, marked, pronounced, severe, extreme, and maximum, despite the fact that it uses a 5-point intensity rating. Thus in order to approach a closer interval/ratio scale of measurement that would be better for a measure of intensity clarity, we arbitrarily recoded the A–E system into a 10-point system as described in this paper for this study, assigning values that we believed best represented the intent of the A–E system.

[9] We tested observer gender differences in judgments by computing chi-square differences on the nominal judgment data separately for each expression. Across 110 expressions, 10 produced a significant result, five indicating that females had higher agreement rates than males, and five indicating the opposite. We concluded, therefore, that there were no observer gender differences in the data set and collapsed all further analyses across both genders.

Table 2
Correlations Between Facial Judgment Accuracy and Signal and Intensity Clarities of Emotion

Emotion	Number of observed critical AUs	Number of observed noncritical AUs	Signal clarity	Intensity clarity
Anger	.375*	−.135	.460*	.349*
Contempt	N/A	.264	−.264	−.441
Disgust	N/A	−.741***	.767***	.126
Fear	.902***	−.003	.883***	.867***
Joy	.655**	−.534**	.704***	.741***
Sadness	.593**	−.196	.623**	.391*
Surprise	.526**	−.251	.531**	.461**
All expressions	.349***	−.252**	.437***	.223**

Note. AC = action unit.
* $p < .05$. ** $p < .01$. *** $p < .001$.

Intensity clarity was positively correlated with accuracy rates for all emotions except contempt and disgust (again most likely due to the restriction in range of the summed intensities for the critical AUs for these expressions because of the small number of critical AUs observed in these expressions). These findings were especially strong for expressions of fear and joy.

To examine the combined influence of signal and intensity clarities on recognition accuracies, we computed a hierarchical multiple regression on the accuracy rates across all expressions, including signal and intensity clarities on the first step (using simultaneous entry) and their interaction on the second. The interaction was not significant, $R^2_{\text{change}} = .007$, $F_{\text{change}}(1, 106) = .90$, *ns*. The regression coefficients indicated that signal clarity was positively correlated with recognition accuracy, $\beta = .61$, $p < .001$; intensity clarity, however, was not, $\beta = -.23$, *ns*. Thus the clarity of the expressions in terms of the ratio of the critical AUs present to the extraneous AUs was relatively more important in influencing judgment accuracies, and when signal clarity was taken into account, intensity differences played less of a role.

Influence of Individual AUs on Judgment Accuracies

We coded each of the critical AUs for each emotion into a dichotomous *present* or *absent* score and computed biserial correlations between these scores and accuracy rates. For anger, AUs 4 and 7 were significantly correlated with accuracy, $r(21) = .62$, $p < .001$, and $r(21) = .37$, $p < .05$, respectively; AUs 5, 23, and 24, however, were not. For contempt, AU 12 was not correlated with accuracy, probably because it occurred in four of the five contempt expressions; the correlation for AU 14 could not be computed because it occurred in all expressions. For disgust, neither AU 9 nor 10 was correlated with accuracy, probably because AU 9 occurred in only two of the 14 disgust expressions, whereas AU 10 occurred in 12 of the 14. For fear, AUs 1, 2, 4, and 5 were all correlated with accuracy, $r(9) = .87$, $p < .001$; $r(9) = .87$, $p < .001$; $r(9) = .87$, $p < .001$; and $r(9) = .65$, $p < .05$, respectively; AU 20, however, was not. For joy, AU 6 was positively correlated with judgment accuracy, $r(18) = .67$, $p < .001$; the correlation for AU 12 could not be computed because it occurred in all expressions. For sadness, AU 15 was correlated with judgment accuracy, $r(18) = .45$, $p < .05$; AU 1 was not, probably because it occurred in 16 of the 18 sad expressions. For surprise, AUs 1 and 2 were correlated with judgment accuracy, $r(25) = .37$, $p < .05$; and $r(25) = .37$, $p < .05$, respectively; AUs 5 and 25/26 were not.

We also examined the association between the intensity of each individual AU when it occurred in each expression and the judgment accuracy rates, separately for each emotion. We present the findings for only those AUs in each emotion for which there were at least 10 cases for analysis. For anger, there were sufficient cases for AUs 4, 5, and 7; none, however, was significant, $r(19) = .27$, $r(17) = .18$, and $r(18) = .14$, all *ns*. For disgust, there were sufficient cases for AU 10, but it was not significant, $r(12) = .14$, *ns*. For joy, the intensity of AU 12 was significantly associated with judgment accuracy, $r(18) = .69$, $p < .001$. For sadness, AU 1 was not associated with judgment accuracy, $r(16) = -.24$, *ns*, and the intensity of AU 4 was *negatively* correlated, $r(15) = -.46$, $p < .05$. For surprise, AUs 1, 2, and 5 were all not correlated with judgment accuracy, $r(22) = -.02$, $r(22) = -.02$, and $r(23) = -.21$, all *ns*. For contempt and fear, there were not enough cases for analysis.

Thus the presence or absence of some of the key critical AUs for each emotion was related to judgment accuracies for those emotions, but their intensity when present was less important. The exception to this was the strong, positive association between the intensity of AU 12 in judgments of joy (although these tended to occur with AU 6).

Discussion

Low-intensity, full-face prototypical expressions of emotion were judged as the intended emotions at rates significantly greater than chance. A number of the proposed FACS variants were also judged as the intended emotions, as were a number of other proposed variants. Both signal and intensity clarities were individually associated with judgment agreement rates; when their interrelationships were taken into account, however, signal clarity independently predicted agreement rates but intensity clarity did not. The presence or absence of specific AUs appeared to be more important to agreement rates than their intensity levels, with the exception of the relationship between AU 12 and agreement rates for judgments of joy.

The findings were not generated without limitation, one of which concerned the presentation method. We utilized a dynamic presentation methodology in which the target expression was imbedded within a forward and backward mask of the same expressor's neutral faces. As mentioned above, several studies have demonstrated that dynamic presentations of stimuli are more ecologically valid (Krumhuber, Kappas, & Manstead, 2013; Sato, Kochiyama, Yoshikawa, Naito, & Matsumura, 2004; Sato & Yoshikawa, 2004) and generally produce better recognition-agreement rates in studies involving low-intensity expressions (Ambadar et al., 2005; Bould & Morris, 2008; Bould et al., 2008). Thus we elected to utilize this methodology in order to obtain the clearest judgments of the apex expression that appeared on the face, which would serve as a baseline for further studies examining the effects of different presentation methodologies on judgments. Although sequential presentations of still images are not as clean as expressions that occur in real life, with smooth onsets, apexes, and offsets, the methodology we employed was more realistic than having observers judge single expressions at apex (a common methodology in this area), which would likely have artificially raised agreement levels. Nevertheless, readers are cautioned to interpret the results accordingly.

Another limitation was that the variant expressions tested were produced based on either those listed in the *FACS manual* or on our own suggestions. There are no data, to our knowledge, that demonstrate that those expressions actually occur in real life and are signals of an internal emotional state. That many of the expressions were judged as portraying an emotional state is certainly suggestive of the possibility that emotions are expressed through these displays, but future production studies reporting data that tie specific subtle expressions to other emotion markers (e.g., physiology, self-report, appraisals, etc.) are necessary to document their ecological validity.

Another limitation of the study was the use of posed expressions. On one hand, having actors produce only certain facial actions considered essential to an emotion signal in a clear and unconfounded way is very difficult. On the other hand, there is no other way to produce expressions that isolate muscle configurations theoretically or empirically linked to emotion. And in any case, many expressions were produced with some extraneous muscle movements in our study (which is why signal clarity was not 1.00 for the expressions). Regardless, readers are cautioned to interpret our results in light of the fact that we utilized posed expressions that were produced in the manner we described.

A final limitation of our study concerned the signal and intensity clarity formulas used. Although the data presented here provided additional evidence for the validity of the signal-clarity formula (in addition to that reported in Matsumoto et al., 2009) and initial validity evidence for the intensity-clarity formula, clearly further tests are necessary, especially those examining signal and intensity clarities of spontaneously produced expressions with other markers of emotion. We do not believe that these formulas are the only or best formulas to use; we encourage scientists interested in these issues to develop better ways of quantifying these important concepts in the future.

One aspect of the current study that was a strength concerned the use of actual facial expressions at their apex, which addressed concerns introduced by morphing different faces or truncating video presentations of full-face, high-intensity expressions. That multiple expressions of multiple expressors were utilized also ensured that judgments were reliable regardless of individual differences in facial physiognomies.

The findings provided support for the notion that subtle expressions have signal value as emotions, as suggested years ago in the original *FACS manual* (Ekman & Friesen, 1978). To our knowledge the findings provided the first evidence in the literature that possible variant expressions of the different emotions that were proposed by the *FACS manual* have emotion signal value. And the current findings extended our knowledge about possible subtle expressions, as many of the other variant expressions that were not originally proposed in the *FACS manual* were recognized at above chance levels as well.

Both signal and intensity clarities were individually associated with judgment agreement rates. Thus both the ratio of the number of critical AUs to the entire expression and their intensity levels influenced emotion judgments. But the results of the multiple regression indicated that when their interrelationships were taken into account signal clarity predicted agreement rates but intensity clarity did not, suggesting that which AUs were included in the expression is relatively more important to emotion judgments than their intensity. At the same time this finding may be relevant only to subtle emotional expressions, as other studies testing full-face, high and low intensity expressions have consistently shown that expression intensity has strong effects on judgments, especially to judgments of the intensity of felt emotions (Hess et al., 1997; Matsumoto et al., 2002; Matsumoto et al., 1999). Thus for subtle expressions it appears that the presence or absence of the specific AU configurations is more important to communicating emotion categories than their intensity.

These findings have several interesting theoretical and empirical ramifications. As mentioned earlier there are two major theories about how subtle expressions are produced, one suggesting that they are learned variants of full-face, high-intensity expressions existing in innate affect programs (Ekman, 2003); the other suggests that subtle expressions occur because they reflect the outcome of the appraisal process of emotion elicitation (Scherer & Ellgring, 2007). Both theories predict the production of the same subtle facial expressions of emotion but differ in their claims about why those expressions are produced (with the innate affect program theory positing the existence of full face prototypes that are modified based on cultural or familial norms, experiences, or even idiosyncrasies, while the appraisal theories link specific muscle actions with specific evaluative steps in an appraisal process). The data provided in this study highlight which expressions and AUs are associated with emotion judgments and thus are the likely candidates to be considered as signals of either modified innate programs or an appraisal process. The goal of this paper was not, however, to examine which claims concerning the underlying reasons why subtle expressions occur are correct. Future research examining these and other theories explaining how and why these particular subtle expressions are produced will be important in this regard.

The current findings also have implications to research in other areas related to emotional expression. For example the role of context in emotion judgments is an issue that has been examined decades ago (e.g., Ekman & O'Sullivan, 1988; Goodenough & Tinker, 1931; Knudsen & Muzekari, 1983; Russell & Fehr, 1987; Russell & Fehr, 1988), and is an active area of research today (e.g., Aviezer et al., 2008; Barrett, Mesquita, & Gendron, 2011; Matsumoto, Hwang, & Yamada, 2012). Findings are inconsistent in the literature; some studies have reported context superiority (Carroll & Russell, 1996; Fernberger, 1928; Russell & Fehr, 1987); others face superiority (Ekman & O'Sullivan, 1988; Ekman, O'Sullivan, & Matsumoto, 1991; Frijda, 1969; Goldberg, 1951; Nakamura, Buck, & Kenny, 1990). Some provided no support for either (Fernandez-Dols, Sierra, & Ruiz-Belda, 1993; Goodenough & Tinker, 1931; Munn, 1940; Vinacke, 1949), while some have supported an additive hypothesis (Aviezer et al., 2008; Bruner & Tagiuri, 1954; Knudsen & Muzekari, 1983; Meeren, van Heijnsbergen, & de Gelder, 2005). The current findings contribute to this literature by demonstrating that signal clarity derived from combinations of specific AUs predicts emotion judgment agreement rates, suggesting that signal clarity be taken into account in theories and studies of the role of context in emotion perception (see also the related discussion on source clarity in O'Sullivan, 1982). The current study also suggests that the face serves as its own context, sometimes providing high signal clarity and sometimes not.

The current work also touches on the literature demonstrating how emotion overgeneralization in neutral faces may guide impression formation. Neutral faces that resemble emotional expressions have predictable and systematic effects on impression formation and person perception (Adams, Nelson, Soto, Hess, & Kleck, 2012; Zebrowitz, Kikuchi, & Fellous, 2010). One explanation for this mechanism is that perceivers "reverse engineer" the expressions (Hareli & Hess, 2010), making inferences about the emotions the expressor experienced and the appraisals that led to them. Our data has implications for this line of research, as we provide evidence that emotions are indeed signaled in low intensity expressions, which in many cases are not very different from neutral expressions (although we realize that our judgment paradigm allowed observers to see expressions change from a neutral baseline).

The current study also has implications for literature concerning the visual processing of facial expressions of emotion, particularly to questions concerning the local versus global processing of faces and possible cultural differences in facial areas of attention (Yuki, Maddux, & Masuda, 2007). If facial expressions of emotion are processed locally (i.e., in specific component areas of the face) and if there are cultural differences in facial areas that receive attention during processing, that would mean that there will be cultural differences in the perception of subtle facial expressions of emotion. Cultures that facilitate processing of the eyes should have lower recognition rates of subtle expressions displayed in the mouth, while cultures that facilitate processing of the lower face should have lower recognition rates of subtle expressions in the brows and eyes. Such differences would have important implications for our understanding of the intercultural communication of emotions and future research should examine such possibilities.

Our data also open the door to new questions about the nature of subtle expressions and emotion in general. For instance one interesting aspect of the findings was the difference in range in mean judgment accuracies among the different types of expressions across the emotions. This range was relatively small for anger (61.74%–70.14%) but relatively large for fear, joy and surprise. This may be related to the specific expressions that were tested in this study; the mean signal clarity for the anger prototypes was lower than that for the fear, joy and surprise prototypes while the mean signal clarities for the anger variants were higher than those for fear, joy and surprise. Because the expressions that were tested were not equivalent in their signal clarities differences in their mean judgment accuracies may have been due to idiosyncrasies in the expressions tested. Alternatively, these data may suggest that there is something special about the display of anger that sets it apart from the other emotions in terms of signal value. Future research will need to replicate this finding with expressions that are equivalent across emotions in signal clarity to determine if this is indeed the case. Other studies examining individual differences in both the production and judgments of subtle facial expressions will be important as well, as individuals may learn to produce variations of the full-face prototypes idiosyncratically and introduce biases when reading emotions in relatively ambiguous signals. Future studies involving judgments of subtle expressions portrayed at different angles, with different dynamic characteristics, are also essential, as well as obtaining judgments from nonstudent samples.

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