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# Eye-movement assessment of the time course in facial expression recognition: Neurophysiological implications

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Happy, surprised, disgusted, angry, sad, fearful, and neutral faces were presented extrafoveally, with fixations on faces allowed or not. The faces were preceded by a cue word that designated the face to be saccaded in a two-alternative forced-choice discrimination task (2AFC; Experiments 1 and 2), or were followed by a probe word for recognition (Experiment 3). Eye tracking was used to decompose the recognition process into stages. Relative to the other expressions, happy faces (1) were identified faster (as early as 160 msec from stimulus onset) in extrafoveal vision, as revealed by shorter saccade latencies in the 2AFC task; (2) required less encoding effort, as indexed by shorter first fixations and dwell times; and (3) required less decision-making effort, as indicated by fewer refixations on the face after the recognition probe was presented. This reveals a happy-face identification advantage both prior to and during overt attentional processing. The results are discussed in relation to prior neurophysiological findings on latencies in facial expression recognition.

The processing of emotional facial expressions has attracted considerable behavioral and neurophysiological research (see reviews in Calder & Young, 2005; Eimer & Holmes, 2007; Frischen, Eastwood, & Smilek, 2008; Palermo & Rhodes, 2007; and Vuilleumier & Pourtois, 2007). Recognition times vary for the six basic emotional expressions (fear, anger, disgust, sadness, surprise, and happiness; see Calvo & Lundqvist, 2008; Palermo & Coltheart, 2004). The present study investigates the time course of such processing differences, with special interest in the earliest and the typical latency of conscious recognition. By using an eye-movement methodology that provides temporally precise measures at consecutive perceptual and cognitive stages, we relate behavioral and neurophysiological research on facial emotion recognition and show that happy faces are processed more efficiently than are other expressions across various stages.

## An Advantage in the Recognition of Happy Faces

In behavioral studies using recognition and categorization tasks, happy facial expressions have been found to be identified faster and more accurately than other expressions. This “happy-face advantage” has been observed for separate comparisons of happiness and sadness (Kirita & Endo, 1995), happiness and disgust (Leppänen & Hietanen, 2004), happiness and anger (Juth, Lundqvist, Karlsson, & Öhman, 2005, Experiment 4; Leppänen, Tenhunen, & Hietanen, 2003), and happiness and fear (Juth et al., 2005). Furthermore, in two studies (Calvo & Lundqvist, 2008; Palermo & Coltheart, 2004), the recognition of all six basic emotional facial expressions was compared. An equivalent pattern of findings appeared in both studies, with recognition performance being fastest and most accurate for happy faces. The fact that different facial stimulus sets (Karolinska Directed Emotional Faces [KDEF; Lundqvist, Flykt, & Öhman, 1998]—Calvo & Lundqvist, 2008; vs. Pictures of Facial Affect [PFA; Ekman & Friesen, 1976] and other stimulus databases—Palermo & Coltheart, 2004) and different response systems (manual: Calvo & Lundqvist, 2008, vs. verbal: Palermo & Coltheart, 2004) were used in each study shows that the happy-face advantage is a robust and generalizable finding.[1]

Furthermore, Calvo and Lundqvist (2008) found that less visual information is required for recognition of happy expressions than of others, since the happy-face advantage became even greater when stimulus display duration was reduced: Only minimal impairment in the recognition of happy expressions was observed as display duration decreased from unlimited time to 500, 250, 100, 50, and 25 msec, whereas recognition of all the other emotional expressions decreased almost linearly as a function of display duration. Convergent evidence shows lower

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identification thresholds for happy expressions than for angry ones (Esteves & Öhman, 1993), and indicates that happy faces are less effectively masked than are angry faces (Maxwell & Davidson, 2004).

### The Time Course in Facial Emotion Processing

Although the superiority in the recognition of happy faces is well established, the behavioral measures and paradigms used in previous studies do not allow us to determine when such an advantage begins to develop and how it accumulates over various cognitive processing stages. Manual or vocal responses have been typically used in facial emotion recognition tasks, with reaction times (RTs) usually around 1 sec in tasks involving categorization of multiple expressions (e.g., Calvo & Lundqvist, 2008; Palermo & Coltheart, 2004). In terms of mental chronometry, this is a large time scale. It is likely that different cognitive processes unfold during this period, but the overall RTs, which reflect the sum of a number of different cognitive and motor processes, cannot be used to analyze them separately. Assessment of the time course in the recognition of facial expressions thus requires more precise measures isolating the processes that may contribute to the overall RTs and allow us to identify specific components.

In a first approach to this issue, Leppänen et al. (2003) tried to separate cognitive from motor processes. These authors measured lateralized readiness potential (LRP), a movement-related brain potential that reflects motor preparation in the precentral motor cortex. When combined with a manual RT measurement, the LRP can be used to divide the stimulus–response chain into two stages: stimulus processing and response selection (from stimulus onset to LRP onset) and response execution (from LRP to response onset). Leppänen et al. compared LRPs elicited by happy, disgusted, and angry faces, and time-locked the evoked responses to the face onset (indexing a cognitive or recognition stage) or to the manual response (indexing a response execution stage). They found shorter latencies for the stimulus-locked LRP for happy than for angry and disgusted faces, and an absence of differences in the latency of response-locked LRPs. These authors concluded that the benefit for happy faces takes place during the face recognition stage. This rules out the involvement of postcognitive factors (e.g., faster programming, or execution of the manual response) and sets the focus on cognitive mechanisms.

Neurophysiological studies using the event-related potential (ERP) technique provide a direct assessment of the time course of emotional facial expression processing. The earliest signs of category-selective responses to faces are observed in the N170 component measured over occipitotemporal sites (Bentin, Allison, Puce, Perez, & McCarthy, 1996), and findings indicate that emotional faces trigger larger N170 amplitudes than neutral faces do (see Eimer & Holmes, 2007; Palermo & Rhodes, 2007). Given the robust happy-face advantage observed in behavioral studies (see above), it is striking that no consistent ERP latency or amplitude differences have appeared when various emotional expressions were compared in ERP studies (Eimer, Holmes, & McGlone, 2003). A happy-face advantage (i.e., a shorter N170 latency) has been found in only one study (Batty & Taylor, 2003). This lack of clear differential ERP effects of expression raises the issue of whether the latency and amplitude modulation of N170 by emotional faces reflects categorization of the expression. Whereas typical behavioral measures involve conscious recognition of the specific content of each emotional expression, ERP measures may not, because ERP correlates of emotional expression processing are typically determined by comparing ERPs elicited on trials with emotional faces with ERPs in response to neutral faces. This implies that although ERP measures can reveal the earliest time when discrimination between emotional and neutral faces begins, it is often difficult to interpret what kind of processes (such as perceptual, affective encoding, or semantic categorization) the observed differences in the ERP waveforms reflect. For example, they may indicate when *some* emotional content, such as valence or arousal level of the face stimulus, is detected, but this does not necessarily mean that a categorical representation of facial expression is obtained. In other words, ERP data themselves do not unambiguously indicate that a *specific* emotional expression has been consciously recognized and discriminated from other emotional expressions.

### The Present Study: Eye-Movement Assessment

In the present study, we combined a paradigm that required explicit recognition of emotional facial expressions with eye-movement monitoring at various processing stages. Recognition performance served to indicate that specific emotional expressions were consciously identified and discriminated. Eye tracking allowed us to explore the time course of emotional face processing with temporal accuracy (500 Hz) approaching that of EEG. By means of this combined paradigm, we examined whether the categorization of facial expressions could begin within the N170 latency range. Furthermore, eye-movement measures can be used to decompose the recognition and response execution period into shorter time windows, and to infer how different cognitive processes unfold over time (see Rayner, 2009). Eyetracking methods have previously been used to decompose expression detection processes in visual search tasks into different cognitive stages, including target localization and decision making (Calvo, Nummenmaa, & Avero, 2008; Reynolds, Eastwood, Partanen, Frischen, & Smilek, 2008). In the present study, we extended the eyetracking approach to determine when the recognition of emotional expressions takes place. Whereas detection (i.e., noticing that an object is in an array of stimuli) can be accomplished on the basis of physical feature processing, recognition is assumed to involve identification of the stimulus meaning (i.e., stating *what* the object is rather than merely noticing it; see Grill-Spector & Kanwisher, 2005).

In sum, prior behavioral research on the recognition of facial expressions of emotion has shown an advantage of happy faces, as indicated by shorter overall manual and vocal RTs as a global index of cognitive processing. Neurophysiological research has ruled out the involvement of response-execution processes in this effect, and has revealed that the processing of facial emotion takes place very early (between 120 and 180 msec from stimulus onset). However, no systematic neurophysiological differences have been found among emotional expressions, and it is difficult to assess whether the early differential ERP waves reflect recognition. The present study aims to make a contribution in various respects. First, our eye-movement paradigm will examine the time course of facial emotion recognition by isolating some critical subprocesses that occur in the overall recognition period between the onset of the stimulus and the motor response. Second, our paradigm will reveal whether the early processing of emotional expressions shown by neurophysiological studies may involve conscious identification of specific expressions at such early stages.

We used two different eyetracking paradigms. In both cases, facial expression recognition was inferred from performance in categorization tasks. In Experiments 1 and 2, we investigated the *earliest point* in time when emotional expressions are identified, by employing a two-alternative forced choice (2AFC) visual discrimination task with saccadic responses (see Kirchner & Thorpe, 2006). An emotional (target) and a neutral (distractor) face of different identities were simultaneously flashed in the left and right visual fields for 30 msec and replaced with saccade target circles. The participants were instructed to saccade as quickly as possible to the side where a prespecified target expression appeared. The latency of the saccades initiated correctly toward the target location revealed the recognition time course. Lateralized presentation of the faces was necessary in this paradigm to assess saccade choice between *two* simultaneous visual stimuli (target and distractor).

In Experiment 3, we extended the time scale to encompass both early and late stages of face recognition. A single face was presented to the parafovea for 500 msec, followed by a centrally presented singleton visual cue (a series of Xs), which was replaced by a probe word (*neutral*, *angry*, etc.) to be matched with the face. Measures were obtained for (1) speed of overt orienting to the face, as indicated by the latency of the first saccade toward the lateralized face; (2) encoding upon fixation on the face, as revealed by the duration of first fixation and dwell times on the face after the visual cue indicated the imminent onset of the probe at a central location; and (3) decision efficiency on whether or not the probe word matched the facial expression, as assessed by the number of refixations on the face, as well as manual response latency from the onset of the probe.

## EXPERIMENT 1

Experiment 1 investigated how rapidly facial expressions can be categorized by measuring the latency of saccadic responses to predefined expressive faces. Eye movements are particularly well suited to measuring processing speed (Kirchner & Thorpe, 2006), because they can be initiated in under 100 msec (Fischer & Weber, 1993), of which only 20–25 msec is consumed by saccade preparation in the brainstem (Schiller & Kendall, 2004). We used a 2AFC recognition task. A verbal label of the target expression was displayed on the screen at the beginning of each trial. An emotional (target) and a neutral (distractor) face were then flashed simultaneously to each side of fixation for 30 msec. A 200-msec gap period was included prior to the faces to accelerate saccade initiation (Fischer & Weber, 1993) by allowing attention to disengage from the fixation point before presentation of the face stimuli. Viewers were asked to make a speeded saccade to the side where the face whose expression matched the label was presented. In addition to median saccade latencies, we also assessed the minimum latency—that is, the earliest time point at which the proportion of correctly directed saccades to the target face exceeded that of erroneous saccades to the distractor. Whereas the median latencies indicate the typical point in time at which most viewers recognize the expression, the minimum latency would reveal when sufficient information is available to perform the task with above-chance accuracy (see Kirchner & Thorpe, 2006).

### Method

**Participants**. Eighteen psychology undergraduates at Turku University and 10 at La Laguna University participated for course credit. They were all female with a mean age of 22 years (age range 18–41 years). All gave informed consent for this and the following experiments.

**Stimuli**. We selected 210 digitized color photographs from the KDEF (Lundqvist et al., 1998) stimulus set. The face stimuli portrayed 30 individuals (15 females—KDEF nos. 01, 02, 03, 05, 07, 09, 11, 13, 14, 19, 20, 26 29, 31, & 33; and 15 males—KDEF nos. 03, 05, 06, 08, 10, 11, 12, 13, 14, 17, 22, 23, 29, 31, & 34), each showing 7 expressions (neutral, happiness, anger, sadness, disgust, surprise, and fear). Each photograph was cropped; nonfacial areas (hair, neck, etc.) were removed by applying an ellipsoidal mask. Each face subtended a visual angle of 8.4º (height) × 6.4º (width) at a 60-cm viewing distance and was presented against a black background.

**Apparatus and Procedure**. The stimuli were presented on a 21-in. monitor with a 120-Hz refresh rate. Participants' eye movements were recorded with an EyeLink II tracker (SR Research Ltd., Mississauga, Ontario, Canada) at a 500-Hz sampling rate and $<0.5º$ spatial resolution in pupil-tracking mode.

Each participant was presented with 12 practice trials and 360 experimental trials in four blocks, randomly. Each trial (see Figure 1) began with a central drift correction circle (0.5º). When the participant fixated this circle, a word representing the target face (such as *happy*) appeared for 1 sec in the center of the screen. This was followed by a fixation circle for a random interval (500–700 msec), and a 200-msec time gap period. Following the gap, two lateralized faces were presented for 30 msec, one to the left and the other to the right of fixation, with the inner edges 2.5º away from the central fixation point. Finally, two circles appeared for 1 sec, each placed at the center of the location where each of the faces had been displayed. The participants were to saccade quickly at the circle where the verbally precued target face had appeared.

Of the two faces on each trial, one was an expressive target matching the preceding word, and the other was a distractor. The target was always an emotional face (happy, sad, angry, fearful, disgusted, or surprised). The distractor was always the neutral face of a different individual. This made the task more ecologically valid, given that in real life the people we see are all different, not clones. Also, by using two different identities we ensured that target-face recognition could not be made on the basis of trivial physical differences between the target and the distractor. In other words, the physical differences resulting from the physiognomy of the two identities were much larger than those arising from the different expressions; thus, the task could not be performed on the basis of low-level visual differences between the images. At the end of the experiment, we asked participants whether they noticed that one of the faces on each trial was neutral; none reported noticing this. This implies that the participants were not simply searching for *any*

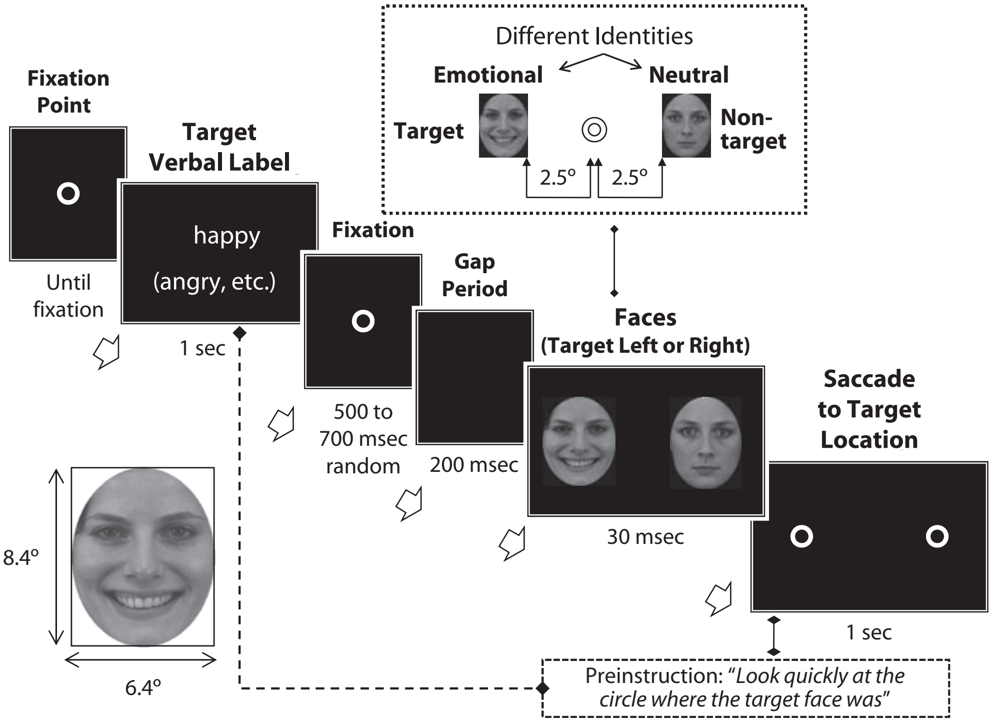

**Figure 1. Sequence of events and overview of basic characteristics of a trial in Experiment 1.**

*nonneutral* face—if so, they would not have needed to recognize *which* emotional face was presented. Rather, the participants tried to look at the specific predefined expression when they saccaded to the target face.

**Assessment of low-level image properties**. Given the profound role of low-level visual features in guiding attention and eye movements (Itti & Koch, 2001), it is possible that differences in physical properties among the different expressions could confound the results, since the task was based on eye-movement target selection. To control for this, we obtained basic image statistics such as luminance, contrast density (root mean square contrast—RMS), skewness, kurtosis, and global energy of the face stimuli with MATLAB 7.0 (The MathWorks, Natick, MA). Differences in these image statistics were then computed between each target and distractor face for each pair of expressive and neutral faces actually presented. In addition, visual similarity of each pair of faces was assessed by two complementary approaches: First, we computed pixel-by-pixel correlations of the intensities (i.e., grayscale luminosity) of the corresponding expressive and neutral faces; second, we used principal component (PC) analyses and assessed how much of the intensity variation of each image pair could be explained by the first PC. The more variation the first PC explains, the more similar the images are.

**Design**. There were two within-subjects factors: expression (happy vs. angry vs. sad vs. disgusted vs. surprised vs. fearful) and visual field of the target (left vs. right). Each emotional target face was presented twice to each participant, once in each visual field, and each time was paired randomly with a neutral face of a different identity.

**Analysis of eye-movement data**. In addition to the proportion of correctly directed saccades, we computed the expressionwise median saccadic latencies for correct responses. These served to estimate the time typically taken to identify each emotional expression. Saccade latencies were recorded from the onset of the face pair until the first eye movement with an amplitude over 2º of visual angle was initiated toward one of the circles that replaced the faces. To estimate the minimum time required for encoding, we first divided the expression-wise saccadic latency distributions into 20-msec "bins." Next, we computed the proportion of correct and erroneous saccades in each bin and searched for the first bin that (1) contained significantly more correct than erroneous responses, and (2) was followed by at least five successive bins with more correct than erroneous responses (see Kirchner & Thorpe, 2006). This five-bin criterion ensured that early anticipatory (although correctly directed) responses would not be classified as indexing recognition.

## Results

A 6 (target facial expression) × 2 (visual field) repeated measures ANOVA was conducted on the dependent measures. Bonferroni corrections ($p < .05$) were used for all post hoc multiple comparisons in this and the following experiment. Mean scores and significant multiple contrasts, as indicated by superscripts, are shown in Figure 2. For saccade response accuracy, there was a main effect of facial expression [$F(5,135) = 42.97$, $p < .0001$, $\eta_p^2 = .61$], but not of visual field ($F = 2.02$, $p = .17$, n.s.) or the interaction ($F < 1$). Multiple contrasts indicated that the proportion of correct responses was higher for happy, surprised, and disgusted faces than for fearful, angry, and sad faces. Median saccade latencies were also reliably affected by facial expression [$F(5,135) = 12.62$, $p < .0001$, $\eta_p^2 = .32$], but not by visual field ($F < 1$) or the interaction ($F = 2.08$, $p = .10$, n.s.). Latencies were faster for happy expressions than for all the others, which did not differ from one another. Expressionwise saccadic latency distributions are presented in Figure 3.

Pairwise *t* tests were calculated to compare the proportion of correct and incorrect saccadic responses for each time bin and to determine where significant differences appeared first (and remained for at least five successive consecutive time intervals). The earliest time window in which the proportion of correct responses exceeded that of

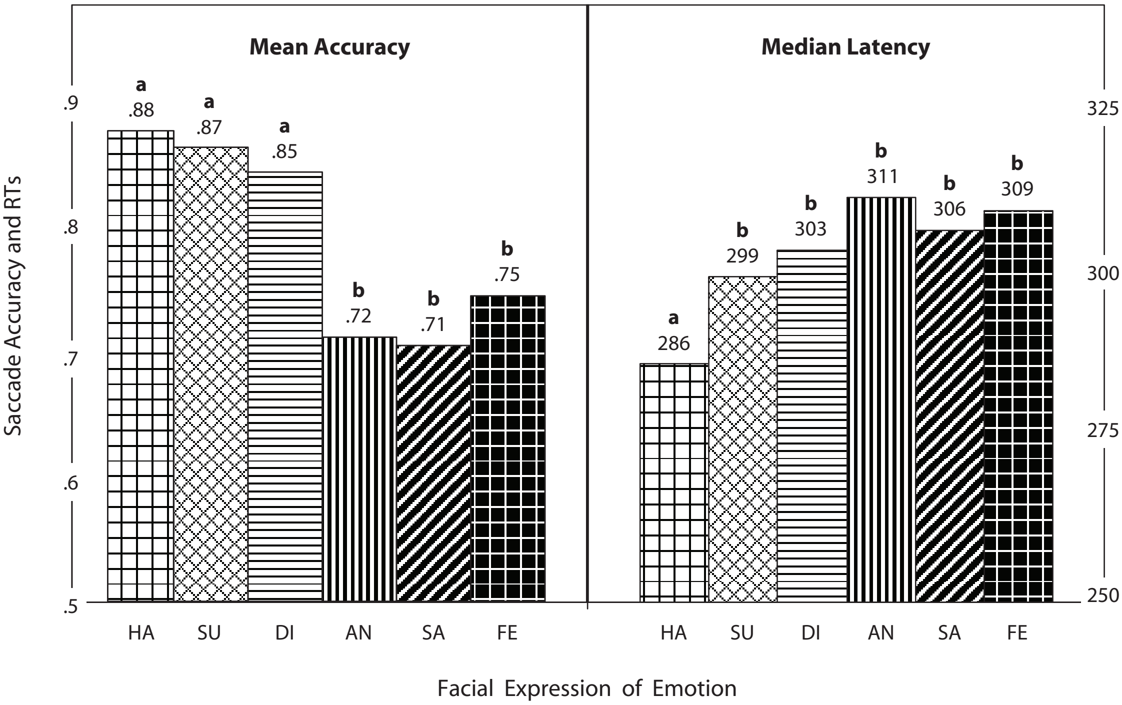

**Figure 2. Mean saccade accuracy (probability of correctly directed saccades) and median saccade latencies (in msec) toward the target face in Experiment 1. Mean scores with a different superscript are significantly different; means sharing a superscript are equivalent. HA, happy; SU, surprised; DI, disgusted; AN, angry; SA, sad; FE, fearful.**

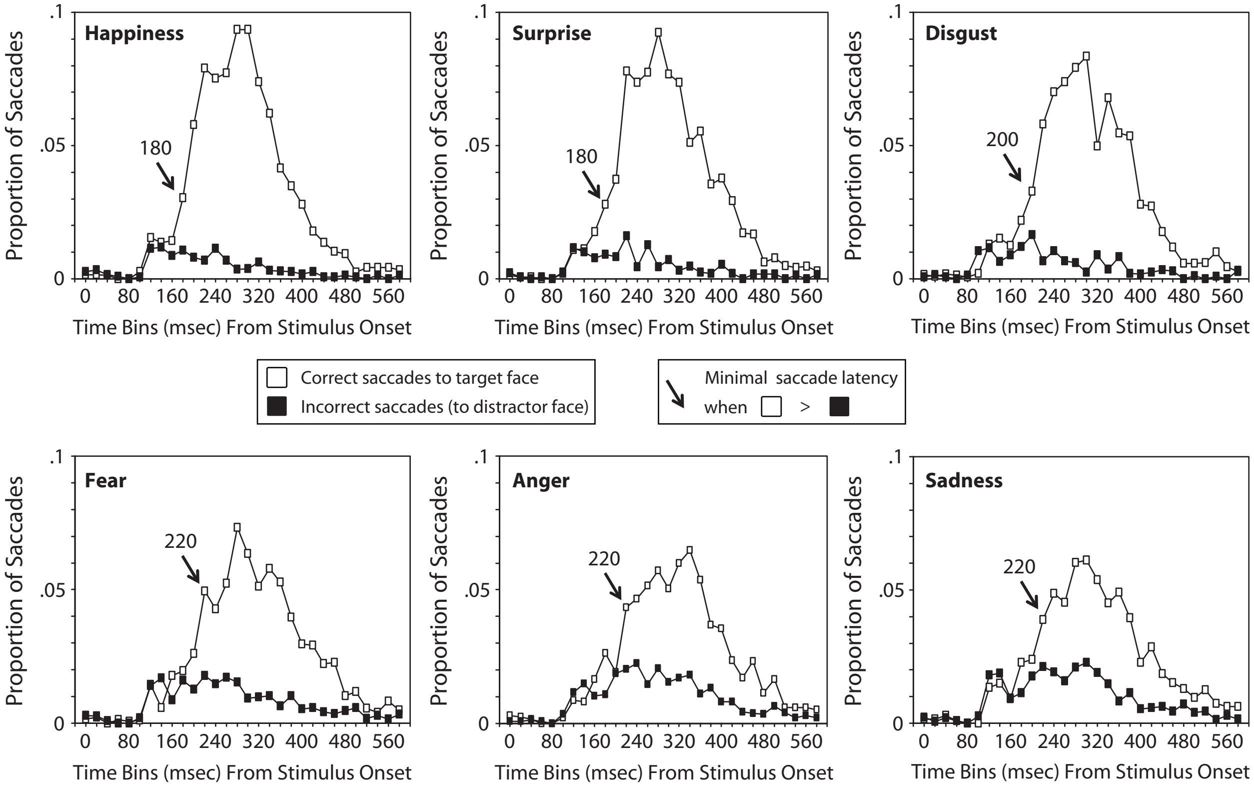

**Figure 3. Saccadic reaction time (RT) distribution of correctly and erroneously directed saccades (in probability of saccades) across 20-msec time bins for each emotional expression, in Experiment 1. Arrows indicate the earliest point in time when correct saccades to the target face significantly exceeded erroneous saccades to the distractor.**

**Table 1**
**Mean Difference Scores in Image Properties Between Neutral (Distractor) and Emotional (Target) Face Stimuli (i.e., Emotional − Neutral), for Each Emotional Expression**

| | Type of Expression | | | | | |
|---|---|---|---|---|---|---|
| | Happy | Surprised | Disgusted | Fearful | Angry | Sad |
| *M* Luminance | −1.08 | −1.19 | −2.28 | −1.84 | −1.31 | −2.10 |
| *SD* Luminance | −1.29 | −1.58 | −2.97 | −2.11 | −2.30 | −3.27 |
| RMS Contrast | −.004 | −.006 | .014 | −.006 | −.014 | −.020 |
| Skewness | .029 | .017 | .004 | .021 | −.010 | −.019 |
| Kurtosis | .119 | .137 | .112 | .127 | .084 | .057 |
| Energy ($\times 10^{-5}$) | 21.96 | 55.83 | −98.31 | −40.98 | −92.61 | −132.88 |
| CRL | .913 | .905 | .911 | .917 | .920 | .927 |
| PCA | 95.92 | 95.46 | 96.00 | 95.86 | 95.92 | 96.21 |

Note—CRL, correlation-based similarity; PCA, principal components analysis based similarity.

incorrect responses was the 180-msec bin for happy faces [$t(27) = 2.87, p < .01$] and surprised faces [$t(27) = 2.69, p < .025$], the 200-msec bin for disgusted faces [$t(27) = 2.30, p < .05$], and the 220-msec bin for fearful [$t(27) = 2.52, p < .025$], angry [$t(27) = 3.01, p < .01$], and sad [$t(27) = 2.41, p < .025$] faces.

**Analysis of low-level image properties**. Differences between the target and the distractor faces in mean and *SD* luminance, RMS contrast, skewness, kurtosis, and energy, as well as PCA and Pearson correlation (CRL) based image similarity metrics, were analyzed by means of one-way ANOVAs (6: emotional expression). (See the mean scores in Table 1.) No effects were statistically significant. Only for energy did the effect approach significance [$F(5,174) = 2.19, p = .057, \eta_p^2 = .27$; all $p$s $>$ .12, after Bonferroni corrections for multiple contrasts]. Accordingly, the faster saccades to the happy faces, relative to other emotional faces, are not related to differences in low-level image properties. If anything, the opposite occurred, as happy faces tended to be more similar—in energy, for example—to the paired neutral faces than were the other emotional faces.

## Discussion

The median saccadic latencies for happy faces in a forced-choice discrimination task were faster than for all the other emotional faces, thus showing an earlier recognition of the happy expressions. This extends prior findings on the happy-face recognition advantage in foveal vision to extrafoveally presented faces, using behavioral measures. The earliest point in time at which correct recognition could be accomplished (i.e., with the proportion of saccades to target faces exceeding saccades to distractor faces) was similar for happy and surprised faces (180 msec), and faster for them than for disgusted (200 msec), fearful, angry, and sad (220 msec) expressions. These results represent a novel contribution to behavioral research on the time course in the recognition of the six basic emotional expressions. This also enables us to pinpoint the shortest possible latency for facial expression recognition in relation to findings obtained with neurophysiological measures.

Electrophysiological studies have consistently implicated the N170 potential (Bentin et al.,1996) observed at 150- to 200-msec poststimulus over occipitotemporal electrodes as the earliest neural signature of category-specific face processing (although see Meeren, Hadjikhani, Ahlfors, Hämäläinen, & de Gelder, 2008). The N170 is believed to be associated with the structural encoding of faces, reflecting global categorization (by differentiating faces from nonface objects), whereas fine-grained differentiation between facial expressions of emotion would emerge later (Leppänen, Kaupinnen, Peltola, & Hietanen, 2007; Schupp et al., 2004). However, this view is challenged in studies showing that emotional expressions modulate the amplitude of N170 (Batty & Taylor, 2003; Caharel, Courtay, Bernard, Lalonde, & Rebaï, 2005; Leppänen, Moulson, Vogel-Farley, & Nelson, 2007). Nevertheless, although the N170 amplitude can be sensitive to facial affect, no consistent differences in N170 latencies have appeared between emotional expressions. In studies comparing the six basic emotional expressions, Eimer et al. (2003) found similar latencies for all the expressions but Batty and Taylor (2003) found that both happy and surprised faces evoked N170 significantly earlier than did all the negative-emotion expressions. The shorter saccade latencies for happy and surprised faces than for the other expressions in our study are consistent with Batty and Taylor's N170 findings.[2]

Beyond this specific empirical consistency, our eye-movement results support and extend the neurophysiological findings on facial emotion recognition. In the present experiment, the proportion of correctly directed saccades began to exceed that of errors around 180–220 msec poststimulus for all expressions. If we assume a delay of about 20–25 msec for the target-guided saccades to be programmed (Schiller & Kendall, 2004), this implies that all expressions could be recognized within a 150–200-msec poststimulus range, which closely corresponds to N170 latency. Furthermore, although the N170 amplitude is influenced by facial expression, the electrophysiological data do not reveal whether information on the emotional expression is already consciously available within this latency range; in other words, it is not known whether the N170 amplitude modulation actually reflects expression recognition. In contrast, saccadic responses in the present forced choice discrimination paradigm *do* require recognition of the emotional expression, since saccades must be selectively performed to faces that have been predefined as targets. Saccade latencies thus provide an unambiguous lower bound estimate of conscious recognition speed. Our results show, therefore, that information regarding facial expression can be consciously available already within the N170 latency range, but it must be noted that the minimum saccade latencies reflect the *earliest* possible time at which the representation of the facial expression category is consciously available (150–200 msec). Accordingly, conscious recognition of the expression might influence the N170 only to a limited extent, given that expression recognition is typically completed later (260–285 msec), as reflected by the median saccade latencies.

## EXPERIMENT 2

A major finding of Experiment 1 was that saccade latencies (minimum saccade RT and/or median saccade latencies) were shorter for happy faces than for all the other facial expressions. Presumably, this indicates that identification of happy expressions begins earlier, in addition to the recognition process being accomplished faster. The early recognition advantage of the happy faces is particularly noteworthy over the four unequivocally negative faces (disgusted, angry, sad, and fearful). In Experiment 2, we addressed two issues that involve alternative accounts of these findings.

First, it is possible that viewers initially distinguish between positive and negative expressions, then discriminate among different expressions within each class. If so, and given that in Experiment 1 there were multiple (four) exemplars of negative expressions but only one exemplar of positive expressions (happy)—with surprised faces not being clearly positively or negatively valenced (see Mendolia, 2007)—the processing advantage of happy faces could reflect their "singleton" status rather than an advantage in identification of the specific expression they convey. In contrast, the negative expressions would be subjected to mutual interference and competition because they share emotional valence, which would delay the identification of each specific expression. Accordingly, we would predict that the time course of recognition of the negatively valenced expressions would be speeded up when only one expression of the negative class is presented, and the happy-face advantage might disappear. To examine this hypothesis in Experiment 2, we presented only one negative expression (anger) in addition to a single positive expression (happiness) and one expression that was neither negative nor positive (surprise).

Second, it is possible that in Experiment 1, in which an emotional and a neutral face appeared simultaneously, the 2AFC task could be performed without viewers needing to identify the specific category of the emotional face that was predefined; that is, participants might not have needed to recognize the expression, but simply to detect which face was emotional and saccade to it, no matter which expression it was. This possibility is unlikely, given that no participant reported noticing that a neutral face was always present on each trial; nevertheless, such a possibility cannot be totally ruled out, given that participants probably inferred that the target face was always present on each trial (whether the other face in the pair was also emotional or was neutral was not mentioned). To further examine and eventually rule out this hypothesis, we modified the task instructions in Experiment 2. The instructions emphasized that on each trial one of the two faces *could* correspond to the predefined expression, and that participants should saccade to the precued face *only if* the target expression was presented. If saccades were guided in Experiment 1 by the recognition of the *specific* expression precued, the same pattern of saccade responses should appear in Experiment 2.

### Method

Twenty psychology undergraduates at La Laguna University, all female between 20 and 22 years old, participated for course credit. The same stimuli, apparatus, procedure, and design were used as in Experiment 1, with the following exceptions. First, only faces from the happy, surprised, and angry emotional categories were presented, in addition to neutral faces. Second, as indicated above, the instructions were modified so that participants were asked to saccade to the predefined face only if it was present in the pair on each trial. Nevertheless, the precued face was present on all trials, and the distractor face was always neutral, in order to maintain the comparison in all other respects with the conditions of Experiment 1. Third, the design involved target expression with three levels (happy vs. angry vs. surprised), in addition to visual field of the target (left vs. right), as within-subjects factors.

### Results

A 3 (facial expression) × 2 (visual field) repeated measures ANOVA was conducted on the dependent measures. For saccade response accuracy, there was a main effect of expression [$F(2,38) = 25.74$, $p < .0001$, $\eta_p^2 = .58$] but not of visual field ($p = .20$) or the interaction ($F < 1$). Multiple contrasts indicated that the proportion of correct responses was higher for happy ($M = .849$) and surprised ($M = .779$) faces than for angry faces ($M = .637$). Median saccade latencies were also reliably affected by facial expression [$F(2,38) = 3.51$, $p < .05$, $\eta_p^2 = .16$], but not by visual field ($F < 1$) or the interaction ($F = 2.08$, $p = .10$, n.s.). Latencies were faster for happy ($M = 280$ msec) than for angry ($M = 307$ msec) faces, which did not differ from surprised faces ($M = 287$ msec).

Pairwise *t* tests were computed to compare the proportion of correct and incorrect saccadic responses for each time-course bin and to determine where significant differences appeared first. The earliest time window where the proportion of correct responses exceeded that of incorrect responses was the 180-msec bin for happy faces [$t(19) = 2.86$, $p < .01$] and surprised faces [$t(19) = 2.71$, $p < .025$], and it was the 200-msec bin for angry faces [$t(19) = 2.09$, $p = .05$; $t(19) = 2.74$, $p < .025$, at 220 msec]. Expressionwise saccadic latency distributions are presented in Figure 4.

The data from trials with happy, surprised, and angry faces in Experiments 1 and 2 were combined in a 2 (experiment) × 3 (facial expression) × 2 (visual field) ANOVA. For response accuracy, main effects of experiment [$F(1,46) = 6.38$, $p < .025$, $\eta_p^2 = .12$] and facial expression [$F(2,92) = 93.60$, $p < .0001$, $\eta_p^2 = .67$], with no interaction [$F(2,92) = 1.21$, $p = .12$, n.s.], revealed that accuracy was higher in Experiment 1 ($M = .822$) than in Experiment 2

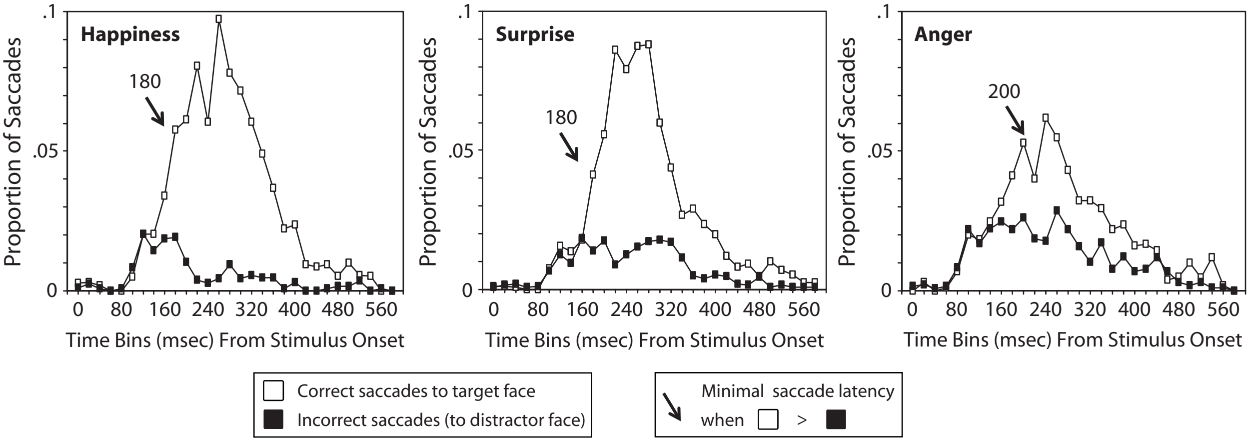

**Figure 4. Saccadic reaction time (RT) distribution of correctly and erroneously directed saccades (in probability of saccades) across 20-msec time bins for each emotional expression, in Experiment 2. Arrows indicate the earliest point in time when correct saccades to the target face significantly exceeded erroneous saccades to the distractor.**

($M = .755$), and for happy ($M = .865$) than for surprised ($M = .824$) faces, which were recognized better than angry faces ($M = .676$; all $p$s $< .05$). For median saccade latencies, only a main effect of expression emerged [$F(2,92) = 12.97$, $p < .0001$, $\eta_p^2 = .22$], with faster responses for happy ($M = 284$ msec) and surprised ($M = 294$ msec) faces than for angry faces ($M = 309$ msec).

Finally, pairwise *t* tests compared the proportion of correct and incorrect saccadic responses for each time-course bin for all 48 participants. For happy faces, correct saccades exceeded incorrect saccades at the 160-msec time bin [$t(47) = 2.10$, $p < .05$], whereas for surprised faces the earliest time bin remained at 180 msec [$t(47) = 3.84$, $p < .0001$; $p = .16$, n.s., at the 160-msec bin]; for angry faces, differences became statistically significant at the 220-msec bin [$t(47) = 2.10$, $p < .05$; the effect did not reach statistical significance at the 200-msec bin, $t(47) = 1.80$, $p = .08$]. This strengthens the view that there is a reliable happy-face recognition advantage at the earliest stages of the processing time course.

### Discussion

The results of Experiment 2 replicated those of Experiment 1 regarding the happy face time-course advantage over angry faces. This implies that the advantage is not merely due to the single status of happy faces in the positive valence dimension and the competition among negative faces, since angry faces were the only negative expressions in Experiment 2. Rather, the new findings suggest that the specific expression category of happy faces is identified earlier than is that of angry faces. There was, however, an interesting new finding in Experiment 2 regarding angry faces: The earliest recognition point in time for these faces was 200 msec (when no other negative face was presented), in comparison with the 220-msec time bin in Experiment 1 (when all four negative expressions were presented). This reveals that the recognition disadvantage of angry faces relative to happy faces depends to some extent—but not exclusively—on the actual competition for discrimination among different negative expressions.

The new findings are not consistent with the hypothesis that the results of Experiment 1 can be accounted for by a processing model in which viewers initially distinguish between positive and negative expressions, and then distinguish among different types of expressions within a class. First, even with a single expression per valence class, the happy expression was recognized faster than the angry expression was. Second, surprised faces are not positively or negatively valenced (Mendolia, 2007), yet they were also at advantage over angry faces. In general, we argue that viewers first identify some facial features that lead them to recognize the whole expression, and affect is then perceived. This would be consistent with the view that people need to know what something is before evaluating it as good or bad (Calvo & Nummenmaa, 2007; Storbeck, Robinson, & McCourt, 2006).

In Experiment 2, the instructions emphasized that on each trial there were two faces, one of which could correspond to the verbal precue, and that viewers should saccade to the target expression only if there were any face of the specified category. With these instructions, we aimed to avoid the possibility of participants simply saccading toward the emotional face regardless of its expression category. Importantly, in these conditions, the same pattern of saccade latencies and relative advantage of the happy faces appeared as in Experiment 1. This suggests that saccades were not determined simply by the decision "this face *differs* from the neutral face," but by the decision "this face *matches* the predefined category." In other words, the saccades were determined by the recognition of specific expressions.

## EXPERIMENT 3

The findings from Experiments 1 and 2 showed that the recognition of facial expressions can be accomplished very rapidly, and that the happy-face advantage begins at about 160 msec poststimulus (i.e., 180 − 20–25 msec for saccade programming). Nevertheless, this represents the *earliest* point in time at which recognition can be accomplished. In contrast, the *median* latencies for correct saccadic responses were around 300 msec for most facial expression categories. This implies that the recognition process typically extends over a longer period. We thus conducted Experiment 3 to broaden the scope in the time-course assessment of facial emotion recognition, by including both early and late recognition stages. Neutral or emotional faces were presented laterally one at a time in a recognition task. The faces were followed by a centrally presented probe word that either matched or did not match the expression of the face. Eye movements were monitored. Saccadic latencies, first-fixation durations, and refixations were computed to assess initial orienting speed, encoding, and decision efficiency. Responses to the probe words served to measure recognition performance.

## Method

**Participants**. Six male and 18 female undergraduate psychology students at La Laguna University (age range, 19–23 years) participated for course credit.

**Stimuli**. The same KDEF stimuli as in Experiment 1 were used, with the same size and at the same viewing distance.

**Apparatus and Procedure**. The apparatus was the same as in Experiment 1. Each participant was presented with 186 experimental trials in three blocks, randomly, in addition to 16 practice trials. Each trial (see Figure 5) began with a central drift correction circle. Three trial periods were defined to inspect orienting, encoding, and decision stages. First, when the participant fixated the drift correction circle, a *prime period* started, in which a face appeared to the left or right for 500 msec. This prime duration was theoretically motivated, since it allows, on average, one fixation on the face (see Rayner, 2009). This prediction was confirmed by the actual data (saccade latency, $M = 175$ msec; saccade duration, $M = 38$ msec; first-fixation duration, $M = 308$ msec; total, 521 msec). The distance between the center of the fixation circle and the inner edge of the face was 3º, which permitted initial parafoveal preview of the face. Second, a 500-msec *cue period* followed, in which a string of five Xs (the cue) appeared in the center of the screen replacing the circle, while the lateral face remained visible. The abrupt replacement of the circle with the Xs was aimed at cuing the viewer's attention to the location where the probe word would appear shortly. Such cuing was assumed to be more effective in attracting overt attention away from the expressions that require less attentional resources to be identified. And, third, in a subsequent *probe period*, a word representing one of the seven expressions replaced the string of Xs (while the face remained visible) and was displayed until the participant responded. The task involved pressing one of two keys, to indicate whether or not the probe word matched the facial expression.

**Design**. There were two within-subjects factors: expression (neutral vs. happy vs. angry vs. sad vs. disgusted vs. surprised vs. fearful) and visual field (left vs. right) of the target face. On half the trials, the probe word matched the expression of the prime face (e.g., the word *happy* and a happy face); on the other half, the face and the word were different in content (e.g., the word *happy* and an angry face). Participants were presented with each facial expression of each model once, in either the left or the right visual field.

**Measures**. Recognition accuracy was indexed by the probability of correctly matching the probe word and the facial expression. Eye-movement data were used to assess orienting, encoding, and decision efficiency. Speed of attentional orienting was measured by means of the latency for initiating the first saccade toward the lateralized face presented at the beginning of the prime period. Encoding of the facial expression was examined by the duration of the first fixation on the face, the probability of making a saccade toward the cue (i.e., away from the face) during the cue period, and dwell time on the face—that is, the time spent looking at the face *after* the onset of the cue that indicated the imminent appearance of the probe at another location. Decision efficiency was determined by the number of refixations on the face during the probe period, and decision times from the probe word onset until response.

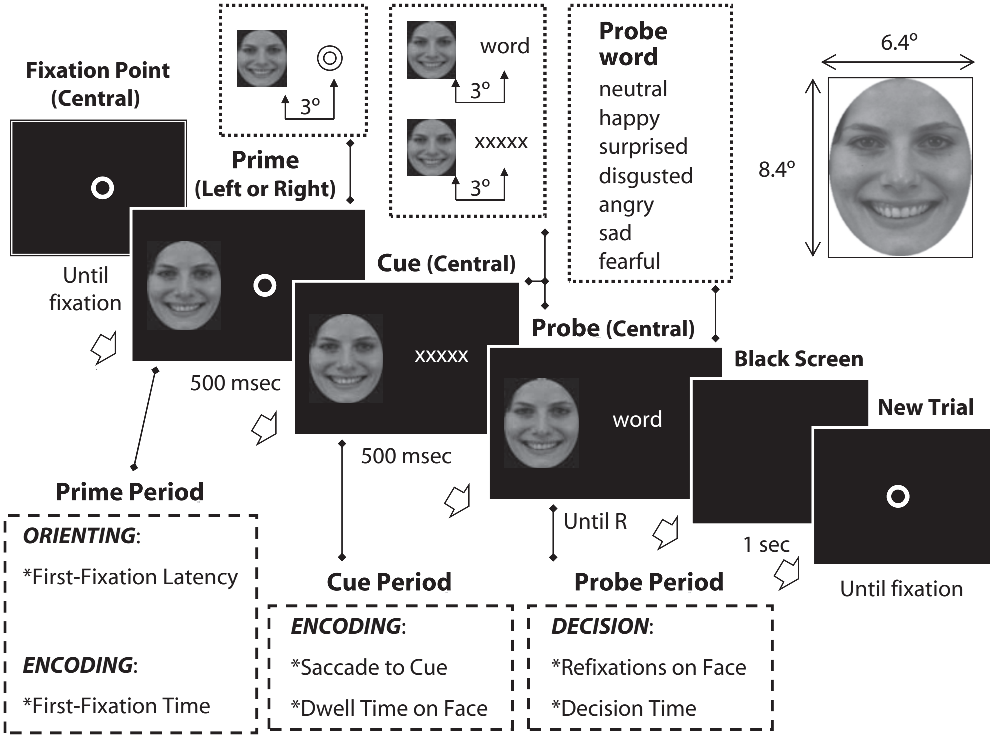

**Figure 5. Sequence of events and overview of basic characteristics of a trial in Experiment 3.**

## Results

A 7 (facial expression) × 2 (visual field) repeated measures ANOVA was conducted on the dependent measures. Mean scores and significant multiple contrasts—as indicated by superscripts—are shown in Figures 6 and 7.

For response accuracy, there was a main effect of facial expression [$F(6,138) = 6.73$, $p < .0001$, $\eta^2_p = .23$]. Response accuracy was higher for happy faces ($M = .979$) than for neutral ($M = .903$), fearful ($M = .887$), sad ($M = .913$), and angry ($M = .934$) faces, with accuracy for disgusted ($M = .958$) and surprised ($M = .941$) faces not being significantly different from any other face.

**Orienting**. First-fixation latency was not reliably affected by facial expression. A tendency for shorter latencies for happy faces (latency, 170 msec; velocity, 153º/sec) than for the other faces (latencies ranging from 171 to 180 msec; velocities from 149º to 152º/sec) was nonsignificant ($F = 2.47$, $p = .059$). After Bonferroni corrections, all post hoc multiple contrasts between the happy faces and the other face categories were $p > .25$.

**Encoding**. The duration of first fixation was affected by expression [$F(6,138) = 3.67$, $p < .01$, $\eta^2_p = .13$]. Happy faces received shorter first fixations ($M = 277$ msec) than did all the other faces (surprised, 308 msec; disgusted, 319 msec; angry, 311 msec; sad, 319 msec; fearful, 310 msec; neutral, 312 msec). A reliable effect of expression on the probability of saccades toward the cue also emerged [$F(6,138) = 6.35$, $p < .0001$, $\eta^2_p = .22$]. Saccades toward the cue were more frequent on trials with a happy face than on trials with any other face. Similarly, there was an effect of expression on dwell times [$F(6,138) = 7.18$, $p < .0001$, $\eta^2_p = .24$]. During the cue display, participants spent less time looking at the happy face than at all the other faces (see Figure 6). No significant differences emerged in any of these three dependent variables among the nonhappy faces.

**Decision efficiency**. The number of refixations on the face during the probe period was affected by expression [$F(6,138) = 12.15$, $p < .0001$, $\eta^2_p = .35$]. Happy faces received fewer refixations than did all the other faces (except disgusted faces: $p = .082$) after the probe word appeared. Finally, for decision times, a main effect of expression [$F(6,138) = 21.35$, $p < .0001$, $\eta^2_p = .48$] revealed that responses were fastest for happy-probe words than for all the other probes.

To control for the effect of probe words on the observed decision times in the recognition of facial expressions, these words were presented alone (without the faces) in a separate experiment conducted for other purposes with 24 new participants. The words representing each facial expression were included in a lexical-decision task (i.e., deciding whether letter strings were meaningful words or not). Each facial-expression word was presented once, 1 at a time, interspersed with 144 expression-unrelated words and 72 pseudowords. A 7 (word) one-way ANOVA was performed on lexical-decision times [$F(6,138) = 7.34$, $p < .0001$, $\eta^2_p = .24$], with significant differences only between the word *neutral* (715 msec) and all the other words (all $p$s $< .05$; *happy*, 630 msec; *surprised*, 633 msec; *disgusted*, 632 msec; *angry*, 618 msec; *sad*, 602 msec; *fearful*, 604 msec), which did not differ from one another.

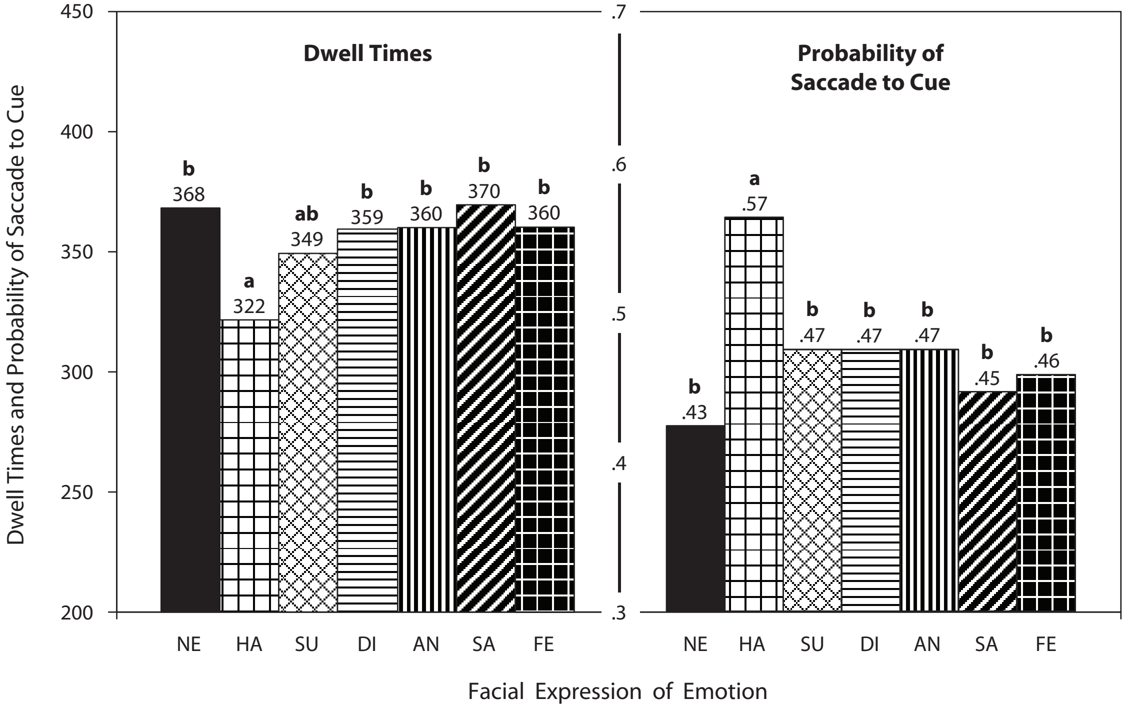

**Figure 6. Mean dwell times on the face (in msec) and probability of saccade to the cue in the presence of the face, as a function of facial expression, in Experiment 3. Mean scores with a different superscript are significantly different; means sharing a superscript are equivalent. NE, neutral; HA, happy; SU, surprised; DI, disgusted; AN, angry; SA, sad; FE, fearful.**

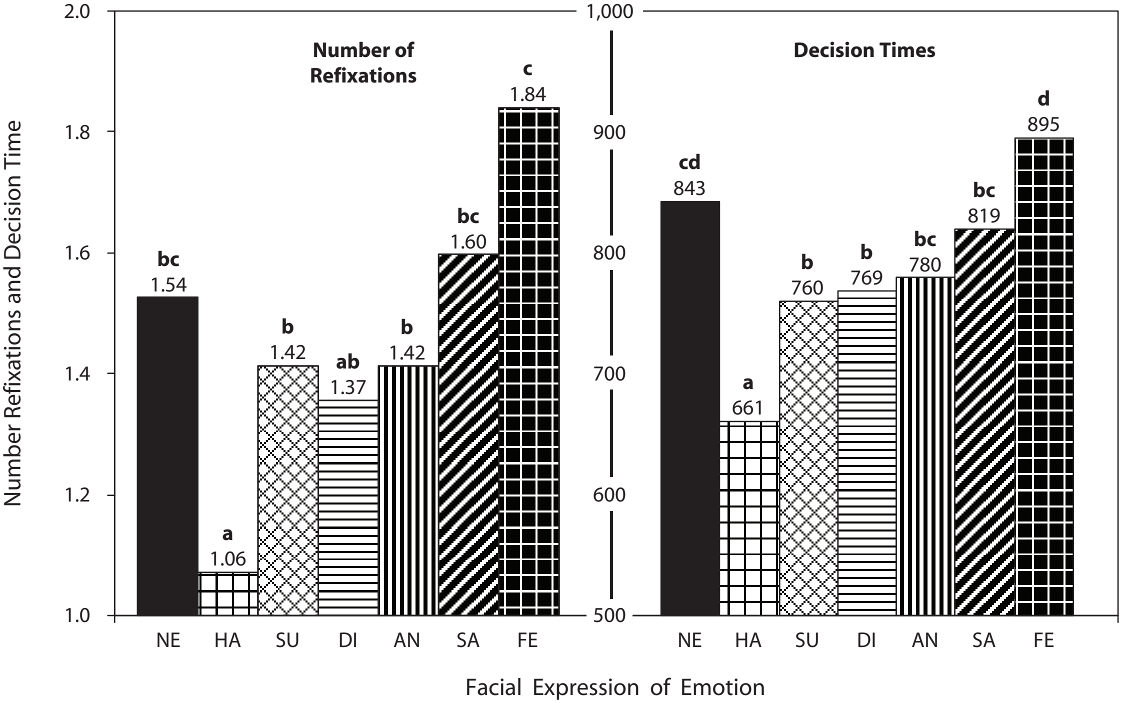

**Figure 7. Mean number of refixations on the face and mean decision times (in msec), as a function of facial expression, in Experiment 3. Mean scores with a different superscript are significantly different; means sharing a superscript are equivalent. NE, neutral; HA, happy; SU, surprised; DI, disgusted; AN, anger; SA, sad; FE, fearful.**

This implies that the advantage of happy faces in decision efficiency (in Experiment 3) was not due to differences in the processing of the probe words themselves.

## Discussion

RTs were faster for probe words that followed and matched a happy facial expression than for words representing other emotional expressions, and this occurred in the absence of differences in RTs to the words alone. This recognition advantage for happy faces is consistent with prior research (Calvo & Lundqvist, 2008; Juth et al., 2005; Leppänen & Hietanen, 2004; Palermo & Coltheart, 2004). Nevertheless, prior research was limited by the use of a single manual or vocal RT measure. The present experiment makes a contribution by decomposing this global response latency measure and the recognition period into cognitive stages. By doing so, our results reveal the time course in the recognition advantage of happy faces. Both encoding and decision making, but not attentional orienting, were more efficient for happy faces than for faces conveying any other expression.

Clear effects of expression appeared during the encoding stage. The duration of the first fixation was shorter for happy expressions than for all the others. Similarly, following the onset of a visual cue indicating the location of an upcoming probe word, dwell times on the happy faces were the shortest. Given that first-fixation duration and dwell times reflect the amount of visual and cognitive resources required for object identification (Rayner, 2009; Underwood & Foulsham, 2006), this finding indicates that happy expressions, to be encoded, need fewer processing resources. Consistent with this, the higher probability of initiating a saccade toward the visual cue while happy faces were displayed suggests that more spare resources—not engaged in processing the face—were available for attending to the cue. The faster disengagement of attention from happy faces upon appearance of the cue further suggests that viewers had categorized the happy expressions faster than they had the other expressions. It is worth noting that only the happy faces had shorter dwell times than the neutral faces; this reveals *faster* attentional disengagement from happy faces rather than *slower* disengagement from the other emotional faces, if neutral face is considered the baseline.

During the decision-making stage, there were fewer refixations on happy faces in the presence of the probe word, and also shorter response latencies from the onset of the probe, than for all the other expressions. Refixations on the face, and the additional time taken for decision after the probe word appeared, indicated that viewers needed to reprocess the face in order to confirm the category of the expression before responding. Accordingly, fewer refixations and shorter responses would reveal decision efficiency in quickly matching the representation of an expression with the corresponding word. The fact that happy faces required fewer refixations suggests that they could be categorized unambiguously, without further processing. Presumably, viewers did not need to look back to the happy face, because they were confident in their correct response by the time the probe appeared (hence the decision-making advantage), which shortened RTs.

The advantage of happy faces in encoding and decision-making stages occurred in the absence of orienting speed differences among expressions. Saccade latency is assumed to index the potency of a visual object in attracting visual attention (see Itti & Koch, 2001; Underwood & Foulsham, 2006). The lack of effects of expression on saccade latency in Experiment 3 is relevant in two respects. First, it rules out the possibility that the encoding and decision-making advantage of happy faces could be contaminated by attentional orienting. Happy faces might have been more potent as attention-capturing visual stimuli, and this might have saved processing time when fixated. Against this hypothesis, the lack of differences in orienting latency reveals that facilitation in encoding and decision making was due to expression recognition rather than to visual confounds influencing attentional deployment. Second, the lack of orienting effects when expressions were not precued semantically in Experiment 3 (i.e., participants were not instructed to look for a specific expression) are also relevant to interpret the effects on saccade latencies in Experiments 1 and 2, where saccade targets were prespecified by a word representing the target facial expression. Faster saccade latencies for happy faces occurred *only* when saccades were semantically guided (Experiments 1 and 2). This is contrary to the hypothesis that the faster saccades could be merely visually driven in a reflexive manner as a function of physical properties, without any identification of the meaning of the expression (see below).

## GENERAL DISCUSSION

Previous research has consistently found a recognition advantage for happy expressions over other facial expressions, manifested both in recognition accuracy and latency (Calvo & Lundqvist, 2008; Juth et al., 2005; Kirita & Endo, 1995; Leppänen & Hietanen, 2004; Leppänen et al., 2003; Palermo & Coltheart, 2004). In the present study, we investigated the time course of this advantage, that is, when it starts and how it unfolds across different perceptual and cognitive stages. Essentially (1) forced-choice saccade latencies in a discrimination task were aimed to determine the earliest as well as the typical latency of expression recognition; (2) first-fixation and dwell times served to assess encoding; and (3) refixations on the face and RTs from the onset of a probe word were assumed to reveal decision efficiency.

### The Time Course: Early and Late Processing Advantage

Prior research using behavioral measures has relied on manual or vocal RTs as a global index of efficiency in facial expression recognition (Calvo & Lundqvist, 2008; Juth et al., 2005; Kirita & Endo, 1995; Leppänen & Hietanen, 2004; Leppänen et al., 2003; Palermo & Coltheart, 2004). In the current study, we decomposed the recognition process into stages from the onset of the face stimulus until the response. Our results revealed that the recognition of happy faces begins and is accomplished earlier than that of other expressions.[3]

First, in a forced-choice discrimination task (Experiments 1 and 2), saccade latencies toward verbally prespecified expressions were faster for happy expressions than for all the other expressions. On average, discrimination of happy faces occurred at 284 msec, with the earliest correct responses estimated to be emerging 160-msec post stimulus or less. Second, in a recognition task (Experiment 3), the duration of the initial fixation on the face was shorter for happy expressions than for other expressions. The happy-face advantage remained after the first fixation, as reflected by shorter dwell times on the happy faces upon appearance of a preprobe cue. This can be interpreted as efficient encoding of happy expressions, which would require fewer cognitive resources than would other expressions. Still later, the advantage continued to build up during a decision-making stage, as revealed by fewer refixations on the happy faces and faster RTs from the onset of the probe, relative to other expressions. Accordingly, recognition of happy expressions is speeded up across all the processing stages.

### Detection of Undifferentiated Emotional Content or Recognition of Specific Emotional Expressions?

Since many electrophysiological studies have assessed the time course of facial expression processing, it is interesting to compare their findings with those obtained in the present experiments. Relative to neutral expressions, emotional faces have been found to result in increased N170 amplitude (see reviews in Eimer & Holmes, 2007; Palermo & Rhodes, 2007). Our latency estimates fall within a similar range, as correct saccades started between 180 and 220 msec (minus 20 msec for saccade programming, i.e., 160–200 msec).

The present study makes two additional contributions. First, we show time course differences in recognition among the six basic emotional expressions. No such differences have generally appeared in neurophysiological research at early stages (N170; Eimer et al., 2003; Leppänen, Kauppinen, et al., 2007; Schupp et al., 2004), with one exception (Batty & Taylor, 2003). In our study, there was a reliable early (i.e., 180-msec time bin) recognition advantage for happy and also surprised expressions. This converges with the Batty and Taylor results showing reduced N170 latency for these two expressions. Second, our data suggest that category-level emotional information is accessible early, and may be also reflected in the early face-sensitive evoked potentials. ERP studies typically compare evoked responses to emotional and neutral faces. When ERP potential is earlier or larger in amplitude for an emotional than for a neutral face, it is inferred that the emotional and the neutral faces have been processed differentially. Such designs are indeed useful to determine when differential processing of expressive versus neutral faces begins, but they do not reveal whether affective content has been extracted, or categorization of the emotional expressions has occurred. In contrast, the forced-choice saccades in the present paradigm require conscious recognition of the expression. Accordingly, our results add to the neurophysiological findings by demonstrating that category-level discrimination of expressions may begin within the N170 latency range.

### Faster Identification of Expressions or Visually Driven Attentional Bias?

We have concluded that the accurate, voluntarily directed saccades toward verbally precued faces allow us to infer that the meaning of facial expressions is encoded. Since the cuing word represented the meaning of the face, saccades were assumed to be guided semantically, but it could also be argued that the faster saccades to the happy faces were due to an attentional bias (i.e., visually driven orienting of attention) rather than to genuine recognition of the emotional expression. Such a bias could be caused by higher visual saliency (i.e., physical properties, rather than significance) of the happy faces (see Calvo & Nummenmaa, 2008). This alternative account is, nevertheless, unlikely to be correct, for the following reasons: First, relative to the other emotional faces, the happy faces were not more different from the neutral faces in low-level image characteristics that could have attracted attention (see Experiment 1). Second, saccade latencies and velocities were not shorter or faster for happy than for other faces when they were presented individually, and saccades were not guided or cued semantically (Experiment 3). And, third, in a recent unpublished study (Calvo, Nummenmaa, & Avero, 2009), viewers were free to move their eyes while two parafoveal faces (an emotional target face and a scrambled version of it) were presented, followed by a recognition probe. No differences between emotional expressions appeared in the probability or the latency of the first saccade to the target face. Accordingly, when the saccade target is not specified in advance, saccades are not faster or more likely to occur for happy faces than for others. Facial expression affects saccades only when attention shifts are semantically guided. This supports the hypothesis that the faster saccade latencies for happy faces in Experiments 1 and 2 revealed faster expression identification.

### Why Are Happy Faces Recognized Faster?

We have shown that happy facial expressions are identified earlier than are other expressions, and that their recognition is facilitated at several perceptual and cognitive stages. In this study we were concerned with the *when* issue—that is, the time course in emotional expression recognition. The next logical step involves addressing the *how* and *why* issues—that is, the mechanisms involved in this recognition advantage. Although these issues are beyond the scope of the present study, we will advance some hypotheses on the basis of the present and related research.

At a general level, more efficient recognition of happy expressions may be due to such expressions being more familiar—more frequently encountered in everyday social environments—than other emotional expressions (see Bond & Siddle, 1996). At a more specific level, the following mechanism can be proposed. First, the findings from the forced-choice saccade task in which lateralized face stimuli were presented for only 30 msec extrafoveally support the hypothesis of identification in the absence of overt visual attention, since there was no time for fixations on the faces. Second, the facilitated access of happy faces in extrafoveal vision could be due to the high visual saliency of the mouth region of these faces, which can be easily detected even at eccentric locations of the visual field (Calvo & Nummenmaa, 2008). Third, once accessed, the shape of the smiling mouth would be used as a diagnostic cue and a shortcut to identification of the expression (Leppänen & Hietanen, 2007), since such a mouth shape is uniquely and systematically associated with these faces (Calvo & Marrero, 2009). Finally, due to the reduced attentional demands in the processing of a single distinctive feature such as the mouth, encoding and decision making would be speeded up, since analysis of the whole facial configuration would not be required.

In conclusion, the recognition advantage of happy faces starts very early, even before the faces are fixated, thus showing that identification of emotional expression can be performed to a significant extent outside the focus of overt attention. The advantage of happy faces also extends over processes such as encoding and decision-making that occur during overt attention, when the faces are fixated. The efficient processing of happy faces is probably due to their salient facial features that can be accessed extrafoveally, and to unique features that make these expressions easily distinguishable. Eye-movement assessment converges with and complements neurophysiological measurement in showing that there is actual discrimination and conscious recognition of specific emotional expressions at early processing stages, temporally close to the N170 ERP effects.

## AUTHOR NOTE

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## NOTES

1. In contrast with the systematic happy-face advantage in categorization tasks involving recognition of singly presented emotional faces, there are some discrepancies in visual search tasks involving detection of a discrepant face in an array of otherwise identical faces, with findings showing an advantage of either happy (e.g., Juth et al., 2005) or angry (e.g., Horstmann & Bauland, 2006) expressions conveyed by real faces (see Calvo & Nummenmaa, 2008, and Frischen et al., 2008, to account for discrepancies).

2. It should, nevertheless, be noted that the faces were presented parafoveally in the present study. This was the only way to present two simultaneous visual stimuli in the 2AFC task. In contrast, in most of the ERP studies, the faces were presented foveally.

3. Although there was no absolute advantage of happy faces over all the other expressions on all the measures, we have given prominence to the happy-face advantage for the following reasons. First, in our study, we wanted to consider and account for the finding of a solid recognition advantage of happy faces in previous behavioral research. Second, happy faces were the only emotional expressions that always differed from neutral expressions, when these were used for comparisons (i.e., in Experiment 3). Third, happy faces were at advantage over all the other emotional expressions on most critical measures, including median saccade latency, probability of saccades to the cue, and decision times. Fourth, although for a few dependent variables the happy faces did not differ significantly from one expression (either surprise or disgust), there was always a clear tendency in favor of the happy expressions. And, finally, when we combined the data from Experiments 1 and 2, a significant happy-face advantage appeared even in comparison with the surprised faces, with greater response accuracy and a shorter minimum saccade RT (160 msec for happy faces vs. 180 msec for surprised faces).

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