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Recognition Thresholds for Static and Dynamic Emotional Faces

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We investigated the minimum expressive intensity that is required to recognize (above chance) static and dynamic facial expressions of happiness, sadness, anger, disgust, fear, and surprise. To this end, we varied the degree of intensity of emotional expressions unfolding from a neutral face, by means of graphics morphing software. The resulting face stimuli (photographs and short videos) were presented in an expression categorization task for 1 s each, and measures of sensitivity or discrimination (A') were collected to establish thresholds. A number of physical, perceptual, categorical, and affective controls were performed. All six basic emotions were reliably recognized above chance level from low intensities, although recognition thresholds varied for different expressions: 20% of intensity, for happiness; 40%, for sadness, surprise, anger, and disgust; and 50%, for fear. The advantage of happy faces may be due to their greater physical change in facial features (as shown by automated facial expression measurement), also at low levels of intensity, relative to neutral faces. Recognition thresholds and the pattern of confusions across expressions were, nevertheless, equivalent for dynamic and static expressions, although dynamic expressions were recognized more accurately and faster.

Keywords: facial expression, dynamic, emotion, recognition thresholds, intensity

Facial expressions involve changes of physical features in the face as a function of unfolding muscle activation, which are assumed to reflect a person's internal feelings and emotions, motives and needs, intentions and action tendencies (e.g., Ekman & Cordaro, 2011; Panksepp & Watt, 2011). For an effective and satisfactory social interaction, expressers must be able to communicate (or inhibit) their emotions carefully, and observers must be able to recognize them accurately. Importantly, in everyday life, expressive changes in a face can be occasionally intense, but social norms often constrain the magnitude of emotional exhibition and, therefore, the explicit changes are relatively subtle. As a consequence, it is important that the observer can detect and interpret also the low-intensity signals. In the current study, we investigated the recognition thresholds for six basic emotions, understood as the lowest stimulus intensity at which an expression can be recognized above chance and distinguished from others. This issue was examined by comparing static expressions, as shown in photographs, and dynamic expressions, as shown in 1-s duration videos.

Most prior research on facial expression recognition has adopted a categorical view, with six basic emotions (happiness, sadness, anger, fear, disgust, and surprise; Ekman, 1992), each characterized by relatively distinct morphological features (Ekman, Friesen, & Hager, 2002). There is evidence that such emotions can be discriminated from each other in recognition tasks. Nelson and Russell (2013) reviewed 17 cross-cultural judgment studies. On average, agreement scores were higher for happy faces (89%) than for all the others, followed by surprise (83%), which were higher than for sadness and anger (71% and 68%, respectively), followed by disgust and fear (65% and 59%), with all recognition scores being above chance level. In addition, in a number of laboratory experiments, recognition efficiency measures—typically, response latencies—were obtained for all six basic expressions (Calder, Young, Keane, & Dean, 2000; Calvo & Lundqvist, 2008; Calvo & Nummenmaa, 2009; Elfenbein & Ambady, 2003; Palermo & Coltheart, 2004). In line with the recognition accuracy data, latencies were consistently shorter for happy versus all the other faces, generally followed by surprised faces, with the longest latencies for fearful faces. This pattern of recognition efficiency holds across different response modalities: manual (Calder et al., 2000; Calvo & Lundqvist, 2008; Elfenbein & Ambady, 2003), verbal (Palermo & Coltheart, 2004), and saccadic (Calvo & Nummenmaa, 2009). Different face databases were used, such as the Pictures of Facial Affect (Ekman & Friesen, 1976), the Karolinska Directed Emotional Faces (KDEF; Lundqvist, Flykt, & Öhman, 1998), or the NimStim Stimulus Set (Tottenham, Borscheid, Ellertsen, Marcus, & Nelson, 2002), which strengthens the reliability of the findings.

Contributions to prior research can be made in several ways, including (a) the comparison of recognition thresholds across

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emotions as a function of expressive intensity, and (b) the comparison between static and dynamic presentation modes. First, most prior studies have used high-intensity prototypical expressions as stimuli. In contrast, facial behavior in daily life involves a great deal of individual idiosyncrasy and variability in both expressive shape and intensity. In fact, ambiguous or blended expressions are encountered very often (Calvo, Gutiérrez-García, Fernández-Martín, & Nummenmaa, 2014; Carroll & Russell, 1997; Krumhuber & Scherer, 2011; Scherer & Ellgring, 2007). As shown by Krumhuber and Scherer (2011), each emotion can be portrayed by multiple facial actions. Accordingly, although prototypical expressions can be categorized consistently and accurately in laboratory tasks, the fuzzier boundaries and greater variability of expressions in daily life probably require a more flexible inferential processing, beyond clear-cut categories. In the same vein, in everyday life, facial expressions very frequently occur with relatively low intensity or even as "microexpressions" (Matsumoto & Hwang, 2014; Yan, Wu, Liang, Chen, & Fu, 2013). It is therefore important to investigate recognition thresholds.

Second, most prior studies have used static images of facial expressions, as captured in snapshots. Yet, facial behavior in daily life is dynamic, and therefore an understanding of the mechanisms underlying expression recognition requires using dynamic stimuli. Prior research has shown that dynamic information improves coherence in the identification of facial affect, particularly for degraded and subtle stimuli, and helps to differentiate between genuine and fake expressions (for a review, see Krumhuber, Kappas, & Manstead, 2013). Dynamic expressions are also discriminated from each other with less confusion across categories than static expressions are (but see Fiorentini & Viviani, 2011, and Jiang et al., 2014, for limits of the dynamic advantage hypothesis). Importantly, however, the recognition pattern is similar for static and dynamic displays, with happy faces identified most accurately, and fearful faces, least accurately (Recio, Schacht, & Sommer, 2013, 2014). Some studies have compared subtle- versus full-intensity dynamic expressions (Ambadar, Schooler, & Cohn, 2005; Bould & Morris, 2008; Bould, Morris, & Wink, 2008; Cunningham & Wallraven, 2009; Fiorentini & Viviani, 2011; Recio et al., 2014). The current study extends this approach by systematically manipulating expressive intensity. This allowed us to combine both major issues, that is, recognition thresholds and static versus dynamic format, and examine whether expressive movement benefits recognition especially at low intensities—and thus lowers the perceptual thresholds—relative to static presentation.

To address these issues, we used a morphing technique, which provides us with fine-grained control over expressive intensity and dynamic unfolding speed. Morphs of six basic emotions of 24 individuals (posers) were generated, with intensities increasing from 20% to 100%. For each individual we created a sequence of frames starting with a neutral face and ending with an emotional face. Each expression was presented at seven intensities in static (single frame) and dynamic (multiple frames) fashion. In a categorization task, static photographs or dynamic video clips were presented for 1 s each. Participants selected one out of six response options (the six expressions) for each stimulus. We computed A' sensitivity for each intensity level, according to signal-detection theory (Macmillan & Creelman, 2005), to determine discrimination thresholds for each emotional expression. To the extent that a given expression has lower recognition thresholds than others, the A' scores will exceed chance level at lower intensities; that is, the expression will need less physical evidence in facial changes to be identified.

In a related study, Hoffmann, Kessler, Eppel, Rukavina, and Traue (2010) presented morphed facial expressions (from 40% to 100% intensities) of six emotions for 300 ms in static photographs. With a large sample of female and male participants, the authors found that women observers were more accurate than men in recognizing subtle facial displays of emotion, whereas there was no sex difference when recognizing highly expressive faces. The current study aimed to extend the Hoffmann, Kessler, et al. (2010) approach. First, in addition to recognition hits and false alarms, we assessed type of confusions, and also A' sensitivity measures, as a critical discrimination index. Second, we compared static and dynamic expressions reaching exactly the same intensities, and increased the range of expressive intensities in the lower range (20% and 30%). Finally, we presented the dynamic stimuli for 1 s, to approximate the average speed of expression unfolding in the full-blown, 100% intensity condition (Hoffmann, Traue, Bachmayr, & Kessler, 2010; Pollick, Hill, Calder, & Paterson, 2003).

Experiments 1A (Static Expressions) and 1B (Dynamic Expressions)

Initially, given the high number of within-subject experimental conditions involving expression (six) and intensity (seven; see below), the current study was split into a between-subjects static (Experiment 1A) versus dynamic (Experiment 1B) display condition. Nevertheless, given that the participant samples were formed randomly from the same pool of undergraduate students, we combined them for analyses, which allowed us to examine interactions between the three experimental factors. For the sake of economy of exposition, both experiments will be presented together.

Method

Participants. Ninety-six university undergraduates (ages 18 to 30 years) participated voluntarily (48 in Experiment 1A and 48 in Experiment 1B; 24 females and 24 males in each experiment). There is a significant—albeit relatively low—effect size (Cohen's $d = .19$) of sex of viewer in expression recognition (see a meta-analysis by Thompson & Voyer, 2014). Accordingly, we included the same proportion of females and males to control for potential sex differences (this sample size was, nevertheless, underpowered to determine the role of sex as an experimental factor).

Stimuli. The photographs of six expressions (happiness, sadness, anger, fear, disgust, and surprise) of 24 posers from the KDEF database (Lundqvist et al., 1998) were used. Potential differences as a function of sex-of-face were controlled by including the same number of female (12 models) and male (12 models) faces for each expression. These face stimuli were subjected to morphing by means of FantaMorph software (version 5.4.2 Deluxe, Abrosoft, Beijing, China, http://www.fantamorph.com/). For each expression of each poser, we created a sequence of 100 frames progressively increasing the intensity of the emotional expression, based on two images: a neutral face as the first frame, and an emotional face (happy, sad, etc.) that served as the final frame (see Figure 1).

For the static version, we selected seven frames for each sequence: Frames 20, 30, 40, 50, 60, 75, and 100, which represented,

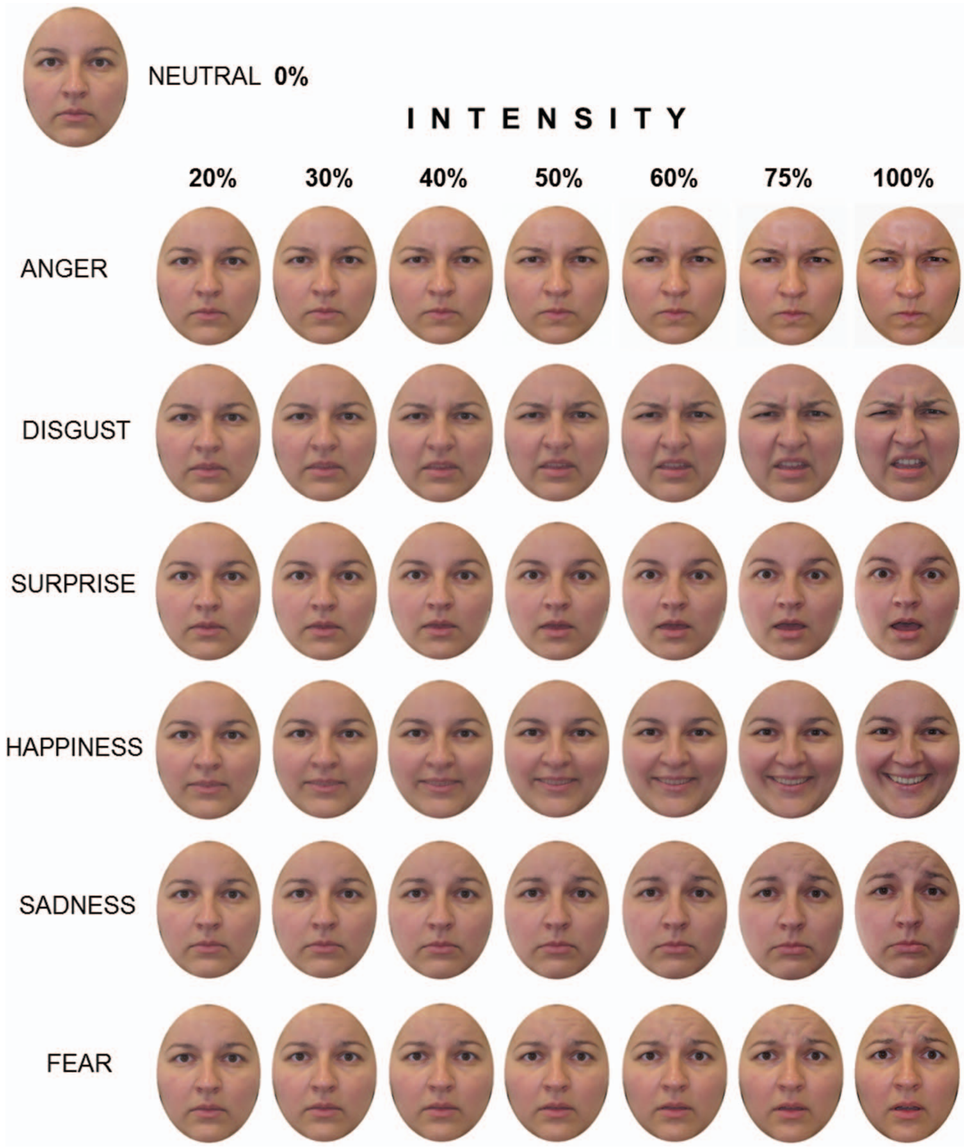

Figure 1. Types of expressions and degrees of intensity. For copyright reasons, different face stimuli are shown, instead of the original Karolinska Directed Emotional Faces pictures. Reprinted with permission. See the online article for the color version of this figure.

respectively, the 20%, 30%, 40%, 50%, 60%, 75%, and 100% of intensities in the development of the emotional expression (see examples in Figure 1). The 10% intensity level was discarded because of the hardly noticeable change from the neutral face. For the dynamic version, 1-s duration video clips were presented at 30 frames per second, with the first frame being always a neutral expression, which developed toward an emotional expression, reaching the maximal target intensity 900 ms after stimulus onset. The last frame was frozen for 100 ms and showed the same images used in the static stimuli, at each of the seven target intensity levels. This way, all the expressions unfolded dynamically for 1 s, although at different rate of expressive change (see Figure 2).[1] In total, 1,008 photographs and 1,008 video clips were used as experimental stimuli (24 posers × 6 expressions × 7 intensities).

Procedure. To avoid presenting a participant with multiple photographs of the same poser and expression at different intensities, they were combined into six different counterbalancings. Within each display format (i.e., Experiments 1A and B), each

[1] While creating the morphs showing different intensity levels of dynamic expressions within 1-s displays for all intensity conditions, we considered two options. One involved varying speed, while keeping the exposure time (100 ms; final frames) constant for the respective (maximum) target intensities. The other involved varying exposure time of the final frames depicting the target intensity, while keeping speed constant for all the intensity conditions. We chose the former alternative on the basis of Recio et al.'s (2013) findings indicating that variable unfolding speed did not affect the recognition of most emotional expressions (except for sadness) or the pattern of differences in recognition across expressions.

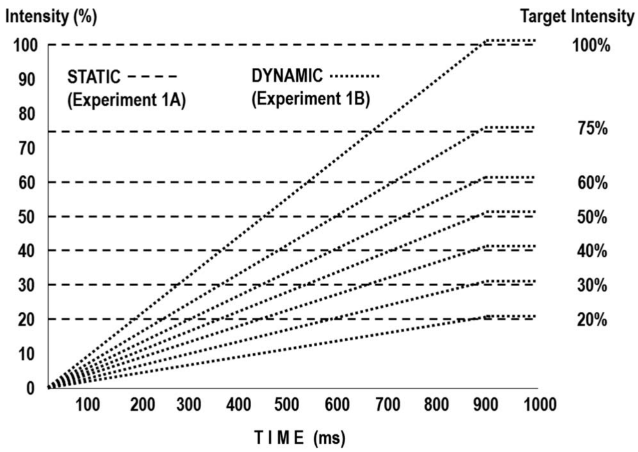

Figure 2. Static versus dynamic display features of the stimuli. The dynamic presentation started with a neutral face (33-ms duration; Frame 1), followed by emotional expression unfolding, with progressive intensity increases. At 900 ms after onset, the maximum target intensity was reached, and the emotional expression was frozen for 100 ms, until stimulus offset. In the static mode, the expression was shown at maximum target intensity from the onset to the end of the display.

participant was presented with two images of each poser and expression (i.e., $2 \times 24 \times 6 = 288$ experimental trials): one image of one intensity level from 20% to 75% and the 100% full-blown intensity display. The face stimuli were shown on a computer screen, in four blocks, with E-Prime 2.0 software. Block order was counterbalanced and trial order was randomized for each participant. Participants were told that photographs or videos of faces would be presented for 1 s each, with different expressions and varying intensities, and were asked to indicate which expression was displayed on each trial, by pressing one key out of six. The six basic expressions were explicitly identified in advance, as well as the location of the keys to be pressed for selecting each expressive category.

The sequence of events on each trial can be seen in Figure 3 (static condition) and Figure 4 (dynamic condition). After an initial 500-ms central fixation cross on a screen, a face photograph appeared for 1 s or a video clip unfolded for 900 ms plus a 100-ms still final frame. The face subtended a visual angle of 10.4° (Height) × 8° (Width) at a 60-cm viewing distance. Following the face offset, there was a 300-ms blank interval, before graphical instructions appeared on the screen for responding. In the response screen, six small boxes were shown horizontally, numbered from 4 to 9, with each box/number associated to a verbal label of an expression (e.g., 4: happy; 5: sad). The assignment of expressions to numbers was counterbalanced across participants (but kept unchanged across trials). We used the 300-ms blank interval between the face offset and the response screen onset to produce a smooth transition and avoid backward masking (due to the graphical content of the response screen). For categorizing each expression, participants pressed one key (from 4 to 9) in the upper row of keys of a standard computer keyboard. The selected response and response times (RTs; from the offset of the 300-ms interval) were collected.

Design and measures. We used a mixed experimental design, with an orthogonal combination of a between-subjects factor (presentation mode: static vs. dynamic) and two within-subjects factors (expressive category: happiness, sadness, anger, fear, disgust, and surprise; and intensity: 20%, 30%, 40%, 50%, 60%, 75%, and 100%). As dependent variables, we first used the probability of hits, that is, the responses that coincided with the displayed expression (e.g., responding "happy" when the face stimulus was intended to convey happiness); and the false alarm rates (e.g., responding "happy" when the face stimulus conveyed sadness, fear, etc.). Second, we assessed sensitivity or discrimination by computing the nonparametric A' index, according to signal-detection theory (Macmillan & Creelman, 2005), with the following formula: $A' = \{0.5 + [(PH - PFA) \times (1 + PH - PFA)]/[(4 \times PH) \times (1 - PFA)]\}$, where P = probability, H = hits, and FA = false alarms. When PH < PFA, the formula was as follows (see Snodgrass & Corwin, 1988): $A' = \{0.5 - [(PFA - PH) \times (1 + PFA - PH)]/[(4 \times PFA) \times (1 - PH)]\}$. A' scores vary from low to high sensitivity in a 0–1 scale, where .5 represents the chance level. Sensitivity measures are particularly useful to determine recognition thresholds: Threshold was operationalized as the lowest level of expressive intensity at which the A' score exceeds the chance level. Third, we assessed the type of confusions, that is, the probability that each target expression (i.e., the actually displayed expression) was judged as each of the other five, nontarget ex-

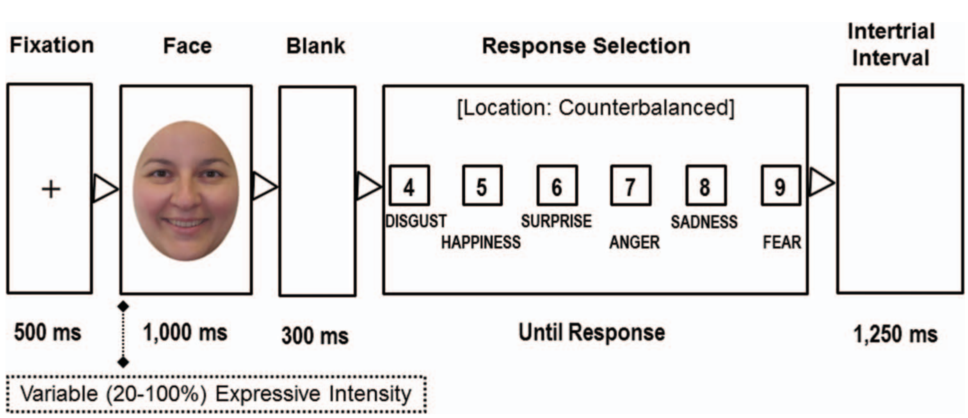

Figure 3. Sequence of events on an experimental trial in the static presentation mode. Reprinted with permission. See the online article for the color version of this figure.

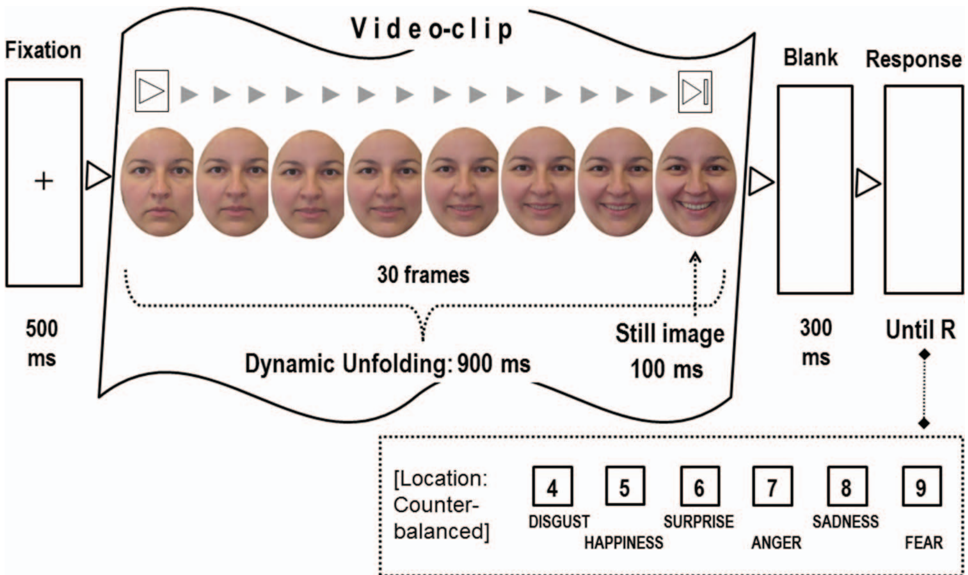

Figure 4. Sequence of events on an experimental trial in the dynamic presentation mode. Reprinted with permission. See the online article for the color version of this figure.

pressions. For example, if the target expression was anger at a given experimental trial, the five nontargets in the analysis of variance (ANOVA) were happiness, sadness, disgust, fear, and surprise.

Results

Initially, the probability of hits and, false alarms, A' sensitivity scores and RTs were analyzed by means of an omnibus 2 (Presentation mode) × 6 (Expression) × 7 (Intensity) ANOVAs. Also, for the analysis of type of confusions, an omnibus 2 (Presentation mode) × 5 (Nontarget Expression) × 7 (Intensity) ANOVA was conducted for each target expression. Subsequently, to decompose the interactions, Expression × Intensity ANOVAs were conducted separately for the static and the dynamic condition. The main effects of expression or intensity were always subjected to post hoc multiple comparisons with Bonferroni ($p < .05$) corrections.

Differences between static and dynamic expressions: Main effects and interactions of presentation mode. To determine differences as a function of presentation mode, we first report the main effects of this factor and its interactions with the other factors. Main effects of presentation mode reflected a benefit for dynamic expressions on hit rate, $F(1, 94) = 4.30$, $p = .041$, $\eta_p^2 = .04$ (static = .68; dynamic = .71), false alarms, $F(1, 94) = 4.09$, $p = .043$, $\eta_p^2 = .04$ (static = .30; dynamic = .28), sensitivity, $F(1, 94) = 4.29$, $p = .041$, $\eta_p^2 = .04$ (static = .70; dynamic = .73), and RTs, $F(1, 94) = 23.19$, $p < .0001$, $\eta_p^2 = .20$ (static = 1,102 ms; dynamic = 929).

A Presentation mode × Intensity interaction consistently appeared for hit rate, $F(6, 564) = 7.16$, $p < .0001$, $\eta_p^2 = .07$, false alarms, $F(6, 564) = 6.66$, $p < .0001$, $\eta_p^2 = .07$, sensitivity, $F(6, 564) = 8.20$, $p < .000$, $\eta_p^2 = .08$, and RTs, $F(6, 564) = 6.61$, $p < .001$, $\eta_p^2 = .07$. An advantage for the dynamic condition emerged at 20% and 30% intensities, respectively: (a) hits, $F(1, 94) = 11.91$, $p < .001$, $\eta_p^2 = .11$ (static = .42; dynamic = .49), and $F(1, 94) = 19.57$, $p < .0001$, $\eta_p^2 = .17$ (static = .49; dynamic = .59); (b) false alarms, $F(1, 94) = 22.95$, $p < .0001$, $\eta_p^2 = .20$ (static = .51; dynamic = .42), and $F(1, 94) = 4.58$, $p = .035$, $\eta_p^2 = .05$ (static = .43; dynamic = .39); and (c) sensitivity, $F(1, 94) = 20.54$, $p < .0001$, $\eta_p^2 = .18$ (static = .35; dynamic = .47), and $F(1, 94) = 11.67$, $p < .001$, $\eta_p^2 = .11$ (static = .47; dynamic = .58). Reaction times were always shorter in the dynamic condition, although the difference was greater at some intensity levels, ranging from $F(1, 94) = 49.06$, $p < .0001$, $\eta_p^2 = .34$ (20%), to $F(1, 94) = 8.12$, $p = .006$, $\eta_p^2 = .06$ (100%).

Regarding type of confusions, there was no significant main effect of presentation mode, but only an interaction between expression and presentation mode, which was significant only for sad faces, $F(4, 376) = 10.05$, $p < .0001$, $\eta_p^2 = .10$. Sad faces were classified as fearful to a greater extent in the dynamic mode, $F(1, 94) = 13.82$, $p < .0001$, $\eta_p^2 = .13$, and as angry in the static mode, $F(1, 94) = 6.64$, $p = .012$, $\eta_p^2 = .07$.

Similarities between static and dynamic expressions: Main effects and interactions of expression and intensity. Beyond the previous effects involving differences as a function of presentation mode, strong main effects of expression, intensity, and their interaction appeared, regardless of presentation mode (i.e., with no three-way interactions), which revealed similarities across static and dynamic displays, for patterns of hits, false alarms, sensitivity, RTs, and type of confusions.

Significant main effects of expression and intensity emerged for hits, $F(5, 470) = 214.07$, $p < .0001$, $\eta_p^2 = .70$ (expression), $F(6, 564) = 276.51$, $p < .0001$, $\eta_p^2 = .75$ (intensity), false alarms, $F(5, 470) = 27.38$, $p < .0001$, $\eta_p^2 = .23$ (expression), $F(6, 564) = 195.67$, $p < .0001$, $\eta_p^2 = .68$ (intensity), sensitivity, $F(5, 470) = 121.44$, $p < .0001$, $\eta_p^2 = .56$ (expression), $F(6, 564) = 281.13$, $p < .0001$, $\eta_p^2 = .75$ (intensity), and RTs, $F(5, 470) = 49.03$, $p < .0001$, $\eta_p^2 = .34$ (expression), $F(6, 564) = 70.58$, $p < .0001$, $\eta_p^2 = .43$ (intensity). After Bonferroni corrections ($p < .05$) for multiple contrasts, as indicated in Table 1, happy faces had the highest hit rate and A'

Table 1
Mean Probability of Hits and False Alarms (FAs), A′ Sensitivity Scores, and Reaction Times (RTs, in Milliseconds), as a Function of Expressive Category, for Static and Dynamic Expressions

Expression	Hits or false alarms	Expressive category					
		Happiness	Sadness	Anger	Surprise	Disgust	Fear
Static	Hits	.875[a]	.744[b]	.732[b]	.747[b]	.603[c]	.406[d]
Dynamic	Hits	.957[a]	.715[b]	.760[b]	.804[b]	.606[c]	.397[d]
Static	FAs	.125[a]	.319[bc]	.346[bc]	.417[c]	.285[b]	.276[b]
Dynamic	FAs	.198[a]	.297[bc]	.280[b]	.382[c]	.236[ab]	.273[b]
Static	A'	.897[a]	.723[b]	.692[b]	.693[b]	.672[b]	.552[c]
Dynamic	A'	.917[a]	.737[b]	.768[b]	.754[b]	.712[b]	.507[c]
Static	RTs	937[a]	1,135[bc]	1,135[bc]	1,081[b]	1,136[bc]	1,188[c]
Dynamic	RTs	692[a]	941[bc]	972[c]	866[b]	981[c]	1,123[d]

Note. Horizontally (i.e., for each row), expressions (columns) having scores with different superscript letters are significantly different from each other in multiple contrasts ($p < .05$, Bonferroni corrected); expressions having scores with the same letter are equivalent.

scores, as well as faster responses, and fearful faces had the lowest hit rate and A' scores, as well as slower responses, relative to the other expressions. In addition, as indicated in Table 2, hit rates increased as a function of intensity for static displays ($\rho = 1$; $p < .0001$, bilateral; $n = 7$; coefficient of determination: $R^2 = .75$, $p = .012$; i.e., intensity accounts for 75% of variance in hit rate) and for dynamic displays ($\rho = 1$; $p < .0001$, bilateral; $n = 7$; $R^2 = .75$, $p = .011$), which was also the case for sensitivity (see Figures 5 and 6). In contrast, false alarms (static: $\rho = -1$, $p < .0001$; $R^2 = .84$, $p = .004$; dynamic: $\rho = -1$, $p < .0001$; $R^2 = .81$, $p = .006$), and response latencies (static: $\rho = -1$, $p < .0001$; $R^2 = .78$, $p = .009$; dynamic: $\rho = -1$, $p < .0001$; $R^2 = .82$, $p = .005$) decreased as a function of intensity.

These main effects were, nevertheless, qualified by Expression × Intensity interactions for hits, $F(30, 2820) = 4.98$, $p < .0001$, $\eta_p^2 = .05$, false alarms, $F(30, 2820) = 6.66$, $p < .0001$, $\eta_p^2 = .07$, and sensitivity, $F(30, 2820) = 4.80$, $p < .0001$, $\eta_p^2 = .05$. Given that the patterns of these interactions were the same for all three measures, they were decomposed only for sensitivity (the interaction is illustrated in Figures 5 and 6) by means of two approaches. First, one-way ANOVA (6: Expression) were conducted on A' sensitivity scores for each intensity level, followed by Bonferroni-corrected multiple comparisons ($p < .05$). At 20% intensity, $F(5, 475) = 22.56$, $p < .0001$, $\eta_p^2 = .19$, A' scores were higher for happy faces than for the rest; and all the other expressions were equivalent, except fear, which had lower scores than disgust. For all the other intensities, A' scores were always the highest for happy faces, the lowest for fearful faces, and equivalent for anger, disgust, sadness, and surprise (all the Fs ≥ 27.89, ps $< .0001$, $\eta_p^2 \geq .23$). Second, one-sample t tests compared the A' scores for each expression against the .5 chance level. At 20% and 30% intensities, scores exceeded this level only for happy faces, ts$(95) \geq 6.80$, $p < .0001$. At 40% intensity, also sad, angry, disgusted, and surprised faces were above chance (all ts > 6.55, ps $< .0001$), but not fearful faces, which needed a 50% intensity, $t(95) = 3.10$, $p = .003$. The Expression × Intensity interaction thus reveals the different recognition thresholds, with the lowest level for happy faces, followed by sad, angry, disgusted, and surprised faces, and, finally, fearful faces.

Regarding type of confusions, main effects of intensity, all Fs$(6, 564) \geq 30.41$, ps $\leq .0001$, $\eta_p^2 \geq .24$, and expression, all Fs$(4, 376) \geq 26.01$, ps $\leq .0001$, $\eta_p^2 \geq .22$, emerged for all the target expressions, except for happy faces, for which only the intensity

Table 2
Mean Probability of Hits and False Alarms (FAs), A′ Sensitivity Scores, and Reaction Times (RTs, in Milliseconds), as a Function of Expressive Intensity, for Static and Dynamic Expressions

Expression	Hit or false alarm	Intensity of expression						
		20%	30%	40%	50%	60%	75%	100%
Static	Hits	.416[e]	.493[d]	.682[c]	.769[b]	.786[b]	.807[ab]	.838[a]
Dynamic	Hits	.487[d]	.592[c]	.704[b]	.773[a]	.784[a]	.798[a]	.805[a]
Static	FAs	.512[f]	.433[e]	.328[d]	.248[c]	.213[bc]	.178[ab]	.150[a]
Dynamic	FAs	.416[c]	.388[c]	.315[b]	.233[a]	.211[a]	.200[a]	.181[a]
Static	A'	.349[f]	.474[e]	.698[d]	.808[c]	.836[bc]	.871[ab]	.899[a]
Dynamic	A'	.470[d]	.580[c]	.725[b]	.811[a]	.836[a]	.850[a]	.856[a]
Static	RTs	1,319[e]	1,242[d]	1,096[c]	1,053[bc]	1,035[abc]	992[ab]	978[a]
Dynamic	RTs	1,036[c]	1,012[c]	940[b]	895[ab]	893[ab]	877[a]	852[a]

Note. Horizontally (i.e., for each row), expressions (columns) having scores with different superscript letters are significantly different from each other in multiple contrasts ($p < .05$, Bonferroni corrected); expressions having scores with the same letter are equivalent.

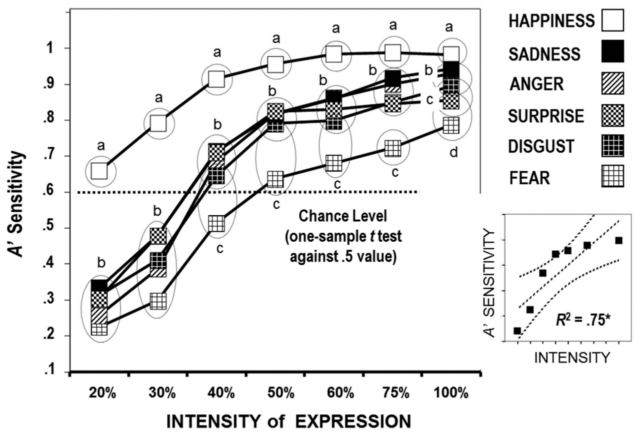

Figure 5. *Static:* A' sensitivity for each emotion and intensity in static expressions. For each level of intensity, expressions with different letters (within different dotted circles or ovals) are significantly different in post hoc multiple contrasts ($p < .05$, Bonferroni corrected); expressions sharing a letter (within the same circle/oval) are equivalent. Lower right-hand square: Graphical representation of the relationship between expressive intensity and A' scores, with the coefficient of regression (R^2; * $p < .05$) and prediction of the mean at 95% confidence interval. R^2: amount of variance in A' that is accounted for by variations in intensity.

effects were significant, $F(6, 564) = 37.43$, $p < .0001$, $\eta^2_p \geq .29$. The overall effects of intensity indicated that errors decreased as a function of target intensity. Table 3 shows the proportions of incorrect classifications of target expressions and the contrasts for the multiple comparisons across nontarget expressions. For happy target faces, there were no significant differences across nontarget expressions, $F = 2.01$, $p = .10$, *ns*, with a very low error rate ($M = 1.66\%$). Sad faces, $F(4, 380) = 37.63$, $p < .0001$,

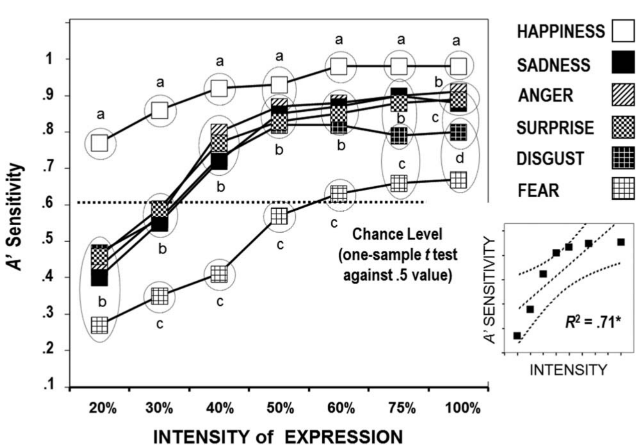

Figure 6. *Dynamic:* A' sensitivity for each emotion and intensity in dynamic expressions. For each level of intensity, expressions with different letters (within different dotted circles or ovals) are significantly different in post hoc multiple contrasts ($p < .05$, Bonferroni corrected); expressions sharing a letter (within the same circle/oval) are equivalent. Lower right-hand square: Graphical representation of the relationship between expressive intensity and A' scores, with the coefficient of regression (R^2; * $p < .05$) and prediction of the mean at 95% confidence interval. R^2: amount of variance in A' that is accounted for by variations in intensity.

Table 3
Mean Probability of Confusions of Static and Dynamic Expressions

	Categorized (response) as					
Target (stimulus)	Happiness	Sadness	Anger	Surprise	Disgust	Fear
Static presentation mode						
Happiness	**.875**	.029	.013	.028	.030	.025
Sadness	.014^{c}	**.744**	.099^{a}	.016^{c}	.056^{b}	.071^{ab}
Anger	.022^{c}	.083^{a}	**.732**	.031^{bc}	.083^{a}	.049^{ab}
Surprise	.058^{b}	.033^{bc}	.019^{c}	**.747**	.011^{c}	.132^{a}
Disgust	.010^{d}	.108^{b}	.220^{a}	.023^{cd}	**.603**	.036^{bc}
Fear	.033^{c}	.112^{b}	.037^{c}	.331^{a}	.080^{b}	**.406**
Dynamic presentation mode						
Happiness	**.957**	.011	.004	.008	.007	.013
Sadness	.024^{cd}	**.715**	.063^{b}	.014^{d}	.045^{bc}	.139^{a}
Anger	.021^{c}	.060^{b}	**.760**	.026^{c}	.096^{a}	.037^{bc}
Surprise	.054^{b}	.022^{c}	.011^{c}	**.804**	.007^{c}	.102^{a}
Disgust	.022^{d}	.110^{b}	.186^{a}	.020^{d}	**.606**	.056^{c}
Fear	.079^{b}	.112^{b}	.030^{c}	.287^{a}	.094^{b}	**.397**

Note. For each target expression (rows), superscript letters indicate differences (scores with different letters) or similarities (scores sharing a letter, or no letter) across non-target expressions, i.e., response confusions (columns), in multiple comparisons ($p < .05$, Bonferroni corrected), excluding correct responses (boldface numbers). Scores with a different superscript (for each row) are significantly different; scores with no superscript or sharing a letter are equivalent. Boldface numbers are correct categorization rates.

$\eta^2_p = .28$, were confused mainly with fear ($M = 10.5\%$) and anger ($M = 8.1\%$); surprised faces, $F(4, 380) = 66.00$, $p < .0001$, $\eta^2_p = .41$, with fear ($M = 11.7\%$); angry faces, $F(4, 380) = 25.86$, $p < .0001$, $\eta^2_p = .21$, with disgust ($M = 8.9\%$); disgusted faces, $F(4, 380) = 121.47$, $p < .0001$, $\eta^2_p = .56$, with anger ($M = 20.3\%$); and fearful faces, $F(4, 380) = 150.59$, $p < .0001$, $\eta^2_p = .61$, were confused mainly with surprise ($M = 30.9\%$).

Discussion

All the recognition measures (hits, false alarms, A' sensitivity, RTs, and type of confusions) were affected by expression and intensity. Happy faces were recognized more accurately and faster, and fearful faces were recognized less accurately and slower, relative to the rest. Hit rate and A' scores increased nearly linearly as a function of intensity, and false alarms and RTs decreased, with the pattern of confusions being similar across intensity levels. Nevertheless, expression and intensity interacted, with recognition thresholds varying for different expressions: Happy faces had the lowest threshold (i.e., starting recognition at 20% intensity), followed by sad, angry, disgusted, and surprised faces (40% intensity), and fear had the highest threshold (50% intensity). Importantly, first, the pattern of these effects, including the types of confusions, was generally equivalent in the dynamic and the static presentation modes. Second, recognition performance was better for dynamic than static expressions, for all the measures (more hits, fewer false alarms, higher A' scores, and shorter RTs), with this advantage being greater at the lowest intensity levels.

Experiment 2: Perceived Intensity and Additional Controls

Experiments 1A and 1B showed that, across both static and dynamic presentation modes, recognition thresholds are lower for happy expressions and higher for fearful expressions than for the others. To explain such differences, we conducted Experiment 2, as well as a number of additional controls, reanalysis of prior data, and computation of physical and facial feature differences across intensity levels for the various expressive categories.

Facial expressions of emotion involve physical and perceptual changes from neutral faces, in addition to inherent differences in categorical and affective properties. The amount of deviation from the neutral baseline might be greater for some expressions (particularly, happy faces) than for others (particularly, fearful), which might account for their respective thresholds. Thus, the end of the morphing continuum (i.e., the full-blown, 100% intensity) might involve greater intensity for some expressions than for others. If so, the reconfiguration change and scaling for each intensity level might not be equivalent across expressions. Accordingly, the recognition thresholds for those expressions with more facial reconfiguration relative to the neutral baseline would be lower because of greater intensity at low levels. This might have especially affected the dynamic condition, where there is an explicit online change and contrast between a neutral and an emotional facial configuration. However, if the endpoint of the morphing continuum is matched across expressions, relative to the baseline, and since the morphing technique controls the degree of intensity, we can assume that expression intensity is matched at intermediate unfolding levels as well.

To address this issue and rule out the possibility that threshold differences were confounded if the stimuli of the various expressive categories were not matched in intensity, we compared the face stimuli in several visual, categorical, and emotional properties. We first assessed the perceived expressive intensity, following prior studies (Goeleven, De Raedt, Leyman, & Verschuere, 2008; Hess, Blairy, & Kleck, 1997; Palermo & Coltheart, 2004). Dynamic expressions were presented in the 100% intensity condition, and thus participants could see both ends (neutral baseline and emotional expression) of the continuum. This provided viewers with an opportunity to judge how intense the expression became. Second, to examine potential physical and perceptual differences between the neutral and the emotional faces, and among the expressions themselves, we analyzed low-level image properties of the face stimuli. We further performed automated analyses of the facial expressions with computer software (see Bartlett & Whitehill, 2011, for an overview), to estimate the amount physical change between neutral face and each expressive intensity level for each emotion. Third, to determine whether some emotional expressions were more categorically similar or different than others relative to neutral faces, we reanalyzed prior data (Calvo & Lundqvist, 2008) regarding the probability that neutral expressions were confused as happy, fearful, and so forth, and vice versa. Fourth, to ascertain whether some expressions differed in affective valence or arousal more than others relative to their respective neutral face, we reanalyzed prior data (Calvo, Gutiérrez-García, Avero, & Lundqvist, 2013) on these affective dimensions.

Method

Participants. In the study (i.e., Experiment 2) assessing perceived intensity, a different group of 24 undergraduates (12 females; 12 males; between 18 and 25 years) participated voluntarily.

Stimuli and procedure. Participants were presented with 144 video clips of the six basic facial expressions of emotion (24 per category), in the neutral-to-100% intensity condition used in Experiment 1B. Six blocks of trials were formed, with all the faces of each expression being presented in one block. Following the Palermo and Coltheart (2004) procedure, at the beginning of each block, the participants were told the expression that the faces in the block were displaying (e.g., "You will see a number of faces that are angry"), and asked to rate the intensity of each expression on a 9-point scale (e.g., "Please rate how intensely you think the expression is displayed using the scale: 1 [very low intensity] to 9 [very high intensity]"). The order of the six blocks was organized into six random orders, and trials within each block were randomized. The rating scale was visible on the screen. Each face was displayed until the participant pressed a key of the computer keyboard labeled from 1 to 9. The selected number was recorded as the dependent measure.

Additional measures and controls of physical, categorical, and affective differences.

Low-level image properties and physical feature change. First, with Matlab 7.0 (The Mathworks, Natick, MA), we computed the following low-level image statistics of each neutral face and the respective 100% intensity emotional faces: mean and variance in luminance, root-mean-square (RMS) contrast, skewness, kurtosis, energy, and signal-to-noise ratio (SNR). Second, with Emotient FACET SDK v4.1 (iMotions, A/S, Copenhagen, Denmark), we analyzed each face stimulus at each intensity level. The program detects facial features at single landmark points (e.g., mouth corners) as well as feature groups (e.g., entire mouth), and then classifies the stimulus image as one or other facial expression by comparing the resulting output maps with images from databases of already classified expressions. Evidence scores are obtained, which quantify the probability of each expression to be present in a given face stimulus. For each stimulus, we then calculated the difference score between the neutral expression (value obtained for the first video frame) and each intensity level (value obtained for the last frame). Since this automated expression analysis ultimately relies on maps of facial features of the whole face (Littlewort et al., 2011), our difference scores reflect the amount physical change from the neutral to each expressive level, including the full-blown display. This allowed us to determine whether changes in the image facial features (that are presumably used to discriminate expressions) are greater for some expressions than for others, and whether such features change at a different rate for different expressions.

Categorical similarity between neutral and emotional faces. A measure of the categorical similarity of neutral expressions and each emotional expression (100% intensity static faces) was obtained by Calvo and Lundqvist (2008) for 40 KDEF models. The face stimuli were presented one at a time, under free time conditions (until the participant responded) or for 500 ms each. Participants judged which expression was displayed by the face, by pressing one of seven keys (neutral, angry, sad, happy, surprised, disgusted, or fearful). The probabilities of judging neutral faces as emotional, as well as the probability of judging each emotional face as neutral, provided a measure of categorical similarity. For the present aims, we borrowed the Calvo and Lundqvist (2008) scores corresponding to the 24 models that were actually used in the current study.

Affective valence and arousal. In a norming study conducted by Calvo et al. (2013), 32 participants rated the valence and arousal of face stimuli (100% intensity static faces). We selected the 24 KDEF models that were used in the current study. Valence and arousal ratings were aimed at measuring the emotionality of expressions along the unpleasantness–pleasantness, and the calm–tension, dimensions. Using the standard self-assessment mannequin procedure (Lang, Bradley, & Cuthbert, 2008), valence and arousal were rated in a 1–9 valence scale ("How emotionally negative or positive is this facial expression?") and a 1–9 arousal scale ("How emotionally arousing is this facial expression?").

Results

Perceived intensity. The rated intensity of expressions in Experiment 2 was analyzed in a one-way (6 expressions: happy, sad, angry, disgusted, surprised, and fearful) ANOVA. The mean scores are provided in Table 4. Although the overall effect of expression was significant, $F(5, 138) = 3.10$, $p = .011$, $\eta_p^2 = .10$, none of the post hoc multiple comparisons reached statistical significance after Bonferroni corrections (all ps $> .08$). Additional one-sample t tests were conducted to determine whether responses were above the 5 midpoint of the scale, and therefore whether the expressions were perceived with sufficient intensity as to exceed the average level. For all the expressions, the rated intensity was significantly above the 5 midpoint, all ts$(23) > 20$, $p < .0001$.

Low-level image properties and automated measurement of the physical change in expressive facial features. Each low-level image property (mean and variance in luminance, RMS, skewness, kurtosis, energy, and SNR) was analyzed by means of one-way (7 expressions: neutral, happy, sad, angry, disgusted, surprised, and fearful) ANOVA. The main effect of expression was not significant for any of the dependent measures (all ps $>$ .18). The mean scores are shown in Table 4.

To determine the amount of physical change in expressive facial features from the neutral face baseline, the difference scores (i.e., emotional minus neutral score) for each emotional expression (calculated from the output, evidence scores, of the automated software analyses) of the 24 experimental models were subjected to an Expression (6) × Intensity (7) ANOVA. Main effects of expression, $F(5, 115) = 138.04$, $p < .0001$, $\eta_p^2 = .86$, and intensity, $F(6, 138) = 356.98$, $p < .0001$, $\eta_p^2 = .94$, emerged. Scores were higher for happy faces ($M = 6.68$) than for the others: disgusted (3.85), surprised (2.67), angry (1.94), sad (1.72), and fearful (1.68). Also, difference scores increased linearly as a function of intensity, with significant differences between each intensity level and all the others. These effects were, nevertheless,

Table 4
Mean Perceived Intensity of Facial Expressions (1–9 Rating Scale), Low-Level Image Statistics, Categorical Similarity to Neutral Faces, and Valence and Arousal Ratings, for Expressions in the 100% Level of Intensity

Variable	Happiness	Sadness	Anger	Surprise	Disgust	Fear	Neutral
	Expressive category						
Perceived intensity	7.67‡	7.45‡	7.43‡	7.73‡	7.71‡	7.66‡	—
Low-level statistics							
M luminance	72.54	71.38	71.54	71.44	70.81	71.38	74.52
SD luminance	46.13	45.07	45.83	46.10	45.48	45.60	47.45
RMS contrast	.637	.631	.643	.645	.643	.639	.637
Skewness	−.454	−.517	−.495	−.449	−.457	−.494	−.508
Kurtosis	1.90	1.89	1.86	1.86	1.88	1.87	1.87
Energy	2,379	2,244	2,324	2,357	2,298	2,293	2,391
SNR ratio	3.47	3.49	3.44	3.44	3.46	3.45	3.50
Categorization							
Emotional (E) as "neutral" (R)							
500-ms display	.58	.79	.99	.33	.13	.07	—
Free time	.00	.58	.63	.38	.13	.63	—
Neutral (E) as "emotional" (R)							
500-ms display	.07[b]	1.98[b]	.46[b]	.70[b]	.00[b]	.00[b]	97.42[a]
Free time	.00[b]	1.25[b]	1.92[b]	.13[b]	.13[b]	.25[b]	96.33[a]
Affect							
Valence	7.59[a]	3.90[d]	2.70[f]	5.75[b]	3.59[e]	3.54[e]	5.03[c]
Arousal	6.68[a]	3.83[d]	6.49[a]	5.38[c]	5.71[b]	5.75[b]	3.33[e]

Note. Expressions with different superscript letters are significantly different in post hoc multiple contrasts ($p < .05$, Bonferroni corrected); expressions sharing a letter (or with no letter) are equivalent. Emotional (E) as "neutral" (R) = percentage of cases responding (R) "neutral" to emotional face stimuli (E). Neutral (E) as "emotional" (R) = percentage of cases responding (R) "emotional" (i.e., "happiness," "sadness") to neutral face stimuli (E).
‡ Scores above the middle 5-point of the 1–9 scale.

qualified by an Expression × Intensity interaction, $F(30, 690) = 30.85$, $p < .0001$, $\eta_p^2 = .57$. In follow-up one-way (expression) ANOVAs for each intensity level (with Bonferroni corrections, $p < .05$, for multiple comparisons), all the Fs$(5, 115) \geq 80.41$, ps $< .0001$, $\eta_p^2 = .78$. Figure 7 shows the similarities and differences between expressions within each intensity level. Difference scores were significantly higher for happy faces than the rest, followed by disgusted faces, at all intensity levels. Differences among other expressions varied for the various intensities, with angry, sad, and fear expressions being generally equivalent (for details, see Figure 7).

Categorical similarity between neutral and emotional faces. In a one-way (7: Expression) ANOVA, when the target face was neutral, there were effects of expression in the free time condition, $F(6, 138) = 9{,}873$, $p < .0001$, $\eta_p^2 = .99$, and the fixed-display 500-ms condition, $F(6, 138) = 3{,}488$, $p < .0001$, $\eta_p^2 = .99$. Post hoc comparisons indicated that the probability of responding "neutral" was higher than the probability of endorsing any other response ("happy," "fearful," etc.), with no significant differences across emotional expressions. Conversely, when the target faces were emotional, the probability that emotional faces were judged as neutral were analyzed in a one-way (6: Expression) ANOVA. Neither in the free-time condition, $F(5, 138) = 2.16$, $p = .07$, *ns*, nor in the 500-ms condition ($F < 1$) were there significant differences. The neutral faces were unlikely to be judged as emotional and this occurred similarly for all six emotional expressions. See the mean scores in Table 4.

Affective valence and arousal. A one-way (7: Expression) ANOVA showed effects for valence, $F(6, 161) = 881.50$, $p < .0001$, $\eta_p^2 = .97$, and arousal ratings, $F(6, 161) = 776.69$, $p < .0001$, $\eta_p^2 = .97$. The neutral faces differed from all the emotional expressions both in valence and arousal; and importantly for the current aims, this happened similarly for all the expressions (all ps $< .0001$, Bonferroni corrected). Also, one-sample t tests compared the valence scores of the neutral expression against the 5 midpoint of the scale, with no significant differences, $t(23) = 0.24$, $p = .46$. Relatedly, one-sample t tests for arousal ratings of the neutral expression revealed that they were below the 5 midpoint of the scale, $t(23) = 43.00$, $p < .0001$. See the mean scores in Table 4.

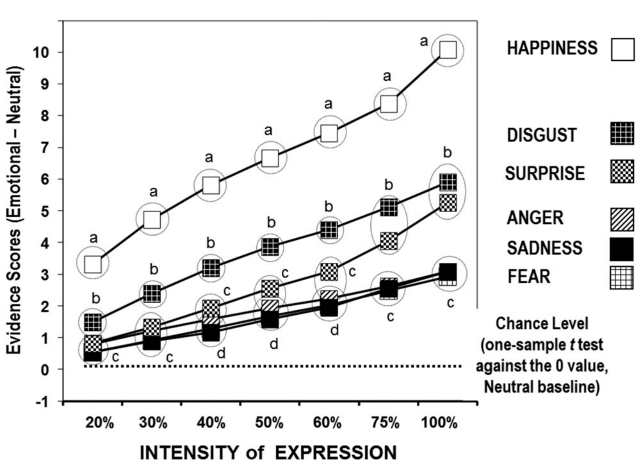

Figure 7. Difference scores representing the physical feature change between the neutral and each emotional expression (emotional minus neutral) across intensity levels, obtained from automated facial expression measurement. For each intensity level, expressions with different letters (within different dotted circles or ovals) are significantly different in post hoc multiple contrasts ($p < .05$, Bonferroni corrected); expressions sharing a letter (within the same circle/oval) are equivalent.

Discussion

Results from Experiment 2, reanalyses of prior relevant data, and additional computations demonstrated that our face stimuli were matched in perceived intensity, physical (low-level image statistics, albeit not in evidence scores of facial feature change; see below), categorical, and emotional properties, relative to their respective neutral faces. This rules out the possibility that recognition threshold differences were confounded with differences in intensity levels between expressions. First, all the emotional faces in the full-intensity condition were perceived as conveying similar intensity within their own expressive category, and this intensity was significantly above the midpoint of the scale. Second, the face stimuli of the different expressions were equivalent in a number of low-level physical image properties; and, importantly, the emotional and the respective neutral expressions were comparable in such properties. Third, there were very few categorical confusions between neutral faces (as stimuli) and emotional faces (as responses), and vice versa; and there were no differences among emotional categories in their being judged as neutral. Fourth, the various emotional faces differed to a similar extent from neutral faces in affective valence and arousal; and relatedly, neutral faces were judged as nonemotional, with valence ratings being in the middle of the unpleasant–pleasantness scale, and arousal ratings being below the midpoint in the calm–tension scale.

Nevertheless, the automated software analysis revealed some differences across expressive categories in physical feature changes from neutral to emotional faces. This affected happy faces, with a greater change than the rest of expressions at all intensity levels. This could explain the higher A' sensitivity scores for happy faces across all the intensities, and their lower recognition threshold, relative to other expressions. In contrast, however, such an explanation cannot account for the recognition differences across the other five emotions, for which there was generally no correspondence between the results from the automated analysis and the recognition measures. First, disgusted faces exhibited greater physical change, relative to neutral, than surprised, angry, and sad faces at all intensities (except the 100% surprise), yet recognition (both A' sensitivity and recognition threshold) was equivalent. Recognition was even equivalent for disgusted and fearful faces at 75% and 100% intensities in the dynamic condition, in spite of the significant physical differences observed between these expressions. Second, fearful faces were equivalent in physical change to sad and angry faces at all intensity levels, and even equivalent to surprised faces at 20% and 30% intensities, yet A' sensitivity scores were lower across all the intensities, and the threshold was higher, for fearful faces than the rest. Third, surprised faces exceeded sad faces in physical change at all intensities from 40% to 100%, yet both expressions were equivalent in A' sensitivity at all intensities, and their recognition threshold was the same. Accordingly, the amount of physical signal change could account for recognition differences between expressions only for happy faces, which is otherwise consistent with the typical recognition advantage of facial happiness (see below).

General Discussion

Our experiments have yielded four major findings. First, basic emotional facial expressions can be recognized above chance level at low intensities following 1-s stimulus displays. Second, recognition thresholds vary for the different expressions, with happy faces having the lowest (i.e., discrimination at lower intensities) and fearful faces having the highest threshold. Third, the thresholds and the pattern of confusions were equivalent for static and dynamic displays, although absolute performance measures indicated better recognition (e.g., higher A' sensitivity and shorter RTs) in the dynamic mode. Finally, relative to their respective neutral baseline faces, the various emotional expressions were equivalent in perceived intensity, low-level image properties, categorical consistency, and affective valence and arousal. Nevertheless, the amount of physical change in facial features was greatest for happy faces, which could account for their lower recognition threshold and higher A' sensitivity scores, compared with other expressions.

Expression Recognition Thresholds

Understandably, recognition of emotional expressions improves as a function of intensity of the facial signal. For static expressions, Palermo and Coltheart (2004) found significant correlations between intensity ratings and categorization accuracy, $r = .67$, $p < .0001$, and RTs, $r = -.54$, $p < .0001$. Hess et al. (1997) reported a significant linear relationship ($\eta^2_p > .80$) between perceived intensity (as rated by observers) and objective intensity (as established by morphing). With dynamic expressions, the effect has not been directly investigated by means of systematic variations of multiple intensity levels, although full-blown expressions are obviously recognized better than subtle expressions (Ambadar et al., 2005; Bould et al., 2008; Bould & Morris, 2008; Cunningham & Wallraven, 2009; Fiorentini & Viviani, 2011; Recio et al., 2014). The neural activity at temporo-occipital visual cortical areas, as assessed by event-related potentials (ERPs), is enhanced by increases in the intensity of static (Leppänen, Kauppinen, Peltola, & Hietanen, 2007; Sprengelmeyer & Jentzsch, 2006) and dynamic (Recio et al., 2014) expressions. Similarly, neuroimaging studies have shown activation in the V5 and fusiform face area to increase as a function of intensity in dynamic expressions (Sarkheil, Goebel, Schneider, & Mathiak, 2013). In the current study, variations in objectively morphed intensity consistently accounted for the variance in all recognition measures (R^2s $\geq .71$), both for static and dynamic faces.

The six basic expressions can be discriminated at low intensities, with thresholds ranging between 20% and 50%, relative to prototypical full-blown expressions. This suggests that the cognitive system is readily attuned to this type of social stimulus, probably because of the communicative importance of facial emotion signals. This also suggests that the frequently occurring low-intensity and microexpressions in many social contexts can yet be identified with reasonable accuracy. Such a facilitated processing is consistent with prior research showing that (static) facial emotion can be recognized above chance even when the face stimuli are displayed for less than 50 ms or pre- and postmasked (Calvo & Lundqvist, 2008; Milders, Sahraie, & Logan, 2008; Svärd, Wiens, & Fischer, 2012; Sweeny, Suzuki, Grabowecky, & Paller, 2013), or when they appear in extrafoveal vision (Bayle, Schoendorff, Henaff, & Krolak-Salmon, 2011; Calvo, Beltrán, & Fernández-Martín, 2014; Calvo, Fernández-Martín, & Nummenmaa, 2014; Goren & Wilson, 2006), or when faces are blurred (Bombari et al., 2013). A common characteristic of all these conditions is that the visual signal is reduced. Accordingly, emotional expressions can be identified from low levels of physical evidence.

Recognition thresholds vary for different expressions. Whereas happiness can be recognized above chance from intensities as low as 20%, sadness, anger, surprise, and disgust, need intensities of 40%, and fear requires at least 50%.[2] Obviously, these figures are relative, within a neutral-to-full-blown expression scale (see below). These results are in line with those recently reported by Rodger, Vizioli, Ouyang, and Caldara (2015), who determined the quantity of signal that is necessary to categorize the six basic facial emotions across age development, using static faces. The happy face advantage, and the disadvantage of fearful faces, is consistent with prior research using static (see Nelson & Russell, 2013; Palermo & Coltheart, 2004) and dynamic (Recio et al., 2013, 2014) full-blown expressions (for a review, see Calvo & Nummenmaa, 2015). The current findings reveal that equivalent recognition patterns remain for both types of displays also at lower intensities. The superiority of happy faces for all the measures (hits, false alarms, A', and RTs) is particularly noticeable. Such an advantage has been attributed to the highly diagnostic value of the smiling mouth, as a distinctive facial feature, whereas the other expressions share some competing features (Calvo & Marrero, 2009; Calvo, Nummenmaa, & Avero, 2010). The fact that the smile is also visually salient (Becker & Srinivasan, 2014; Calvo, Fernández-Martín, & Nummenmaa, 2012; Calvo & Nummenmaa, 2008) would allow it to be detected under reduced physical-signal conditions, hence the advantage at low intensities.

Static Versus Dynamic Expressions

The same recognition patterns (i.e., relative differences across expressions) appeared for static and dynamic displays for all measures, including type of confusions. Yet, in absolute terms, there was an advantage for dynamic expressions (with more hits, fewer false alarms, higher A' scores, and shorter RTs than static expressions). The fact that this superiority occurred mainly at low intensities (see also Ambadar et al., 2005) reveals that intensity moderates the extent to which motion results in recognition benefits (Bould & Morris, 2008), which is consistent with the dynamic advantage when expressions are subtle rather than full-blown (see Krumhuber et al., 2013). Altogether, despite the quantitative benefits of movement, the thresholds were similar for dynamic and static stimuli. Thus dynamic presentation contributes to identify emotional expressions faster and more accurately, but does not reduce the amount of expressive intensity that is necessary to

[2] The absolute recognition threshold for fear was slightly higher in the dynamic than in the static condition, although all the other indices (hits, FAs, A', and RTs) showed equivalent performance. Importantly, the relative threshold position for fear in comparison with the other expressions remained the same, with fear always having the highest threshold.

recognize the emotions. The dynamic advantage is, nonetheless, intriguing, if not paradoxical, because total exposure time of emotional expression per se was, actually, longer in static stimuli. That is, in static displays, the emotion was shown at each target intensity level for the whole 1-s exposure, from onset to end. In contrast, dynamic displays always started from a neutral face unfolding toward an emotional face, which was only visible at the target intensity level in the last 100 ms. This implies that movement makes a contribution beyond mere exposure duration.

The dynamic recognition advantage has been hypothesized to lie on the perception of the temporal unfolding and the direction in which facial expressions change, and the information provided by the online visible *contrast* between a neutral and an emotional face (Ambadar et al., 2005; Bould et al., 2008; Krumhuber et al., 2013). Neuroscientific research has shown that dynamic and static displays evoke differential neural activation, and also a functional dissociation (i.e., with different visual brain pathways involved) between the processing of static and dynamic expressions (Richoz, Jack, Garrod, Schyns, & Caldara, 2015). Particularly, first, higher activity has been observed in brain regions associated with the processing of social-relevant (superior temporal sulci) and emotion-relevant (amygdala) information, when viewing dynamic versus static expressions (Arsalidou, Morris, & Taylor, 2011; Trautmann, Fehr, & Herrmann, 2009). The posterior areas of the superior temporal sulcus (pSTS) play a critical role in encoding dynamic and changeable aspects of faces (Calder & Young, 2005; Engell & Haxby, 2007), and the pSTS is especially sensitive to changes in expressive intensity (Harris, Young, & Andrews, 2012). This may underlie the observed dynamic advantage. Second, larger ERPs have been shown for dynamic expressions at temporo-occipital, visual processing areas (early posterior negativity), and centro-parietal areas involved in categorization (late positive complex; Recio, Sommer, & Schacht, 2011). This suggests that dynamic presentation boosts recognition because motion captures and focuses attention on the relevant, that is, diagnostic, facial features changing from neutral to emotional. Enhanced attention would thus facilitate early perceptual processing and subsequent evaluation allowing for expression recognition (Jiang et al., 2014; Recio et al., 2011).

Alternative Explanations and Potential Limitations

A major issue deserves additional consideration: The recognition threshold differences across expressions; particularly, the advantage of happy faces and the disadvantage of fearful faces, with the other expressions in between.[3] It could be argued, first, that by using a uniform speed for all six expressions, we artificially constrained their natural unfolding. In fact, some studies have shown that each expression has particular natural temporal dynamics, which may impact upon emotion identification (Hoffmann, Traue et al., 2010; Recio et al., 2013; Sato & Yoshikawa, 2004; see Krumhuber et al., 2013, for a review). In an attempt to control for such differences, we chose a common 1-s dynamic display, thus encompassing the optimal and most natural range between 500 and 1,100 ms for all the expressions (Hoffmann, Traue et al., 2010; Pollick et al., 2003; Recio et al., 2013). As a result, our uniform speed for all the expressions at a particular intensity level might have benefited the recognition of some of them and impaired others. Against this explanation, however, the threshold differences across expressions were practically the same in both the static and the dynamic condition. Thus even in the absence of motion, the same pattern remained. This implies that the relative expression recognition advantages and disadvantages were not due to artificial, uniform speed constraints.

Second, it could be argued that the end of the intensity continuum, that is, the full-blown 100% intensity, might be different across expression categories. Given that the lower intensity levels were established by steps between the neutral baseline and the end of the continuum, a greater 100% intensity (e.g., for happy vs. fearful faces) would imply that the lower levels also involved greater intensity (e.g., the 20% level could be more different from the neutral baseline for happy than for other expressions). If so, the recognition threshold and sensitivity differences across expressions would be uninformative, as the scaling would not be equivalent. In favor of this hypothesis, there was greater physical change (as assessed by automated measurement) for happy faces, which also reached higher recognition sensitivity and had a lower recognition threshold, relative to the other expressions. Against this hypothesis, however, differences between the neutral baseline and the 100% intensity were generally equivalent for the six emotion categories: (a) the emotional faces of all six expressions were perceived as conveying similar intensity; (b) all the emotional faces were equivalent in low-level image properties, and comparable to their respective neutral faces; (c) all the emotional faces were similarly and very unlikely to be confused with neutral faces and vice versa; (d) all the emotional faces differed to a similar extent from neutral faces in both rated affective valence and arousal, with neutral faces being judged as nonemotional; and (e) there was no correspondence between the amount of physical change and recognition for all the nonhappy expressions. Altogether, this implies that recognition thresholds and sensitivity differences were not confounded with intensity scaling differences across expressive categories, except for happy faces (which otherwise may reflect their natural idiosyncrasy, with a visually salient smile).

A possible limitation of the present findings is concerned with the ecological validity of our dynamic stimuli. We used morphed expressions, which have also been widely used in prior behavioral and neurophysiological research (e.g., Harris, Young, & Andrews, 2014; Kessels, Montagne, Hendriks, Perrett, & de Haan, 2014). Although morphing allows for control and a systematic variation of dynamic features, morphed and natural expressions may have some relevant differences regarding their unfolding time course. Morphing involves linear motion changes between a neutral face starting point and an expressive face end point. In such a linear unfolding, all the features in the face change at the same time, and the overall timing or speed is uniform across steps. In contrast, for natural expressions, the unfolding and the path of change might develop in a rather asynchronous and asymmetrical manner, with not all the features in a face unfolding at the same time and with the same intensity. To our knowledge, only in one study have

[3] It is unlikely that seeing the neutral baseline in the dynamic condition might have favored the recognition of some expressions (e.g., happiness) over others (e.g., fear), because the recognition pattern was comparable for dynamic and static expressions. Such an explanation could not account for the pattern of results in the static presentation mode, in which no neutral baseline preceded the expression unfolding.

dynamic morphed and natural expressions been directly compared (Lander, Chuang, & Wickham, 2006). These authors compared the recognition of identity (rather than expression) from natural and morphed smiling faces. Results showed a recognition benefit for natural over morphed smiles, and that recognition was impaired by motion speeding in natural but not in morphed format. This suggests that there might be quantitative and qualitative differences between natural and morphed faces. Nevertheless, this conclusion should be strengthened and nuanced with further evidence, and extended to expression recognition.

Conclusions

The six basic facial expressions of emotion can be recognized above chance from low expressive intensities, both in static and dynamic presentation modes. Recognition thresholds vary for different expressions: 20% of intensity for happy faces; 40% for sad, angry, surprised, and disgusted faces; and 50% for fearful faces. Such differences occur in the absence of physical (except for happy expressions), perceptual, categorical, or affective differences across emotions relative to neutral faces. The same recognition pattern and type of confusions occur for static and dynamic displays across expressions as a function of intensity. There is, nevertheless, a quantitative recognition advantage (i.e., more accurate and faster responses) for dynamic relative to static displays. The fact that basic emotions can be recognized at very low levels of intensity has considerable practical relevance for everyday life, where many emotional expressions are subtle, due to social constraints.

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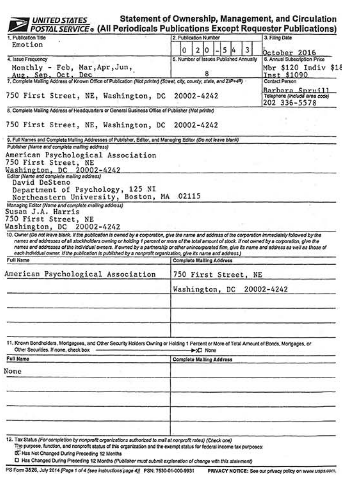

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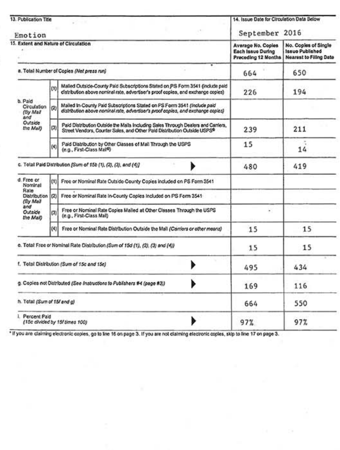

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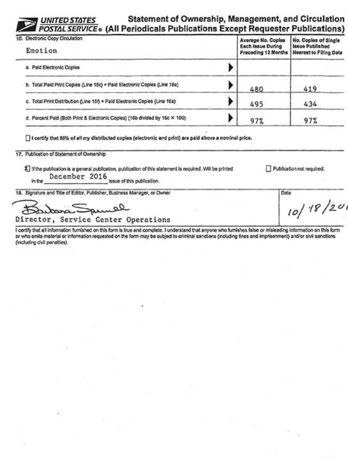

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16. Electronic Copy Circulation: Emotion	Average No. Copies Each Issue During Preceding 12 Months	No. Copies of Single Issue Published Nearest to Filing Date
a. Paid Electronic Copies		
b. Total Paid Print Copies (Line 15c) + Paid Electronic Copies (Line 16a)	480	419
c. Total Print Distribution (Line 15f) + Paid Electronic Copies (Line 16a)	495	434
d. Percent Paid (Both Print & Electronic Copies) (16b divided by 16c × 100)	97%	97%

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18. Signature and Title of Editor, Publisher, Business Manager, or Owner: Barbara Spruill, Director, Service Center Operations
Date: 10/18/2016

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