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Abstract Cross-cultural and laboratory research indicates that some facial expressions of emotion are recognized more accurately and faster than others. We assessed the hypothesis that such differences depend on the frequency with which each expression occurs in social encounters. Thirty observers recorded how often they saw different facial expressions during natural conditions in their daily life. For a total of 90 days (3 days per observer), 2,462 samples of seen expressions were collected. Among the basic expressions, happy faces were observed most frequently (31 %), followed by surprised (11.3 %), sad (9.3 %), angry (8.7 %), disgusted (7.2 %), and fearful faces, which were the least frequent (3.4 %). A significant amount (29 %) of non-basic emotional expressions (e.g., pride or shame) were also observed. We correlated our frequency data with recognition accuracy and response latency data from prior studies. In support of the hypothesis, significant correlations (generally, above .70) emerged, with recognition accuracy increasing and latency decreasing as a function of frequency. We conclude that the efficiency of facial emotion recognition is modulated by familiarity of the expressions.

Keywords Facial expression · Recognition · Emotion · Frequency · Observation

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Introduction

Prior research on facial expression recognition has consistently found that happy expressions are categorized and discriminated more accurately and faster than the other basic emotions (sad, angry, fearful, disgusted, and surprised). Among the non-happy expressions, recognition agreement is often lower and responses are slower for fearful faces, although differences are not great and there is some variation across cultures (see Nelson and Russell 2013, and the "Appendix", below). This evidence is shown by both laboratory experiments (e.g., Calder et al. 2000; Calvo and Lundqvist 2008; Calvo and Nummenmaa 2009; Leppänen and Hietanen 2004; Loughead et al. 2008; Milders et al. 2008; Palermo and Coltheart 2004; Svärd et al. 2012; Tottenham et al. 2009) and cross-cultural judgment studies (see Nelson and Russell 2013). In the current study, we examined the hypothesis that the frequency with which expressions occur in our everyday life, and therefore our familiarity with them, contributes to the recognition performance differences across expressions. This hypothesis was addressed in comparison with three alternative explanations, i.e., the adaptive value, the affective uniqueness, and the saliency-and-distinctiveness hypotheses.

A first explanation is conceptualized in terms of the *adaptive importance* of the information conveyed by each expression. The facilitated processing of happy faces can be related to their functional value in the initiation and maintenance of social bonds (Tomkins 1962; see Juth et al. 2005, and Leppänen and Hietanen 2007). Recognition of happy expressions would thus be instrumental in maximizing the receipt of reward from other people and establishing alliance and collaboration. This proposal, however, seems at odds with a biological perspective when we consider the negatively valenced expressions. According to an adaptive function view, threat (e.g., angry or fearful faces) rather than benefit (i.e., happy faces) detection should be prioritized automatically (Williams 2006): To first survive and then prosper, organisms must have evolved in a way that gives precedence to signals of danger (which, accordingly, should engage the neurocognitive mechanisms for sensory input and processing very early and accurately) to avoid harm; in contrast, signals of potential reward would be processed only after safety is assured. As a consequence, we should expect faster and more accurate recognition of threat-related relative to non-threat expressions. This is, however, not consistent with the finding of a happy face recognition advantage in categorization tasks, and therefore the adaptive value hypothesis cannot account for such findings.

An *affective uniqueness* hypothesis would draw on the fact that, in expression judgment or categorization tasks, facial happiness is generally the only expression conveying positive affect while the others are negatively valenced (anger, fear, sadness, and disgust) or affectively ambiguous (surprise; see Mendolia 2007). This uniqueness would make happy faces easily discriminable, whereas the others would be subjected to mutual interference, thus reducing their discriminability for recognition. This conceptualization can, nevertheless, be downplayed. First, it does not explain why there are recognition differences among the negative expressions. Second, the happy face advantage occurs even when only one negative expression (e.g., disgust: Leppänen and Hietanen 2004; or sadness: Kirita and Endo 1995) is used with happy faces. In addition, Calvo and Nummenmaa (2009; Exp. 2) presented angry and happy faces, along with surprised faces amenable to both a negative and a positive interpretation, and in such conditions as well were the happy faces recognized faster than angry faces. Finally, Calvo and Nummenmaa (2011) found that perceptual (visual saliency) and semantic (category membership) characteristics of the expressions made a greater contribution to discrimination speed than emotional valence did. Accordingly, the recognition advantage may be due to intrinsic properties of facial happiness (i.e., regardless of how many different expressions are used in a task) that have more to do with perceptual and categorical than with emotional uniqueness.

In relation to such perceptual and categorical properties, a *saliency-and-distinctiveness* hypothesis has been put forward to explain the happy face recognition superiority (Calvo and Nummenmaa 2008; Calvo et al. 2010, 2012). The smiling mouth of happy faces involves two properties that critically contribute to expression recognition: perceptual saliency and categorical distinctiveness. *Saliency* is an index of the visual prominence of an image region in relation to its surroundings, and it is defined as a combination of physical image properties such as luminance, contrast, and spatial orientation (Borji and Itti 2013; Itti and Koch 2000). Calvo and Nummenmaa (2008) found that the smiling mouth is, in fact, more salient and captures the viewers' initial eye fixation more likely than any other region of happy and non-happy faces. Categorical *distinctiveness* refers to the degree that a facial feature is unambiguously linked with a particular expression category. The smile is systematically and uniquely associated with—and thus highly diagnostic of—happiness, whereas other facial features overlap to some extent across different categories (Calvo and Marrero 2009; Kohler et al. 2004). Being a single diagnostic feature, the smile can be used as a shortcut for a quick and accurate feature-based categorization of a face as happy (Adolphs 2002; Calvo and Beltrán 2014; Leppänen and Hietanen 2007). In contrast, the recognition of non-happy expressions would require configural processing of specific combinations of facial features, which makes recognition slower and more fallible.

The saliency-and-distinctiveness hypothesis accounts for the consistent recognition advantage of happy over other expressions. However, it fails to do so for the recognition performance differences among the various non-happy expressions, probably because they are more similar to each other in saliency and distinctiveness. In the current study, we propose a complementary explanation, which we call the *frequency-of-occurrence* hypothesis. It predicts that the recognition of the different facial expressions of emotion will be dependent on the frequency with which they occur in the everyday social environment. The more frequently a given expression is encountered, the more familiar we become with it. A more frequent exposure to a given expression will provide observers with more information about its facial morphology, and also about its function or meaning due to contextual association. This will make the facial configuration and the significance of an expression more distinct in the visual system and more accessible in memory, thus facilitating recognition. Although not yet articulated, this notion was suggested by Biehl et al. (1997), who speculated that agreement levels across individuals when judging facial expressions might be affected by the frequency of their occurrence in real life. It might be the case that happy and surprised expressions—which accrue more judgment agreement than the other expressions—would occur most frequently, whereas fear and disgust—which accrue less agreement—would be the most infrequent.

To our knowledge, no study has yet examined the objective frequency of occurrence of expressions in everyday life. Nevertheless, some prior findings are relevant to this hypothesis. First, Somerville and Whalen (2006) obtained retrospective estimates of the occurrence of different facial expressions. These authors presented a large sample of 1,393 participants with a list of labels of the six basic emotional facial expressions, and asked them to rank-order the labels based upon the frequency with which they believed they had encountered the respective expressions in their lifetimes. The expressions were ranked in this order from highest to lowest frequency: happiness, sadness, anger, surprise, disgust, and fear. Thus the most (happy) and the least (fearful) frequent expressions are also the ones that are recognized most and least accurately in categorization tasks (see above).

Second, Beaupré and Hess (2005, 2006) asked participants to estimate the probability of occurrence of each expression in everyday life, and then correlated these perceived frequency scores with performance in an expression categorization task. Frequency was significantly related to confidence judgments (Beaupré and Hess 2006), although not to judgment accuracy (Beaupré and Hess 2005). Third, the *in-group advantage* effect (see Elfenbein 2013; Elfenbein and Ambady 2002) reveals that individuals are more accurate when judging emotional expressions from their own cultural group versus foreign groups. This implies that the amount of cultural exposure—hence familiarity of the expressions—improves the effectiveness of emotion recognition judgments.

Accordingly, prior research has provided suggestive, albeit limited, evidence supporting the frequency of occurrence (henceforth, frequency) hypothesis. In the current study, we tested this hypothesis directly. First, we obtained objective on-line recording—rather than retrospective off-line estimates—of the frequency of each expression. To this end, 30 observers recorded the actual frequency of each expression under natural conditions in their daily life for a total of 90 days (3 days per observer over a 2-month period). The gender and the approximate age of expressers (children, adults, and elderly people) were also recorded. The observational data collection was performed in Spain. Nevertheless, as a complementary measure, we also obtained estimated frequencies in two different countries (Spain and Finland), as an extension of those obtained by Somerville and Whalen (2006; USA). The combination of the on-line recording and the retrospective estimates in the current study represents a useful approach. Both types of measures were assessed and compared, and their relative predictive value of expression recognition was explored. This served to determine how reliable our memory of the frequency of expressions (i.e., retrospective estimates) is, in relation to the real experience (i.e., observed frequency) of the respective emotional faces. In addition, by using two complementary measures, we could examine the extent or strength of the relationship between frequency and recognition.

Second, by means of correlation analyses, we examined the relationship between the frequency indices and the actual recognition performance scores reported by prior laboratory and cross-cultural studies. For this approach, we used the mean recognition *accuracy* scores reported by Nelson and Russell (2013), encompassing a wide range of cross-cultural studies (Western, non-Western, and illiterate samples; see below). In addition, we correlated the frequency scores with response *latencies* in prior studies using this measure in expression categorization tasks (with all the six basic expressions; Calder et al. 2000; Calvo and Lundqvist 2008; Calvo and Nummenmaa 2009; Elfenbein and Ambady 2003; Palermo and Coltheart 2004). Response latencies reflect recognition efficiency, that is, the amount of on-line cognitive processing resources that each expression requires to be identified. Furthermore, although both latencies and accuracy are generally convergent (with correlations ranging between $r = -.80$ and $-.97$, in the five aforementioned studies), latencies are a more sensitive measure of expression discrimination than accuracy is. Accordingly, the inclusion of response latencies will presumably provide us with a more precise index of the relationship between frequency and recognition.

Method

Participants

To assess the actual frequency of expressions in everyday life, 30 psychology undergraduate students (21–23 years old; 22 females) participated as observers for course credit or monetary compensation (20 euros a day). All the participants provided informed consent prior to their inclusion in the study, and the study was approved by the ethics committee of the University of La Laguna.

Procedure

In a pre-recording *training* phase, all the participants/observers were presented with 24 (12 female; 12 male) digitized photographs of each of the six basic emotional expressions (happy, sad, angry, fearful, disgusted, and surprised) in addition to 24 neutral faces of the same individuals, taken from the KDEF set (Karolinska Directed Emotional Faces; Lundqvist et al. 1998). Each photograph and the corresponding verbal label were displayed for 3 s, followed by a 2-s blank interval. The observers were not informed of the real purpose of the study (i.e., the relationship between frequency and recognition of expressions), as this information could have biased their observations. The participants were simply told that the aim of the study was to determine how frequently different facial expressions of emotion occur in our daily experience.

The *recording* period encompassed 2 months, during which each of the 30 observers recorded expression frequencies for three pre-assigned non-consecutive days. To obtain the objective, on-line measures of the frequency of expressions, the observers were asked to be attentive to emotional expressions they noticed in other people's faces throughout the day. They were instructed to note down (by means of a mark in a structured observational recording sheet) each time they saw a facial expression that could be assigned to any of the six prototypical emotion categories (happy, sad, angry, fearful, disgusted, and surprised). Nevertheless, they were also told to pay attention to expressions that could not be clearly assigned to any of the basic categories, and choose a verbal label for each of them (a list of possible non-prototypical expressions was not provided). In the post-observation analysis phase, the recorded non-prototypical expressions were grouped in two categories: positively valenced (love, enthusiasm, pride, interest, joy, pleasure, desire, hope, excitement, content), and negatively valenced (shame, guilt, contempt, pain, anxiety, disappointment, frustration, helplessness).

In the recording sheet, each expression was located in one column. A column "Others" was added so that each observer could note down a label for non-prototypical expressions. Within each column, rows included age group (0–17 years; 18–65 years; >65 years) and gender (female; male) of the expresser, as well as social context (family or couple, friends, socialization, work or study, street, and TV/movies). Every time the observers detected a facial expression, they were to make a mark in the corresponding column (expression) and row (age, gender, and context). The observers estimated the age of the expresser when they did not know it in advance. The context data were not ultimately analyzed due to permeability or insufficient separation across the different contexts. The observers were told to record the frequency of the emotional expressions they saw without asking the expressers how they felt. The observers were instructed to behave in a natural fashion, without intentionally provoking any reaction in the expressers, who should not be aware that they were being observed.

Internet Survey

To obtain the subjective or retrospective estimates of the frequency of expressions, Spanish ($N = 199$; M years of age $= 27.71$; $SD = 8.64$; 70.4 % females) and Finnish ($N = 194$; M age $= 27.60$; $SD = 6.32$; 85.1 % females) new participants responded to an internet survey (see below). None of the observers participated in this survey, which was announced for students and faculty members at the University of La Laguna (Spain), and Aalto University, and Universities of Helsinki, Turku, Tampere, and Jyväskylä (Finland), with participation being voluntary. The survey consisted of two short phases. In the first phase, participants were presented with the verbal labels of the six basic expressions, and were asked to rank-order the labels based upon the frequency with which they believed they encounter the expressions during a typical day of their lives. In the second phase, they were again presented with the verbal labels of the basic expressions, and asked to report how many times they thought they see each expression during a typical day. Order of presentation of the verbal labels for the expressions was randomized for each participant, to avoid any response bias.

Results

Analyses of Objective Frequency of Expressions

Reliability analyses were initially conducted on the frequency scores provided by the 30 observers for the eight expression categories (i.e., the six basic expressions, plus the positively and the negatively valenced non-prototypical expressions). Intraclass correlation (ICC) analyses across observers revealed a high consistency of the relative frequencies of each expression (standardized $\alpha = .988$; single measure ICC = .697; average value ICC = .986; $p < .0001$).

A total of 2,462 observational samples were collected across 90 days (30 observers × 3 days each). The raw frequency scores for each expression as a function of age group and gender are shown in Table 1; the relative frequencies, in Fig. 1. For the following analyses, the scores of the 3 days for each observer were added up separately for each expression category, age group, and gender. Greenhouse-Geisser correction was applied to the ANOVAs, and Bonferroni corrections ($p < .05$) were used for all the contrasts involving post hoc multiple comparisons.

First, we analyzed the frequency of each expression as a function of age and gender of the expressers, by means of an Expression (8: happiness, sadness, anger, fear, disgust, surprise, others-positive, and others-negative) × Age group (3: 0–17 vs. 18–65 vs. >65 years old) × Gender (2: females vs. males) fully within-subjects ANOVA where observers were treated as random factors. The Expression × Age group × Gender ANOVA yielded main effects of expression, $F(7, 203) = 69.90$, $p < .0001$, $\eta^2_p = .707$, age, $F(2, 58) = 430.06$, $p < .0001$, $\eta^2_p = .937$, and gender, $F(1, 29) = 25.77$, $p < .0001$, $\eta^2_p = .471$. Post hoc multiple comparisons indicated that happy faces were observed more frequently and fearful faces were observed less frequently than any other expression. See the contrasts across expressions in the bottom row of Table 1. In addition, expressions were observed more frequently in adults, followed by the younger people, with fewer expressions in the elderly. Finally, females displayed more emotional expressions than males. These effects were, nevertheless, qualified by interactions of expression and age, $F(14, 406) = 39.46$, $p < .0001$, $\eta^2_p = .576$, expression and gender, $F(7, 203) = 3.29$, $p = .013$, $\eta^2_p = .102$, and age and gender, $F(2, 58) = 8.67$, $p < .01$, $\eta^2_p = .230$. The three-way interaction was not significant ($F = 1.72$, $p = .13$).

Table 1 Objective raw frequencies of facial expressions of emotion a function of age group and gender

Gender and age group	Facial expression of emotion								
	Happiness	Surprise	Sadness	Anger	Disgust	Fear	Other Positive	Other Negative	TOTAL
Girls (0–17 years)	89	27	24	15	31	15	71	52	324
Boys (0–17 years)	69	19	18	18	35	9	61	53	282
Women (18–65 years)	337	121	85	81	66	37	133	111	971
Men (18–65 years)	250	97	66	84	29	23	122	90	761
Old women (>65 years)	11	10	27	6	12	0	5	6	77
Old men (>65 years)	7	5	9	9	6	0	5	6	47
Total	763	279	229	213	179	84	397	318	2,462
Per observer and day	8.48[a]	3.10[c]	2.54[cd]	2.37[cd]	1.99[d]	0.93[e]	4.41[b]	3.53[bc]	27.35

Different superscripts (a, b, c, d, e) indicate significant differences between expressions (horizontally); means with the same superscript are equivalent

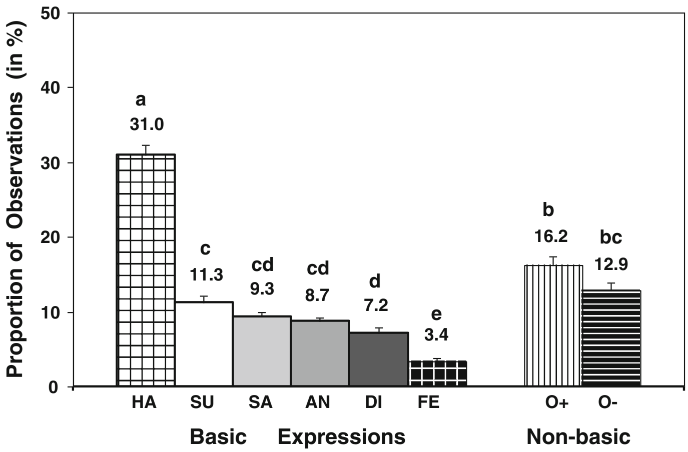

Fig. 1 Relative frequency (in % of observational samples) of each expression. *HA* Happiness, *SU* Surprise, *SA* Sadness, *AN* Anger, *DI* Disgust, *FE* Fear, *O+* Other expressions, Positively valenced, *O−* Other expressions, Negatively valenced. Different superscripts (*a, b, c, d*) indicate significant differences between expressions; means with the same superscript are equivalent. *Error bars* represent standard errors of the mean

To decompose the expression by age interaction, a one-way (8: expression) ANOVA was conducted for each age group separately. The effects of expression were significant in all the age groups: the younger, $F(7, 203) = 28.13$, $p < .0001$, $\eta_p^2 = .492$, the adults, $F(7, 203) = 55.89$, $p < .0001$, $\eta_p^2 = .658$, and the elderly, $F(7, 203) = 5.95$, $p < .001$, $\eta_p^2 = .170$. The interaction arose from the fact that the expression effect was stronger, and the differences across expressions were more pronounced in the adult group than in the younger group, with minor differences in the older group (see the respective contrasts in Table 2).

To decompose the expression by gender interaction, we performed pairwise comparisons between females and males for each expression separately. Happy, $t(29) = 3.58$, $p < .001$, sad, $t(29) = 3.10$, $p < .01$, fearful, $t(29) = 2.52$, $p = .017$, surprised, $t(29) = 2.15$, $p = .040$, and disgusted, $t(29) = 2.33$, $p = .027$, expressions were observed more frequently in females than in males, whereas differences were not significant for anger, or for the negatively or the positively valenced non-prototypical expressions.

Finally, to analyze the age by gender interaction, we conducted pairwise comparisons between females and males for each age group separately. For the younger group, the tendency for females to exhibit more emotional expressions than males did not reach statistical significance, $t(29) = 1.73$, $p = .095$, whereas such a difference was reliable in the adult group, $t(29) = 4.24$, $p < .0001$, and also in the older age group, $t(29) = 2.49$, $p = .019$.

Descriptive Statistics of the Estimated Frequency of Expressions

Mean rank order values and absolute frequency scores of each expression obtained from the internet surveys in Spain and Finland are reported in Table 3. Corresponding USA values (Somerville and Whalen 2006) are also shown for comparison. Nevertheless, it must be noted that Somerville and Whalen used neutral expressions in addition to the six basic

Table 2 Average (per observer and day) frequencies of facial expressions of emotion for each age group

Age group	Facial expression of emotion							
	Happiness	Surprise	Sadness	Anger	Disgust	Fear	Other Positive	Other Negative
Younger	1.75[a]	0.51[cd]	0.47[cd]	0.37[d]	0.73[bc]	0.27[d]	1.47[a]	1.17[ab]
Adults	6.52[a]	2.42[b]	1.68[b]	1.83[b]	1.05 [cd]	0.67[d]	2.83[b]	2.23[b]
Elderly	0.20[ab]	0.17[ab]	0.40[a]	0.17[a]	0.20[a]	0.00[b]	0.11[ab]	0.13[ab]

Different superscripts (a, b, c, d) indicate significant differences between expressions (horizontally); means with the same superscript are equivalent

emotional expressions, and also these authors obtained rank order estimates but not absolute frequency estimates, and therefore their results are not totally comparable with ours. For rank order, there was a significant non-parametric (Spearman *Rho*) correlation between the Spanish and the Finnish samples ($r = .94$, $p < .01$; $n = 6$ expressions), and between the Spanish and the American samples ($r = .83$, $p < .05$), whereas the effect was significant only in one-tailed test between Finnish and American samples ($r = .71$, $p = .05$).

A two-way ANOVA was conducted on the absolute frequency scores, with country (Spain vs. Finland) as a between-subjects factor, and expression (happiness, sadness, anger, fear, disgust, and surprise) as a within-subjects factor. The ANOVA was not conducted for the rank-order values, as the use of a parametric statistic might not be appropriate for a variable on an ordinal scale. A significant main expression effect emerged for frequencies, $F(5, 1955) = 186.27$, $p < .0001$, $\eta^2_p = .323$, but no country effect was observed ($p = .85$, *ns*). There were significant differences across all the expression categories except between disgust and fear (see the contrasts in Table 3). An expression by country interaction, $F(5, 1955) = 13.25$, $p < .0001$, $\eta^2_p = .033$, followed by pairwise contrasts revealed higher estimated frequencies of happy faces, $t(391) = 2.81$, $p < .01$, in Finland, and higher frequencies of sad, $t(391) = 3.32$, $p < .001$ and angry, $t(391) = 7.64$, $p < .0001$, faces in Spain, with no significant differences for surprised, disgusted, and fearful faces.

Relationship Between Frequency of Expressions and Recognition Performance

We also examined the relationship between the frequency values for each expression and the corresponding recognition performance indices in prior laboratory and cross-cultural studies. Given the large number of studies that have collected recognition *accuracy* measures, we used the classification provided by Nelson and Russell (2013), i.e., studies on Western, non-Western, and illiterate societies, separately (all between 1992 and 2010), as well as a final category combining all the studies (including those published earlier), and the respective mean scores for each basic expression. In contrast, there is a reduced group of studies in which *latencies* of accurate categorization responses have been collected for all six basic expressions (Calder et al. 2000; Calvo and Lundqvist 2008; Calvo and Nummenmaa 2009; Elfenbein and Ambady 2003; Palermo and Coltheart 2004) and so we included each of them in the correlation analyses. The recognition accuracy and latency scores of the prior studies (with which frequency scores were correlated) are reported in the "Appendix".

We computed correlations between (a) our objective frequency scores, and also the rank order estimates for Spanish and Finnish samples (current study), and American samples (Somerville and Whalen 2006), and (b) the recognition accuracy and latency scores for the

Table 3 Estimated rank order (1–6, Spain and Finland; 1–7, USA) and Frequencies (per day) of each Expression in Spanish and Finnish Samples (current study) and American Samples (Somerville and Whalen 2006)

	Emotional facial expression					
	Happiness	Surprise	Sadness	Anger	Disgust	Fear
Rank order						
Spain	1.38 (1st)***	3.14 (2nd)**	3.18 (3rd)**	3.28 (4th)	4.95 (5th)**	5.06 (6th)***
Finland	1.10 (1st)***	2.53 (2nd)**	3.58 (3rd)**	4.72 (5th)	4.23 (4th)	4.86 (6th)***
Mean (Spain/Finland)	1.24^{a}	2.84^{b}	2.37^{c}	3.99^{d}	4.60^{e}	4.96^{f}
USA	1.86 (1st)***	4.89 (4th)	3.65 (2nd)	4.03 (3th)	5.37 (5th)**	5.93 (6th)***
Frequencies						
Spain	15.24	5.64	5.52	5.62	2.44	2.48
Finland	21.20	6.32	3.56	2.17	2.50	1.91
Mean (Spain/Finland)	18.18^{a}	5.98^{b}	4.55^{c}	3.92^{d}	2.47^{e}	2.20^{e}

Different superscripts (a, b, c, d, e, f) indicate significant differences between expressions (horizontally); means with the same superscript are equivalent. *** = same rank all three samples (Spanish, Finnish, and American); ** = same rank, two samples; no asterisk: no agreement across samples six basic expressions in prior studies. Given the small number of items (i.e., expressions) to be correlated, we first performed non-parametric (Spearman *Rho*) correlations (see Table 4). A considerable number of these reached or were above the required statistical significance level ($p = .05$, two-tailed test; $r = .81$, for an $n = 6$). In addition, the coefficient of determination (known as R^2) was computed on the log-normal distribution of scores. This coefficient is interpreted as the goodness of fit of a regression: The higher the

Table 4 Non-parametric (Spearman Rho) correlation and coefficient of determination (R^2) between objective frequency (Current Study) and estimated rank-order frequency (Spain and Finland, current study; USA, Somerville and Whalen 2006) of facial expressions of emotion, and recognition performance indices in prior studies

	Objective frequency		Estimated rank-order frequency		
	Rho	R^2	Rho Spain	Rho Finland	Rho USA
Frequency					
Objective Frequency (Spain)	–	–	−1.0*	−.94*	−.83*
Estimated Rank Order (Spain)	−1.0*	.86*	–	.94*	.94*
Estimated Rank Order (Finland)	−.94*	.82*	.94*	–	.71#
Estimated Rank Order (USA)	−.83*	.81*	.83*	.71#	–
Recognition					
Nelson and Russell (2013)					
Accuracy (Western)	.89*	.72*	−.89*	−.71#	−.71#
Accuracy (Non-western)	1.0*	.80*	−1.0*	−.94*	−.83*
Accuracy (Illiterate)	.94*	.82*	−.94*	−.1.0*	−.71#
Accuracy (Combined)	1.0*	.90*	−1.0*	−.94*	−.83*
Calder et al. (2000)					
Accuracy	.71#	.62#	−.71#	−.83*	−.77#
Manual RTs	−.60	.85*	.60	.77#	.60
Elfenbein and Ambady (2003)					
Accuracy	.83*	.84*	−.89*	−.94*	−.83*
Manual RTs	−.83*	.78*	.71#	.89*	.37
Palermo and Coltheart (2004)					
Accuracy	.83*	.78*	−.49	−.82*	−.60
Vocal RTs	−.83*	.93*	.49	.82*	.60
Calvo and Lundqvist (2008)					
Accuracy (free time)	.55	.91*	−.55	−.46	−.81*
Accuracy (25–500 ms display)	.60	.89*	−.60	−.49	−.89*
Manual RTs	−.77#	.89*	.77#	.83*	.49
Calvo and Nummenmaa (2009)					
Accuracy	.49	.29	−.49	−.60	−.09
Saccadic RTs	−.71#	.74*	.71#	.89*	.37

To interpret the *Rho* correlations, it must be noted that *rank order* is *inversely* related to frequency (i.e., the lower the score in rank order, the higher the estimated frequency). As a consequence, a negative correlation means that recognition accuracy increases, and response latencies (RTs) decrease, with increasing frequency. In contrast, *objective frequency* scores are *directly* related to actual frequency. R^2 is an estimation of the amount of variance in recognition that is accounted for by expression frequency

* $p < .05$, two-tailed test; # $p \leq .05$, one-tailed test

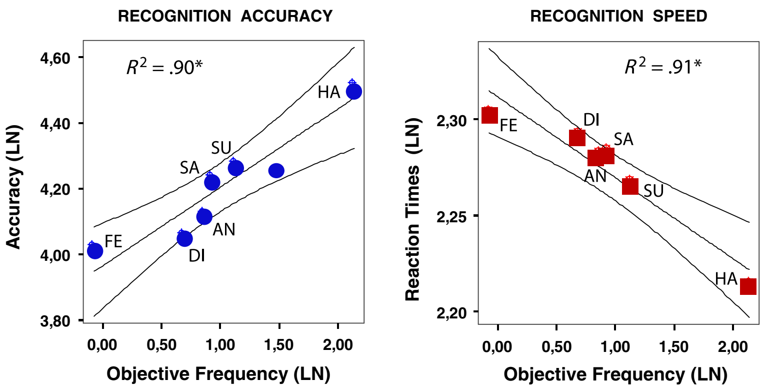

Fig. 2 Relationship between objective frequency in the current study and average recognition accuracy (Nelson and Russell 2013) or latencies of correct responses (Calder et al. 2000; Calvo and Lundqvist 2008; Calvo and Nummenmaa 2009; Elfenbein and Ambady 2003; Palermo and Coltheart 2004), with the coefficient of determination (R^2) and prediction of the mean at 95 % confidence interval (*$p < .05$). All the scores are log-n transformed (LN). *HA* Happiness, *SU* Surprise, *SA* Sadness, *AN* Anger, *DI* Disgust, *FE* Fear

coefficient, the larger the variance of the dependent variable (e.g., expression recognition accuracy or latency) that is explained by the independent variable (e.g., frequency). In most cases, the variance reached or was above the significance level ($p = .05$; $R^2 = .66$; i.e., 66 % of variance; see Table 4). Essentially, recognition accuracy increased both with objective and with estimated frequency, which were generally related to faster correct recognition responses. An illustration of these associations between frequency and recognition performance (using combined scores across studies) is shown in Fig. 2.

Discussion

The current study tested the hypothesis that the frequency of facial expressions of emotion in real life predicts recognition performance (accuracy and latency) in expression categorization or judgment tasks. In support of this hypothesis, first, our findings revealed that happy faces are the most frequently encountered in everyday social contexts, followed by surprised, sad, angry, disgusted, and fearful faces, which are the least frequently observed. Second, this is consistent with the well-documented recognition advantage (i.e., more accurate and faster responses) of happy expressions and the disadvantage (i.e., less accurate and/or slower responses) of fearful expressions in laboratory (e.g., Calder et al. 2000; Calvo and Lundqvist 2008; Palermo and Coltheart 2004) and cross-cultural studies (see Nelson and Russell 2013). Third, a reanalysis of the recognition performance data in prior studies as a function of the current study frequency scores revealed that both measures are highly related: Recognition accuracy significantly increases, and response latency decreases, with increasing frequency of an expression.

A Frequency Explanation of Facial Expression Recognition

This suggests that expression frequency in day-to-day social interaction contributes to expression identification. Presumably, the expressions we observe more often lead us to construct a more accurately tuned visual template of their facial features and configural structure, which can then facilitate recognition. In addition, a frequent exposure to an expression provides observers with a more refined meaning of its significance or informative value. This would be due to the association of an expression with the particular contexts in which it occurs and the kind of experience a person undergoes in such conditions. As a consequence, the corresponding mental representation of the expression becomes readily accessible and distinctive and, therefore, new exemplars can be recognized more easily. In sum, a greater prior experience of an expression provides observers with a better knowledge base for identifying it—both its morphology and its significance—later.

The interpretation of our findings within the frequency-of-occurrence conceptualization is strengthened by two additional findings. First, our objective or on-line frequency measure was highly correlated with retrospective estimates or off-line frequency indices in various countries (Spain, Finland, and the USA). Furthermore, the estimated frequency values in all three countries showed similar relationships with the actual recognition performance data. Such an agreement suggests (1) that a relatively stable distribution of frequencies of expressions exists across different socio-cultural contexts, and (2) that people construct accurate memory representations of the real occurrence of emotional expressions in social encounters. It is, therefore, understandable that frequency can influence the recognition of expressions. Second, many of the prior cross-cultural and laboratory studies used different face databases as stimuli, such as the Pictures of Facial Affect (POFA; Ekman and Friesen 1976), the Karolinska Directed Emotional Faces (KDEF; Lundqvist et al. 1998), the NimStim Stimulus Set (Tottenham et al. 2002), the Montreal Set of Facial Displays of Emotion (MSFDE; Beaupré et al. 2000), the Japanese and Caucasian Facial Expressions of Emotion (JACFEE; Matsumoto and Ekman 1988), and others. The fact that the frequency-recognition relationship was, nevertheless, equivalent across studies, strengthens the reliability and generalizability of the finding.

Alternative Accounts

The frequency hypothesis can be contrasted with some alternatives. First, according to the adaptive value hypothesis, the neurocognitive system should preferentially detect and identify threat relative to non-threat signals, to quickly avoid or get ready to cope with potential harm. This implies that angry, fearful and, possibly, disgusted expressions should be processed earlier and more accurately than the others (Williams 2006). Against this prediction, however, happy and even surprised (neither clearly positive nor negative; Mendolia 2007) expressions are recognized more accurately than the negative ones. It is, nevertheless, possible that both hypotheses are valid depending on the type of processes involved. *Generic affective value* could be preferentially processed for negatively valenced expressions. Electrophysiological research has indeed shown that angry (Calvo et al. 2013; Rellecke et al. 2012; Schupp et al. 2004; Willis et al. 2010), fearful (Frühholz et al. 2009; Luo et al. 2010; Williams et al. 2006), and even disgusted faces (Sprengelmeyer and Jentzsch 2006), generally elicit neural activity earlier than other expressions. The early processing of the negative affective value would, nonetheless, be insufficient for identifying the *specific expressive category* (Calvo and Beltrán 2013). Such a process would require an additional step whereby a perceptual facial configuration is assigned to a conceptual category of the corresponding expression. It is for this additional discrimination between specific expressions that frequency would matter, and contribute to recognition differences.

Second, according to the saliency-and-distinctiveness hypothesis, the recognition advantage of happy expressions is due to their having a diagnostic, unique facial feature—a smile—that is also visually highly salient (Calvo et al. 2010, 2012). Non-happy expressions also have their own diagnostic facial features on which recognition relies, with angry and fearful expressions depending more on information in the eye region, disgust being conveyed mainly by the mouth, and sadness and surprise being similarly recognizable from both regions (Calder et al. 2000; Kohler et al. 2004; Nusseck et al. 2008; Smith et al. 2005). However, such non-happy eye or mouth regions are not so distinctive of the respective expressions, and they are not so salient, as the smile is for happy faces (Calvo et al. 2014). Accordingly, the saliency-and-distinctiveness hypothesis empirically predicts a recognition superiority of happy expressions over all the others—which is supported by the data—but not recognition differences among the non-happy expressions. The fact that such differences exist—albeit smaller and less consistent—reveals the limited and insufficient scope of this hypothesis. Therefore, to account for the recognition differences among the non-happy expressions, the saliency-and-distinctiveness hypothesis needs to be complemented with the frequency hypothesis: In the absence of clear differences in saliency and distinctiveness, the frequency of each expression predicts how easily it will be recognized.

Complementary Issues: Non-basic Expressions, Gender and Age

Although not central to the aims of this study, two issues deserve some consideration, as they add to prior research. One is concerned with the frequency of non-prototypical expressions; the other, with the role of gender and age of the expressers. Thus far, we have focused on the six basic expressions (i.e., happiness, anger, fear, sadness, disgust, and surprise; Ekman 1994). In real life, however, there is considerable individual idiosyncrasy and variability, with ambiguous or blended expressions being encountered often (Carroll and Russell 1997; Scherer and Ellgring 2007). Krumhuber and Scherer (2011) have presented evidence against the existence of fixed patterns of facial responses for each emotion. In the same vein, Riediger et al. (2011) have demonstrated that raters use multidimensional expression evaluation, as opposed to merely discrete categorizations. Consistent with this, in the current study, nearly one-third (29 %) of all the observed emotional faces could not be strictly assigned to any of the basic categories. We were, nevertheless, able to classify them into two groups, depending on whether they conveyed positive (love, enthusiasm, pride, interest, joy, pleasure, desire, hope, excitement, content; 16.1 % of frequency) or negative (shame, guilt, contempt, pain, anxiety, disappointment, frustration, helplessness; 12.9 % of frequency) feelings.

Regarding the effects of gender, the *relative* frequencies of expressions were equivalent for both females and males in the current study. Nevertheless, in *absolute* frequencies, emotional expressions were observed more often in females for all the prototypical expressions except anger, for which there was an opposite trend. This is consistent with prior research, where females have proved to be more expressive than males (see Brody and Hall 2008; Fischer et al. 2004; Gard and Kring 2007). Not only the reported emotional experience but also physiological responses and facial expressivity are enhanced for females (Bradley et al. 2001). Such gender differences appear early during childhood and increase with age (see Chaplin and Aldao 2013).

Regarding age, we found a decline of the frequency of emotional expressions in the elderly. Although this age cohort was under-represented, it is possible that old people are in fact less expressive, due to increased emotional control (Gross et al. 1997). It is also possible that facial expressions are more difficult to identify for older than for younger faces (Ebner et al. 2011; Riediger et al. 2011), due to the reduction of signal clarity, because of age-related loss of flexibility of muscle tissue, or wrinkles and folds in the skin (Hess et al. 2012). If so, not only would facial expressions of emotion be less observable on older faces, but differences among expressions would be less pronounced, which was the case in the current study.

Conclusions, Limitations and Implications

In normal daily life (in the three countries under comparison, i.e., Spain, Finland, and USA), happy faces are the most frequently observed, and fearful faces, the least, in comparison with the other basic emotional expressions: surprise, sadness, anger, and disgust (in decreasing order of observed frequency). This pattern is highly consistent: (a) correlations between objective observations and retrospective estimates range between .83 and 1; and (b) the retrospective estimates of expression frequency correlate between .71 and .94 across three countries. Most importantly, there is a significant correlation (generally, >.70) between the frequency of facial expressions in daily social settings and the accuracy and speed with which expressions are identified in cross-cultural and laboratory studies: The more frequently an expression occurs, the more accurately and faster it is recognized. This suggests that frequency contributes to recognition and that frequency accounts for the recognition differences among expressions. We must, nevertheless, note that all three countries share some cultural similarities as Western societies, and "normal daily life"—and therefore the relative frequencies of expressions—might be somewhat different in other cultures.

Some limitations of the current approach and their theoretical implications must be acknowledged. First, we have assumed that the observers can accurately recognize the emotions conveyed by the expressers. To this end, the participants in this study were trained in expression categorization. The observers later reported confidence in their identification of expressions during the observation process. In addition, we might think that expression recognition in a real-life situation—with expressions unfolding dynamically in relation to contextual changes—could be easier than in a typical categorization task with decontextualized and static displays of photographic faces.[1] Nevertheless, the context itself can probably affect the observers in a number of ways, making them less than purely objective decoders of the expressions they see. Particularly in situations of close personal or social interaction, the observers cannot keep a detached attitude. In such situations, the presence of the observer might alter the frequency of expressions, by inhibiting some emotions and facilitating others. Also, the observers' involvement in the interaction might prevent them from keeping strict on-line recording, and then bias their memory of the frequency of the previously observed expressions.[2] This might thus reduce the reliability of the measurement.

[1] In fact, dynamic expressions are recognized more easily and accurately than static expressions (Recio et al. 2013), and expressive facial movement benefits multiple aspects of emotion recognition (Krumhuber et al. 2013), at least in laboratory conditions. Also, the emotions in facial expressions are made meaningful in context (Hassin et al. 2013), which would attune perceivers to distinctions between expressions (Parkinson 2013). Nevertheless, the empathic accuracy literature (see Flury and Ickes 2001; Rollings et al. 2011) suggests that natural or spontaneous expressions in real-life situations or in vivo tasks (even though dynamic and contextualized) might be more difficult to recognize than static and isolated prototypical expressions.

[2] Often, observers had to interact with the expresser. In such cases, the recording had to be made off-line, i.e., delayed until the end of the interaction. It is possible that, in those conditions, the recording accuracy suffered, due to reliance on memory. We do not know whether the off-line recording affected all the expressions similarly. No observer, however, mentioned this type of difficulty in the interview with the researchers at the end of the observation period. In addition, a strict dichotomy between interactive and non-interactive contexts, and the corresponding comparisons to address this issue, could not be made because of the great variability of situations.

Second, we have assumed that the collected observational measures represent the frequencies with which expressions really *occurred*. However, we might argue that observation scores reflected the expressions that were *noticed* by the observers. Given that some expressions have proved to be recognized better and faster than others in judgment and categorization tasks with photographic stimuli, it is possible that, in the current study, they were noticed more (or less) frequently because they were more (or less) *easily recognizable* when they occurred, regardless of their frequency. Although this interpretation cannot be ruled out, we can probably downplay its importance when expressions occur in real situations. In isolated and static displays of photographic facial expressions, recognition needs to rely on the noticeable facial features, as this is the only available information. In contrast, contextual information and expressive movement in real situations presumably facilitate emotion recognition for *all* the expressions, thus making recognition much less dependent on the morphological pattern or features of the face. If so, we could expect that the observed frequencies did correspond to the actual occurrence of each expression, rather than merely to perceived noticeability.[3]

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Conflict of interest The authors declare that they have no conflict of interest.

Appendix

See Table 5.

Table 5 Mean recognition accuracy and latency of correct responses (RTs) in cross-cultural (see Nelson and Russell 2013) and prior laboratory studies (Calder et al. 2000; Calvo and Lundqvist 2008; Calvo and Nummenmaa 2009; Elfenbein and Ambady 2003; Palermo and Coltheart 2004)

	Emotional facial expression					
	Happiness	Surprise	Sadness	Anger	Disgust	Fear
Nelson and Russell (2013)						
Accuracy (Western) (%)	89	81	74	75	65	69
Accuracy (Non-western) (%)	91	86	67	61	52	46
Accuracy (Illiterate) (%)	88	54	51	33	44	30
Accuracy (Combined) (%)	90	71	68	61	57	55
Calder et al. (2000)						
Accuracy (%)	99	79	91	78	86	75

[3] To disentangle these two possibilities (i.e., that either the actual occurrence or rather the perceived noticeability can account for the observed frequencies), an experimental approach should manipulate the objective frequency of expressions while keeping the recognition demands constant; or, alternatively, the easiness of recognition should be varied while keeping the frequency constant. However, although this approach could possibly be implemented under laboratory conditions, it would denaturize the real experience people gather from their normal social life.

Table 5 continued

	Emotional facial expression					
	Happiness	Surprise	Sadness	Anger	Disgust	Fear
Manual RTs (ms)	1,178	1,748	1,742	1,910	1,738	2,041
Elfenbein and Ambady (2003)						
Accuracy (%) *	1.415	0.769	0.787	0.497	0.578	0.462
Manual RTs (ms) #	3.19	3.42	3.48	3.54	3.46	3.53
Palermo and Coltheart (2004)						
Accuracy (%)	99	85	62	83	68	52
Vocal RTs (ms)	634	1,409	1,940	1,456	1,868	2,710
Calvo and Lundqvist (2008)						
Accuracy (Free Time) (%)	98	86	87	89	87	79
Accuracy (25–500 ms display)	98	81	85	85	82	75
Manual RTs (ms)	1,091	1,299	1,508	1,444	1,361	1,715
Calvo and Nummenmaa (2009)						
Accuracy (Free Time) (%)	88	87	71	72	85	75
Saccadic RTs (ms)	286	299	306	311	303	309

Elfenbein and Ambady (2003) reported the arcsin-transformed scores (*) for accuracy and the logn-transformed scores (#) for response latencies, rather than the raw scores. The average scores for the American and the Chinese expressions are reported here

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