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Recognition of all basic emotions varies in accuracy and reaction time: A new verbal method of measurement

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To study different aspects of facial emotion recognition, valid methods are needed. The more widespread methods have some limitations. We propose a more ecological method that consists of presenting dynamic faces and measuring verbal reaction times. We presented 120 video clips depicting a gradual change from a neutral expression to a basic emotion (anger, disgust, fear, happiness, sadness and surprise), and recorded hit rates and reaction times of verbal labelling of emotions. Our results showed that verbal responses to six basic emotions differed in hit rates and reaction times: happiness > surprise > disgust > anger > sadness > fear (this means these emotional responses were more accurate and faster). Generally, our data are in accordance with previous findings, but our differentiation of responses is better than the data from previous experiments on six basic emotions.

Keywords: Facial emotion recognition; Verbal reaction; Basic emotions; Emotion; Reaction times.

Emotional facial expressions of conspecifics are crucial stimuli that provoke different adaptive reactions. In human culture, an adequate recognition of emotional facial expressions is required in interpersonal and professional communication. Previous research accumulated extensive knowledge about how emotions are recognised from facial expressions. Furthermore, many researchers have studied why individuals with psychiatric and neurological diseases are often impaired in their ability to recognise facial emotion expressions (see a recent review of Collin, Bindra, Raju, Gillberg, & Minnis, 2013).

To study different aspects of facial emotion recognition, valid methods are needed. The most prevalent of these methods, to our knowledge, is to present to participants static photographic pictures of emotional faces and ask them to label these emotions. For example, in two systematic reviews, describing impairments of facial emotion recognition in depression (Dalili, Penton-Voak, Harmer, & Munafò, 2015) and alexithymia (Grynberg et al., 2012), we found 41 studies where pictures were used as stimuli, and only six studies where video clips were used. Several sets of pictures were used in previous research. Some of them have been standardised, that is, the means and standard deviations of all pictures were obtained in large samples and can be compared to future results. Palermo and Coltheart (2004) standardised five different databases by Ekman and Friesen (1976), Gur et al. (2002), Mazurski and Bond (1993), Tottenham, Borscheid, Ellertsen, Marcus, and Nelson (2002). Goeleven, De Raedt, Leyman, and Verschuere (2008) standardised the Karolinska Directed Emotional Faces collection (Lundqvist, Flykt, & Öhman, 1998), that we used in our study. Despite the high popularity of static pictures in studies of facial emotion recognition, we suggest that this way of stimulus presentation is not ecologically valid or realistic. Krumhuber, Kappas, and Manstead (2013) noted in their review that dynamic information improves coherence in the identification of emotion and helps differentiate between genuine and fake expressions. Moreover, neurological data suggest that there are different pathways for recognition of static and dynamic faces (Kilts, Egan, Gideon, Ely, & Hoffman, 2003). As Krumhuber, Kappas, and Manstead (2013, p. 44) concluded, "we will fail to arrive at a proper understanding of what faces do if we continue to use static snapshots of faces as a paradigm for researching facial expressions." It is important to note that the databases of facial emotion video clips began to appear (e.g., Qu, Wang, Yan, & Fu, 2016), however, as it has been noted in the reviews and meta-analyses mentioned throughout our article, the great majority of scientists prefer to use pictorial stimuli.

Another way to present faces is the so-called morph task. Participants gradually scroll a facial photograph from the neutral expression to an emotion (Niedenthal, Halberstadt, Margolin, & Innes-Ker, 2000) or from one emotion to another (Kosonogov, Titova, & Vorobyeva,

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2015) and should indicate at what frame each emotion appears on the face. This way seems less ecological than video clips because in daily life people cannot "scroll" faces of others. There are also some indirect methods of studying facial emotion recognition, like the filtration of emotional faces from different stimuli or decision on the gender of actors, but they examine a possible influence of emotional load on other variables rather than the recognition of emotions.

Another question is what variables we should measure to study facial emotion recognition. Most researchers record only hit rates (i.e., the percentage of right answers). For example, in their review of 29 studies of schizophrenia Edwards, Jackson, and Pattison (2002) found only six studies that measured reaction times of facial emotion recognition and supposed that correspondent deficits in patients could be found, among other things, by the measurement of reaction times. We suppose that reaction times could provide a better differentiation between participants and between stimuli.

The third characteristic of experiments on recognition is the way participants are asked to react to stimuli. Typically, participants are asked to press a button. But when there are six alternatives (six basic emotions), the reactions are supposed to be influenced by other variables (e.g., memory volume, the position of the finger between six buttons, etc.). That is why we decided to employ a rarely used method of measurement of verbal reaction times. It is convenient for participants because they do not need to remember button labels. They loudly speak words into a microphone. We found only several articles where verbal reaction times to facial emotions were analysed; although static pictures (Palermo & Coltheart, 2004) or chimeric faces (David, 1993) were used in those studies, or no between-emotion data were presented (Weathers, 2004).

Overall, we combined three features to make our paradigm more realistic: (a) the presentation of dynamic faces (like in most everyday situations), (b) the measurement of reaction times (not only hit rates as in most studies), and (c) verbal reaction (without remembering button labels). To test this paradigm we compared the hit rates and reaction times of verbal responses to six basic facial emotional expressions (anger, disgust, fear, happiness, sadness, surprise; Ekman & Friesen, 1976). Previous experiments showed some differences between reactions to different emotions. Happiness was recognised more accurately and faster than other emotions, and fear was recognised less accurately and slower than other emotions, whereas reactions to other emotions did not differ (Palermo & Coltheart, 2004). Goeleven et al. (2008), measuring only hit rates, found the same pattern. The most subtle differences we found in the literature were reported by Kirouac and Doré (1983). In their study (static pictures and pressing buttons were used), happiness was recognised more accurately than all basic emotions, except for surprise. Surprise was recognised more accurately than sadness and fear. Recognition of disgust was more accurate than of sadness and fear and finally, anger and sadness had better recognition levels than fear. Happiness and surprise were recognised faster than anger, sadness and fear. Disgust was recognised faster than fear; whereas reaction times to anger, sadness and fear did not differ significantly. We hypothesised that our paradigm would distinguish reactions to basic emotions. Video clips would differentiate participants between each other and emotions between each other better than static pictures do, because some emotions are recognised at earlier frames than others (Kosonogov et al., 2015). Reaction time measurement would find subtle differences that have not been found with the hit rate measurement (that has a less precise scale).

METHODS

Participants

A sample of 66 student volunteers (51 females and 15 males), aged between 18 and 64 (Mean = 25.6; SD = 6.4), participated in the study. All subjects gave informed consent and received course credits for participation in the experiment. All procedures were conducted in accordance with the Declaration of Helsinki.

Materials and design

We used 120 video clips that we made from 140 coloured photographs[1] of faces from the Karolinska Directed

[1]The photographs from the KDEF used in the study are AM1AFS, AM1ANS, AM1DIS, AM1HAS, AM1NES, AM1SAS, AM1SUS, BM5AFS, BM5ANS, BM5DIS, BM5HAS, BM5NES, BM5SAS, BM5SUS, AM6AFS, AM6ANS, AM6DIS, AM6HAS, AM6NES, AM6SAS, AM6SUS, AM10AFS, AM10AN, AM10DIS, AM10HAS, AM10NES, AM10SAS, AM10SUS, BM11AFS, BM11ANS, BM11DIS, BM11HAS, BM11NES, BM11SAS, BM11SUS, BM12AFS, BM12ANS, BM12DIS, BM12HAS, BM12NES, BM12SAS, BM12SUS, AM14AFS, AM14ANS, AM14DIS, AM14HAS, AM14NES, AM14SAS, AM14SUS, AM23AFS, AM23ANS, AM23DIS, AM23HAS, AM23NES, AM23SAS, AM23SUS, BM25AFS, BM25ANS, BM25DIS, BM25HAS, BM25NES, BM25SAS, BM25SUS, BM31AFS, BM31ANS, BM31DIS, BM31HAS, BM31NES, BM31SAS, BM31SUS, AF1AFS, AF1ANS, AF1DIS, AF1HAS, AF1NES, AF1SAS, AF1SUS, BF3AFS, BF3ANS, BF3DIS, BF3HAS, BF3NES, BF3SAS, BF3SUS, AF7AFS, AF7ANS, AF7DIS, AF7HAS, AF7NES, AF7SAS, AF7SUS, BF9AFS, BF9ANS, BF9DIS, BF9HAS, BF9NES, BF9SAS, BF9SUS, BF10AFS, BF10ANS, BF10DIS, BF10HAS, BF10NES, BF10SAS, BF10SUS, BF16AFS, BF16ANS, BF16DIS, BF16HAS, BF16NES, BF16SAS, BF16SUS, AF19AFS, AF19ANS, AF19DIS, AF19HAS, AF19NES, AF19SAS, AF19SUS, BF20AFS, BF20ANS, BF20DIS, BF20HAS, BF20NES, BF20SAS, BF20SUS, AF25AFS, AF25ANS, AF25DIS, AF25HAS, AF25NES, AF25SAS, AF25SUS, AF26AFS, AF26ANS, AF26DIS, AF26HAS, AF26NES, AF26SAS, AF26SUS.

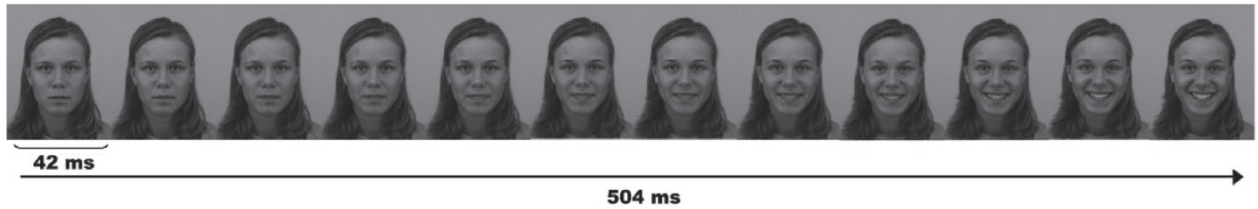

Figure 1. The structure of a video clip depicting happiness.

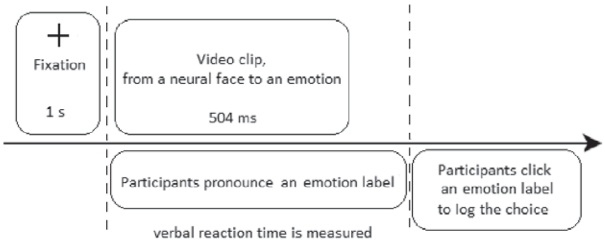

Figure 2. The flowchart of a trial.

Emotional Faces collection (KDEF; Lundqvist et al., 1998). There were coloured full-face photographs of 10 Nordic men and 10 Nordic women (randomly chosen from KDEF) depicting seven facial expressions: anger, disgust, fear, happiness, sadness, surprise and neutral. With the help of the software Sqirlz Morph 2.1 by Xiberpix, we made 120 "neutral-emotion" morph pairs (six emotional expressions × 20 actors). In the photos, we indicated key points of the face for the software to prepare a gradual change of 12 frames from the first neutral expression to the final emotional one. Thus, each video clip contained 12 frames (42 ms each) and lasted 504 ms (Figures 1 and 2). The trials were quasi-randomised: each quarter of trials (1–30, 31–60, 61–90 and 91–120) contained the same number (5) of each emotion. An emotion or an actor was not presented more than twice in a row. All participants viewed the same sequence of 120 video clips.

Procedure

The participants were seated in the experimental chamber in front of a 19-inch computer screen at the distance of 60 cm. A microphone (frequency band: 20–16,000 Hz; sensitivity: 54 dB; impedance: 2.2 kΩ) was attached to their auricles so that its sensor was 2 cm from their lips and could not be moved by involuntary movements. Participants were told that they would watch video clips depicting six basic emotions. The experiment was conducted in OpenSesame. Each trial began with a fixation period (a cross in the middle of the screen for 1 second), then participants were presented with a video clip for 504 ms. They were asked to announce loudly the emotion label as soon as possible (verbal reaction times were measured). Then the emotion labels appeared, and participants clicked a corresponding label to indicate what emotion they had just recognised (labels in their native language were sorted alphabetically: anger, disgust, sadness, happiness, fear, surprise). A technician watched participants' actions on her screen to confirm that they clicked the same label that they pronounced, and to correct the log file, if needed.[2] Participants rested as long as necessary, and then clicked the "next" button to watch the next trial. Before the experimental session, participants passed six training trials demonstrating each emotion on the face of an actor who was not presented in the experimental session.

Data acquisition and analysis

Two dependent variables were analysed: the hit rates and verbal reaction times of the right answers. Hit rates were defined as the percentage of right answers. We also built a confusion matrix and calculated unbiased hit rates, as proposed by Wagner (1993). As dependent variables were not normally distributed (Shapiro–Wilk's Ws < .95, ps < .05), nonparametric statistical methods were applied. For each dependent variable, we performed Friedman analysis of variance for dependent samples with six levels of the independent variable emotion (anger, disgust, fear, happiness, sadness and surprise) and *post-hoc* analysis (each level with all the other levels) based on mean rank differences, recommended for non-parametrical analysis of variance (Conover, 1980). Kendall's W was used to measure the level of agreement between participants (an analogue of effect size that ranges from 0 to 1; .7 meaning a strong agreement). We also calculated effect sizes (Cohen's d) between all pairs of discrete emotions for both hit rates and verbal reaction times.

[2]Participants clicked a title on the screen that did not correspond to the verbal reaction 15 times of 7920 trials (66 participants × 120 trials). That was corrected in the log file.

TABLE 1
Descriptive statistics of hit rates of emotion recognition and mean rank differences between discrete emotions

				The mean rank difference from				
	Median	*IQR*	*The mean rank*	*Surprise*	*Disgust*	*Anger*	*Sadness*	*Fear*
Happiness	100.0	100.0–100.0	5.64	**0.92**[a]	**1.71**[a]	**2.44**[a]	**3.23**[a]	**4.55**[a]
Surprise	95.0	95.0–90.0	4.72		**0.79**[a]	**1.52**[a]	**2.31**[a]	**3.63**[a]
Disgust	89.7	94.7–84.2	3.93			**0.73**[a]	**1.52**[a]	**2.84**[a]
Anger	82.8	88.8–77.7	3.20				**0.80**[a]	**2.11**[a]
Sadness	75.0	85.0–61.1	2.41					**1.32**[a]
Fear	36.8	55.0–25.0	1.09					

[a]Critical rank difference ($p < .05$) was computed as 0.30.

TABLE 2
Means, standard deviations of hit rates of emotion recognition and effect sizes between discrete emotions

			Cohen's d				
	Mean	*SD*	*Surprise*	*Disgust*	*Anger*	*Sadness*	*Fear*
Happiness	98.62	2.90	**1.15**	**1.80**	**2.50**	**2.41**	**5.31**
Surprise	91.97	8.71		**0.46**	**1.00**	**1.42**	**3.71**
Disgust	87.94	8.98			**0.55**	**1.12**	**3.39**
Anger	82.76	9.79				**0.73**	**2.93**
Sadness	72.34	18.90					**1.68**
Fear	40.62	18.95					

RESULTS

Hit rates

We found a significant main effect of emotion on hit rates, $\chi^2(5,\ 66) = 256.1$, $p < .001$, $W = .78$. *Post-hoc* analysis of mean rank differences showed that reactions to each emotion significantly differed: happiness was recognised better than surprise; surprise better than disgust; disgust better than anger and so on (Tables 1 and 2).

We also constructed the confusion matrix of responses (the percentage of hits, misses and false alarms) and calculated unbiased hit rates (Table 3). We found only one case where false alarms were greater than the random probability of 16.67% (participants responded *surprise* instead of *fear* in 34.92% of cases). In addition, when unbiased hit rates were used, anger occupied second place, while surprise went down to fourth place (first place means the best recognition here).

Verbal reaction times

We found a significant main effect of emotion on verbal reaction times, $\chi^2(5,\ 66) = 213.3$, $p < .001$, $W = .71$. *Post-hoc* analysis of mean rank differences showed that reactions to each emotion significantly differed: happiness was recognised faster than surprise; surprise faster than disgust; disgust faster than anger and so on (Tables 4 and 5).[3]

DISCUSSION

Our results showed that verbal responses to six basic emotions differed in hit rates and reaction times (happiness > surprise > disgust > anger > sadness > fear). Generally, our data are in accordance with previous findings. Happiness was recognised better than other emotions; recognition of fear was the worst, like in the studies mentioned above. In addition, Kirouac and Doré's pattern (1983) seems to be our pattern's fragment. Their results, both for hit rates (happiness > disgust, anger, sadness > fear; surprise > sadness) and for reaction times (happiness > anger, sadness, fear; surprise > anger, sadness, fear; disgust > fear), correspond closely to our more general pattern (happiness > surprise > disgust > anger > sadness > fear). Overall, our differentiation of responses to emotions is better than the data of the experiments on six basic emotions we found in the literature (e.g., Goeleven et al., 2008; Palermo & Coltheart, 2004). Incidentally, Palermo and Coltheart (2004), who recorded verbal reactions to static emotional faces, found similar results, but not so

[3]Using the same procedure, we also analysed the verbal reaction times of all participants to the six emotion labels (words written on the screen). We did not find a main effect of words on reaction times ($p = .31$); the means of verbal reaction times to different labels were 565–607 ms. We suggest these data allow us to conclude that differences in the pronunciation of emotion labels did not influence the verbal reaction times to video clips with emotional faces.

TABLE 3
The percentage of responses to each stimulus type and unbiased hit rates

		Responses						
		Anger	*Disgust*	*Sadness*	*Happiness*	*Fear*	*Surprise*	*Unbiased hit rates*
Stimuli	Anger	82.76	6.80	2.99	0.00	1.72	5.73	72.03
	Disgust	7.51	87.94	3.24	0.08	0.40	0.84	67.33
	Sadness	2.25	13.66	72.34	0.69	3.08	7.98	58.53
	Happiness	0.30	0.46	0.00	98.62	0.15	0.46	93.85
	Fear	3.23	8.84	12.17	0.23	40.62	34.92	34.90
	Surprise	0.00	0.08	0.08	4.19	3.69	91.97	62.50
	Sum of responses	96.05	117.78	90.81	103.81	49.66	141.89	

TABLE 4
Descriptive statistics of verbal reaction times of emotion recognition and mean rank differences between basic emotions

				The mean rank difference from				
	Median	*IQR*	*The mean rank*	*Surprise*	*Disgust*	*Anger*	*Sadness*	*Fear*
Happiness	1117.0	1242–1025	1.14	**1.18**[a]	**2.21**[a]	**3.08**[a]	**3.47**[a]	**4.24**[a]
Surprise	1296.3	1525–1164	2.32		**1.03**[a]	**1.89**[a]	**2.29**[a]	**3.06**[a]
Disgust	1600.2	1752–1423	3.35			**0.86**[a]	**1.26**[a]	**2.03**[a]
Anger	1791.3	2081–1465	4.21				**0.39**[a]	**1.17**[a]
Sadness	1823.4	2039–1567	4.61					**0.77**[a]
Fear	2129.8	2438–1787	5.38					

[a]Critical rank difference ($p < .05$) was computed as 0.35.

precise (a small number of significant differences). We suggest that the usage of video clips in our study led to smaller standard deviations and greater differences: SDs of hit rates for each emotion = 2.90–18.75 (mean $SD = 11.37$) in our study and SDs of hit rates for each emotion = 2.83–28.75 (mean SD = 20.17) in their study; SDs of reaction times for each emotion = 337.15–978.50 (mean SD = 580.43) in our study and SDs of reaction times for each emotion = 186.23–1155.17 (mean SD = 746.35) in their study.

As in many studies (e.g., Zhao, Zhao, Zhang, Cui, & Fu, 2017), our participants confused fearful and surprised faces. They responded *surprise* instead of *fear* in 34.92% of cases (that is greater than the random probability). A probable reason is that eyes and mouths are open in both expressions. However, in our study the differences between fear and surprise in both the hit rates and reaction times were significant.

It is important to note that some authors reported other patterns of differences between emotions. For example, Gosselin and Larocque (2000) presented emotional faces to children and found that sadness was recognised more accurately than anger, fear and disgust. In a similar study of Boyatzis, Chazan, and Ting (1993), anger was the least recognised expression. However, in both studies, the number of trials was very small (one or three of each basic emotion) and the photographs were accompanied by brief descriptions of situations that provoked emotions, that, perhaps, facilitated the recognition. We are inclined to believe that the specifics of each method could cause the results to be different from the typical pattern.

We suppose that both the applied method and the discovered pattern may have practical implications. For example, anxious people recognise fear better than control participants (Surcinelli, Codispoti, Montebarocci, Rossi, & Baldaro, 2006). Antisocial populations, on the contrary, demonstrate specific deficits in recognising fearful expressions (see a meta-analysis of Marsh & Blair, 2008). However, behavioural studies of facial emotion recognition in autism spectrum disorder patients (see a review of Uljarevic & Hamilton, 2013) and borderline personality disorder patients (see a meta-analysis of Mitchell, Dickens, & Picchioni, 2014) have led to controversial results. Both groups of authors pointed to inconsistencies of experimental paradigms in different studies that led to different results. Thus, Uljarevic and Hamilton (2013) noted that many researchers did not measure reaction times that makes a meta-analysis impossible. This measure, however, would reveal subtle differences between patients and non-patients. We suggest that our paradigm may provide a better differentiation of responses in studies, where facial emotion recognition is a crucial variable and reveal new relationships between variables under study: both the characteristics of patients and stimulus features.

We also should outline some limitations of our paradigm. Like in most studies on emotion recognition, we applied forced choice. In other words, participants were asked to choose an emotion from the list that we

TABLE 5
Means, standard deviations of verbal reaction times of emotion recognition and effect sizes between discrete emotions

			Cohen's d				
	Mean	*SD*	*Surprise*	*Disgust*	*Anger*	*Sadness*	*Fear*
Happiness	1194.00	346.70	**0.55**	**1.18**	**1.65**	**1.61**	**1.91**
Surprise	1383.46	337.15		**0.68**	**1.23**	**1.31**	**1.63**
Disgust	1632.63	396.11			**0.61**	**0.87**	**1.20**
Anger	1915.19	524.91				**0.39**	**0.71**
Sadness	2196.20	899.22					**0.27**
Fear	2451.15	978.50					

proposed. However, as we wanted to measure reaction times, we had to give a simple and definite set of possible answers. In our opinion, free labelling could lead to very diverse reaction times. In addition, more stimuli should be examined with our paradigm. For example, a greater variety of faces expressing basic emotions, such as children's and elderly people's faces, and the faces of different ethnicities. Facial emotion recognition is influenced by age (Durand, Gallay, Seigneuric, Robichon, & Baudouin, 2007), sex (Hoffmann, Kessler, Eppel, Rukavina, & Traue, 2010), ethnicity (see a meta-analysis of Elfenbein & Ambady, 2002) and other typical characteristics. For this reason, these variables could be examined with our paradigm with the aim of detecting subtle individual differences. As our method enabled us to reveal the differences in recognition of all facial emotions, we admit that future studies could find differences in recognition of facial emotions between representatives of different groups (e.g., whether young or elderly people recognise some emotions more accurately and faster).

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