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Assessment of perception of morphed facial expressions using the Emotion Recognition Task: Normative data from healthy participants aged 8–75

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The ability to recognize and label emotional facial expressions is an important aspect of social cognition. However, existing paradigms to examine this ability present only static facial expressions, suffer from ceiling effects or have limited or no norms. A computerized test, the Emotion Recognition Task (ERT), was developed to overcome these difficulties. In this study, we examined the effects of age, sex, and intellectual ability on emotion perception using the ERT. In this test, emotional facial expressions are presented as morphs gradually expressing one of the six basic emotions from neutral to four levels of intensity (40%, 60%, 80%, and 100%). The task was administered in 373 healthy participants aged 8–75. In children aged 8–17, only small developmental effects were found for the emotions anger and happiness, in contrast to adults who showed age-related decline on anger, fear, happiness, and sadness. Sex differences were present predominantly in the adult participants. IQ only minimally affected the perception of disgust in the children, while years of education were correlated with all emotions but surprise and

The Emotion Recognition Task that includes the norms described in this paper is distributed as part of the computerized DiagnoseIS neuropsychological assessment system (www.diagnoseis.com) free of charge, available in English, Dutch, German, and French. The authors of this article are in no way affiliated with the publisher of this computerized assessment system.

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disgust in the adult participants. A regression-based approach was adopted to present age- and education- or IQ-adjusted normative data for use in clinical practice. Previous studies using the ERT have demonstrated selective impairments on specific emotions in a variety of psychiatric, neurologic, or neurodegenerative patient groups, making the ERT a valuable addition to existing paradigms for the assessment of emotion perception.

The ability to perceive emotional facial expressions is important for everyday social interaction and interpersonal communication. Numerous studies have identified six basic emotions that can be universally recognized: anger, disgust, happiness, surprise, sadness, and fear (see, for instance, Ekman, 1992). Prefrontal and temporal-lobe structures are important in the perception of these emotions in general (Ruffman, Henry, Livingstone, & Phillips, 2008), and there is some evidence that specialized brain regions may be involved in the recognition of specific emotions. For example, the amygdala may be specialized in threat perception (LeDoux, 2003) and as such is also implicated in the perception of fearful facial expressions, which may signal threat (Adolphs, 2008). In addition, disgusted facial expressions may elicit activation of the insular cortex (Aleman & Swart, 2008; Schienle, Schäfer, & Vaitl, 2008), whereas angry facial expressions activate the orbitofrontal and cingulate cortex (Blair, Morris, Frith, Perrett, & Dolan, 1999). The notion that specific emotions have their own 'neural substrate' is also supported by evidence showing selective impairments in emotion perception in patients with psychiatric disorders, such as depression or schizophrenia (Garrido-Vásquez, Jessen, & Kotz, 2011), and neurological disorders, for example, Huntington's disease (Henley *et al.*, 2012).

Perception of facial emotional expressions is also mediated by other variables, such as other cognitive abilities, age, and sex. For example, Ruffman *et al.* (2008) performed a meta-analysis on 17 studies comparing young adults with older people with respect to emotion perception (total $N = 1397$). They demonstrated large age-related effect sizes for the emotions anger, sadness and fear, and only small effect sizes for the emotions surprise and happiness, with older people performing worse than the young adults. A non-significant reverse trend was found for the emotion disgust, with older people being able to label this emotion better compared with the young. However, these findings were limited to the perception of full-blown emotional facial expressions or ambiguous morphs (e.g., videos morphing from one to another emotion). Another limitation of the studies reported in that meta-analysis is that young adults and older adults were compared using a dichotomous approach, rather than looking at life span-related changes in a more continuous manner (e.g., regression-based). Also, developmental changes in children were not considered. More recent large-sample studies examined the perception of morphed facial expressions, that is, expressions gradually changing from a neutral face to a full-blown emotional expression. West *et al.* (2012) demonstrated negative age effects for fearful, angry, and sad expressions in a large group of participants ($N = 482$) using morphed emotional facial expressions at different levels of intensities. In addition, Horning, Cornwell, and Davis (2012) studied 732 participants using facial stimuli morphing from neutral to full-blown emotional expressions, also including children from the age of 5. Here, they demonstrated an inverted U-shaped trajectory for emotion perception ability. An increase in the ability to correctly label facial emotional expressions was found during childhood and adolescence, while in (older) adults, the overall emotion perception ability deteriorated especially for the emotions fear, sadness, and happiness. Thus, existing studies point towards an ageing-related decline in the ability to perceive the negative emotions anger, fear and sadness, while reporting a clear improvement in overall emotion perception during development.

Another factor potentially affecting emotion perception is sex. For example, Campbell *et al.* (2002) showed a more accurate performance in women for the emotions anger and disgust. In addition, Montagne, Kessels, Frigerio, De Haan, and Perrett (2005) demonstrated sex differences in the advantage of women for the emotions sadness, surprise, anger, and disgust. Whittle, Yücel, Yap, and Allen (2011) reviewed the literature on sex differences for emotion perception in relation to neuroimaging, and showed that females displayed higher temporal-limbic activation levels than men during emotion perception, even if the performance accuracy did not differ between men and women. While most studies showed a female advantage in emotion perception, mixed results have been reported with respect to the selectivity of the findings, possibly also due to methodological issues (see Kret & De Gelder, 2012, for a review).

Finally, other cognitive functions have been found to affect emotion perception. For example, it has been suggested that overall ageing-related cognitive decline may explain the overall decrements in emotion perception, but this cannot explain the selectivity of some of the findings (Ruffman *et al.*, 2008). For example, a recent study by Suzuki and Akiyama (2012) showed that overall cognitive ability could not account for ageing-related decline in the ability to perceive anger and disgust. Also, difference in intellectual ability have been found to uniquely affect perception of the emotions anger, surprise, and disgust (Horning *et al.*, 2012). As many emotion perception tasks require participants to label emotions verbally, verbal intellectual ability should be taken into account when examining individual differences in emotion perception (Montebarocci, Surcinelli, Rossi, & Baldaro, 2011).

An example of an emotion perception task that is widely used in clinical practice is the Ekman 60 Faces Test included in the FEEST (Young, Perrett, Cabler, Sprengelmeyer, & Ekman, 2002). In this test, 60 black and white photographs of full-blown, easy-to-recognize facial expressions of the six basic emotions are presented (male and female). This test – or variations thereof – has been used in studies on emotion perception in a wide range of clinical disorders, such as Huntington's disease (Henley *et al.*, 2012), multiple sclerosis (Henry *et al.*, 2011), traumatic brain injury (Bornhofen & McDonald, 2008), Alzheimer's disease (McCade, Savage, & Naismith, 2011), and Parkinson's disease (Gray & Tickle-Degnen, 2010). While the Ekman 60 Faces Test has proven very useful in clinical practice, it also has some limitations. First, a ceiling effect is present for the emotion happiness (mean performance of 9.9 from a maximum of 10 in healthy participants). Near-ceiling performances for recognition of this emotion are commonly found (see, e.g., Suzuki, Hoshino, & Shigemasu, 2006), as happy faces are easy to recognize in the absence of other positive emotions as possible distractors. However, although ceiling performances do not affect a test's specificity, they do reduce a test's sensitivity, which may be problematic in clinical practice. Second, only full-blown emotional expressions are presented in the Ekman 60 Faces Test. It could be argued that presenting facial expressions at lower intensities would promote the detection of more subtle performance differences. Third, the stimuli are static photographs. It has been suggested that dynamic presentation of facial expressions (i.e., a neutral face gradually unfolding into an emotional expression) would, to a greater extent, resemble facial expression in everyday communication (Kamachi *et al.*, 2001). Furthermore, movement is an important aspect of the perception of facial expressions that may even affect the accuracy of the perception (see Fiorentini & Viviani, 2011, for a discussion).

To overcome these shortcomings, the Emotion Recognition Task (ERT) was developed, in which dynamically morphed facial expressions of the six basic emotions are presented at different levels of intensities (Montagne, Kessels, De Haan, & Perrett, 2007). This paradigm (sometimes with slight variations in the administration procedure) has been validated in various patient groups, such as Korsakoff's amnesia (Montagne, Kessels, Wester, & De Haan, 2006), obsessive-compulsive disorder (Montagne *et al.*, 2008), bipolar disorder (Gray *et al.*, 2006), post-traumatic stress disorder (Poljac, Montagne, & De Haan, 2011), amygdalectomy (Ammerlaan, Hendriks, Colon, & Kessels, 2008), Huntington's diseases (Montagne, Kessels, Kammers, *et al.*, 2006), frontotemporal dementia (Kessels *et al.*, 2007), schizophrenia (Scholten, Aleman, Montagne, & Kahn, 2005), autism spectrum disorder (Law Smith, Montagne, Perrett, Gill, & Gallagher, 2010), social phobia (Montagne, Schutters *et al.*, 2006), depersonalisation disorder (Montagne, Sierra *et al.*, 2007) and stroke (Montagne, Nys, Van Zandvoort, Kappelle, De Haan, & Kessels, 2007). To date, this test could not be used for neuropsychological assessment in clinical practice, but the ERT has recently been made available as part of the computerized *DiagnoseIS* neuropsychological assessment system (www.diagnoseis.com).

The aim of the present study is twofold (1) to examine effects of age, sex, and intellectual ability on the performance on the ERT, which employs morphed stimuli for different emotional intensities in a group of healthy participants; (2) to use these results to construct normative data that can be used in clinical practice, using a wide age range of participants between 8 and 75.

Methods

Participants

A total of 373 healthy volunteers (186 males) participated. Inclusion criteria for all participants were normal or corrected-to-normal vision and no history of neurological or psychiatric disease. A group of 163 typically developing children aged 8–17 were recruited through two regular primary schools ('De Wegwijzer' in Den Dungen and 'De Wingerd' in Tegelen) and one secondary school ('De Isselborgh' in Doetinchem) in the Netherlands, and from secondary schools from the Dublin area in Ireland. All children were recruited as healthy controls for studies on Autism Spectrum Disorders (see, e.g., Kessels, Spee, & Hendriks, 2010; Law Smith *et al.*, 2010). Participation was approved by the local school boards, informed consent was obtained from all children's parents, and assessment took place individually inside the child's school. Depending on the study sample and child's age, intelligence was assessed using Raven's Coloured or Standard Progressive Matrices (Raven, Raven, & Court, 1998), the Groningen/Netherlands Educational Intelligence tests (GIVO; Van Dijk & Tellegen, 1994; /NIO; Van Dijk & Tellegen, 2004) or the Peabody Picture Vocabulary Test – Third Edition (PPVT-III; Dunn & Dunn, 1997). A group of 210 adults between the ages of 18 and 75 participated as healthy volunteers in several studies performed in the Netherlands, Australia, Ireland, and Germany (see for details Montagne, Kessels, *et al.*, 2007; Kessels *et al.*, 2007; Law Smith *et al.*, 2010; Ammerlaan *et al.*, 2008; Rosenberg, McDonald, Dethier, Kessels, & Westbrook, 2012; Kessels, Freriks, De Kleijn, Verhaak, & Timmers, 2010; Wingbermühle, Egger, Verhoeven, Van der Burgt, & Kessels, 2012). For the adults, the number of years of education was recorded and intelligence was assessed in 141 of the 210 adult participants using the National Adult Reading Test (Nelson & Willison, 1991; Schmand, Lindeboom, & Van Harskamp, 1992), the Wechsler Adult Intelligence Scale – Third Edition (Wechsler, 1997), the PPVT-III (Dunn & Dunn, 1997) or the Wechsler Test of Adult Reading (Psychological Corporation, 2001). For all intelligence tests, standardized IQ scores were calculated based on the available normative data ($M = 100$, $SD = 15$). Table 1 shows the characteristics for the participants, divided into 11 age groups for presentation purposes.

Table 1. Characteristics of the 373 participants

Age group	N	Sex M:F	Education in years M	Education in years SD	Education in years Range	IQ M	IQ SD	IQ Range
8	31	16:15				103.6	14.2	79–135
9	28	13:15				104.0	9.8	82–121
10	28	13:15				102.8	10.7	85–128
11	31	18:13				106.6	12.5	84–126
12–17	45	41:4				107.3	12.4	77–127
18–25	59	15:44	12.5	2.8	8–18	97.6	11.3	74–124
26–35	46	16:30	14.6	3.4	9–20	101.8	13.2	82–125
36–45	19	9:10	11.5	3.0	6–18	102.1	13.2	73–124
46–55	42	17:25	12.1	3.3	6–18	99.8	15.1	74–127
56–65	32	20:12	11.7	3.2	6–18	100.9	18.0	79–126
65–75	12	8:4	9.6	3.0	6–15	105.5	2.1	104–107

Materials

The Emotion Recognition Task is a computerized paradigm in which morphed video clips of facial emotional expressions at different intensities are presented that have to be labelled using a six-alternative force choice response (Montagne, Kessels, *et al.*, 2007), with no time restriction. The stimulus set was developed by the Perrett lab (University of St. Andrews, UK) for studies on emotion perception (see Frigerio, Burt, Montagne, Murray, & Perrett, 2002; for a detailed description of the stimuli). In short, photographs were taken in frontal view of 26 Caucasian individuals who were asked to look neutral and to express the emotions happiness, anger, disgust, sadness, surprise and fear. All pictures were rated by a student panel and the four individuals (two men, two women). The most recognizable expressions were selected for inclusion in the test. To create the morphs, the actors' faces were manually delineated by 179 feature points defining the shape of the important facial features (Rowland & Perrett, 1995). A computer-generated program based on algorithms by Benson and Perrett (1991) enabled real-time interactive morphing between two endpoint facial expressions (always starting with a neutral expression) of the same identity. In the version of the ERT presented here, morphs from neutral to four different intensities were included, that is 0–40%, 0–60%, 0–80%, and 0–100% emotional intensity (see Figure 1). The number of frames and the length of the video depended on the emotional intensity presented. That is, for the 40% emotional intensity trials, eight frames were presented; for the 100% trials, 20 frames were presented. The duration of the video clips ranged from approximately 1 (40% emotion) to 3 s (100% emotion). The order of the presentation of the morphs was fixed for all participants (4 blocks of 24 trials, administration duration approximately 10 min), always starting with the lower intensities and then proceeding to the higher intensities. 215 Participants completed the long version of the ERT (i.e., including nine levels of emotional intensities, 0–20%, 0–30%, and so on until 0–100%; see Montagne, Kessels, *et al.*, 2007), the administration duration of which is too long for use in clinical practice (20 min). For these participants, the short form was derived from the long form by only analysing the trials with the intensities of interest (40%, 60%, 80%, and 100%).

Procedure

The ERT starts with an instruction screen in which the following instruction is presented (in the mother language of the participant): *You will see a photograph of a face that will*

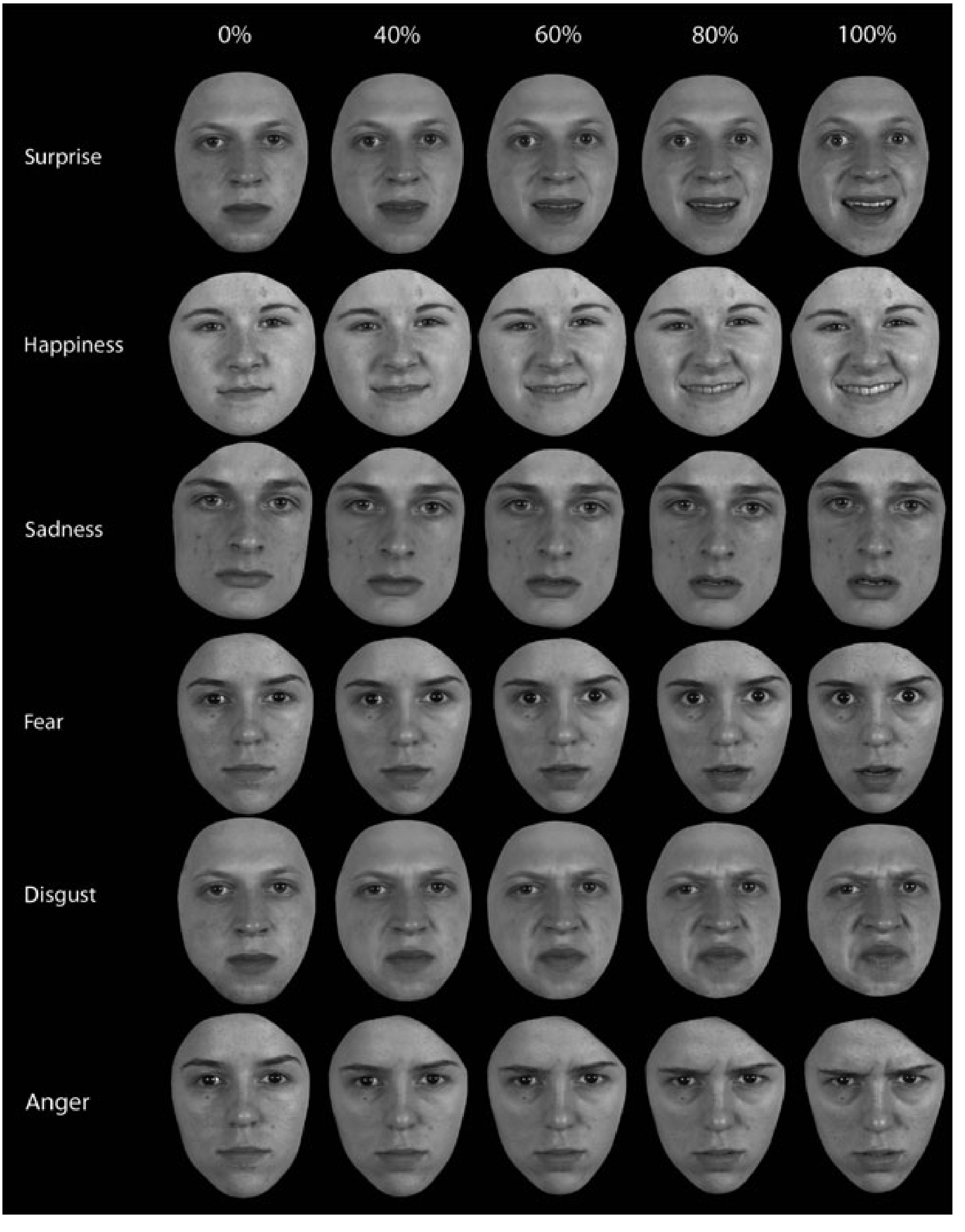

Figure 1. Examples of facial expressions of the ERT.

gradually express an emotion. Your task is to select the appropriate emotion from the labels presented on the screen: angry, disgusted, happy, sad, surprised, or fearful. The task will start with more difficult expressions and will later become easier. There is no need to hurry, but taking a long time to think about the correct expression is often not very helpful. Just pick the emotional label that seems most appropriate. If you need assistance with clicking the buttons, you may ask the examiner for help.

The examiner also read aloud these instructions. For children under 12, an additional instruction was given. This was done to familiarize the children with the verbal labels of the six basic emotions Here, the child was asked *Do you know what an emotion is?* If the child answered positively, the examiner asked for an example. If the answer was negative, the examiner said *An emotion is a feeling, such as feeling happy or very angry, and you can see this in someone's face. If you're happy, you'll see a smile, and if you're sad, how does your face look like then? Can you show this?* Next, the examiner gives examples of the six emotions (for instance, *Disgust is something people may feel if they have to eat something they absolutely do not like*), showing the matching full-blown facial expression on a paper sheet.

After the instructions, three practice trials were presented showing angry, happy disgusted facial expressions of actors that were not part of the eventual stimulus set. After the participant understood the instructions and knew how to respond, the actual test started after a pause. If not, the instructions and practice trials were repeated. The verbal labels on the response buttons were presented in the language of the participant, always to the left of the emotional expression. Responses could be made by mouse click or touch screen; if participants were unsure how to operate the mouse or touch screen, the examiner assisted by asking which label they would find most appropriate (and click it if necessary). In the primary school children, the examiner always clicked the buttons after the child had said the emotion aloud.

Analyses

Performance was recorded as the number of correctly labelled expressions per emotion per intensity (max = 4). For the purpose of data reduction, a total score was computed for each emotion by adding the number correct for the 40%, 60%, 80%, and 100% intensities (max = 16 per emotion). Also, a total score for the ERT was computed by adding the individual totals per emotion (total = 96).

To examine age effects, the participants were divided into two age groups (children 8–17 vs. adults 18–75), as a developmental effect is expected for the children and a possible age-related decline for the adult participants (i.e., an inverted U-shape previously also reported in Horning *et al.*, 2012). In the youngest age group, IQ was used to examine the effects of intelligence. In the adult group, years of education was used as a measure of intellectual achievement, in agreement with other normative data sets, as IQ assessments were not available in all participants. Pearson correlations were computed between age and IQ or education for the two respective age groups. To examine sex differences, ANOVA was performed on the ERT variables with age as between-group factor, for the children and adults separately. Ceiling effects were investigated by determining the number of participants who obtained a perfect score on the different ERT variables.

To construct the normative data, possible age- and IQ/education effects were taken into account. Non-linear curve fits (logarithmic, quadratic) for estimating the relation between age and performance on the ERT were considered, but did not explain more variance than a linear approach (note that for the children, neither the linear nor the non-linear curve fits were significant for the ERT Total Score, all R^2-values <0.017; in the adults, the explained variance for the linear curve fit on the ERT Total Score was $R^2 = 0.13$, compared to R^2-values between 0.11 and 0.13 for the non-linear curve fits, all p-values $< .0005$). As a result, data were analysed using correlations and linear regression. That is, if age or IQ/education level correlated significantly with one of the ERT measures, their effects were estimated using linear regression (to account for multiple testing, only correlations with a p-value $< .01$ were considered relevant). Expected scores (ES) were then computed using the parameters of the linear regression formula for all individuals (again per age group). Residue scores were then computed by subtracting the ES from the observed score (OS): RS = OS − ES. Next, the percentile distribution was computed for all ERT variables (again per age group) on the raw scores (if age and IQ/education did not significantly correlate with that score) or the RS (see Van den Berg *et al.*, 2009, for a more detailed description of this method).

Results

Table 2 shows the performance for the 11 age groups on the six basic emotions as well as on the ERT Total Score for descriptive purposes. Table 3 shows the correlations between the ERT measures and age, IQ, or education. With respect to correlations between age and IQ for the children, only the performance on Disgust was positively correlated with IQ ($p < .0005$). Age was moderately negatively correlated with the performance on Anger and positively with Happiness (both $p<.01$). For the adults, negative correlations between age and the emotions Anger ($p < .0005$), Fear ($p < .0005$), Happiness ($p < .01$), Sadness ($p < .0005$), and ERT Total ($p < .0005$) were found. Years of education were positively correlated with Fear, Happiness, Sadness, and ERT Total (all p-values $< .0005$) in the adults. Figure 2 shows the results for males and females separately, for the children and adults. In the children, only Anger showed a sex difference, with girls outperforming boys $F(1, 161) = 9.4$, $p < .003$. In the adults, significant sex differences were found on the emotions Anger $F(1, 208) = 20.9$, $p < .0005$, Fear $F(1, 208) = 5.2$, $p < .03$, and Sadness $F(1, 208) = 4.9$, $p < .03$), as well as on the Total Score $F(1, 208) = 10.1$, $p < .002$ in favour of women. As the sex differences in absolute terms were, however, small, normative data were constructed taking males and females together. With respect to ceiling performance, 71 participants obtained the maximum score of 16 on the emotion Anger, 28 on the emotion Disgust, and 171 participants performed at the maximum level on the emotion Happiness. Only four participants obtained the maximum score for Surprise, and none for Fear and Sadness. On the ERT Total Score, none of the participants obtained a perfect score (highest score obtained was 82).

To determine normative data in the youngest age group, linear regression was performed for the emotions Anger and Happiness with age as predictor, and for Disgust with IQ as predictor, which resulted in Functions (1)–(3).

$$\mathrm{ES}_{\mathrm{Anger}} = 15.779 - 0.235 \times \mathrm{age} \tag{1}$$

$$\mathrm{ES}_{\mathrm{Disgust}} = -1.612 + 0.114 \times \mathrm{IQ} \tag{2}$$

$$\mathrm{ES}_{\mathrm{Happiness}} = 13.176 + 0.162 \times \mathrm{age} \tag{3}$$

For the adults, regression analyses were performed for the emotion Anger with age as predictor and for the variables Fear, Happiness, Sadness, and ERT Total with age and years of education as predictors, resulting in Functions (4)–(8).

Table 2. Descriptive overview of mean (+*SD*) performance per ERT variable for the different ages

	Anger (max = 16)		Disgust (max = 16)		Fear (max = 16)		Happiness (max = 16)		Sadness (max = 16)		Surprise (max = 16)		ERT Total (max = 96)	
Age group	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
8	13.9	2.2	10.0	4.7	4.4	3.4	14.4	1.5	5.1	2.2	6.8	2.8	54.5	8.9
9	13.8	2.6	9.0	4.7	4.7	3.5	14.6	2.1	5.8	2.7	6.9	2.5	54.6	8.3
10	13.1	2.4	11.5	3.7	4.7	3.3	14.8	1.2	6.6	3.6	7.3	2.9	58.0	8.3
11	13.8	2.0	10.9	3.7	4.7	3.2	15.2	1.1	6.5	2.8	7.0	2.7	58.1	7.4
12–17	12.4	2.3	10.7	2.6	4.1	2.7	15.3	1.2	6.2	2.7	7.3	2.1	56.0	7.7
18–25	14.1	2.1	10.5	3.5	6.3	3.4	15.1	1.3	8.1	2.9	8.8	2.8	62.8	9.4
26–35	14.0	2.1	11.7	2.9	8.2	3.0	15.3	1.0	9.0	2.6	8.8	2.9	66.9	7.7
36–45	12.9	2.8	10.2	4.4	5.8	3.3	14.7	1.7	5.7	3.0	8.9	3.4	58.3	11.7
46–55	12.2	3.4	11.5	3.7	4.6	2.9	15.0	1.3	5.8	2.8	9.2	3.0	58.3	9.8
56–65	11.8	2.9	11.3	4.8	4.3	3.0	14.7	1.3	5.0	2.7	9.0	3.9	56.0	12.1
65–75	9.8	3.4	10.9	3.4	4.6	3.0	13.7	3.3	5.3	1.5	7.7	4.1	51.9	10.8

Table 3. Correlations (Pearson's *r*) between age, IQ and years of education for the six emotions and the ERT total score

	Children 8–17		Adults 18–75	
ERT score	Age	IQ	Age	Years of education
Anger	–0.21*	–0.07	–0.42**	0.17
Disgust	0.08	0.35**	0.04	0.13
Fear	–0.04	–0.02	–0.31**	0.27**
Happiness	0.23*	0.09	–0.19*	0.26**
Sadness	0.11	0.01	–0.45**	0.27**
Surprise	0.05	0.09	0.00	0.07
Total	0.06	0.20	–0.36**	0.32**

*$p < .01$, **$p < .0005$.

$$ES_{Anger} = 15.943 - 0.075 \times \text{age} \quad (4)$$

$$ES_{Fear} = 5.630 - 0.06 \times \text{age} + 0.211 \times \text{years of education} \quad (5)$$

$$ES_{Happiness} = 14.360 - 0.019 \times \text{age} + 0.096 \times \text{years of education} \quad (6)$$

$$ES_{Sadness} = 7.947 - 0.076 \times \text{age} + 0.163 \times \text{years of education} \quad (7)$$

$$ES_{ERT\ Total} = 58.485 - 0.191 \times \text{age} + 0.782 \times \text{years of education} \quad (8)$$

For these variables, RS were computed using the ES and OS (RS = OS − ES). Tables 4 and 5 show the percentile distributions for the ERT variables for the younger and older age groups that can be used in clinical practice. Cut-off scores can be determined by taking the score corresponding with the 5th percentile (i.e., *SD* 1.65 below the normative mean), but more strict or lenient cut-off scores can also be applied in clinical practice (see Lezak, Howieson, Bigler, & Tranel, 2012, for a more extensive discussion on cut-off scores).

Discussion

In this study, we examined the effects of age, education level, IQ and sex on the ERT with the aim to provide normative data, which can be used for clinical assessment, using healthy participants from a wide age range. First, we examined the effects of age across the life span. Interestingly, in children aged 8–17, only a small developmental effect was found on the ability to perceive happy facial expressions. In turn, the ability to perceive angry expressions was slightly negatively correlated with age in the children. Age was neither significantly correlated with any of the other emotions, nor with the overall performance on the ERT in the children. Our findings are in line with the results of De Sonneville *et al.* (2002), who examined perception of morphed emotional facial expressions in 7- to 10-year olds. In that study, accuracy of performance also did not increase with age, but performance speed did. We did not examine children younger than eight, but a previous

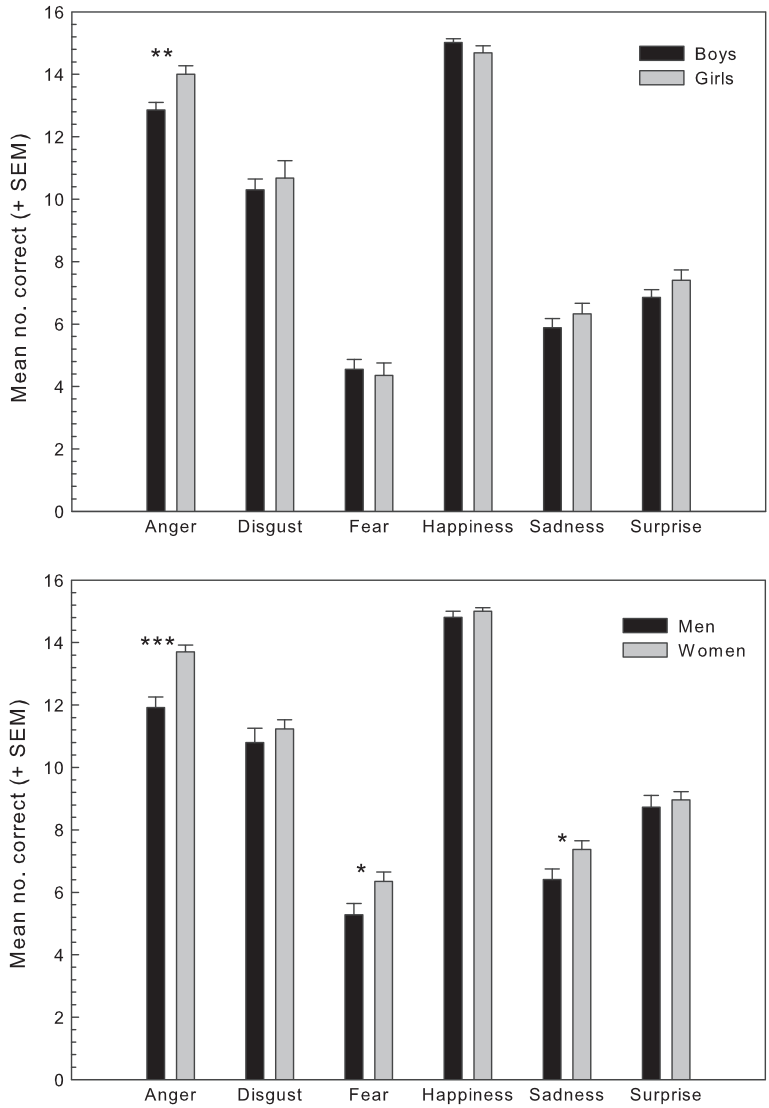

Figure 2. Sex differences on the specific emotions for the children aged 8–17 (top) and the adults aged 18–75 (bottom). * p<0.05, ** p<0.01, *** p<0.001.

study has examined face perception even in 5-year olds, albeit with static facial expressions, demonstrating age differences in performance compared with older children (Durand, Gallay, Seigneuric, Robichon, & Baudouin, 2008). Also, Horning *et al.* (2012) included children from the age of 5 and demonstrated a clear developmental improvement in the perception of morphed emotional expressions. It should be noted, however, that the ability to verbally label emotional expressions depends greatly on language skills, making it difficult to reliably assess emotion perception in younger children. Our negative correlation between age and anger recognition is not in agreement with previous results. It has been reported that younger children are more likely to display anger than older children (Thomas, De Bellis, Graham, & LaBar, 2007). Moreover, others

Table 4. Percentile distribution for the age group 8–17 per emotion and for the ERT total score

Percentile	Anger (RS)	Disgust (RS)	Fear	Happiness (RS)	Sadness	Surprise	Total
2	–6.0	–8.9	0	–3.5	1	2	40
5	–4.9	–7.2	0	–2.6	2	3	44
10	–3.0	–5.2	1	–1.8	2	4	46
15	–2.5	–3.7	1	–1.5	3	4	47
20	–2.0	–3.1	2	–1.0	4	5	48
30	–0.7	–1.6	2	–0.4	5	6	51
50	0.5	0.6	4	0.5	6	7	56
70	1.3	2.0	6	0.9	8	8	62
80	2.1	3.2	7	1.0	9	9	63
85	2.2	3.8	8	1.2	9	10	66
90	2.6	4.5	9	1.4	9	11	68
95	2.8	5.9	11	1.4	11	12	71
98	3.2	6.2	13	1.5	13	12	73

RS = residue score, see text on how to compute this score.

Table 5. Percentile distribution for the age group 18–75 per emotion and for the ERT total score

Percentile	Anger (RS)	Disgust	Fear (RS)	Happiness (RS)	Sadness (RS)	Surprise	Total (RS)
2	–8.0	2	–6.6	–4.6	–6.0	2	–22.6
5	–5.4	4	–5.1	–2.5	–4.8	4	–17.1
10	–3.6	5	–4.0	–1.4	–4.0	5	–12.8
15	–2.2	7	–3.5	–0.9	–2.9	6	–9.9
20	–1.6	8	–3.0	–0.7	–2.6	6	–6.6
30	–0.9	10	–1.8	–0.3	–1.5	7	–4.1
50	0.5	12	–0.2	0.3	0.1	9	0.0
70	1.7	14	1.6	0.7	1.8	11	4.7
80	2.1	14	2.9	1.0	2.5	12	7.7
85	2.3	15	3.4	1.2	3.0	12	10.0
90	2.8	15	4.3	1.5	3.4	13	12.6
95	3.3	16	5.6	1.7	4.2	14	16.2
98	3.8	16	6.3	1.9	5.0	16	18.8

RS = residue score, see text on how to compute this score.

have demonstrated no significant developmental increase for matching the emotion anger, while such an effect was found on all other emotions (Herba, Landau, Russell, Ecker, & Phillips, 2006). However, these findings cannot not explain why the adolescents perform worse than the younger children on labelling this emotion in our sample. Still, it should be noted that the overall accuracy levels in the children for anger recognition were much higher than accuracy levels of all other emotions (apart from happiness; see also Table 2).

With respect to the effect of ageing in the adults, performance deteriorated with age for the emotions anger, fear, happiness, and sadness. Also, the ERT total score correlated negatively with age. Our findings replicate the results by West *et al.* (2012) who showed ageing-related effects for fearful, angry, and sad expressions. In contrast to our results, they did not find an age effect for happy expressions, possibly because of near-ceiling effects on this emotion, even for the lowest intensities (25% and 50%). This may have been due to their inclusion criteria, resulting in a study sample that consisted only of highly intelligent adults (M_{IQ} = 120 and higher). It has been suggested by some that positive emotions such as happiness and surprise are more accurately perceived in older adults (Kaszniak & Menchola, 2012), which might be due to an overall bias towards positive stimuli in older people compared with young adults. However, neither the meta-analysis of Ruffman *et al.* (2008), nor the present study demonstrated positive correlations between age and the perception of happy facial expressions, albeit that the negative correlation we found was smaller than for the negative emotions (in line with Horning *et al.*, 2012). Interestingly, whereas the perception of the emotion surprise did not deteriorate with ageing, we did not find a positive correlation here either. Thus, our findings support the notion that age is strongly correlated with decrements in the ability to perceive negative emotions, but do not support claims that positive emotions are better perceived by older people. It should be noted that our sample did not include participants over the age of 75. One could argue that a positivity bias is especially present in the 'oldest of the old'. However, West *et al.* (2012) and Horning *et al.* (2012) included participants up to the age of 89 and did not demonstrate positive correlations between age and recognition of happy or surprised faces. In all, our findings support the notion that selective ageing effects can be found in relation to recognition accuracy of specific emotions (Ruffman *et al.*, 2008).

We found differential sex differences on the ERT for the children and the adult participants. That is, for the children, we only demonstrated a difference between boys and girls for the emotion anger, with girls outperforming boys. For the adults, however, we found a female advantage on accuracy for the emotions anger, fear, and sadness, as well as on the ERT Total Score. The differential sex differences between the children and the adults are interesting. Possibly, sex differences in emotion perception do not emerge until after puberty. Indeed, using functional neuroimaging Killgore, Oki, and Yurgelun-Todd (2001) showed that sex-specific changes in amygdala and dorsolateral prefrontal cortex reactivity to affective facial expressions emerged during puberty. Our findings in the adults partly replicate previous results in a group of 68 psychology undergraduate students, in which sex differences were found in the advantage of women for the emotions sadness, surprise, anger, and disgust (Montagne *et al.*, 2005). However, apart from the study sample, there are methodological differences between the current set-up and the previous study, in that in Montagne *et al.* (2005), the emotional expressions were presented in side-view perspective as well. Also, in addition to assessing accuracy for labelling (similar to the present study), sensitivity for the emotions was assessed by asking the participants to move through the animated sequence and indicate the point at which they start to recognize the expression. These methodological differences may explain the discrepancy between study findings in relation to sex differences in emotion perception (Kret & De Gelder, 2012), as some paradigms are more sensitive to small between-group differences than others. Indeed, Hoffmann, Kessler, Eppel, Rukavina, and Traue (2010) demonstrated that facial expressions presented at lower intensities resulted in sex differences in favour of females, but this effect disappeared when full-blown emotional expressions were shown. However, we would like to emphasize that in our study (and in general), sex differences in recognition of emotional expressions are small and great overlap is present in the performance of men and women.

IQ was only positively correlated with the ability to recognize disgust in the children. Possibly, the verbal label of disgust may be relatively difficult compared with the other emotions, and better understood by children with higher levels of intelligence. Brechet, Baldy, and Picard (2009), for instance, demonstrated that the ability to understand the emotion disgust was relatively poor in children overall (i.e., only 40% correct responses even in a group of 11-year olds). Indeed, and in line with our results, intelligence was found to predict the performance on disgust in the study by Horning *et al.*, 2012 as well. In adults, years of education (which is highly correlated with intellectual ability) correlated strongly with the recognition of fear, happiness, sadness, and the ERT Total Score. As years of education is a predictor of performance on many cognitive tests (Lezak *et al.*, 2012), we adjusted our normative data accordingly (in addition to age).

Looking at the differences in performance across the six emotions, differences were found that are in accordance with other findings (e.g., Young *et al.*, 2002; Montagne, Kessels, *et al.*, 2007; Ruffman *et al.*, 2008). That is, happy facial expressions are typically easy to recognize, and emotions such as fear, sadness, and surprise are more difficult. Still, the inclusion of lower intensities of emotional expressions has resulted in the reduction of ceiling effect on most emotions, apart from happy facial expressions where the maximum performance was obtained in more than 40% of the participants. On the ERT Total Score, none of the participants obtained the maximum score, making this measure probably the most appropriate one for use in clinical assessment.

Regarding the quality of our normative sample, the norms are based on a relatively large number of participants from a wide age range. Still, we did not include older people over the age of 75. As deficits in the perception of emotional expressions are present in several forms of dementia that are more prevalent at older age, data on the ERT in healthy participants aged 75+ should be collected in the future. Also, children below the age of 8 were not included, but assessment of young children lacking reading skills and with still developing language ability would probably require adjustments of the paradigm.

If we compare our normative data set with other emotion recognition paradigms, the present data set has a number of advantages to previously published results. The norms for the Ekman 60 Faces Test from FEEST (Young *et al.*, 2002; $N = 227$), for example, do not include participants under the age of 20. Furthermore, their cut-off scores do not adjust for education level or IQ. More importantly, all participants in their normative sample had an IQ > 90 (>25th percentile), which by definition means that a quarter of the normal population is not represented in the norms of the Ekman 60 Faces Test. While it is always a challenge to recruit healthy participants with below-average IQs for participation in normative data collection, the present study was able to include participants with below-average IQs, making our data set probably more representative for the general population. Comparing our sample with the recently published results in 482 participants between the age of 20 and 89 on an emotion perception task similar to ours (West *et al.*, 2012), it is unfortunate that that study only recruited highly intelligent participants with higher socioeconomic status and that only a small sample of males was included compared with females. As a result, the West *et al.* (2012) results cannot be used as normative data in clinical practice. While they included older people up to the age of 89, participants younger than 20 were also not included.

Previous studies demonstrated the validity of this version of the ERT (i.e., using accuracy of the performance as the dependent measure, administered either in its short form or in its long form) in a wide range of patient groups, often showing impairments that are selective for specific emotions. Post-neurosurgery patients with lesions of the ventromedial prefrontal cortex (Jenkins *et al.*, 2012) or the amygdala (Ammerlaan *et al.*, 2008) were found to be specifically impaired on the perception of fearful facial expressions. Patient with schizophrenia performed worse than controls on all emotions (Scholten *et al.*, 2005) and alcoholic Korskakoff patients performed worse than controls on angry, fearful and surprised expressions (Montagne, Kessels, Wester, *et al.,* 2006). In high-functioning adolescents with autism spectrum disorder (ASD), results with the ERT were mixed. That is, Kessels *et al.* (2010) did not demonstrate differences between adolescents with ASD and matched controls on the ERT, whereas Law Smith *et al.* (2010) showed a worse performance on the emotions disgust, anger and surprise in a comparable sample of adolescents with ASD. Patients with post-stroke depressive symptoms performed worse on the emotions anger, happiness, disgust, and sadness, while non-depressed stroke patients performed at control level, but in this study, the emotions fear and surprise were not included (Montagne, Nys, *et al.,* 2007). No impairments on the ERT were found in a group of patients with Noonan syndrome (Wingbermühle *et al.*, 2012). PTSD patients had lower accuracy on fear and sadness compared with matched controls (Poljac *et al.*, 2011). With respect to neurodegenerative disease, specific impairments in the recognition of disgust and anger were found in a small group of patients with Huntington's disease (Montagne, Kessels, Kammers, *et al.*, 2006) and the perception of anger and surprise was compromised in frontotemporal dementia patients (Kessels *et al.*, 2007). Moreover, other research groups also showed intensity-dependent deficits in emotion perception in clinical groups (see, e.g., Assogna *et al.*, 2010; Csukly, Czobor, Szily, Takács, & Simon, 2009), indicating that morphing tasks may be of added value in clinical practice compared with existing, more static emotion-perception tasks.

Finally, we would like to address some limitations of our study. First, while the overall sex distribution is balanced, females are underrepresented in the 12- to 17-year olds, while males are overrepresented in the 18- to 25-year olds. In addition, our study sample consisted of participants from different countries, increasing the external validity of our findings, but all were from Western cultures. In relation to this, the ERT only contains Caucasian actors. Our results, as a result, cannot be generalized to people from non-Western cultures or different ethnic backgrounds. Furthermore, intelligence levels were estimated using different intelligence tests, and IQ estimates were not available for all adults. However, in clinical practice, educational level is more often applied than IQ for adjusting performance in adults, as IQ estimates may also not always be available. The use of regression-based normative data has also been under debate (e.g., Fastenau, 1998; Heaton, Avitable, Grant, & Matthews, 1999). We would like to emphasize, however, that the use of regression-based norms takes potential confounding factors into account (in our case age, intelligence or education level) by using the data of the total study sample. This is in contrast to stratified normative data, which often rely on small comparison groups consisting of people of a specific age range and education level (see also Van Breukelen & Vlaeyen, 2005).

In sum, the present paper presents regression-based normative data for the ERT based on a sample of 373 healthy individuals between 8 and 75 years of age from all education levels, which is a representative sample of the general population. Findings obtained using the ERT are in agreement with those previously reported in large data sets (Horning *et al.*, 2012; Ruffman *et al.*, 2008; West *et al.*, 2012), but the availability of normative data makes this paradigm applicable to clinical practice. The ERT is available for use in clinical practice and is a feasible and easy-to-administer computerized task to assess the perception of morphed facial expressions presented at four different intensities (40%, 60%, 80%, and 100%).

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