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Measuring the speed of recognising facially expressed emotions

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Faces provide identity- and emotion-related information—basic cues for mastering social interactions. Traditional models of face recognition suggest that following a very first initial stage the processing streams for facial identity and expression depart. In the present study we extended our previous multivariate investigations of face identity processing abilities to the speed of recognising facially expressed emotions. Analyses are based on a sample of $N = 151$ young adults. First, we established a measurement model with a higher order factor for the speed of recognising facially expressed emotions (SRE). This model has acceptable fit without specifying emotion-specific relations between indicators. Next, we assessed whether SRE can be reliably distinguished from the speed of recognising facial identity (SRI) and found latent factors for SRE and SRI to be perfectly correlated. In contrast, SRE and SRI were both only moderately related to a latent factor for the speed of recognising non-face stimuli (SRNF). We conclude that the processing of facial stimuli—and not the processing of facially expressed basic emotions—is the critical component of SRE. These findings are at variance with suggestions of separate routes for processing facial identity and emotional facial expressions and suggest much more communality between these streams as far as the aspect of processing speed is concerned.

Keywords: Recognition; Facially expressed emotions; Facial identity; Speed.

Faces are highly salient objects for humans, providing identity- and emotion-related information—basic cues for mastering social interactions. Despite extensive research on the recognition of facial identity and facial expression of emotions (see Leeland, 2008, for an overview), on coding of facial behaviours (Ekman & Rosenberg, 1997), and their neuronal foundations (e.g., Calder & Young, 2005; Haxby, Hoffman, & Gobbini, 2000), important questions about face processing remain to be addressed. Here, we report data on individual differences in the speed of recognising facially

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expressed emotions and relate them to the speed of recognising face identity. The findings contribute to the question of individual differences in these abilities on the one hand and to the long-standing debate about the independence versus interplay of processing face identity and facial expressions on the other hand. Essential starting points for the development of our test battery on face processing were theoretical models—derived from experimental and clinical work—and measurement standards established in cognitive ability research (Herzmann, Danthiir, Schacht, Sommer, & Wilhelm, 2008).

Functional models of face processing inform models on individual differences and vice versa

Functional and neuroanatomical models of face processing postulate the existence of two relatively distinct systems in charge of processing facial information. Bruce and Young (1986) suggested that following an initial stage of constructing view-centred descriptions from the retinal input (the initial stage of structural encoding), the processing stream separates into two pathways—one for identifying the person and one for recognising the emotion displayed by the person. This claim was based on and confirmed by experimental data with normal participants, double dissociations in brain-damaged patients, single-cell recording in non-human primates, and many imaging studies (see Calder & Young, 2005, for a recent review). For example, Calder, Young, Kean, and Dean (2000) showed that even configural processing of facial identity and facial expressions is dissociable. In terms of the model by Bruce and Young, this seems to indicate that the pathways separate after the construction of view-centred descriptions. Haxby et al. (2000) integrated these findings and suggested a neurocognitive model, including a processing system for *invariant*, identity-related and another one for processing *changeable aspects* of faces. The latter system handles expression-related information. These systems are essentially seen to be independent, both setting out from the inferior occipital cortex and proceeding towards the inferior temporal cortex (identity) and the superior temporal cortex (STS; emotional expressions), respectively.

Nevertheless, the model by Haxby et al. (2000) also suggests some interactions between both processing streams. Thus, stronger responses of neurons—particularly, in the face-selective fusiform areas—to emotional expressions indicate an overlap between networks that are involved in both non-emotional and emotional face processing (see Calder & Young, 2005; Vuilleumier & Pourtois, 2007, for reviews). Moreover, based on principle component analysis of faces, Calder, Burton, Miller, Young, and Akamatsu (2001) suggested that facial expressions and facial identity is coded in a common space. A relative dependence of face identity and emotion expression is also supported by further empirical studies. Thus, Fox and co-workers (Fox & Barton, 2007; Fox, Oruc, & Barton, 2008) showed that expression analysis is influenced by face identity but not vice versa. Similar asymmetric interactions between the processing streams have been observed in the Garner interference paradigm, where it was easy to ignore irrelevant variation of facial expression during identity processing but difficult to ignore irrelevant variations of identity in an expression recognition task (e.g., Schweinberger & Soukup, 1998).

Evidence for interactions between face identity and expression processing comes also from studies using event-related brain potentials (ERPs). Wild-Wall, Dimigen, and Sommer (2008) reported evidence for a late perceptual but premotoric facilitation of expression categorisation by face familiarity, whereas facial expressions influenced identity processing during response selection. Most recently, Martens, Leuthold, and Schweinberger (2010a, 2010b) showed that information about facial expression is available more readily for familiar than unfamiliar faces. Interestingly, these authors also found some early interactions (at the N170 component of the ERP) between identity and expression. Together, these findings indicate that the processing of facial expressions and facial identity may interact at early stages but then run in parallel. However, it is not clear at which specific stage the processing streams separate, and how strict and invariant this separation is.

One way to quantify the level of interdependence of these systems is to investigate the correlation between tasks of identity recognition and tasks of emotion recognition across individuals. There is some evidence for moderate to high correlations between single measures of the two systems, for example from patients with temporal and frontal lobectomy (Braun, Denault, Cohen, & Rouleau, 1994). However, this evidence is predominantly based on single tasks with small and primarily clinical samples, which do not allow conclusions on the level of ability constructs. Therefore, further studies with large samples and multiple tasks are needed to clarify the relationship between processing face identity and facial expressions on the basis of latent variable analyses, taking task-specific variance and measurement error into account.

Functional models described above are characterised by a hierarchical structure, as they distinguish between successive stages of processing. For example, Bruce and Young (1986) distinguished between structural encoding (including view-centred descriptions transformed into expression-independent descriptions) and stages that contain stored representations of faces and associated knowledge. Haxby et al. (2000) distinguished between a *core* and an *extended* system of processing. The core system provides the (early) perception of facial features or changeable facial aspects and the extended system processes the meaning of the information gleaned from the face.

Transcribing the suggestions of such models into terms specific for individual differences research one may postulate latent factors for four domains: *face perception*, *face recognition* (memory), *expression perception*, and *emotion recognition*. A further distinction between processing speed and accuracy, well established in intelligence research (Carroll, 1993), can also be applied to tasks of processing facial identity and facially expressed emotions allowing for a more comprehensive consideration of multiple abilities in this domain. Hence, at least two more ability components can be postulated: the *speed of recognising facial identity* and the *speed of recognising facially expressed emotions*.

In prior work (Herzmann et al., 2008; Hildebrandt, Sommer, Herzmann, & Wilhelm, 2010; Hildebrandt, Wilhelm, Schmiedek, Herzmann, & Sommer, 2011; Wilhelm et al., 2010), we developed and evaluated a comprehensive multivariate test battery for the measuring of different aspect of face identity processing, using stimuli with neutral facial expressions and following the suggestions derived from functional models as outlined above. In several studies, we established and replicated a three-factorial model, which distinguishes between *face perception*, *face memory*, and the *speed of face cognition*. Face perception represents the ability to accurately discern facial features and their configuration, face memory is considered to underlie the encoding, storing, and accurate retrieval of faces from long-term memory. The speed of face cognition represents the ability to perceive and recognise faces quickly, and is based on latency data in face perception and recognition tasks, where decisions are easy to make. We will use the term *speed of recognising facial identity* to refer to the speed factor of face cognition in the model described in those previous works.

Aims of the present investigation

The aim of the present study was to investigate individual differences in the speed of recognising facially expressed emotions. Three tasks of *facial emotion recognition* were administrated within a psychometric study on face cognition (see Herzmann et al., 2008). The goals of this paper are to: (1) Assess and evaluate the psychometric properties of the emotion recognition tasks; (2) establish a measurement model of emotion recognition based on latency data; and (3) investigate the relation on the level of latent factors between the speed of recognising facially expressed emotion (SRE), the speed of recognising facial identity (SRI), and the speed of recognising non-face stimuli (SRNF), labelled by Carroll (1993) as perceptual speed and defined as the “rate of search and comparison” (p. 465) of visual information.

These relations are relevant for two reasons. First, the relations between SRE, SRI, and SRNF will at least partially inform functional models of face processing about the validity of the assumption of independent routes for processing facial identity and expression. We say partially, because the analyses presented in this paper are based on latency data. Accuracy data and corresponding latent variables will have to be considered independently. Second, evidence regarding the specificity of SRE compared to SRI and also SRNF is needed to substantiate the discriminant validity of speeded emotion recognition measures—a relevant topic from an applied perspective and valuable information for prevailing theories of emotion processing.

High accuracy levels in recognising facial expressions of basic emotions

A widespread notion, formulated already by Darwin (1872/1965) and reformulated, for instance, by Izard (1971) and Ekman (1972), is the assumption of the universality of emotion expressions in the face. Although not undisputed (e.g., Hess & Thibault, 2009; Russell, 1994), cross-cultural studies designed to investigate the universality of emotion expressions strongly supported high accuracy levels for recognising so-called basic emotions (Izard, 1971). Therefore, tasks of emotion recognition, using stimuli with clear expressions of basic emotions, do not provide large interindividual variability in terms of accuracy of performance. Although most healthy individuals will understand the facial expression of a basic emotion, it does not imply that there are no relevant individual differences in the speed of processing emotional expressions. Faster emotion recognition might help to anticipate critical points in communication and to trigger appropriate behaviour to achieve certain goals. Faster face recognition might also help to be a better eyewitness in cases involving brief encounters.

In order to overcome the problem of high accuracy of expression recognition for measuring individual differences, some researchers have attempted to increase difficulty in such tasks (Matsumoto et al., 2000; O'Sullivan, 2007). Most frequently, limited exposition of stimuli has been used, for example in the Japanese and Caucasian Brief Affective Recognition Test (JACBART; Matsumoto et al., 2000) or in the Facially Expressed Emotion Labelling Test (FEEL; Kessler, Bayerl, Deighton, & Traue, 2002). Limited stimulus exposition effectively decreases accuracy levels, but such measures are speed tests, according to the established definition of *processing speed* by Horn and Noll (1994), p. 173): "Rapid scanning and responding in intellectually simple tasks (in which almost all people would get the right answer if the task were not highly speeded)". Further procedures to decrease high accuracy levels are the presentation of small (Ekman, Brattesani, O'Sullivan, & Friesen, 1979) or distorted stimuli (Wallbott, 1992). However, these procedures were less successful in decreasing high accuracy levels. Otherwise, the faces subtest of the Mayer–Salovey–Caruso Emotional Intelligence Test (MSCEIT; Mayer, Salovey, Caruso, & Sitarenios, 2003) uses idiosyncratic facial expressions. Such expressions are harder to recognise. However, the recognition of such idiosyncratic stimuli was completely unrelated to scores on JACBART, which uses clear facial expressions of basic emotions under speeded presentation (Roberts et al., 2006).

Available tests of facial expression recognition (emotion perception) are based on mainly disparate measurement paradigms and use partly different kinds of facial stimuli (see Mayer, Roberts, & Barsade, 2007, for an overview). Therefore, we propose to systematically investigate the ability of emotion recognition measured by available tests with larger samples and analyses at the latent level (for an explanation of structural equation modelling see methods). The present study is one step towards this goal.

Research questions and hypotheses

Our first research question was, whether a general ability of SRE can account for variances in the implemented tasks. We postulated that a higher order measurement model for the speed of recognising facially expressed emotions with lower order task factors and emotion specific indicators would fit the data acceptably (*Hypothesis 1*; see Figure 1).

The second research question refers to the specificity of SRE as compared to SRI. If the correlation between two latent factors is substantially below unity, this would constitute meaningful and strong evidence for the discriminant validity of SRE. However, if the correlation between SRE and SRI is very high or not distinguishable from unity, this would constitute strong evidence that SRE is not emotion specific. Given the suggestions reviewed above, that there is at least a common initial stage of expression and identity processing, on the one hand, and the absence of prior psychometric work that convincingly shows that SRE is distinct from SRI, on the other hand, the most parsimonious account is to claim that measures of both constructs are indicative of the same single underlying ability. Therefore, we assume that the processing of facial stimuli—and not the processing of basic emotions—is the critical component in SRE and SRI. Accordingly, we expected a high correlation between SRE and SRI (*Hypothesis 2*).

The third research question refers to the relation between SRE and SRI with SRNF. If indeed the processing of facial stimuli is critical in both SRE and SRI, both latent variables should not be correlated very highly or perfectly with SRNF. Because SRE, SRI, and SRNF are all constructs indicating the speed of mental capacities, the relations with SRNF should show a moderate or substantial level. The relations between SRE and SRNF and SRI and SRNF should both be lower than the relation of SRE with SRI (*Hypothesis 3*).

METHOD

Sample

Participants were 153 young Caucasian adults (53% female). Mean age was 24 years ($SD = 4.5$), and the sample was heterogeneous with respect to educational background (46% without high school degree, 44% with high school degree, and 10% with academic degrees). Participants were recruited via newspaper ads, posters in various institutions, radio broadcast, and invitations by friends. Visual acuity of participants was normal or corrected to normal, and 92.8% of them reported being right-handed. Each participant completed all tasks.

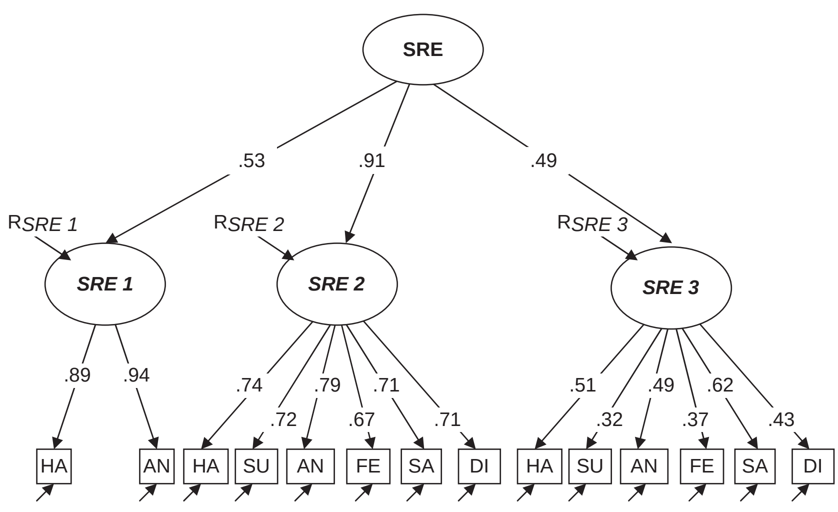

Figure 1. *Measurement model—Speed of recognising facially expressed emotions. Notes: SRE—Speed of recognising facially expressed emotions; SRE 1–Facially expressed emotion decision; SRE 2–Emotional odd-man-out; SRE 3–Facially expressed emotion labelling;* HA–*Happiness;* SU–*Surprise;* AN–*Anger;* FE–*Fear;* SA–*Sadness;* DI–*Disgust;* R–*Residual.*

Procedure and apparatus

Participants worked on three tasks measuring the recognition of facially expressed emotions, 15 tasks of face identity recognition, using portraits with neutral expressions, and two tasks of perceptual speed, measuring the speed of non-face stimulus recognition. For the purpose of the present study, 10 of these measures are relevant and the subsequent exposition is limited to these measures: Three tasks of measuring the *speed of recognising facially expressed emotions*, five measures for the *speed of recognising facial identity*, and two *speed tasks of recognising non-face stimuli*. The data set of the present paper includes 10 additional measures of identity processing. These measures are not considered in the remainder of this paper, because all of these tasks were accuracy-based measures of face perception and face memory (see Herzmann et al., 2008; Hildebrandt et al., 2010, 2011; Wilhelm et al., 2010). The aim of the present work was to investigate the status of speeded emotion recognition measures as compared to further measures of speed.

All tasks were computerised and administrated in a fixed sequence to all participants. Experimenters were trained student assistants. Groups of up to nine participants were tested by one experimenter. After up to ten practice trials—with trial-by-trial feedback about accuracy—participants completed the experimental trials, for which no feedback was provided. Responses were made by pressing labelled buttons on a standard keyboard or by using the computer mouse.

All tasks were programmed using Inquisit 2.0© and conducted on PCs with 17-inch screens with refresh rates of 85 Hz. Viewing distance was approximately 50 cm.

Stimuli

All stimuli displayed Caucasian faces. Female and male portraits were balanced in number for every task. For task trials, which involved the concurrent presentation of two or three faces, only portraits of the same sex were used.

Photographs for the tasks analysed in this work were obtained from a series of different databases of emotional face stimuli (*AR Face Database*—Martinez & Benavente, 1998; *MACBRAIN Expressive Face Database*; *Karolinska Directed Emotional Faces*—Lundqvist, Flykt, & Öhman, 1998; and Caucasian Faces of the *Japanese and Caucasian Facial Expressions of Emotion*—Matsumoto & Ekman, 1988) and neutral face stimuli (*Psychological Image Collection at Stirling*; *Extended M2VTS Database*—Messer, Matas, Kittler, Luettin, & Maitre, 1999; *Japanese and Caucasian Neutral Faces*—Matsumoto & Ekman, 1988; the Colour FERET database—Phillips, Moon, Rizvi, & Rauss, 2000; and further stimuli used by Carbon, 2003; and Schacht, Werheid, & Sommer, 2008).

All portraits were converted to greyscale and edited in the same format by fitting them into a vertical ellipse of 200 by 300 pixels (5.1×7.6 cm). This procedure aimed to eliminate external, non-face-specific cues (hair, ears, and clothing) in order to make sure that task performance was primarily influenced by the processing of face-internal features. Only portraits of persons without glasses, beards, salient make-up, moles, or other facial marks were used.

Tasks

*Speed of recognising facially expressed emotions (*SRE*)*

Facially expressed emotion decision (SRE 1). Face stimuli with happy and angry expressions were used in this two-choice reaction time task. In each trial, a face with neutral expression was presented for 500 ms, which served as an anchor for the emotion decision. The neutral portrait was followed by a blank screen for 500 ms, and thereafter the same person expressing happiness or anger was displayed in the middle of the screen. Each identity was used with exclusively one emotion expression. Participants were asked to press the left key for faces expressing anger and the right key in the case of faces showing happiness and worked on a total of 30 trials.

Emotional odd-man-out (SRE 2). Faces expressing one of the six basic emotions (happiness, surprise, anger, fear, sadness, and disgust) were used for this task. One identity appeared only once with one specific emotion during the whole task. In each trial, three faces of different persons (but of the same sex) were presented in a row. Two of the faces showed the same emotion and the third a different one (odd-man-out). The face with the different expression was always placed at the left or right. Participants were asked to indicate the side of the odd-man-out by a left or right button press. Each basic emotion was used as target and as distractor across the trials. There were 30 trials in total.

Facially expressed emotion labelling (SRE 3). This task was designed to measure the recognition of the six basic emotional expressions in Caucasian faces with timed stimulus exposition. It was inspired by the FEEL (Kessler et al., 2002) and the JACBART (Matsumoto et al., 2000). Similar to *SRE 1*, a face with a neutral expression was presented first for 1 s, followed by a mask consisting of three Xs, presented for 500 ms in the centre of the screen. Subsequently, a portrait of the same person, expressing one of the basic emotions was displayed for 200 ms (target). Each identity appeared once during the whole task. When the target disappeared, a bar with six labels of emotions (happiness, surprise, anger, fear, sadness, disgust) was presented. Participants had to indicate which emotion was displayed by the target and to select the appropriate label with the computer mouse. The task consisted in 30 trials in total.

*Speed of recognising facial identity (*SRI*)*

Simultaneous matching of morphs (SRI 1). Faces with neutral expressions were used for this task. Stimuli were derived with the morphing method from two parent faces (A and B). In each trial, two morphs (Face 1 and Face 2) were presented, either similar (Face 1: 50% parent A and 50% parent B; Face 2: 30% parent A and 70% parent B) or dissimilar (Face 1: 20% parent A and 80% parent B; Face 2: 80% parent A and 20% parent B) and participants had to make a similarity–dissimilarity decision on a total of 30 trial (half of them were similar).

Simultaneous matching of upper face halves—with conditions aligned (SRI 2) and non-aligned (SRI 3). In this task (Young, Hellawell, & Hay, 1987) neutral faces were used. Faces were divided horizontally into upper and lower halves approximately halfway down the nose. The upper half of one face was added to the lower half of another face, which formed a stimulus. In each trial two stimuli were presented. Lower halves of the two stimuli for a given trial always originated from different persons. Upper halves originated either from the same or from different persons. Participants had to decide whether the upper parts of two concurrently presented stimuli were the same or different. In the aligned condition, face halves were attached to form a new normally structured face. In the non-aligned condition, the left or right edges of the top face halves were positioned above the nose of the bottom face halves. Half of the trials were aligned and the other half non-aligned. Participants completed a total of 30 trials.

Simultaneous matching of faces from different viewpoints (SRI 4). Face stimuli with neutral expressions in frontal and three-quarter view were used. Two faces, one frontal photograph and one portrait in three-quarter view, from the same or different persons were presented arranged on the diagonal of the screen. Participants indicated whether photographs displayed the same or different persons on a total of 30 trials.

Delayed non-matching to sample (SRI 5). A neutral target face was presented for 1000 ms followed by the display of a blank screen for 4000 ms. Then the target face and a new face were shown. Participants had to indicate the novel face on a total of 30 trials. This task was designed to measure recognition speed.

Recognition speed of learned faces (SRI 6). This task was a composite of four parts. Each part consisted of a learning and a recognition phase. Four faces were presented for 30 seconds to allow robust encoding. Participants had to memorise the faces. After a delay of four minutes (during this time a reasoning test was completed) four learned and four new faces were presented one at a time. Participants had to indicate whether or not the presented face had been shown in the study phase. This task was also designed to capture recognition speed.

*Speed of recognising non-face stimuli (*SRNF*)*

Number comparison (SRNF 1). This task is widely used for measuring perceptual speed (Carroll, 1993). Two columns of number strings, with varying length of 3 to 13 digits, were presented. Participants compared the strings in a line and clicked on the box marked “Yes”, if the strings were identical and “No”, if they were not.

Symbol comparison (SRNF 2). This task (Danthiir, Wilhelm, Schulze, & Roberts, 2005) is a figural version of the number comparison task. The font of the number strings from *SRNF 1* were simply changed to Wingdings font.

Data treatment and scoring

Relevant performance indicators used in the models presented in this paper are reaction times (RTs). Descriptive statistics for accuracy (proportion correct) will be presented to describe performance on the speed measures more exhaustively. Statistical analyses of the speed data are based on latencies of correct responses. The inverted average latencies (1000/RT in milliseconds) across the trials of a given task were defined as dependent variables. These scores represent the number of correctly processed trials per second (see “reciprocal transformation” in Cohen, Cohen, West, & Aiken, 2003, p. 232). We used this metric instead of expressing performance as milliseconds per correct response because the univariate and multivariate frequency distributions of the data are more normally distributed. A replication of the analysis reported in the paper using traditional latency measures (data scored as milliseconds per correct response) led to the same conclusions.

In order to minimise the influence of outliers on the dependent variables (Ratcliff, 1993), RTs smaller than 200 ms or longer than 3.5 *SD*s above the individual mean for a specific task were set to missing values. If 40% or more of the trials of a specific task were missing for a participant, the score for this task was set to missing value. Individual mean RTs for a particular task were also set to missing if they were more than 3 *SD*s above the group mean RT. Two participants were excluded from the analyses because they had missing values for more than five tasks. The analyses were conducted with the remaining 151 participants. The few remaining missing data points were replaced using the Expectation–Maximisation (EM) algorithm implemented in SPSS 12.0, which presupposes that the missing data are missing completely at random. The MCAR chi-square test (Little, 1988), $\chi^2 = 4.37$, $p = .41$, indicated that the assumption of missing completely at random should not be rejected.

Statistical analysis

We conducted confirmatory factor analysis (CFA) and structural equation modelling (SEM) with Mplus 5.1 (Muthén & Muthén, 1998–2007). With CFA and SEM it is possible to test whether theoretically derived models are capable of explaining the observed covariances. Usually, measurement models and structural models are distinguished. In a measurement model, the main interest is to find a model that explains the internal structure of a group of indicators. In a structural model, the main interest is to test relations between latent factors. In CFA or SEM, a theoretical or model-implied covariance matrix is compared with the observed (empirical) covariance matrix. Various statistical tests and fit indices have been developed to evaluate such comparisons.

There is a broad variety of statistics and indices to assess the fit or adequacy of measurement or structural models (Bollen & Long, 1993). An important and commonly referred to statistic is the chi-square-value associated with each model for a given data set. The chi-square test expresses how similar the model-implied covariance matrix and the observed covariance matrix are. Ceteris paribus higher values of chi-square indicate

Table 1. *Means performances in all tasks—accuracy and latency*

	M_A	SD_A	*Skew*	*Kurtosis*	M_L	SD_L	α_L
SRE 1							
Happiness	0.98	0.03	−2.57	7.25	1.69	0.36	.89
Anger	0.93	0.09	−1.48	1.59	1.31	0.35	.82
SRE 2							.83
Happiness	0.88	0.15	−0.86	−0.23	0.47	0.13	—
Sadness	0.92	0.12	−1.32	0.63	0.60	0.16	—
Anger	0.96	0.10	−2.20	4.15	0.52	0.14	—
Fear	0.81	0.13	−0.84	3.42	0.44	0.12	—
Surprise	0.95	0.11	−1.87	2.68	0.55	0.13	—
Disgust	0.76	0.20	−0.28	−1.06	0.47	0.16	—
SRE 3							.81
Happiness	0.93	0.10	−1.42	2.93	0.78	0.15	—
Sadness	0.79	0.21	−1.13	1.68	0.54	0.18	—
Anger	0.75	0.22	−0.64	−0.35	0.64	0.18	—
Fear	0.61	0.28	−0.41	−0.65	0.45	0.15	—
Surprise	0.92	0.16	−2.28	5.80	0.67	0.16	—
Disgust	0.71	0.25	−0.86	0.13	0.54	0.16	—
SRI 1							
All trials	0.92	0.06	−1.20	2.17	0.79	0.17	.84
SRI 2 & SRI 3							
Condition align	0.96	0.06	−3.05	12.30	0.72	0.17	.88
Condition non-align	0.95	0.06	−2.04	5.66	0.72	0.17	.82
SRI 4							
All trials	0.92	0.06	−0.76	0.64	0.56	0.14	.88
SRI 5							
All trials	0.97	0.04	−1.36	1.65	1.01	0.20	.90
SRI 6							
All trials	0.90	0.09	−0.62	−0.48	0.93	0.17	.75
SRNF 1							
All attended trials	—	—	—	—	0.36	0.07	.83
SRNF 2							
All attended trials	—	—	—	—	0.28	0.05	.83

Notes: *SRE 1*–Facially expressed emotion decision; *SRE 2*–Emotional odd-man-out; *SRE 3*–Facially expressed emotion labelling; *SRI 1*–Simultaneous matching of morphs; *SRI 2*–Simultaneous matching of upper face halves—condition aligned; *SRI 3*–Simultaneous matching of upper face halves—condition non-aligned; *SRI 4*–Simultaneous matching of faces from different viewpoints; *SRI 5*–Delayed non-matching to sample; *SRI 6*–Recognition speed of learned faces; *SRNF 1*–Number comparison; *SRNF 2*–Symbol comparison; M_A–mean accuracy; SD_A–standard deviation of the mean accuracy; M_L–mean inverted latency, calculated as 1000/RT in milliseconds (scores represent the number of correctly processed trials per second); SD_L–standard deviation of the mean inverted latency; skew and kurtosis are displayed for the accuracy data.

stronger deviations of the observed from the implied covariance matrix. If these deviations are larger than can be expected by chance, the chi-square is evaluated as indicating significant departure from close fit between model and data. Relying on fewer estimated parameters improves parsimony of a model but usually impairs model fit. Differences in the fit of two models can be tested inferentially in some cases. Such comparisons can be established by deriving competing measurement or structural models from each other. This can be done by constraining estimated parameters to specific values. These comparisons of nested models can be performed with a chi-square test. Here the chi-square statistic is the difference of the two chi-square values and the degrees of freedom are equal to the difference of degrees of freedom of both models. Significant values of this test indicate that constraining some of the estimated parameters impaired model fit. The less parsimonious model is then preferred. Comparisons that turn out to be statistically non-significant should usually lead to accepting the more parsimonious model.

For some aspects of assessment of model fit the chi-square test is not optimal because its power heavily depends on sample size. Therefore, additional fit indices compensating for these shortcomings ought to be reported. The root mean square error of approximation (RMSEA) estimates the misfit due to model misspecification per degree of freedom. The standardised root mean-square residual (SRMR) reflects the standardised difference between observed and predicted covariance. The comparative fit index (CFI) is an incremental fit index that expresses the proportion of improvement in overall fit relative to the independence model, that is, a model assuming no correlations between the manifest variables.

Taken together, these fit measures allow the assessment and evaluation of model fit. Strict recommendations for minimal values of these fit indicators are not sensible (Hu & Bentler, 1995, 1999). Nonetheless, some cut-off values have been established as rules of thumb. If the sample size is not very large, the chi-square statistic should not surpass the conventional level of significance very far. Regardless of sample size the CFI values should be 0.90 or higher, RMSEA values should be .06 or smaller, and SRMR values should be .08 or smaller.

In order to facilitate reanalysis of the data, the correlations between all variables included in the measurement and structural models and/or a complete data set is available upon request.

RESULTS

Descriptive analyses

Level of accuracy, mean values of performance speed, and Cronbach's alpha for the latencies in all tasks are displayed in Table 1. For the emotion recognition tasks, statistics are presented separately for all emotions. Performance was highly accurate in nearly all tasks or task conditions. Accuracy levels of recognising the expression of disgust was somewhat lower (*SRE 2* = .76 and *SRE 3* = .71). This was also the case for anger and fear in *SRE 3* (.75 and .61, respectively). Persistently high negative skew values for the accuracy distributions (Table 1) indicate expected ceiling effects.

Alphas for the latency scores in all tasks were acceptable to high (.75 to .90; Table 1). Summing up, all tasks or task conditions had low difficulty estimates and sufficiently consistent speed estimates to use them as speed measures.

Measurement model: Speed of recognising facially expressed emotions

In a first step we tested the postulated higher order measurement model (*Hypothesis 1*) of individual differences in the speed of recognising facially expressed emotions (Figure 1). Inverted latencies across emotion-specific trials were defined as dependent variables, thus as indicators of task-specific factors. A general factor of the speed of recognising facially expressed emotions was postulated to account for the common variance across the three task-specific factors. The fit of the higher order measurement model was reasonable: $\chi^2(74) = 120.2$, $p = .00$, CFI = .94, RMSEA = .06, SRMR = .06. Standardised factor loadings of the emotion-specific indicators were all larger than 0 at $p > .01$ and ranged between $\lambda = .89$ and .94 in the case of *SRE 1*, $\lambda = .67$ and

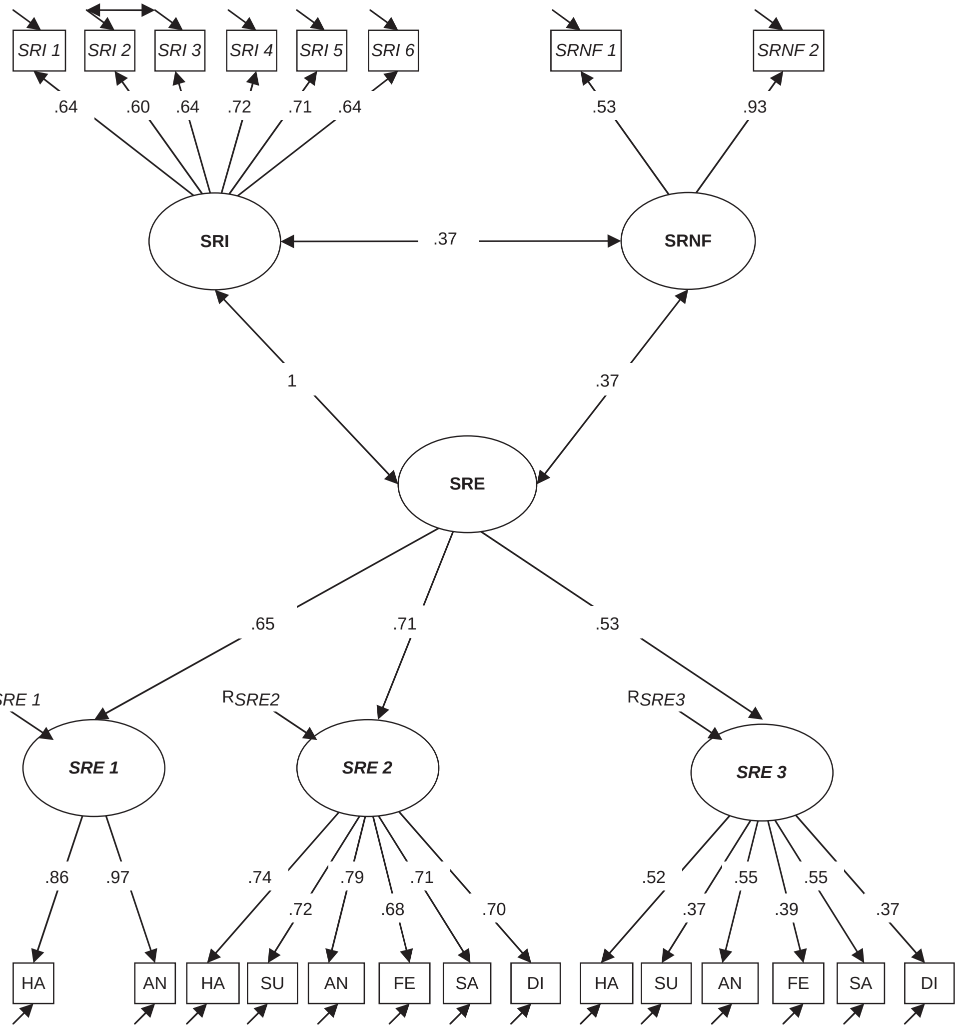

Figure 2. *Structural model—Relations with the speed of recognising facial identity and the speed of recognising non-face stimuli. Notes: SRE–Speed of recognising facially expressed emotions; SRE 1–Facially expressed emotion decision; SRE 2–Emotional odd-man-out; SRE 3–Facially expressed emotion labelling;* HA–*Happiness;* SU–*Surprise;* AN–*Anger;* FE–*Fear;* SA–*Sadness;* SRI–*Speed of recognising facial identity; SRI 1–Simultaneous matching of morphs; SRI 2–Simultaneous matching of upper face halves—condition aligned; SRI 3–Simultaneous matching of upper face halves—condition non-aligned; SRI 4–Simultaneous matching of faces from different viewpoints; SRI 5–Delayed non-matching to sample; SRI 6–Recognition speed of learned faces;* SRNF–*Speed of non-face stimulus recognition; SRNF 1–Number comparison; SRNF 2–Symbol comparison; R–Residual.*

.79 for *SRE 2*, and $\lambda = .32$ and .62 for *SRE 3* (Figure 1). Loadings of the task-specific factors on the general factor were considerable and larger than 0 as well: $\lambda = .53$ for *SRE* 1, $\lambda = .91$ for *SRE 2*, and $\lambda = .49$ for *SRE 3*. The variance accounted for in the indicators can be computed by squaring the loading coefficients reported in Figures 1 and 2, respectively. The general factor accounts for a large amount of variance in *SRE 2* ($R^2 = .82$) but substantially less in *SRE 1* ($R^2 = .28$) and *SRE 3* ($R^2 = .24$), indicating that these two tasks show more unique variance. Based on the reasonable model fit of this model we accept the expectation formulated in *Hypothesis 1*. Note that this model does not allow for emotion-specific relations across the three tests.

Structural model: Relations with the speed of recognising facial identity and the speed recognising non-face stimuli

In a second step we fitted a structural model to test latent level correlations between the general speed factor of recognising facially expressed emotions and the speed of recognising facial identity (*Hypothesis 2*), on the one hand, and of both factors (SRE and SRI) with the speed of recognising non-face stimuli (*Hypothesis 3*), on the other hand. Compared to the measurement model described above, in this second model two further factors were defined (speed of recognising facial identity and the speed of recognising non-face stimuli) and postulated as being correlated with the general speed factor of recognising facially expressed emotions (Figure 2).

The fit of the structural model was also reasonable: $\chi^2(202) = 277.1$, $p < .01$, CFI = .95, RMSEA = .05, SRMR = .06. Standardised factor loadings on the side of the measurement model of emotion recognition are highly similar with those described above. Loadings of the speed indicators of face cognition were also considerable, ranging between $\lambda = .60$ and .72. Residual correlations between *SRI 2* and *SRI 3* were theoretically expected because these indicators are two conditions of the same task. This residual correlation was estimated to $r = .86$. Factor loading of the speed indicators of recognising non-face stimuli were also significant and large: $\lambda = .53$ and .93.

In line with our expectation specified in *Hypothesis 2* the correlation between SRE and SRI was perfect: $r = 1$. This means that the speed of recognising facially expressed emotions and the speed of recognising facial identity are indistinguishable abilities in terms of individual differences. Individual differences in the speed of recognising facially expressed emotions are perfectly related with the speed of recognising facial identity. Because this correlation is freely estimated to be unity, fixing this coefficient to unity and the correlation of SRE and SRI with SRNF to equality delivers two additional degrees of freedom without deteriorating fit to the data, $\Delta\chi^2 = 1.6$, $\Delta df = 2$; model fit with fixed parameters: $\chi^2(204) = 278.8$, $p < .01$, CFI = .95, RMSEA = .05, SRMR = .06.

Hypothesis 3 postulated a moderate or substantial correlation between SRE and SRI on one side and SRNF on the other side. Because SRE and SRI are perfectly correlated and the model fixing this relation to unity was accepted, the relations (SRE with SRNF and SRI with SRNF) are equal. The value for the correlation of SRE/SRI with SRNF is $r = .37$. The coefficient is reliably larger than zero and smaller than unity and expresses a moderate relation. This confirms *Hypothesis 3* and suggests that the processing speed of non-face stimuli (numbers, symbols) is distinguishable from the processing speed of facial identity and of recognising facially expressed emotions, which indeed were not distinguishable from each other.

DISCUSSION

The present study aimed to: (1) investigate psychometric properties of three speed tasks of emotion recognition; (2) establish a measurement model of individual differences in the speed of recognising facially expressed emotions (*Hypothesis 1*); (3) test the latent level correlation between SRE and SRI (*Hypothesis 2*); and (4) investigate their relation with SRNF (*Hypothesis 3*).

Descriptive analyses of the accuracy data in emotion recognition reinforce previous findings about people's high fidelity in recognising expressions of six basic emotions (happiness, surprise, anger, fear, sadness and disgust) from the face. Even strict time limitations of stimulus exposition in *SRE 3* did not lead to a serious decrease of the correctness of recognition. We doubt the fruitfulness of the method of highly speeded presentation of stimuli for designing a measure of accuracy, as done in the JACBART or FEEL and we classify such tasks as speed measures. The relation of such emotion-specific speed measures to established speed measures of processing face stimuli should be clarified.

Hypothesis 1: Measurement model

We postulated and confirmed a higher order model of individual differences in the speed of recognising facially expressed emotions. There are two important conclusions that can be drawn from this model. First, the model shows that decision speed in a task of emotion recognition, where stimuli are exposed for a very limited time, can serve as an indicator of a general SRE factor alongside two more prototypical speed tasks (two-choice reaction time tasks), which use emotional face stimuli. Second, it shows that emotion specificity does not need to be accounted for in a model with task-specific first-order factors. Inspection of residual correlations and modification indices confirms that emotion specificity is irrelevant for the three SRE measures. Therefore, there is no systematic variation across individuals in the speed with which specific emotions are recognised once general SRE has been taken into account. It is still unclear whether or not emotion specificity is more important for accuracy measures of emotion recognition. Obviously, more appropriate accuracy measures are required to answer the question.

Hypothesis 2: Relation to the speed of recognising facial identity

The main question of this study was, whether SRE and SRI can be distinguished. Suggestions for the existence of neuroanatomical and functional overlap in processing neutral and emotional face stimuli from experimental studies (see introduction) make it essential to test behavioural overlap in the abilities to perceive/recognise neutral versus emotional faces. This can be done by testing large samples and using a latent variable approach in order to attain ability estimations, which are adjusted for task specificity and measurement error. In the present investigation we tested this overlap for the speed of processing and found that individual differences in the speed of recognising facial identity cannot be distinguished from the speed of recognising facially expressed emotions. Therefore, SRE—as measured in the present study—has no uniqueness and cannot have discriminant validity relative to SRI.

As reviewed in the introduction, all models of face processing claim early common processes, and there is also some evidence for later interactions (Wild-Wall et al., 2008). Thus, Bruce and Young (1986) suggested that both expression and identity analyses start from view-centred descriptions. Calder et al. (2001) suggested a common coding space for facial expressions and facial identity, and Martens et al. (2001a, 2001b) proposed that structural encoding—which entails also view-independent descriptions—is a common stage for both processing streams.

The present findings are in line with the idea that the analyses of identity and of expression have a common basis, for example, in structural encoding. If the face identity and the expression tasks in our study had tapped just structural encoding, the perfect correlation found between the latent factors SRE and SRI may have been expected. Thus, for the face perception tasks, it might be argued that they can be executed on the basis of structural encoding alone. But this cannot apply to the face memory tasks because they rely also on memory representations of faces, arguably face recognition units in terms of Bruce and Young (1986). An exclusive reliance on structural encoding appears also to be implausible for our expression recognition tasks; all of them required not only structural encoding but also—at least to some extent—the retrieval of knowledge about facial expressions. Specifically, *SRE 1* required the classification of expressions as showing anger or happiness, *SRE 2* the recognition of a deviant emotional expression, and *SRE 3* even the classification of an expression as one of six basic emotions. It is a striking result that individuals show the same rank ordering (i.e., high positive correlation) of factors reflecting perception speed but also face recognition speed and retrieval speed of knowledge about the meaning of emotional expressions.

One way to approach this riddle is to remember that a similar result consistently showed up when face identity processing was considered (Hildebrandt et al., 2010; Wilhelm et al., 2010).

In speed data, perception and memory factors were indistinguishable. This contrasted with accuracy data where perception and memory factors segregated. Possibly, speed and accuracy in multivariate data are not two sides of the same coin. Instead, they may reflect fundamentally different aspects of performance (Carroll, 1993). The situation might be similar when the speed of recognising facially expressed emotions is concerned. The speed of recognising emotional expressions seems to depend on the same, more general, ability as the speed of recognising facial identity. It would therefore be highly interesting to extend the present study by using tasks that tap performance accuracy rather than speed. Possibly, one could find a separation between identity and expression factors then. However, as described in the introduction, due to the intrinsic robustness of processing basic emotional expressions this will not be easy.

Hypothesis 3: Relation to the speed of recognising non-face stimuli

A further aspect of deepening our understanding of SRE was to assess its relation with a speed factor of recognising non-face stimuli (*Hypothesis 3*). We postulated a lower correlation with the speed of recognising non-face stimuli as compared to the correlation between the two speed factors of recognising facial stimuli. According to the present results the speed of recognising non-face stimuli is clearly distinguishable from SRE. There are two limitations of the analyses around *Hypothesis 3*. First, the speed factor of recognising non-face stimuli relies on only two indicators. Therefore, the factor is more task- and method-specific than a factor that is built upon a larger number of measures representing a broader variety of speed measures of recognising non-face stimuli. Second, presentation and response format were different in the speed tasks of recognising non-face stimuli. Multiple stimuli were presented on one screen and responses were to be given with the computer mouse. This kind of stimulus–response mapping was only used in the *SRE 3*. All other tasks were two-choice RT tasks. The correlations between the speed of recognising non-face stimuli, SRE and SRI could have been higher in the case of more strongly overlapping response formats. We predict a stronger but far from perfect relation between SRE/SRI with SRNF, if these two shortcomings are eliminated.

Future directions

One might object to our findings inasmuch as they are specific to the tasks used here. Further studies might substantiate the degree of task specificity of the present data. Supposedly, alternative speed measures of SRE should show relations comparable to those reported here, unless the measurement concepts are substantially modified. A variety of competing measurement approaches for SRE should be used. If alternative approaches to measuring SRE are successful in the sense that some uniqueness of a new latent SRE factor emerges, one corollary of the present results is that such a new latent SRE factor is distinct from the present SRE factor to the same degree. Such a result would be problematic because the SRE measures used here are mainstream measures for the assessment of SRE. We infer from this result that it is highly desirable to construct new measures of emotion perception and recognition that do show uniqueness. We recommend focusing on accuracy-based measures. Such new measures of emotion perception and recognition should fulfil several criteria. First, they should not include a dominant speed component. Second, they should use validated expressions of emotions (i.e., expressions that can clearly be categorised using validated coding systems of facial behaviour). Idiosyncratic expressions for which the scoring key is derived from some not veridical consensus (Mayer et al., 2003) should not be used. Third, stimuli may be developed following componential emotion theories (Scherer, 2001; Scherer & Ellgring, 2007) and tests may also use expressions with varying intensity within an expression-family of basic emotion (e.g., fear family: panic fear, anxiety; see Bänziger, Grandjean, & Scherer, 2009). Once developed, such tests should undergo a systematic validation process, by testing the following assumptions:

1. New measures show at least moderately positive correlations with available tests of recognising facially expressed emotions, demonstrating convergent validity.
2. They do not correlate perfectly with measures of face cognition, showing discriminant validity—the battery of face cognition tests developed by Herzmann et al. (2008) can be used as criterion measure for testing this assumption.
3. They correlate only moderately with tests of abstract cognition.
4. They can be related to specific neurophysiological events in a theoretically meaningful way.

CONCLUSION

The main message of the present paper is that speed measures of emotion recognition fail to show uniqueness compared to speed measures of perceiving/recognising face identity. The factorial equivalence of speed measures of emotion recognition and of identity recognition has profound theoretical implications. In the light of the cognitive processes required by the administered tasks (as discussed above)—that go beyond structural encoding—the present results suggest that the common basis of identity and expression recognition not only include early perceptual processes, but also later processing stages, like encoding and retrieval. Results substantiate this for speed data. Previous findings show factorial equivalence for perception speed and recognition speed but factorial dissociation for perception accuracy versus recognition accuracy of faces (Hildebrandt et al., 2010; Wilhelm et al., 2010). Together with the present results, we conclude that the speed and accuracy of performance are reflecting different aspects of face processing and are not two sides of the same coin (face cognition constructs). This is essential because models of face cognition were frequently only tested on the basis of speed data. We recommend measuring and interpreting the speed versus accuracy of face cognition as different performance constructs.

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