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Recognition of emotional expressions is affected by inversion and presentation time

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Abstract. It has been repeatedly shown that face inversion affects the recognition of emotional faces. However, previous results are heterogeneous concerning the affected emotions and the influence of presentation time is unclear. We examined the impact of limited presentation time (200 ms) on the face-inversion effect during recognition of basic emotions in 128 healthy young adults. Data analysis revealed differential inversion effects for emotional expressions, further modified by limitation of presentation time: when presentation was limited, we observed inversion effects for angry and neutral faces which were absent in the unlimited trials. In the unlimited condition, inversion particularly affected recognition of disgust and sadness. No general inversion effect occurred for neutral expressions. Error analysis highlighted specific confusions for the inverted condition, except for happy and neutral expressions. Hence, emotion recognition is affected by inversion—an indicator for configural processing, and presentation time—an indicator for cognitive effort of processing.

1 Introduction

Facial expressions are the most salient cues for social interaction and enable an immediate inference to the feelings of other people. It has been well documented that processing of facial identity relies on a slightly different neural network than processing of facial emotions (eg Schyns et al 2002), and according to Prkachin (2003), several processing steps are necessary to correctly recognise the emotional expression in a face: (i) one has to determine whether it is a face or not; (ii) then it has to be assessed whether any expression is shown; and, finally, (iii) the specific emotion has to be categorised (angry, sad, fearful, etc).

Recent face processing models postulate two fundamental categories of information: local and configural features (eg Bartlett et al 2003), though definitions for these terms are not used homogeneously. Local information mostly refers to distinct circumscribed characteristics of the face, such as the mouth or the nose. General spatial relations of the face (eg the eyes are above the nose, etc) are usually described as configural information or first-order relations, whereas second-order relations refer to specific spatial relations (eg distance between eyes and nose) and possess a higher discriminative value (Leder and Carbon 2006). Finally, a holistic account assumes that faces are processed as a whole ('Gestalt') with no or limited decomposition (Leder and Carbon 2005; for overview see Maurer et al 2002). Evidence has accumulated that the global analysis underlying face recognition also applies to facial-emotion recognition, being dependent upon facial features and spatial arrays (eg Calder et al 2000; Schyns et al 2002).

Using bubbles to randomly mask several parts of the face, Schyns et al (2002) observed that happy faces were mainly recognised when the mouth was shown, whereas for neutral faces screening of the eye region was more important, suggesting that emotional expressions are characterised by a distinct underlying pattern of facial features that will not need to be scrutinised but are quickly recognised as a particular emotion (cf Prkachin 2003).

For face recognition, inversion of faces has been frequently used to characterise the processing of these unique stimuli, demonstrating disproportionally decreased performance for upside-down faces compared to other inverted objects (eg Yin 1969; Carbon and Leder 2005, 2006a; for a review see Valentine 1988): these results suggest that there is a different processing strategy for inverted faces, which is thought to be derived from impaired 'configural' processing (Searcy and Bartlett 1996; Carbon et al 2007). Other researchers have asserted that inversion interferes with the encoding of configural and holistic information but not the encoding of explicit isolated facial features (White 1999; Fallshore and Bartholow 2003; Leder and Carbon 2005). Hence, while we benefit from local and configural information to recognise upright faces, processing of local information is sufficient and thus the strategy applies to inverted faces.

There have been only a few studies of the effect of inversion on the processing of emotional expressions. This is rather astonishing as there is now overwhelming evidence that the inversion effect as such can be used as an indicator for configural processing (Lewis and Johnston 1997; Carbon et al 2007). Thus, by comparing performances of upright with inverted processing of facial emotions we have a powerful measure to test for configural-based or holistic processing of these emotions. A review of empirical findings regarding processing of emotional faces demonstrates rather inconsistent results: while McKelvie (1995) observed impaired emotion recognition for all negative emotions presented, performance for happy faces remained unaffected. Calvo and Nummenmaa (2008) also observed a less pronounced inversion effect for happy faces though inversion slowed down all reaction times. While Prkachin (2003) reported an inversion effect for all emotions presented irrespective of valence, Fallshore and Bartholow (2003) observed inversion effects for anger, fear, happiness, and sadness, but recognition of surprise and disgust remained unimpaired. Finally, Goren and Wilson (2006) demonstrated several significant effects, interestingly with happy faces being the most affected by inversion, while no such effect occurred for anger, somewhat contradicting previous results. See table 1 for a more detailed survey of the listed studies.

In sum, not only the negative emotions consisting of a combination of several facial features were affected by inversion, but also happy faces that are well characterised by a specific feature—the upturned mouth—and thus easy to differentiate from all other expressions. Hence, inversion seems to affect the recognition of all emotions in faces, though it is currently unclear whether all basic emotions are similarly affected or some, due to their configural complexity, undergo stronger effects showing themselves in decreased recognition accuracy and longer response times. One possible reason for the reported inconsistencies of previous results might be the heterogeneity of sensitivity of the methods used [eg stimulus material, task instruction, the variety of presentation time ranging from 100 ms to 15 s, etc (see table 1)].

Consequently, the present study was designed to compare recognition accuracy for upright and inverted faces depicting five basic emotions and neutral expressions using an explicit emotion-recognition task for a large sample of subjects. Furthermore, we addressed the effect of presentation time by using two experimental blocks, one with unlimited and the other with 200 ms presentation time, in view of recent results of Veres-Injac and Schwaninger (2008) who proclaimed that at least 150 ms is required to correctly process inverted neutral faces. Therefore, if emotional facial expressions are not recognised as featural parts but rather in a 'Gestalt' manner, then one can argue that subjects do not benefit from the additional time to identify the emotion during the unlimited time presentation. Alternatively, one can also assume that, if the time to process emotional faces is limited, recognition accuracy will be significantly lower for inverted faces as identification of the configural characteristics of these expressions might not be accurate enough, and one can only rely on feature-focused, part-based face processing strategies.

Table 1. Overview and details of previous studies of the effect of inversion on the recognition of emotional expressions, including reference, number of participants, type of stimuli, presentation time, emotions presented, and for which emotions inversion effects occurred (marked with an asterisk).

Reference	Subjects N (F : M)	Type of stimulus	Time/ms	Emotions presented
McKelvie (1995)	126 (47 : 31)	pictures of facial affect (Ekman and Friesen 1976)	15 000	happiness, sadness*, fear*, anger*, disgust*, neutral
Fallshore and Bartholow (2003)	140 (ns)	schematic drawings of basic emotions (Sullivan et al 1995)	2 000	happiness*, sadness*, fear*, anger*, disgust, surprise
Prkachin (2003) experiment I	12 (6 : 6)	pictures of facial affect (Ekman and Friesen 1976)	100	happiness*, sadness*, fear*, anger*, disgust*, surprise*
Prkachin (2003) experiment II	108 (54 : 54)	pictures of facial affect (Ekman and Friesen 1976)	33	happiness*, sadness*, fear*, anger*, disgust*, surprise*
Goren and Wilson (2006)	8 (5 : 3)	synthetic line drawings derived from black – white photographes (Wilson et al 2002)	110	happiness*, sadness*, fear*, anger
Calvo and Nummenmaa (2008) experiment 3	48 (34 : 14)	Karolinska directed emotional faces (Lundquist et al 1998)	unlimited — until button press	happiness, sadness*, fear, anger*, disgust, surprise, neutral

2 Methods and material

2.1 *Participants*

Seventy-three female (mean age: 21.9 years, SD = 3.3 years) and fifty-five male students (mean age: 26.0 years, SD = 3.9 years) of the University of Vienna were voluntarily enrolled in this study. Participants did not differ in their age ($t = -1.603$, $p = 0.134$), nor in their mean years of education ($t = -0.209$, $p = 0.836$), and all had normal or corrected-to-normal vision.

2.2 *Material and procedure*

The explicit emotion-recognition task consisted of 90 coloured photographs of facial expressions portraying an equal number of five basic emotions (anger, disgust, fear, happiness, and sadness) as well as neutral expressions. All expressions were taken from a stimulus set, which has been standardised and used repeatedly as neuro-behavioural probes in behavioural and neuroimaging research (see Gur et al 2002 for development; Fitzgerald et al 2006; Habel et al 2007; Moser et al 2007; Derntl et al

2008a, 2008b, 2009a, 2009b, 2009c). The stimulus material applied here was also validated for the European population (Hoheisel and Kryspin-Exner 2005) and only evoked expressions were shown. The stimuli were balanced for emotion (15 per each emotion plus 15 neutral faces) and gender and experimental trials were randomised by the experimental software PsyScope 1.25 PPC (Cohen et al 1993). To investigate the influence of orientation, the set of 90 coloured photographs was randomised to be presented either upright or inverted, with each picture presented in both orientations once during the duration of the test. Moreover, in a second experimental block test, followed after a short break we presented the same stimuli (upright and inverted) for only 200 ms to examine the influence of presentation time on explicit emotion recognition in upright and inverted faces. In both trials the instruction was to recognise the emotion depicted as quickly and as accurately as possible. A forced-choice answering format with all emotions given at all times was used. The labels of the presented emotions were shown on the right side next to each picture and participants had to choose the correct emotion from the list of emotions by pressing the corresponding button. Measurement of reaction time was started with stimulus onset and stopped when the button was pressed. The button-press triggered the presentation of the next trial. Pictures were presented with a resolution of 282×400 pixels yielding a visual angle of approximately 3.1 deg $\times$ 4.4 deg.

All tasks were presented on a Macintosh eMac 1000 with integrated 17-inch CRT monitor running with a refresh rate of 100 Hz.

After the experiment, we assessed how confident each subject felt when giving the answer by obtaining rating scores on how confident he/she was to respond correctly in each condition (unlimited upright, unlimited inverted, limited upright, limited inverted; 1 = very confident, 4 = not confident).

2.3 *Data analysis*

Individual data were averaged across emotion, orientation, and presentation time. Correct responses of the emotion-recognition task were analysed with a repeated-measures ANOVA with emotion, orientation, and presentation time as within-subjects factors and gender of rater as between-subjects factor. Another repeated-measures ANOVA with the same factors (emotion, orientation, and presentation time as within-subjects factors; gender as between-subjects factor) was computed for reaction times. Greenhouse – Geisser corrected p-values were used for all ANOVAs and a posteriori results were Bonferroni – Holm corrected. Effect sizes are reported with partial eta-squared (η_p^2) estimators.

Analysis of error rates was accomplished by calculating confusion matrices for each emotion (eg how often an angry face was labelled as angry, sad, happy, etc). Influence of inversion and presentation time on these emotion-specific frequencies was checked by comparing error rates (inverted versus upright; unlimited versus limited) using paired-samples t-tests. p-Values were corrected by the Bonferroni method.

The effect of orientation of stimuli and presentation time on the self-rating data (confidence of correct responses in total) was analysed with a repeated-measures ANOVA, including orientation and presentation time as within-subjects factors and gender as between-subjects factor. Finally, to assess any association of self-ratings with the demonstrated performance we correlated the self-rating data with behavioural performance parameters (recognition accuracy and reaction times).

3 Results

3.1 *Emotion-recognition accuracy*

For emotion-recognition accuracy, repeated-measures ANOVA revealed a significant main effect of emotion ($F_{3.9,\,494.7} = 194.3$, $p < 0.001$, $\eta_p^2 = 0.607$), with the highest accuracy demonstrated for happy and neutral faces, followed by angry and fearful faces, and last by sadness then disgust (see figure 1 and table 1). A very large orientation effect ($F_{1,126} = 729.821$, $p < 0.001$, $\eta_p^2 = 0.853$) was revealed, indicating better performance for upright recognition and a significant presentation time effect ($F_{1,126} = 59.784$, $p < 0.001$, $\eta_p^2 = 0.322$), with better performance for unlimited trials. No main effect of gender of rater ($F_{1,126} = 1.494$, $p = 0.224$) was observed. Furthermore, significant interactions of emotion × orientation ($F_{4.1,517.3} = 98.628$, $p < 0.001$, $\eta_p^2 = 0.439$), emotion × presentation time ($F_{4.4,548.6} = 8.207$, $p < 0.001$, $\eta_p^2 = 0.061$), emotion × orientation × presentation time ($F_{4.7,585.9} = 19.211$, $p < 0.001$, $\eta_p^2 = 0.132$), as well as emotion × orientation × gender ($F_{4.1,517.3} = 2.603$, $p = 0.034$, $\eta_p^2 = 0.020$), emerged. All other interactions remained non-significant.

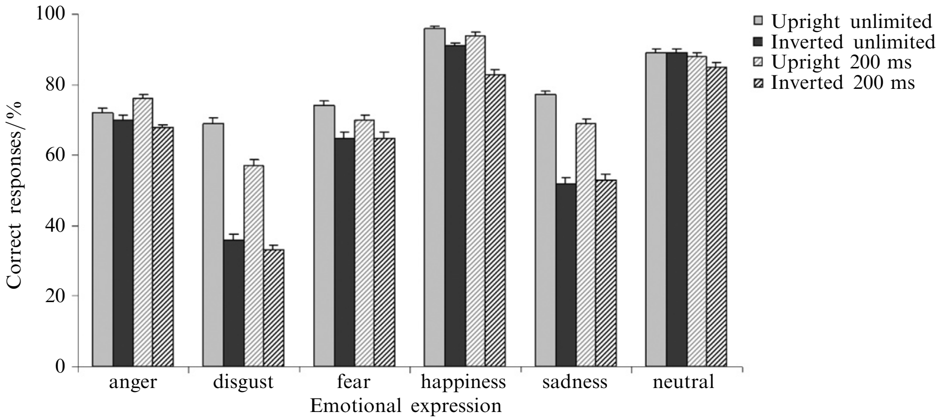

Figure 1. Emotion-recognition accuracy for upright and inverted emotional expressions in both presentation-time conditions. Data analysis revealed a significant general inversion effect for all emotional expressions (all ps < 0.001) but none for recognition of neutral expressions ($p = 0.083$).

A posteriori tests for the significant emotion × orientation interaction revealed a significantly better identification performance of all emotions during upright presentation (disgust, sadness, fear, anger, and happiness: $p < 0.001$), except for the recognition of neutral faces which was not affected by inversion ($p = 0.083$).

For the emotion × presentation-time interaction a posteriori tests demonstrated significantly better performance during unlimited presentation for disgust and happiness (both ps < 0.001), sadness ($p = 0.004$), and neutral ($p = 0.021$). No significant effect of presentation time emerged for fear ($p = 0.998$) and anger ($p = 0.394$).

A posteriori tests dismantling the significant emotion × orientation × presentation-time interaction confirmed the inversion effect (irrespective of presentation time) for disgust (limited and unlimited: $p < 0.001$), fear (limited and unlimited: $p < 0.001$), happiness (limited and unlimited: $p < 0.001$), and sadness (limited and unlimited: $p < 0.001$). Recognition of angry ($p < 0.001$) and neutral expressions ($p = 0.021$) was negatively influenced by inversion only during the limited-presentation-time condition. On comparing the two presentation times, a significantly higher accuracy was found for unlimited presentation than for limited presentation for upright sad faces ($p < 0.001$), disgust ($p < 0.001$), happiness ($p = 0.030$) and fear ($p = 0.042$), as well as for inverted neutral ($p < 0.001$) and happy faces ($p < 0.001$). Better accuracy during limited compared to unlimited presentation time was obtained only for upright angry faces ($p = 0.032$).

Regarding the significant emotion × orientation × gender interaction, a posteriori tests revealed that, within the female sample, increased accuracy was observed for upright faces depicting disgust, fear, happiness, and sadness (ps < 0.001) while no inversion effect was observed for angry ($p = 0.150$) and neutral ($p = 0.342$) expressions. Males performed better for all emotions when presented upright (ps < 0.001), but for neutral recognition no inversion effect occurred ($p = 0.128$). No gender differences occurred in recognising emotions in upright or inverted faces when directly comparing females and males.

Figure 1 illustrates accuracy for upright and inverted emotional expressions in both presentation-time conditions across subjects.

3.2 *Reaction times*

Analysis of reaction times revealed a significant emotion effect ($F_{5,630} = 138.553$, $p < 0.001$, $\eta_p^2 = 0.524$), with fastest response times to happy faces; a significant orientation effect ($F_{1,126} = 52.217$, $p < 0.001$, $\eta_p^2 = 0.293$), and a significant presentation-time effect ($F_{1,126} = 353.903$, $p < 0.001$, $\eta_p^2 = 0.737$), but again no significant main effect of gender occurred ($F_{1,126} = 0.873$, $p = 0.352$). Moreover, a significant emotion $\times$ orientation interaction ($F_{5,630} = 6.701$, $p < 0.001$, $\eta_p^2 = 0.050$), emotion $\times$ presentation-time interaction ($F_{5,630} = 60.385$, $p < 0.001$, $\eta_p^2 = 0.324$), a significant interaction of presentation time with gender ($F_{1,126} = 4.528$, $p = 0.035$, $\eta_p^2 = 0.035$), a significant orientation $\times$ presentation-time interaction ($F_{1,126} = 4.875$, $p = 0.029$, $\eta_p^2 = 0.037$), and a significant emotion $\times$ orientation $\times$ presentation-time interaction ($F_{5,630} = 6.233$, $p < 0.001$, $\eta_p^2 = 0.047$) emerged. All other interactions remained not significant.

Further analysis of the significant emotion $\times$ orientation interaction showed significantly faster reactions in the upright orientation for expressions of anger ($p = 0.009$), disgust ($p < 0.001$), happiness ($p < 0.001$), and sadness ($p < 0.001$). For fearful ($p = 0.581$) and neutral ($p = 0.140$) expressions no such interaction occurred.

Regarding the significant emotion $\times$ presentation-time interaction, a posteriori tests demonstrated a significant effect for all emotions indicating faster responses in the limited condition (ps < 0.001).

A posteriori analysis of the significant gender $\times$ presentation-time interaction revealed no significant difference (limited presentation time: $p = 0.684$; unlimited presentation time: $p = 0.141$). Moreover, the a posteriori tests on the significant orientation $\times$ presentation-time interaction showed significantly faster responses for upright faces, irrespective of presentation time (ps < 0.001).

A posteriori tests disentangling the significant emotion $\times$ orientation $\times$ presentation-time interaction revealed faster recognition times of all emotional expressions with limited presentation time irrespective of orientation (both ps < 0.001). Additionally, reaction times for angry and neutral expressions were lower when the faces were presented upright in the limited condition (anger: $p < 0.001$; neutral: $p = 0.003$), whereas happy, sad, and disgusted expressions were always faster recognised in the upright condition (ps < 0.001). Reaction times for upright versus inverted fearful and neutral expressions in the unlimited condition did not differ significantly (fear: $p = 0.848$; neutral: $p = 0.433$).

Figure 2 depicts reaction times for inverted and upright emotional expressions for both presentation-time conditions across all subjects.

3.3 *Error analysis*

Emotion-specific identification errors were analysed for confusions in emotion recognition by directly comparing the frequencies of each misjudgment (anger mistaken as disgust, anger mistaken as fear, etc).

Generally, disgust and anger were often confused with each other, particularly in the inverted orientation. Additionally, disgust and sadness as well as fear and anger were often confused with each other in both conditions (ps < 0.001). Sadness was often mistaken for neutral in the inverted condition ($p < 0.001$).

Intuitively one would expect confusions to be higher in the inverted condition, but we did not consistently find that pattern. Sadness was significantly more often mistaken

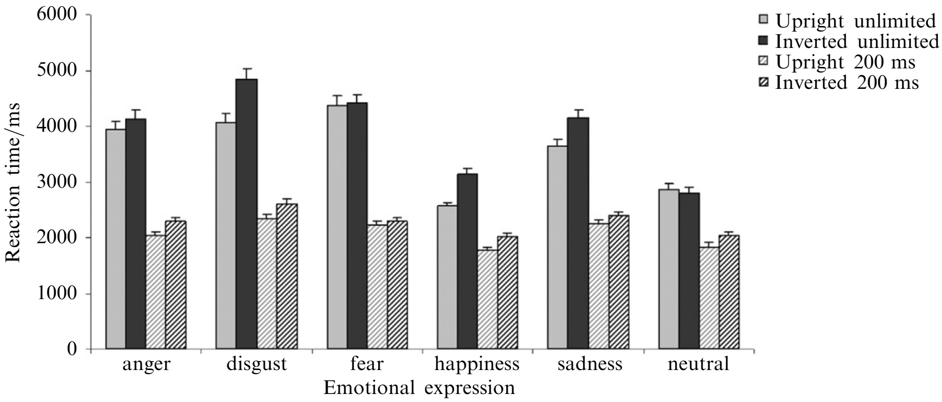

Figure 2. Reaction times for upright and inverted emotional expressions in both presentation-time conditions. Data analysis revealed a significant inversion effect for all emotional expressions and neutral faces (ps < 0.001) that was influenced by presentation time.

for neutral in the inverted than in the upright condition and disgust for sadness and anger, as well as anger for disgust. Additionally, fear was significantly more often mislabelled as anger in the inverted than in the upright condition, whereas anger was significantly more often confused with fear in the upright than in the inverted condition. Furthermore, fear was also significantly more often mistaken for sadness in the upright than in the inverted condition, even if these conditions were only 6% of all possible answers. The influence of inversion on the error rates is shown in table 2.

Simply put, the error rates depending on the two different presentation times showed quite similar patterns compared with the error rates depending on inversion (which is plausible since every face was shown upright and inverted during both presentation-time conditions). Disgust and anger, disgust and sadness, as well as fear and anger were often confused with each other in both presentation-time conditions (ps < 0.001).

Table 2. Confusion matrix on the basis of all emotional expressions indicating the impact of orientation (upright versus inverted). Values express the average proportion of identification of the specific emotional expression. Hits are shown with grey background.

Identification	Orientation	Emotional expression presented					
		happy	sad	anger	disgust	fear	neutral
Happy	upright	0.948***	0.023	0.014	0.033	0.023	0.005
	inverted	0.867	0.070***	0.033***	0.084***	0.058***	0.007
Sad	upright	0.012	0.732***	0.026	0.207	0.057***	0.055
	inverted	0.028***	0.527	0.040***	0.312***	0.041	0.059
Anger	upright	0.004	0.016	0.737***	0.062	0.120	0.043
	inverted	0.029***	0.043***	0.691	0.132***	0.138**	0.038
Disgust	upright	0.008	0.146	0.080	0.632***	0.053	0.003
	inverted	0.020***	0.151	0.105**	0.344	0.059	0.005
Fear	upright	0.005	0.044	0.124***	0.049	0.722***	0.009
	inverted	0.011**	0.052	0.090	0.073***	0.653	0.021***
Neutral	upright	0.017	0.036	0.021	0.016	0.024	0.884
	inverted	0.044***	0.156***	0.044***	0.054***	0.050***	0.869

Note: ** $p < 0.01$, *** $p < 0.001$ for two-tailed t-test comparing the average proportion in upright and inverted faces.

Generally, one would expect significantly higher error rates in the limited compared to the unlimited time condition. The frequent confusions of disgust and sadness with each other were significantly higher in the limited compared to the unlimited presentation-time condition. Additionally, disgust and fear were also significantly more often mistaken for anger in the limited compared to the unlimited presentation time. Concerning particular confusion tendencies in recognising angry faces, no significant differences were found between the limited and unlimited presentation-time conditions. The influence of presentation time is demonstrated in table 3.

Table 3. Confusion matrix on the basis of all emotional expressions indicating the impact of presentation-time condition (limited versus unlimited). Values express the average proportion of misinterpretations made during the identification and the average proportion of hits (with grey background).

Identification	Presentation time	Emotional expression presented					
		happy	sad	anger	disgust	fear	neutral
Happy	limited	0.883	0.049	0.021	0.064*	0.033	0.008**
	unlimited	0.933***	0.044	0.023	0.054	0.048***	0.003
Sad	limited	0.026***	0.609	0.030	0.273*	0.049	0.061
	unlimited	0.014	0.649**	0.036	0.246	0.049	0.053
Anger	limited	0.029***	0.040***	0.718	0.111***	0.146***	0.046
	unlimited	0.004	0.019	0.710	0.083	0.111	0.035
Disgust	limited	0.024***	0.160*	0.095	0.451	0.058	0.006**
	unlimited	0.007	0.137	0.085	0.525***	0.054	0.002
Fear	limited	0.010	0.043	0.102	0.067	0.678	0.014
	unlimited	0.006	0.053	0.112	0.055	0.697	0.016
Neutral	limited	0.030	0.096	0.032	0.033	0.034	0.863
	unlimited	0.030	0.096	0.033	0.037	0.039	0.890*

Note: $*p < 0.05$, $**p < 0.01$, $***p < 0.001$ for two-tailed t-test comparing the average proportion in limited and unlimited time.

3.4 *Self-ratings*

Analysis of self-rating data revealed a significant effect of orientation ($F_{1,125} = 292.211$, $p < 0.001$, $\eta_p^2 = 0.700$), with higher confidence ratings for upright faces, and a significant presentation-time effect ($F_{1,125} = 135.687$, $p < 0.001$, $\eta_p^2 = 0.520$), indicating that the unlimited condition was easier for subjects. However, no significant gender effect ($F_{1,125} = 0.547$, $p = 0.461$) nor any significant interaction occurred.

Table 4 presents means and standard deviations of the rating data for each condition.

Table 4. Mean ratings (and standard deviations) on confidence of correct response for the four conditions (1 = very confident to 4 = not confident).

Condition	Mean rating (SD)
Upright, unlimited	1.91 (0.562)
Inverted, unlimited	2.71 (0.579)
Upright, 200 ms	2.51 (0.699)
Inverted, 200 ms	3.30 (0.622)

Correlation analysis between behavioural performance and self-rating data demonstrated only one significant association between confidence of correctly recognising upright expressions during the limited presentation-time condition and the corresponding recognition accuracy, $r = -0.308$, $p < 0.001$, indicating that the higher the confidence rating (lower scores) the higher the recognition accuracy. All other correlations with behavioural performance parameters (accuracy and reaction time) did not reach significance ($ps > 0.104$).

4 Discussion

In the present study we examined the influence of face inversion and limitation of presentation time on explicit emotion recognition in a sample of one hundred and twenty-eight healthy young adult females and males.

In agreement with previous studies (McKelvie 1995; Prkachin 2003), we observed a significant inversion effect during emotion recognition for evoked expressions of disgust, sadness, fear, and anger. Following the idea that inversion impairs configural face processing (Valentine 1988; Leder and Carbon 2006) we infer that, particularly, the processing of disgust and sadness depends more on configural information than on face components. In this regard, we further assume that particular configural changes in the mouth and eye region (eg the distance between eyes and eyebrows or mouth and nose) may account for this pronounced inversion effect and also for the frequent confusions of these two emotional expressions which should be highlighted in future studies.

Despite the prominent role of the smiling mouth in happy recognition and its visual salience which shortens detection time (Calvo and Nummenmaa 2008), our data show that happy-face recognition is also affected by inversion indicating that subjects do not exclusively rely on the (upturned) mouth in identifying happy faces but also on configural information. These results are in contrast to those of McKelvie (1995) while being compatible with those of Prkachin (2003). It seems that the most evident difference between McKelvie's and both other studies lies in a different use of presentation times. McKelvie used a much longer presentation time of 15 s compared with the ones in our study (200 ms versus empirically found 2 s) and Prkachin's (2003) study (33 ms).

Interestingly, neutral faces demonstrated no general inversion effect. In the set of emotional expressions used in the present study, the neutral expression was the only expression that showed no variation in expression style, ie no smiling mouth, and no widely opened eyes. To detect a neutral expression, we seem to strongly rely on face components. Hence, to differentiate between neutral and emotional expressions subjects might have only looked for specific features associated with a neutral face. In the case of an emotional face, they not only have to detect the emotional characteristics but also have to ascribe the correct emotion. It is important to point out that the high and stable performance of detecting neutral faces does not seem to be based on artificial ceiling effects, as the performance with happy faces was even higher than that with neutral faces, but happy faces did show inversion effects.

Additionally, there appeared to be a relationship between the ability to label all the expressions in the upright orientation and the degree of impairment with inversion, which is in line with the results of Prkachin (2003). Disgust, sadness, and fear were more difficult to recognise in the upright orientation, and also were more strongly affected by inversion. Hence, our data partly support the assumption of Prkachin (2003) who hypothesised that inversion seems to have a quantitative influence with a decrease in accuracy but no real change in the nature of the recognition process. In contrast to this partial support, we observed evidence of a change of processing quality caused by inversion that was obvious in the recognition of sadness, which was frequently labelled as neutral in the inverted but not in the upright condition. It appears that inversion affects the ability to recognise the emotional content in sad faces; thus, our data rather suggest that the presented emotions are affected differently by inversion probably owing to their specific configural processing load. This favours the idea of a qualitative, instead of a purely quantitative, influence of inversion on emotion processing and emotion recognition.

Recognition of disgust suffered most from the inverted condition (and also from the limited presentation time) since recognition accuracy was, in fact, not better than chance (inverted versus upright: 34% correct versus 63% correct; limited versus unlimited: 45% correct versus 52% correct), and reaction times were the longest of all emotions. Additionally, participants labelled disgust more frequently as sadness and anger in the inverted than in the upright condition. Disgust used to be 'the forgotten emotion' (Phillips et al 1997); however, a lot of research has been carried out recently to gain more knowledge. Three experiments by Rozin et al (1994), using posed expressions of disgust, revealed that nose wrinkle and the combination of gape and tongue extension are most clearly associated with negative sensory events and oral irritation—the 'core disgust'. These authors also discuss the upper-lip retraction as a sign for 'extended disgust', which might be more strongly influenced by cultural background. Our evoked expressions of disgust clearly differed in facial expression with half of the stimuli showing upper-lip retraction and the other half gape and tongue extension. Probably, this complexity and variety in expression style led to the decreased accuracy ratings and slower reaction times in our study.

When we considered the influence of presentation time and inversion on the accuracy of emotion recognition, we found that angry and neutral faces were affected by inversion only in the limited time condition. Thus, recognising neutral expressions in an emotion recognition task requires correct extraction of the missing emotional content, which seems to be affected by inversion only during brief presentation times. It is plausible that subjects are less confident to exclude any emotional content in a briefly presented face when focusing on emotion recognition, and thus evaluate whether there are any emotional features apparent in the face or not, as has been discussed above. For anger identification we observed a significant interaction of presentation time and orientation: while inversion affected recognition of angry faces during brief presentation times, no impairment in recognition accuracy was found for anger identification in upright faces in the limited time presentation condition. Hence, our results suggest that inversion affects salient configural cues (shape of mouth, nose, and eyebrows; spatial relation between them) for quickly recognising anger. This finding contradicts the results of Goren and Wilson (2006) with anger not being affected by inversion when presented for only 110 ms. However, Goren and Wilson used artificial facial expressions without texture information (eg wrinkling) which apparently makes it easier to identify anger even in inverted faces.

Regarding presentation time, one might expect better emotion recognition accuracy in the unlimited compared to the limited time presentation condition as participants had more time to scrutinise the facial expressions. This was the case for disgusted, fearful, sad, as well as neutral faces, while no effect of presentation time was apparent in the recognition of happy faces. Unexpectedly, our data indicate that subjects actually demonstrated better accuracy in recognising upright angry faces in the limited time presentation condition than in the unlimited one which also showed itself in faster reaction times, probably indicating that bottom–up processes are more important than top–down processes here.

Veres-Injac and Schwaninger (2008) investigated the effect of presentation time on face inversion and observed that a minimum of 150 ms presentation time is required for processing inverted faces. An unlimited time condition did not result in better performance in a facial matching task. The limited presentation time in our study was 200 ms in duration, which therefore seems to be sufficient for subjects to process both upright and inverted faces. It has been asserted that inversion interferes more with the processing of configural as well as holistic information rather than the processing of explicit isolated features (White 1999; Fallshore and Bartholow 2003; Carbon and Leder 2005, 2006b). In our study, recognition accuracy was significantly higher during the unlimited condition for disgust, sadness, happiness, and neutral expressions, supporting the configural processing approach. Furthermore, limitation of presentation time reduced recognition accuracy for disgust, happy, sad, and neutral expressions, probably indicating that holistic processing of these emotions is time-dependent. However, upright angry facial expressions demonstrated the unique characteristic of being more accurately recognised when presented in the limited than in the unlimited presentation-time condition. Fox and colleagues (2000) reported that, in an emotion discrepancy task, subjects were more likely to detect an angry face than any other emotional face, supporting the theory that rapid detection of angry facial expressions has an evolutionary advantage. The anger-superiority hypothesis states that angry faces are detected more efficiently than friendly faces (Hansen and Hansen 1988; Horstmann and Bauland 2006). Examining the differences in reactions to fear and anger, Springer and colleagues (2007) reported that viewing facial expressions of anger was associated with a significantly heightened startle response relative to viewing fear, happy, and neutral faces. Consequently, they suggest that while anger and fear faces convey messages of threat, their priming effect on startle circuitry differs. It would appear that it is of evolutionary benefit to be able to quickly and accurately identify negative emotional facial expressions such as anger than positive emotional facial expressions such as happiness, and our data impressively demonstrate this anger-superiority effect.

We observed no significant gender effect on emotion recognition accuracy neither for upright nor for inverted faces which is in accordance with some previous studies (eg Grimshaw et al 2004). Probably, there is no female superiority for this explicit emotion recognition task and, moreover, females and males experience the same perception difficulties when confronted with an inverted face because of being largely exposed to upright faces during the whole lifetime (Schwaninger et al 2003; Carbon et al 2007).

We observed a significant negative association between self-ratings of confidence (the lower the more confident) and recognition accuracy for upright faces in the limited presentation-time condition, indicating that the more confident participants were with their response the better they actually performed. Interestingly this correlation emerged for the limited presentation-time trials not for the unlimited presentation-time trials that should have been easier by indicating that we rate our performance rather accurately in the time-constraint condition.

4.1 *Limitations*

There are, however, also limitations in our study. As we focused on inversion effects, we did not employ a fully randomised inversion × presentation-time nor a balanced design of the order of presentation-time blocks. The consequence of conducting the block of unlimited presentation times always before the limited version, might lead to order effects. Importantly, such effects might primarily negatively affect the recognition of unlimited presentation times, not the limited ones, as participants working on the limited presentation-time block had already seen the faces in an unlimited presentation-time fashion. Thus, decreases of performance when presentation times were limited could still be explained. We would also include any strong habituation effects as accuracy decreased for all but the upright angry faces from the block with unlimited to the block with limited presentation times.

It could be of further interest, not to just compare behavioural performances of females and males, but to derive in future studies emotional experience and personality traits that are typically related to females and males. Then we will be able to investigate whether such variables affect recognition accuracy and reaction times for upright and inverted emotional expressions.

We conclude that inversion affects recognition of all emotional expressions presented but spares neutral faces which show no emotional feature. Our data provide only a limited support for the assumption that inversion has a quantitative influence with a decrease in accuracy, but does not affect the nature of the recognition process as outlined by Prkachin (2003). Instead, and for the first time, we partly found evidence of a qualitative influence, probably driven by the configural processing load, of an expression that consequently affects recognition accuracy of inverted facial expressions of disgust and sadness. Moreover, we observed intriguing results on the anger-superiority effect since these emotional expressions were the only ones that benefit from the limited presentation time.

Since we assume that inversion effects originate in an impaired configural processing of emotional faces, one possible next step to further characterise the impact of inversion on the recognition of facial emotion may be the additional implementation of an eye-tracker to measure either the point of gaze or the movement of the eyes when trying to recognise an emotional expression, thereby further elucidating human processing strategies of facial expressions. This will be particularly interesting, when scan paths of upright presentations are compared with those of inverted ones and may help to throw light on certain erratic judgments, eg why inverted sad faces were frequently misjudged as neutral. It is plausible that inversion results in inefficient 'scanning' processes, and consequently affects the recognition. However, during inversion, differentiation between emotional expressions and attaching the correct label to the expressions might also be impaired; thus, explicit emotion recognition tasks with a variety of answering options (only one emotion to choose: correct versus incorrect; several emotions to choose; open answering format) might further highlight how inversion affects emotion recognition.

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