NO EFFECT OF INVERSION ON PERCEIVED SIMILARITY OF FACIAL EXPRESSIONS OF EMOTION

Galina V. Paramei[1], David L. Bimler[2], Slawomir J. Skwarek[3]
[1]*Liverpool Hope University, Hope Park, L16 9JD Liverpool, United Kingdom*
[2]*Massey University, Private Bag 11-222, Palmerston North 4442, New Zealand*
[3]*University of St. Gallen, Dufourstrasse 40a, CH-9000 St. Gallen, Switzerland*
parameg@hope.ac.uk; d.bimler@massey.ac.nz; slawomir.skwarek@unisg.ch

Abstract

We studied discrimination of briefly presented upright vs. inverted emotional facial expressions (FEs), hypothesising that inversion would disrupt holistic FE processing and hence decoding emotions. Stimuli were photographs of seven emotion prototypes, of a male and female poser (Ekman & Friesen, 1976), and eight intermediate morphs. Subjects made Same/Different *judgements on pairs of upright or inverted FEs, presented for 500 ms.* %Same *judgements were taken as an index of pairwise perceptual similarity and analysed with multidimensional scaling. The outcome was a 4D 'emotion expression space', with* Happy–Sad, Surprise/Fear, Disgust *and* Anger *dimensions. Inverting FEs caused minor changes in the structure or dimensional salience, but solutions for the two posers differed substantially more. The findings imply that briefly presented FEs are processed as patterns of lightness and texture. However, upright and inverted FEs with elements of* Happiness *were processed categorically, indicating that mouth curvature – conveying* Happiness *– is processed very early.*

Facial expressions (FEs) contain information about emotional state but despite decades of research, the nature of this information is still far from definite. Nor is it clear what stages of visual processing are involved in decoding FE pictorial cues that convey information on certain emotion. If a perturbation of FEs, in particular *inverting* them selectively disrupted some aspects of facial information more than others, this would provide clues to the underlying mechanics of FE perception and extraction of affective information.

An extreme possibility is that inverting FEs takes away their emotional content (Parks *et al*., 1985). However, examining misidentifications and confusions among inverted FEs displayed for 15 seconds, McKelvie (1995) found that these inverted faces were mislabelled more often than in the upright mode of presentation, but still conveyed emotions more accurately than chance would predict. The overall pattern of confusions was similar in both modes, with relatively high confusion rates between particular pairs of emotions (e.g. a fearful expression could be mislabelled as *Surprise* and vice versa). It would seem that the disruptive impact of inversion upon FE processing is not complete, and is general rather than being confined to specific expressions.

Confusions of this kind can be regarded as a behavioural index of similarity between facial stimuli and implicit, latent prototypes of emotional expression, in line with methodology well-established in the FE domain. The similarities examined here take the form of the *probability* of wrongly identifying two different (but similar) FEs as duplicates in a speeded *Same*/*Different* (*S/D*) task. *S/D* errors have been used as a surrogate for similarity in several studies of categorical perception, in order to locate the boundary between two emotion categories (e.g. Roberson *et al*., 1999).

The present study follows a number of precedents by representing FEs as points in a spatial model – a multidimensional 'map' – so that geometrical distances between points summarise and approximate the corresponding (dis-)similarities. The map's dimensions are identified as the affective qualities on which an expression can vary (Bimler & Paramei, 2006). Here, this methodology involves comparing the overall structure of similarities among inverted FEs to the similarities among the same stimuli when they are upright. Note that similarity data do not speak directly to the presence of emotional content after inversion since the judgements may use information from an earlier stage of visual processing. However, any evidence that the stimuli are perceived categorically could be taken as a hint that emotional categories are present.

The challenge in this research program is to extract from similarity data any clues they might conceal about perceptual processing, and in particular, about the *level* of processing accessed when determining similarity. Subjects might base their FE comparisons upon the visual images in a relatively raw, unprocessed form, where inversion would have little impact. Conversely, later stages of visual processing would be involved if the comparisons draw upon cues or information *extracted* from FE stimuli: in particular, featural or configural information. If both forms of information are used, and one is more easily extracted from upright faces, then inverting the stimuli will reduce the contribution of these cues to perceived inter-stimulus dissimilarity.

There is evidence from a closely-related perceptual domain – that of facial *identity* and recognition – that inversion selectively disrupts configural cues. Inverting faces impairs their recognition in a qualitative rather than quantitative way (Yin, 1969). The question, then, is whether configural cues are equally important in processing facial *emotional expressions*.

Method

Stimuli

Photographs of FEs were selected from Ekman and Friesen (1976) that represented the prototype emotions: *Happiness, Surprise, Anger, Sadness, Fear, Disgust, Neutral*. Seven images featured a female poser MO while the other seven a male poser WF. The "MO series" and "WF series" were both extended by eight morphs produced by image interpolation midway along the continua between two 'parent' prototypes (Figure 1).

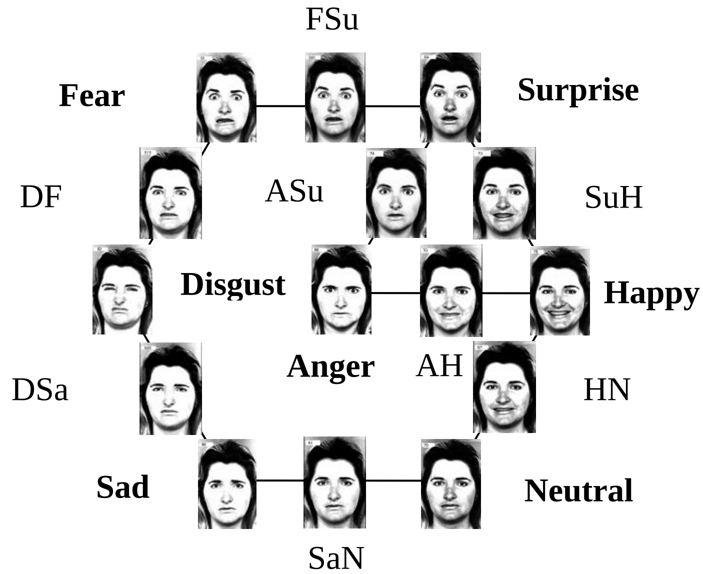

Fig. 1. FE stimuli illustrated by the "MO series" arranged in a distorted circumplex (Russell, 1980). The prototype FEs are accompanied by emotion names and morphs by abbreviations.

Participants

Four undergraduate psychology students, aged 21 to 25 years old, participated as experimental subjects for pay. Subject gender and poser gender were counterbalanced: stimuli from the "MO series" were presented to one female (DK) and one male (HK) observer; likewise the "WF series" was presented to one female (SB) and one male (BF) observer.

Procedure

On a monitor, a FE image occupied 12.8 x 8.7 cm (subtending 10° x 6.7°; viewing distance: 74 cm). On each trial, two FEs were presented symmetrically side-by-side with a 3.8 cm gap between them (subtending 3°). The exposure duration was 500 ms. After this, the screen went blank until the subject responded via a two-button keyboard. Subjects were instructed to judge whether the *emotion* expressed in the two stimuli was *Same* or *Different* as quickly and correctly as possible. A MS-DOS program controlled presentations and recorded the response (*Same* or *Different*). Each response was followed by an inter-stimulus interval of 300-400 ms, during which a small red fixation cross was displayed on the monitor.

In a single run, all possible 15 x 15 = 225 pairings of FEs were presented in randomised order. Within a run, all FE pairs were either Upright (U) or Inverted (I). Runs alternated between upright and inverted stimulus pairs. Each of the FE pairs was presented 100 times in the course of 30 sessions, spread out over four months.

Analysis

For each different-expression pair, percentage of *Same*-responses was registered. The %*Same* values were treated as index of perceptual similarity between pairs of FEs. Each similarity matrix was analysed with non-metric multidimensional scaling (MDS) (PROXSCAL MDS algorithm implemented within SPSS). A MDS solution consists of points in a low-dimensional spatial model, each point representing a stimulus, arranged so that the similarity between two stimuli is reflected by the geometrical proximity of the corresponding points.

The data proved to be sufficiently robust that individual MDS solutions could be fitted to each %*Same* matrix, i.e. to each combination of subject, poser and presentation mode. To provide a common framework for qualifying the impact of inversion on perceptions of FE similarity, the Upright and Inverted mode data were examined separately for each stimulus set, using the 'repeated measures' feature of MDS to combine the %*Same* matrices from two subjects into a single configuration. This led to four MDS solutions, which can be labelled MO-U, MO-I, WF-U and WF-I.

The concordance between Upright-Inverted solutions was quantified in three ways:

(a) *Cophenetic correlation*: the correlation between each inter-point distance in one solution and its counterpart in the second solution;

(b) *Procrustes analysis*: superimposing the two solutions, rotating and rescaling them to minimise the total distance (g_l) between corresponding pairs of points. g_l drops to 0 if the solutions are geometrically congruent and the points coincide after rotations and rescaling;

(c) *Weighted-Euclidean model of individual differences*: analysing responses for the Upright and Inverted FEs in conjunction to explore variation in dimensional-salience parameters (w_l). Two 'group configurations', for MO and WF series, were produced, each based on data from two subjects. The w_l reflect the fit between the group configuration and individual solutions, as well as between subject's responses under both modes of presentation.

Results and Discussion

MDS analysis: Solution dimensionality and variability

We examined separate MDS solutions, MO-U and MO-I for the MO (female) pictures, and

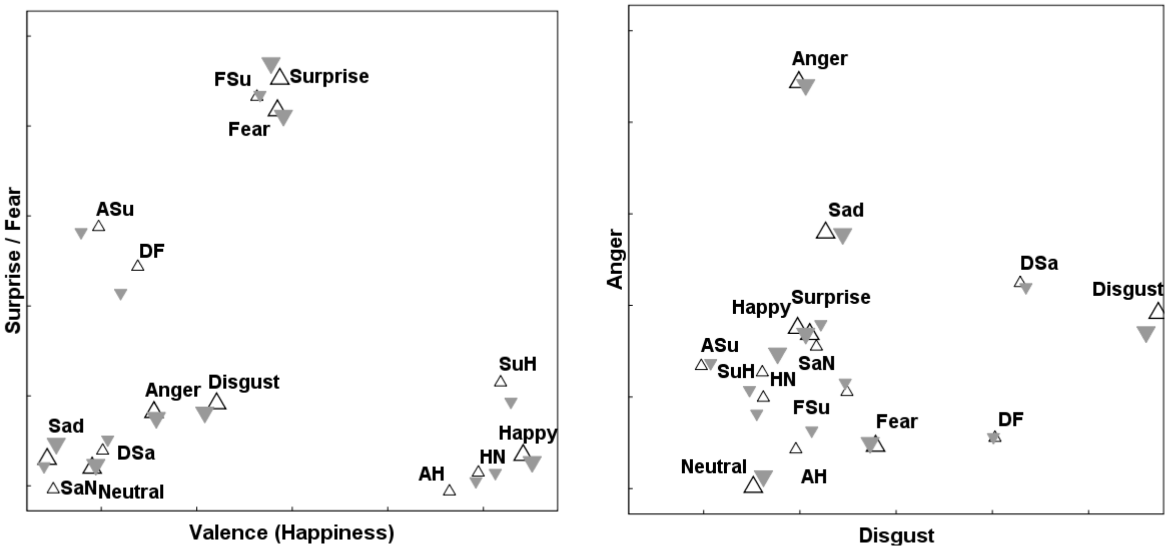

Fig. 2. Superimposed 4D solutions for the Upright and Inverted FEs of the "MO series" (female poser). Projections onto the $D1/D2$ (left panel) and $D3/D4$ (right panel) planes. △ – Upright prototypes; △ – Upright morphs; ▼ – Inverted prototypes; ▼ – Inverted morphs.

WF-U and WF-I for the WF (male) images. In all four cases, four dimensions appeared to be optimal, yielding $Stress_1$ values 0.048, 0.039, 0.061 and 0.076 respectively that were substantial improvements on the values for three dimensions. In Figure 2, the Upright and Inverted, MO-U and MO-I, solutions are superimposed to emphasise the essential overlap between the two structures. The same tendency was observed for the two WF solutions (not shown here).

After rotation of the solutions for Upright and Inverted FEs, axes in all four spaces lend themselves to interpretation as affective dimensions. D1 was found to be a bipolar "Valence" dimension, running from *Sad* (negative) to *Happy* (and the part-*Happy* morphs) at the positive extreme. D2, D3 and D4 are unipolar axes of *Surprise/ Fear, Disgust* and *Anger* respectively.

MDS analysis: Comparison of the solutions for Upright vs. Inverted FEs

Comparing the Upright vs. Inverted solutions, cophenetic correlations and Procrustes distances g_l (Table 1) show that the two "MO" spaces, MO-U and MO-I, are very similar, as are the two "WF" spaces, WF-U and WF-I. This clearly indicates that inversion has had no gross effect on the subjects' ability to recognise whether two stimuli were the same or different. The main distinction in Table 1 is between the MO and WF series of expressions. This may be attributed to stylistic variation within an 'expression prototype': posers can differ in the underlying muscle movement involved in an expression, without affecting the emotional message (Bimler & Kirkland, 2001).

Table 1. Cophenetic correlations (above the diagonal) and Procrustes distances g_l (below the diagonal) between 4D solutions. Upright (U) and Inverted (I) FEs; MO – female, WF – male.

	MO-U	MO-I	WF-U	WF-I
MO-U	–	0.93	0.78	0.74
MO-I	0.006	–	0.80	0.74
WF-U	0.047	0.051	–	0.95
WF-I	0.051	0.058	0.010	–

Table 2. Dimensional-salience parameters w_l fitting the MO and WF group configurations to individual subjects' responses, for the Upright (U) and Inverted (I) modes of FE presentation.

Subject	Poser/ Mode	Happy–Sad (D1)	Fear/Surprise (D2)	Disgust (D3)	Anger (D4)
DK	MO-U	.105	.113	.144	.130
	MO-I	.118	.119	.119	.120
HK	MO-U	.122	.116	.118	.118
	MO-I	.120	.118	.117	.120
SB	WF-U	.122	.120	.119	.116
	WF-I	.115	.122	.127	.120
BF	WF-U	.118	.115	.127	.123
	WF-I	.118	.121	.120	.123

For individual subjects, minor variations of dimensional salience w_l were found relative to the group configuration (MO or WF) and between the two, Upright vs. Inverted, modes of FE presentation (Table 2). DK is slightly more attuned to the *Disgust* axis (D3) in Upright stimuli but other subjects do not exhibit any major axial difference. That is, inversion had no systematic effect on the subjects' sensitivity to differences in the content of (e.g.) Disgust or Anger between stimuli

Categorical perception (CP)

Evidence of CP can be seen for FEs containing any element of *Happiness* (Figure 2): the *Surprise/Happy*, *Angry/Happy* and *Neutral/Happy* morphs are all close to the *Happiness* prototype, with a gulf between them and the other FEs. In other words, the perceptual difference between *no* smile and 50%-smile is considerably greater than the difference between 50%-smile and a complete smile. This finding confirms that the visual salience of smiling mouths (Calvo & Nummenmaa, 2008) stimulates a 'smile detector'– an expression template attuned to the mouth curvature which saturates at quite mild degrees of curvature.

Similarity of briefly presented facial expressions: Probing the processing mechanisms

Inversion made no substantial difference to the perceptual salience of any of the emotion prototypes, i.e. the contribution of the corresponding dimension to inter-stimulus similarity. The question arising from this result is whether early low-level visual processing suffices to assess the similarity in a pair of facial expression, or, alternatively, the images require undergoing higher stages of visual processing that are interlocked with emotion attribution.

An explanation for the lack of emotion-specific effect from FE inversion in the present study may relate to the rather brief exposure time of the stimulus pair (500 ms): if one allocates ca. 200 ms for a saccade, this leaves ca. 150 ms for inspecting each of the two images. This implies that, in spite of the explicit reference to *emotion* in the instruction, the subjects' judgements of FE 'similarity' only tapped into early stages of visual processing. In this case it is possible that early processing treats FE images as patterns of edges and grey tones, devoid of affective connotations, and performs the equivalent of pixel-by-pixel comparison (cf. PCA treatment of FEs; Calder *et al*., 2001).

It is also conceivable, though, that similarity judgements in our exposure condition were based on more advanced visual processing – featural information. Indeed, Lipp *et al*. (2009), employing a visual search task with an array of nine FEs presented for 6,000 ms, again found no effect of inversion on either detection speed or verbal ratings. The authors conclude that at low-level processing efficient decoding of expressions is mediated by feature-based information. This in effect is in accord with the broadly accepted view that featural cues are relatively insensitive to face orientation, compared to the inversion-related impairment of visual processing of configural cues (reviewed by Maurer *et al*., 2002).

The low-level FE analysis is presumed to be followed by extraction of the configural information coupled with its affective attribution and categorisation at “the locus of emotion perception” (de Gelder *et al.*, 1997; p. 20). ERP studies indicate, indeed, that FE configuration and affective content are processed in parallel and that the latter is still being processed 300 ms after FE onset (e.g. Eimer & Holmes, 2002).

Since at longer exposure times (15 sec) inverting FEs does not completely disrupt their verbal labelling (McKelvie, 1995), we propose that the effect of FE inversion takes the form of a *slowing* of configural processing. The brief (500 ms) FE presentation, precluding it, allows the low-level visual analysis which apparently is not affected by FE inversion.

Acknowledgements

We thank the participants for their time and collaborative spirit, S. Willems for assistance in carrying out experiments and W. Bösche for the stimulus generation software. Advice on the experimental design by E. N. Dzhafarov and H. Colonius is highly appreciated.

References

Bimler, D. & Kirkland, J. (2001). Categorical perception of facial expressions of emotion: Evidence from multidimensional scaling. *Cognition and Emotion, 15*, 633-658.

Bimler, D. L. & Paramei, G. V. (2006). Facial-expression affective attributes and their configural correlates: Components and categories. *Spanish Journal of Psychology, 9*, 19-31.

Calder, A. J., Burton, A. M., Miller, P., Young, A. W., & Akamatsu, S. (2001). A principal components analysis of facial expressions. *Vision Research, 41*, 1179-1208.

Calvo, M. G. & Nummenmaa, L. (2008). Detection of emotional faces: Salient physical features guide effective visual search. *Journal of Experimental Psychology: General, 137*, 471-494.

de Gelder, B., Teunisse, J.-P., & Benson, P. J. (1997). Categorical perception of facial expressions: Categories and their internal structure. *Cognition & Emotion, 11*, 1-23.

Eimer, M. & Holmes, A. (2002). An ERP study on the time course of emotional face processing. *Neuroreport, 13*, 1-5.

Ekman, P. & Friesen, W.V. (1976). *Pictures of facial affect*. Palo Alto, CA: Consulting Psychologists Press.

Lipp, O.V., Price, S. M., & Tellegen, C. L. (2009). No effect of inversion on attentional and affective processing of facial expressions. *Emotion, 9*, 248-259.

Maurer, D., Le Grand, R., & Mondloch, C. J. (2002). The many faces of configural processing. *Trends in Cognitive Sciences, 6***,** 255-259.

McKelvie, S. J. (1995). Emotional expression in upside-down faces: Evidence for configurational and componential processing. *British Journal of Social Psychology, 34***,** 325-334.

Parks, T. E., Coss, R. G., & Coss, C. S. (1985). Thatcher and the Cheshire cat: Context and the processing of facial features. *Perception, 14*, 747-754.

Roberson, D., Davidoff, J., & Braisby, N. (1999). Similarity and categorisation: Neuropsychological evidence for a dissociation in explicit categorisation tasks. *Cognition, 71*, 1-42.

Russell, J.A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology, 39*, 1161-1178.

Yin, R. K. (1969). Looking at upside-down faces. *Journal of Experimental Psychology, 81*, 141-145.