Illumination induced apparent orientation shift of human faces depends on absolute orientation

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1 INTRODUCTION

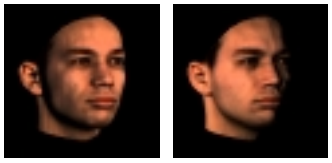
The image of a human face contains various kinds of information relevant in the social context of recognition and communication. The human brain appears to be highly specialized to extract this information. We can identify a familiar person from a single view and we can make reliable judgements about age, sex and the facial expression of unfamiliar faces. To a great extent these abilities are invariant to changes of the orientation of a face in space.

Orientation itself is an attribute that humans seem to be able to derive from the image of a face. As human heads are approximatly bilaterally symmetric, the orientation is well defined (e.g. with respect to the frontal view). Not only may knowledge about the orientation of a face play a role in achieving viewpoint invariance for recognition, but it may also contain important information about the direction of attention or movement.

What are the mechanisms underlying the ability to judge the orientation of a 3D object from a 2D image?

We approach this question by investigating a phenomenon that we discovered in the course of recent experiments dealing with the ability to generalize to new illuminations (Troje & Bülthoff, 1996):

The perceived orientation of a head is significantly influenced by the illumination



Orientation (f_1) = + 30 deg
Illumination (l_1) = + 30 deg

Orientation (f_2) = + 30 deg
Illumination (l_2) = − 30 deg

In a series of four experiments, we will first demonstrate and quantify this phenomenon and then test for its dependence on the following parameters:

Mean orientation of the two faces (Exp. 1)

Magnitude of the illumination change (Exp. 2)

Visibility of gaze direction (Exp. 3)

Visibility of the occluding contour of the faces (Exp. 4)

2 METHODS

Illumination induced apparent orientation shift (IAOS) was determined by measuring the physical orientation change necessary to compensate for it.

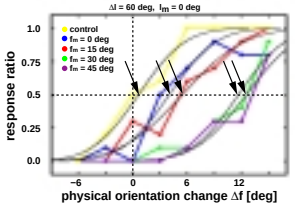
PROCEDURE:

- A single trial showed a sequence of two images (4 degs visual angle) of the same face separated by a distracting mask.
- Using a 2AFC paradigm subjects were asked to report the direction (right/left) of the perceived orientation change.
- Each trial was characterized by the following parameters:
  - f_m : mean orientation of the two images $f_m = (f_1 + f_2)/2$
  - Δf: physical orientation change $\Delta f = f_2 - f_1$
  - l_m: mean light source position $l_m = (l_1 + l_2)/2$
  - Δl: position change of the illumination $\Delta l = l_2 - l_1$

DESIGN:

- 5 blocks (80 trials each) per experiment: 4 conditions + 1 control
- Within each block only the physical orientation change was varied: 8 steps from −6 degs to 15 deg (with respect to the direction of Δl)
- The order of the blocks as well as the order of the trials within each block were randomized for each subject. 8 different subjects participated in each experiment.

EXAMPLE:
data for one subject (Exp.1)

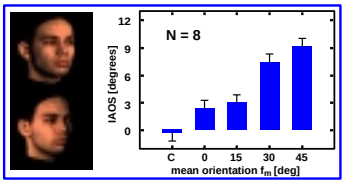


To determine the IAOS a sigmoid function (gaussian) was fitted to the data of each condition.

3 RESULTS

Exp. 1: Effect of the mean orientation

- black background
- Δl = 60 deg, l_m = 0 deg
- 4 conditions: f_m = 0, 15, 30, 45 deg
- control: f_m = 0 deg, l_m = 0 deg, Δl = 0 deg

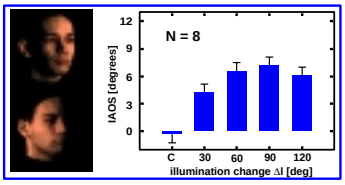


IAOS increases significantly with mean orientation

$F_{4,28} = 33.4$, $p < 0.01$

Exp. 2: Dependence on angle between light sources

- black background
- f_m = 30 deg, l_m = 0 deg
- 4 conditions: Δl = 30,60,90,120 deg
- control: f_m = 30 deg, l_m = 0 deg, Δl = 0 deg

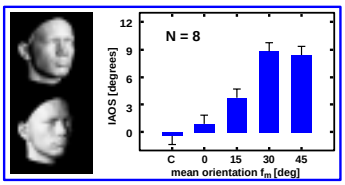


IAOS first increases with magnitude of the illumination change, but then saturates for $\Delta l > 60$ deg

$F_{4,28} = 16.1$, $p < 0.01$

Exp. 3: Influence of gaze direction

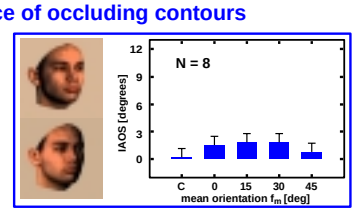
- black background
- constant albedo
- variables as in Exp. 1



IAOS similar to results in Exp. 1

Exp. 4: Importance of occluding contours

- beige background
- variables as in Exp. 1



No significant difference between treatments

IAOS reduced to values < 2 deg

4 DISCUSSION

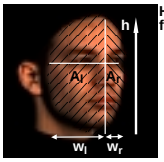
An azimutal position change of the illumination induces an apparent orientation shift of the face in the opposite direction of the illumination change.

Our experiments are reminiscent of studies by Koenderink et al. (1996), who described illumination induced changes in local surface attitude judgements. However, IAOS can not be fully explained by these findings for two reasons:

IAOS is reduced to values of less than 2 degrees

- for frontal view faces (Exp. 1) and
- when the occluding contour is visible (Exp . 4).

Orientation judgement is probably based on the integration of different cues. Our results indicate that a very important cue is derived from the position of the border line between the face and the background.



Hypothetical predictors for face orientation:

- $\frac{w_r}{w_l}$
- $\frac{w_r}{h}$
- $\frac{A_r}{A_l}$

f_1= +25.5 degs
l_1 = −30 degs

f_2= +34.5 degs
l_2 = +30 degs

- perceptually equivalent orientations
- geometrical relations identical

5 REFERENCES

Troje, N. F. and Bülthoff, H. H. (1996) *What is the basis for good performance to symmetric views of faces?* **Paper presented at ARVO 1996 [Abstract published in Investigative Ophthalmology and Visual Science, 37 (3), S194.]**

Troje, N. F. and Bülthoff, H. H. (in press) *How is bilateral symmetry of human faces used for recognition of novel views?* **Vision Research.**

Koenderink, J. J., van Doorn, A. J. and Christou, C. (1996) *Shape constancy in pictorial relief.* **Perception 25: 155−164.**