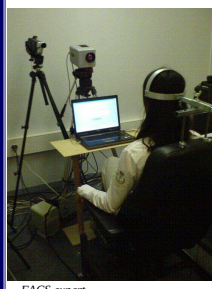
Thermal Imaging of Facial Expressions: Facial Action Units Classification

Jarlier S.[1,2], Grandjean D.[1], N'Diaye K.[1,2], Delplanque S.[1], Sander D.[1], Vuilleumier P.[1,2], & Scherer K.R.[1]

[1]Swiss Center for Affective Sciences, University of Geneva, Switzerland,

[2]Laboratory of Behavioural Neurology and Imaging of Cognition (LabNIC), University Medical Center, Geneva, Switzerland

INTRODUCTION



FACS expert face to the thermal camera

Emotional facial expressions can be systematically coded using the Facial Action Coding System (FACS). This systems aims at describing specific action units (AUs) elicited during a given facial expression. In this study we investigated the thermal modifications concomitant to specific facial movements produced by four FACS expert coders. Contrary to electromyography, thermal imaging of the face can noninvasively track dynamic changes in temperature for any facial movements at any distance (>0.4m), with a high temporal (<20ms) and thermal (<0.02°C) resolutions.

AIM

The aim of this study was to test this thermal imaging technique as a tool to assess the fluctuations of facial heat patterns induced by facial expressions.

PROTOCOL

- 4 FACS experts
- Head till
- Thermal and visible-spectrum cameras
- 9 different Action Units or combinations of AUs: 12 / 6+12 / 12+25 / 25 / 14 / 1+2 / 4 / 5 / 9+10
- 3 expression intensities: Just perceptible / Normal / High
- 2 speeds of motion: Slow / Fast

Block design (1 image each 17ms)

The requested AUs →

METHOD

THERMAL FACIAL IMAGES ACQUISITION

- Infrared FLIR camera SC3000
- ThermaCAM software for recording and exporting images into .MAT files
- Thermal images arrays processed with Matlab (Release 14, The Mathworks Inc.) and all images rescaled to 210x150 by bilinear interpolation

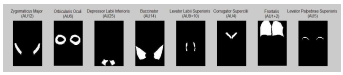
FACIAL IMAGES NORMALIZATION

- Rigid realignment of images within each sequence using the correlation as a parameter of our similarity criteria-based method
- Individual faces were spatially normalized to the average face of the Karolinska Directed Emotional Faces database using 12 control points

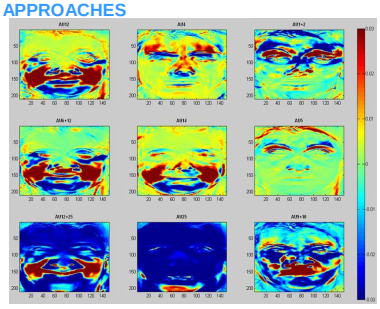
PATTERN RECOGNITION: 3 DIFFERENT APPROACHES

- Data-Driven approach:
  - •Phases determination using PCA
  - •Images subtraction

  Map = Iapex-(Ionset+Ioffset)/2



Anatomical ROI masks (based on ARTANATOMY) (2nd and 3rd approaches)

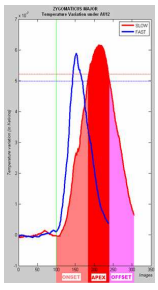


Representative maps of AUs (1st approach)

- Anatomical ROI approach 1: temperature variations
- Anatomical ROI approach 2: optical flows (Horn-Schunck)

APEX PHASE DETERMINATION

- 20% of extreme distribution curve at slow / fast speed



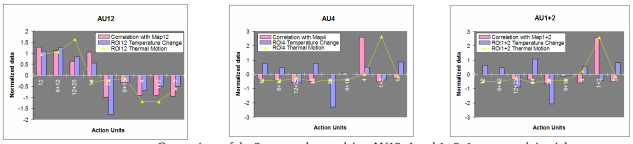
Temperature variation in zygomaticus area during AU12 to determine APEX at slow and fast speed

CLASSIFICATION

- Holdout (H) method
  - ▪Training phase with n-1 subjects
  - ▪Test with the remaining subject
- Possible classifier's parameters
  - ▪Correlations with AU representative maps
  - ▪Highest temperature change in ROI during APEX
  - ▪Highest displacement in ROI during APEX

RESULTS

COMPARISON OF THE 3 APPROACHES

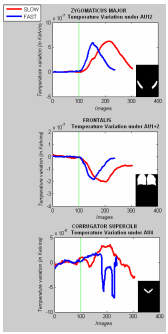


Comparison of the 3 approaches studying AU12, 4 and 1+2. 1st approach in pink (PCA and correlation with resulting maps); 2nd approach in blue (ROI temperature change); 3rd approach in yellow (ROI thermal motion)

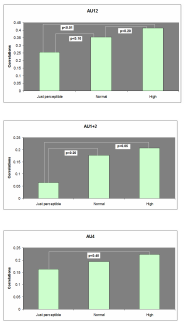
Conclusion: The data-driven approach seems more reliable for discriminating the facial expressions

THERMAL SENSITIVITY TO KINETICS & INTENSITIES

Kinetic patterns (Anatomical approach 1) →



Intensity patterns (Data-driven approach & permutations 1000 times) →



Conclusion: Thermography is sensitive to kinetics and intensities

SPECIFIC SKIN TEMPERATURE CHANGES PATTERN DISCRIMINATION

Observed AUs → / Requested AUs ↓	AU12	AU6+12	AU12+25	AU14	AU25	AU9+10	AU4	AU1+2	AU5
AU12	27.3	**33.3**	9.1	30.3	0	0	0	0	0
AU6+12	**33.3**	27.3	18.2	9.1	0	3	0	9.1	0
AU12+25	20.7	3.4	**69**	0	3.4	0	3.4	0	0
AU14	21.2	0	9.1	**66.7**	3	0	0	0	0
AU25	0	0	0	0	**70**	23.3	6.7	0	0
AU9+10	0	9.4	6.3	0	0	**75**	6.3	3.1	0
AU4	2.6	2.6	2.6	2.6	2.6	5.1	**61.5**	15.4	5.1
AU1+2	4.2	4.2	8.3	4.2	6.3	8.3	8.3	**43.8**	12.5
AU5	0	0	0	3.7	14.8	7.4	18.5	11.1	**44.4**

Classification results in % using the 1st approach; in orange lower face expressions; in green upper face expressions

Conclusion: Principal Components Analysis allows us to reliably discriminate the AUs recruited by each voluntary facial expression based on the specific topographical thermal maps

CONCLUSION

- Thermal fluctuations are sensitive to the produced AUs, their intensity and the speed of contraction.
- The data-driven approach (PCA) seems to be more robust than anatomical region of interest techniques.
- These results open new avenues for studying emotional facial expression as well as other cognitively induced facial movements, in a noninvasive manner.

Contact: Sophie.Jarlier@cisa.unige.ch

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