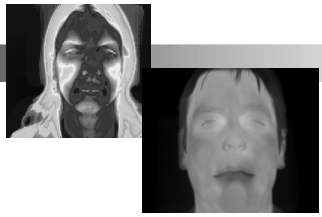
Thermal imaging of facial expressions: investigating thermal correlates of Facial Action Units activities



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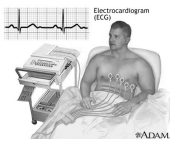
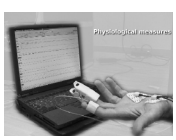
Thermography for emotions study, why?

PHYSIOLOGICAL MEASURES



Cardiac pulse (ECG)

Muscles activation (EMG)



Skin conductance

FLIR SC3000

THERMAL IMAGING
A NEW PHYSIOLOGICAL MEASURE

* Non invasive technique
* Avoids overloading equipment
* Investigation of original physiological patterns (skin temperatures)

Thermography for emotions study, why?

PUBLIC SERVICES

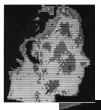
For environment purposes

Security in airports (thermal scanners for fever screening and detection of stress in terrorists)

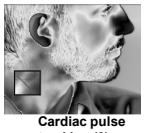
Mechanical inspections
Gas leak

Thermography used by firefighters to see persons through smoke

MEDECINE DIAGNOSIS



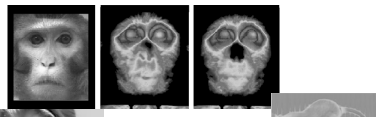
Human breath tracking (2)



Cardiac pulse tracking (3)

Muscles troubles (1)

1. F. Mongini et al. 1990, B. Gratt et al. 1995, C. Herry et al.
2. Z. Zhu and J. Fei. 2005
3. N. Sun et al. 2006



Stress detection in human and animals (5, 6, 7)

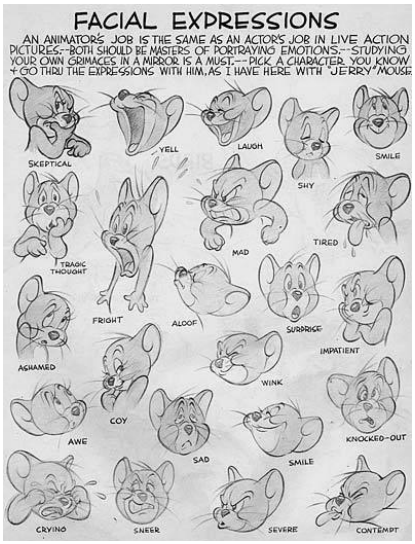
EMOTIONS

Emotion discrimination (1, 2, 3)

Deception detection (4)

1. H. Tanaka et al. 1998
2. S. Rimm-Kaufman and J. Kagan 1996
3. A. Watts et al. 2006
4. P. Tsiamyrtzis et al. 2007
5. C. Puri et al. 2005
6. D. Vianna and P. Carrive 2005
7. K. Nakayama et al. 2005

Our 1st validation study



http://riendetout.over-blog.org/article-14411041-6.html

Goal of this work:

Validating the thermal imaging technique for assessing the fluctuations of facial heat patterns.

Measuring the camera sensitivity to kinetics, intensities and specificities

First interest: facial heat patterns

Emotional facial expressions can be systematically coded using Facial Action Coding System (FACS)

FACS experts as subjects

Thermal correlates of facial action units

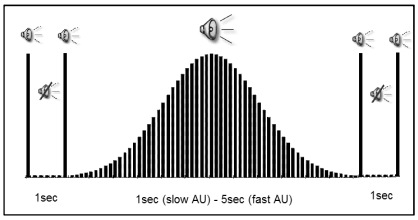
Questions and Hypotheses

- **QUESTIONS**
  - **Kinetics**
    Is thermography sensitive to **kinetics**?
  - **Intensities**
    Is thermography sensitive to **intensity**?
  - **Specificity**
    Is thermography sensitive to muscles **specificity**?

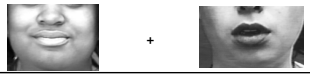
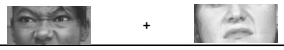
- **HYPOTHESES**
  - Each AU has a specific recognizable facial heat pattern associated
  - Temperature changes in specific muscles are correlated with their associated action unit simulation
  - Thermography can be an adapted tool for studying kinetics and intensities of the AUs

Protocol

- 4 FACS experts: 1 man and 3 women from 28 to 51 years old all right-handed except one woman
- 9 different AUs
- 3 intensities: just perceptible / normal / high
- 2 speeds: slow(5sec) / fast(1sec)
- Thermal camera + optical camera
- Head till



The Action Units

AU	DESCRiPTION	MUSCLE	IMAGE
AU1+2	Inner and outer brow raiser	Frontalis	
AU4	Brow lowerer	Corrugator	
AU5	Upper lid raiser	Levator palpebrae superioris	
AU6+12	Cheek raiser and lip corner puller	Orbicularis oculi + zygomaticus major	
AU12	Lip corner puller	Zygomaticus major	
AU12+25	Lip corner puller and lips part	Zygomaticus major + depressor labii inferioris	
AU25	Lips part	Depressor labii inferioris	
AU9+10	Nose wrinkler and upper lip raiser	Levator labii superioris	
AU14	Dimpler	Buccinator	

http://www.cs.cmu.edu/afs/cs/project/face/www/facs.htm

Methods

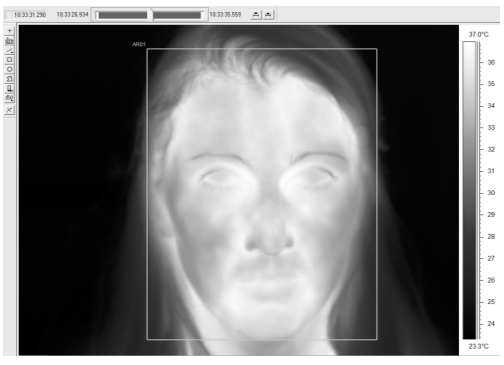
- **1st step: thermal images registration**
  - Images alignment using similarity criteria
  - Registration using control points and a template constructed from Karolinska mean faces
- **2nd step: two different approaches to answer the questions**
  - Principal Component Analyses (data-driven)
  - Anatomical approach using the ARTANATOMY tool (ROI)

http://www.artanatomia.net Victoria Contreras Flores SPAIN 20005

FIRST STEP
Thermal images registration

Images exportation

- Exportation from ThermaCAM
  - Images -> .MAT files
- Reduction of facial images for speed and disk space optimization
  - the 4 FACS experts head should fit into the rectangle during all sequences
  - Chosen size : 210x150
- Facial images extraction and creation of one images array per sequence
  - 238 images for FAST AU sequences
  - 306 images for SLOW AU sequences
  - 1 image each 17ms

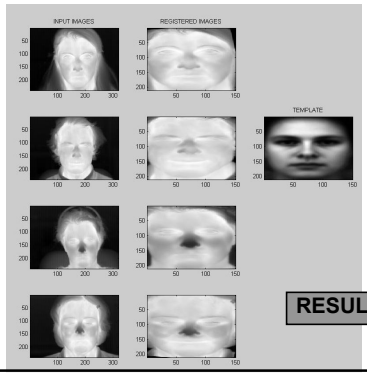


Thermal images registration

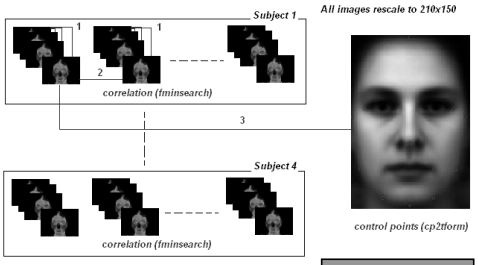
Facial images normalization

Processing:

0. All images rescaled to 210x150
1. All images of a given sequence aligned on its 1st image
2. All images from all sequences of a given subject aligned on 1st image 1st sequence
3. All images registered on the Karolinska's mean face (man+woman average)



RESULTS



PROCESSING

Methods:

Rescaling:
bilinear interpolation

Alignment:
MATLAB's optimization routine 'fminsearch' (with correlation as parameter)

Registration for inter-subjects normalization:
MATLAB's spatial transformation routine from control point pairs (with 'lwm' as transformation type)

SECOND STEP

Data-driven approach	ROI approach
Principal Component Analysis	Anatomically-based

The 2 approaches

Baseline mean corrected on registered images

DATA-DRIVEN APPROACH: PCA

- **Representative heat patterns production**

  Principal Components mean grouping by AU using one of these criteria:
  - Components whose **eigenvalue>1**: our retained criteria
  - Visual selection of interesting components: time-consuming and subjective analysis
  - 90% explained variance: automatic and objective but not as good results as with the eigenvalue criteria

- **Kinetics + phases determination**
  - Plot PC grouping same AUs by speed (F/S)
  - 20% extreme curve

- **Intensities**
  - Plot factor scores and correlations grouping same AUs by intensity (JP/N/H) + permutations

- **Specificities and Pattern recognition: Are these maps good indicators of the AUs?**
  - Correlations between each image of each sequence with each heat pattern maps
  - Non-parametric permutation analysis 1000times

ROI APPROACH: ANATOMICALLY-BASED

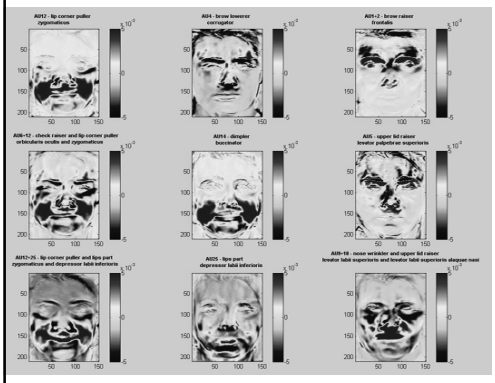
- **Facial ROI definitions**
  - Anatomical template creation: ARTANATOMY + previous registration technique
  - Masks creation: MATLAB's routine '*roipoly*' on the registered template
  - ROIs-temperature mean under each condition

- **Kinetics + phases determination**
  - Plot ROI temperature variations grouping same AUs by speed (F/S)
  - 20% extreme curve

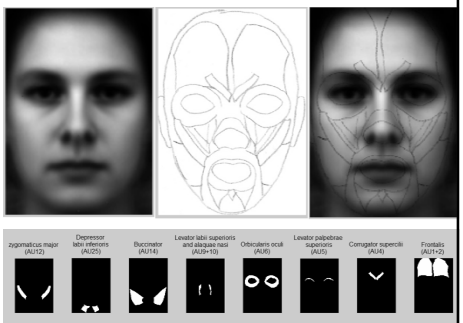
- **Intensities**
  - Plot ROI temperature variations grouping same AUs by intensity (JP/N/H) + permutations

- **Specificities and Pattern recognition: Are these ROIs-temperature good indicators of the AUs?**
  - Non-parametric permutation analysis 1000times

Heat patterns and anatomical ROI

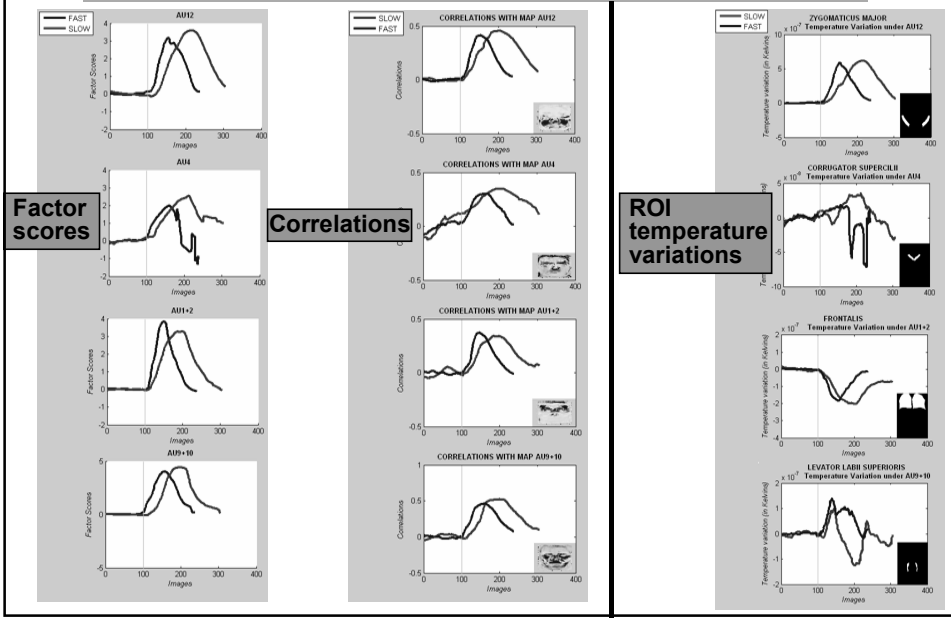


Facial heat patterns



Anatomical ROI

Is thermography sensitive to kinetics?

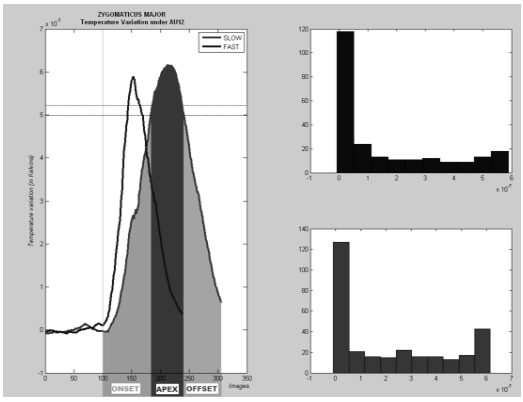


ONSET, APEX or OFFSET phases determination

ONSET PHASE = phase where the muscles are contracting and the appearance of the face changes as the facial action grows stronger

APEX PHASE = phase where the facial action is at its peak and there are no more changes in facial appearance due to this particular facial action

OFFSET PHASE = phase where the muscles are relaxing and the face returns to its neutral appearance



In literature: onset duration is 0.935sec (i.e. 55 frames)

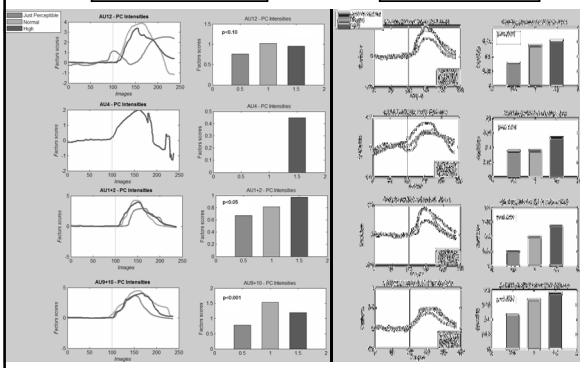
Fully Automatic Facial Action Unit Detection and Temporal Analysis. Valstar, M. Pantic, M. Imperial College London, UK; : ***Computer Vision and Pattern Recognition Workshop, 2006***

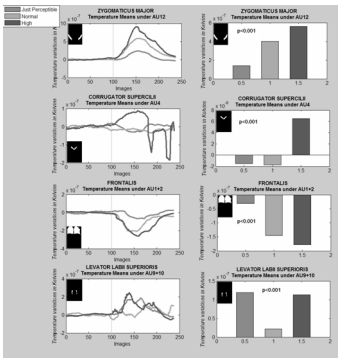
-> do not differentiate slow from fast AU

Principal Component Analysis

Is thermography sensitive to intensities?

Factor scores | **Correlations** | **ROI**





Is thermography sensible to muscles specificities?

Pattern recognition of FAST AU on APEX phase

PCA

	MAP AU12	MAP AU6+12	MAP AU12+25	MAP AU14	MAP AU25	MAP AU9+10	MAP AU4	MAP AU1+2	MAP AU5
AU12	**0.31086 n.s**	0.30632 p<0.001	0.25544 p<0.001	**0.2766 p<0.10**	-0.078821 p<0.001	0.088323 p<0.001	0.038473 p<0.001	0.018409 p<0.001	-0.0075632 p<0.01
AU6+12	0.34095 p<0.05	**0.37279 n.s**	0.30024 p<0.001	**0.29664 n.s**	-0.10171 p<0.001	0.1779 p<0.001	-0.012616 p<0.001	0.016968 p<0.001	0.013127 p<0.001
AU12+25	0.2063 p<0.001	0.2154 p<0.001	**0.35303 n.s**	0.17024 p<0.001	0.05983 p<0.001	0.15003 p<0.001	0.0051646 p<0.001	0.01303 p<0.001	0.023301 p<0.001
AU14	0.24721 p<0.001	0.22284 p<0.001	0.22414 p<0.001	**0.30699 n.s**	-0.10555 p<0.001	0.057458 p<0.001	0.012785 p<0.001	0.025974 p<0.001	-0.001984 p<0.001
AU25	-0.063843 p<0.001	-0.032034 p<0.001	0.028257 p<0.001	-0.086749 p<0.001	**0.28042 n.s**	0.030055 p<0.001	0.020249 p<0.001	0.0021604 p<0.001	0.052161 p<0.001
AU9+10	0.11242 p<0.001	0.1666 p<0.001	0.18847 p<0.001	0.017506 p<0.001	-0.0011469 p<0.001	**0.37107 n.s**	0.018135 p<0.001	-0.02854 p<0.001	0.031781 p<0.001
AU4	0.0044146 p<0.001	0.016662 p<0.001	0.0024493 p<0.001	-0.019613 p<0.001	0.024253 p<0.001	0.044122 p<0.001	**0.24483 n.s**	-0.15936 p<0.001	-0.11915 p<0.001
AU1+2	0.0014319 p<0.001	-0.0010676 p<0.001	0.0050745 p<0.001	0.0043309 p<0.001	0.025131 p<0.001	0.0034113 p<0.001	-0.012689 p<0.001	**0.25561 n.s**	0.040643 p<0.001
AU5	-0.022657 p<0.001	-0.014988 p<0.001	-0.0040876 p<0.001	-0.020511 p<0.001	0.02075 p<0.001	0.019269 p<0.001	0.0053085 p<0.001	-0.061155 p<0.001	**-0.020469 n.s**

Mean correlations and significative differences with mean PC maps

Permutation 1000x

FONT
Red significative difference with AU map
Black no significative difference

FILL
Brown muscles from upper part of the face
Orange muscles from lower part of the face

Is thermography sensible to muscles specificities?

Pattern recognition of FAST AUs on APEX phase

ROI

	ROI AU12	ROI AU6	ROI AU25	ROI AU14	ROI AU9+10	ROI AU4	ROI AU1+2	ROI AU5
AU12	**3.7877e-007 n.s**	-5.6628e-008 p<0.001	-1.3684e-007 p<0.001	**2.7866e-007 p<0.20**	-8.824e-008 p<0.001	**1.4178e-008 n.s**	-1.8128e-008 p<0.001	-1.6379e-008 p<0.001
AU6+12	4.5308e-007 p<0.020	**-1.2078e-007 n.s**	-1.8582e-007 p<0.001	3.0487e-007 p<0.01	-1.6947e-008 p<0.001	-2.0061e-008 p<0.001	-4.2351e-009 p<0.001	-3.3317e-008 p<0.001
AU12+25	2.7397e-007 p<0.001	-1.6711e-007 p<0.001	-5.3839e-008 p<0.001	**2.1072e-007 p<0.20**	-1.6215e-007 p<0.001	-1.1719e-007 p<0.001	**-1.3896e-007 p<0.20**	-1.5987e-007 p<0.001
AU25	-2.3962e-007 p<0.001	-2.2262e-007 p<0.001	**3.5292e-008 n.s**	-2.6978e-007 p<0.001	-1.9064e-007 p<0.001	-2.0924e-007 p<0.001	-2.1963e-007 p<0.001	-2.6311e-007 p<0.001
AU14	2.3434e-007 p<0.001	2.4722e-008 p<0.001	-9.4156e-008 p<0.001	**2.4399e-007 n.s**	4.8037e-008 p<0.001	4.8518e-008 p<0.001	4.1566e-008 p<0.001	5.1471e-008 p<0.001
AU9+10	2.4917e-008 p<0.001	-3.1044e-007 p<0.001	-1.494e-007 p<0.001	-5.5438e-008 p<0.001	**8.2813e-008 n.s**	-5.7625e-008 p<0.001	-4.2082e-008 p<0.001	-2.3107e-007 p<0.001
AU4	-2.0237e-008 p<0.001	**-1.159e-007 n.s**	-4.4608e-009 p<0.001	-1.6986e-008 p<0.001	2.0782e-008 p<0.001	**1.375e-008 n.s**	1.6828e-008 p<0.001	-2.015e-007 p<0.001
AU1+2	1.0749e-008 p<0.001	1.8122e-007 p<0.001	1.3319e-008 p<0.020	1.1848e-008 p<0.001	2.0357e-009 p<0.001	-9.767e-008 p<0.001	**-1.2266e-007 n.s**	6.6972e-008 p<0.001
AU5	4.3539e-009 p<0.001	-1.311e-008 p<0.001	1.0253e-008 p<0.01	7.2841e-009 p<0.001	1.8644e-008 p<0.001	-2.236e-009 p<0.001	1.9618e-008 p<0.001	**1.26e-007 n.s**

Mean temperatures and significative differences between AUs

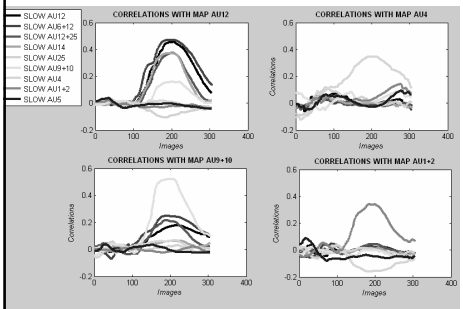
Permutation 1000x

FONT
Red significative difference with AU map
Black no significative difference
FILL
Brown muscles from upper part of the face
Orange muscles from lower part of the face

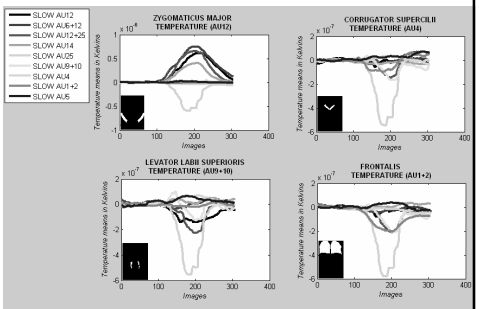
Is thermography sensible to muscles specificities?

Pattern recognition - SLOW AUs

PCA - Correlations



ROI



Conclusions

PCA

Is thermography sensitive to kinetics?

In general yes.

Possibility to determine a precise APEX phase

Problem with: AU12+25 (factor scores) / AU9+10 (in both methods)

Is thermography sensitive to intensities?

In general yes.

Problem with: AU12 (factor scores) / AU14 (factor scores) / AU12+25 (correlations) / AU4 and 5 (missing significative PC @JP intensity)

Is thermography sensitive to muscles specificities?

In general yes.

Creation of specific facial heat pattern associated to each AU

Eigenvalue criteria better than 90% of variance criteria for constructing these maps.

Problem with: AU12 confusion with Map AU14 @fast / AU6+12 confusion with Map AU14 @fast / AU6+12 confusion with Maps AU12+25 and AU14 @slow / AU1+2 confusion with Map AU5 @slow

ROI

Is thermography sensitive to kinetics?

In general yes.

Possibility to determine an APEX phase

Problem with: AU25

Is thermography sensitive to intensities?

In general yes.

Problem with: AU25

Is thermography sensitive to muscles specificities?

In general yes.

Zygomaticus and corrugator contractions seem to be associated with an increase of temperature while frontalis activations is linked with a decrease of temperature

Problem with: AU12 confusion with Map AU14 @fast&slow / AU12+25 confusion with ROI14, 1+2 @fast and ROI12 and 25 not recognized / AU4 confusion with ROI6 @fast / AU1+2 confusion with ROI9+10 @slow

Anatomically-based approach

Discussion

Possible reasons for decreasing temperature in frontalis area?

- Inter-individual anatomic differences:

  - Presence and position of arterial veins in the frontal head
  - Size of brows (cold area) passing on the frontalis zone studied while raising brows
  - Hairs can be present in the top of the frontalis area
  - Crumpling of the skin while contracting the frontalis

- AU simulation performances:

  - The results could depend on the quality of the simulation.
  - Subject 4 was the FACS teacher and has bigger activation and clear corrugator heating and frontalis colding but she was also closer from the camera than other and simulated less AUs.
  - Possible overlap between AU9+10 / AU5 / AU1+2, difficult task

General conclusion

- Thermography proved to be an adaptive tool for detecting movements in the face
- ***PCA or Anatomical approach, most appropriate method?***
  - Anatomical approach seems to be more sensitive to kinetics and intensities
  - PCA is a global method without a-priori while anatomically-based approach implies some presumptions and appropriate ROIs selection and these ROIs are greatly influence by movements of facial skin.
  - PCA with eigenvalue criteria give facial heat patterns associated to AUs

PCA and anatomical approaches seem to be complementary, PCA can be used for a 1st exploratory analysis, while anatomical method can further investigate regions appearing on PCA for differentiating for example AU6+12 from AU12 (smiles).

- Next investigations:

Is global facial temperature an indicator of real emotions?

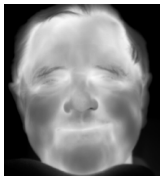
-> Experiment with spontaneous emotions with odors and images

Is it possible to differentiate what is muscles movement warming from what is emotion-induced skin warming?

These last results that can differentiate AU12, from AU4, AU1+2 and 9+10 let us believe that spontaneous emotions will be detectable with this thermal imaging technique.

Sylvain Delplanque

Patrik Vuilleumier



Klaus Scherer

Karim N'Diaye

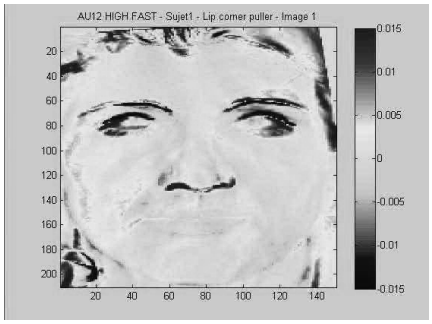
Thank you for your attention

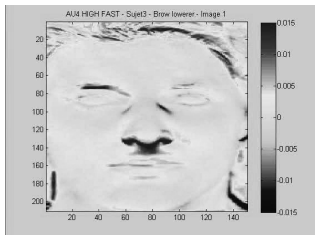
David Sander

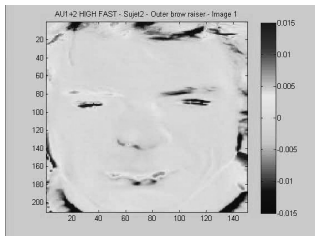
Lucas Tamarit

Thermal images registration

First data exploration – mean corrected







Thermal images registration

SLOW AUs and approach emotions




SLOW	MAP AU12	MAP AU9+10	MAP AU4	MAP AU1+2
AU12 happiness	**0.32464 n.s**	0.14547 p<0.001	0.0073592 p<0.001	0.0013459 p<0.001
AU9+10 disgust	0.096306 p<0.001	**0.34672 p<0.30**	0.044122 p<0.001	-0.02955 p<0.001
AU4 anger	-0.016283 p<0.001	0.027657 p<0.001	**0.27705 n.s**	-0.12438 p<0.001
AU1+2 surprise	-0.024567 p<0.001	-0.0055427 p<0.001	0.075332 p<0.001	**0.20774 n.s**




SLOW	ROI AU12	ROI AU9+10	ROI AU4	ROI AU1+2
AU12 happiness	**4.2412e-007 n.s**	-1.1016e-007 p<0.001	-1.2945e-008 p<0.001	-3.416e-008 p<0.001
AU9+10 disgust	1.1579e-008 p<0.001	**-1.9168e-008 n.s**	-6.1722e-008 p<0.001	-9.1063e-008 p<0.001
AU4 anger	-3.3665e-008 p<0.001	4.8753e-008 p<0.001	**1.7595e-008 n.s**	-1.8942e-008 p<0.001
AU1+2 surprise	-7.3719e-009 p<0.001	**-1.0417e-008 p<0.20**	-5.0716e-008 p<0.001	**-1.4696e-007 n.s**

FAST	MAP AU12	MAP AU9+10	MAP AU4	MAP AU1+2
AU12 happiness	**0.31086 n.s**	0.088323 p<0.001	0.038473 p<0.001	0.018409 p<0.001
AU9+10 disgust	0.11242 p<0.001	**0.37107 n.s**	0.018135 p<0.001	-0.02854 p<0.001
AU4 anger	0.0044146 p<0.001	0.044122 p<0.001	**0.24483 n.s**	-0.15936 p<0.001
AU1+2 surprise	0.0014319 p<0.001	0.0034113 p<0.001	-0.012689 p<0.001	**0.25561 n.s**

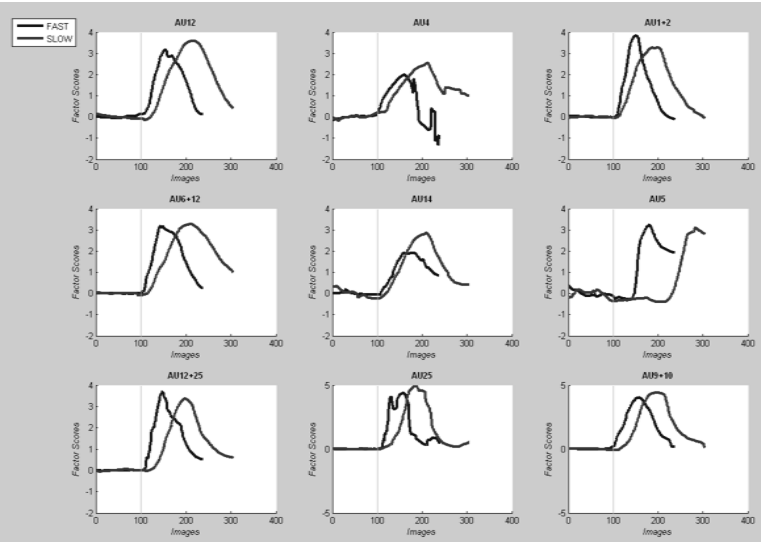
FAST	ROI AU12	ROI AU9+10	ROI AU4	ROI AU1+2
AU12 happiness	**3.7877e-007 n.s**	-8.824e-008 p<0.001	**1.4178e-008 n.s**	-1.8128e-008 p<0.001
AU9+10 disgust	2.4917e-008 p<0.001	**8.2813e-008 n.s**	-5.7625e-008 p<0.001	-4.2082e-008 p<0.001
AU4 anger	-2.0237e-008 p<0.001	2.0782e-008 p<0.001	**1.375e-008 n.s**	1.6828e-008 p<0.001
AU1+2 surprise	1.0749e-008 p<0.001	2.0357e-009 p<0.001	-9.767e-008 p<0.001	**-1.2266e-007 n.s**

MORE PCA RESULTS

Principal Component Analysis

Is thermography sensitive to kinetics?

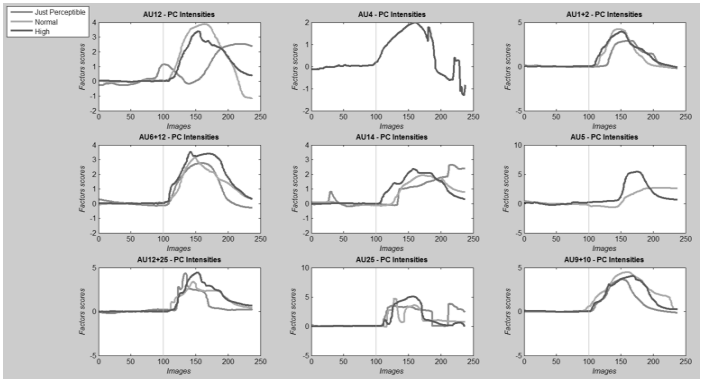
Using Factor Scores

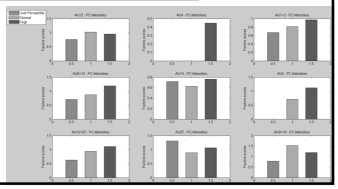


Principal Component Analysis

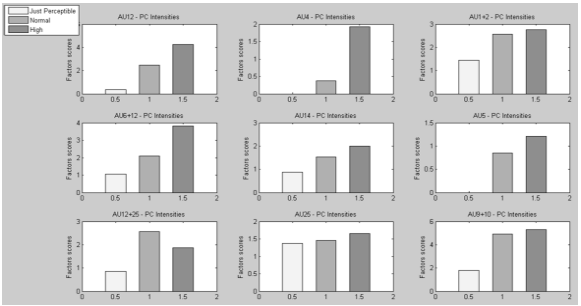
Is thermography sensitive to intensities?

Using Factor Scores





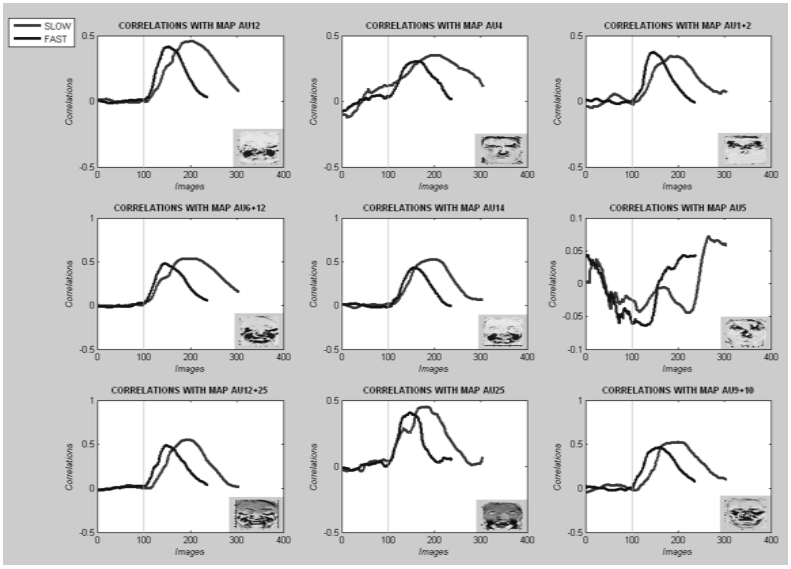
- Mixing slow and fast AUs



Principal Component Analysis

Is thermography sensible to kinetics?

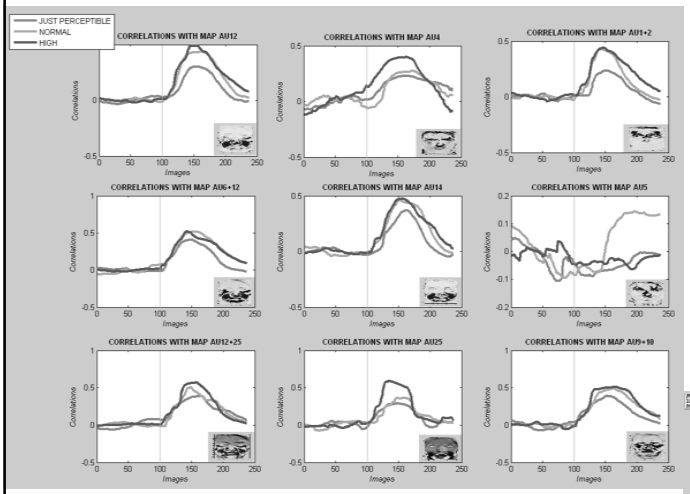
Using Images Similarity Metric (correlation)

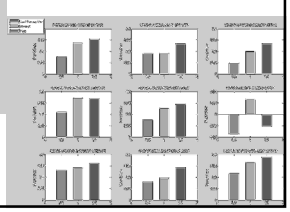


Principal Component Analysis

Is thermography sensible to intensities?

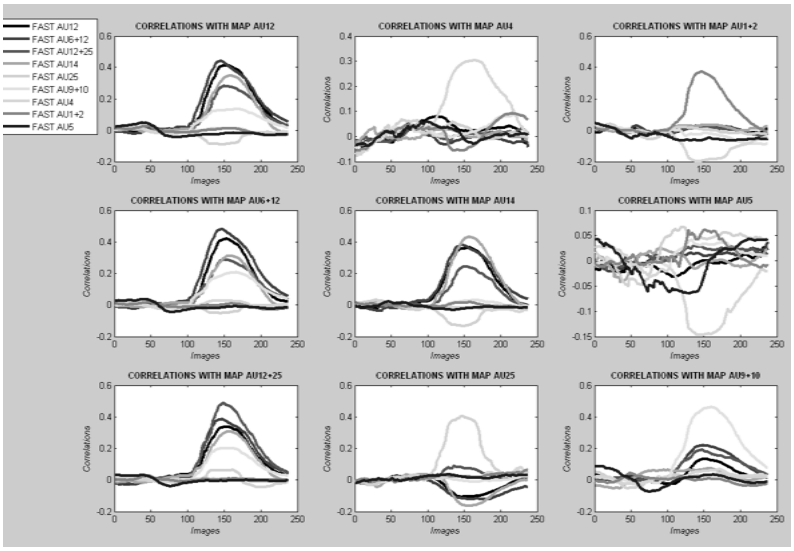
Using Images Similarity Metric (correlation) during FAST AUs





Principal Component Analysis

FAST AUs correlations with MAP AU in time



Principal Component Analysis

Is thermography sensible to muscles specificities?

Pattern recognition of SLOW AU on APEX phase

	MAP AU12	MAP AU6+12	MAP AU12+25	MAP AU14	MAP AU25	MAP AU9+10	MAP AU4	MAP AU1+2	MAP AU5
AU12	**0.32464 n.s**	0.33365 p<0.001	0.26263 p<0.020	0.27293 p<0.05	-0.082875 p<0.001	0.14547 p<0.001	0.0073592 p<0.001	0.0013459 p<0.001	-0.0073334 p<0.001
AU6+12	0.36624 p<0.01	**0.41108 n.s**	**0.29095 p<0.40**	**0.28693 p<0.20**	-0.097467 p<0.001	0.20108 p<0.001	-0.010726 p<0.001	-0.0047885 p<0.001	0.039345 p<0.001
AU12+25	0.21989 p<0.001	0.21367 p<0.001	**0.30863 n.s**	0.15744 p<0.001	0.032674 p<0.001	0.12907 p<0.001	-0.012011 p<0.001	0.010644 p<0.001	0.073367 p<0.001
AU14	0.20689 p<0.001	0.18927 p<0.001	0.17598 p<0.001	**0.31082 n.s**	-0.13011 p<0.001	0.045077 p<0.001	-0.0055732 p<0.001	-0.012458 p<0.001	-0.018726 p<0.001
AU25	-0.066163 p<0.001	-0.032884 p<0.001	-0.017356 p<0.001	-0.081775 p<0.001	**0.21697 n.s**	0.014702 p<0.001	0.0049866 p<0.001	-0.011303 p<0.001	0.04108 p<0.001
AU9+10	0.096306 p<0.001	0.1517 p<0.001	0.14251 p<0.001	0.019103 p<0.001	0.00087234 p<0.001	**0.34672 p<0.30**	0.044122 p<0.001	-0.02965 p<0.001	0.019666 p<0.05
AU4	-0.016283 p<0.001	-0.0052125 p<0.001	-0.007196 p<0.001	-0.034764 p<0.001	0.042337 p<0.001	0.027657 p<0.001	**0.27705 n.s**	-0.12438 p<0.001	-0.095122 p<0.001
AU1+2	-0.024567 p<0.001	-0.016023 p<0.001	0.007995 p<0.001	-0.018292 p<0.001	0.045064 p<0.001	-0.0055427 p<0.001	0.075332 p<0.001	**0.20774 n.s**	**0.011738 n.s**
AU5	-0.020225 p<0.001	-0.010072 p<0.001	-0.0090605 p<0.001	-0.020287 p<0.001	0.049199 p<0.001	-0.013088 p<0.001	0.022823 p<0.001	-0.05024 p<0.001	**0.011034 n.s**

Mean correlations and significative differences with mean PC maps

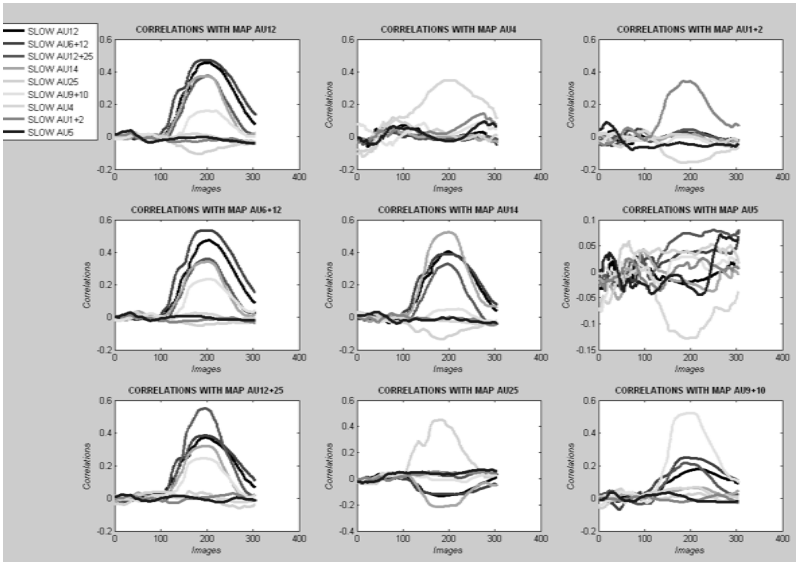
Permutation 1000x

FONT
Red significative difference with AU map
Black no significative difference

FILL
Brown muscles from upper part of the face
Orange muscles from lower part of the face

Principal Component Analysis

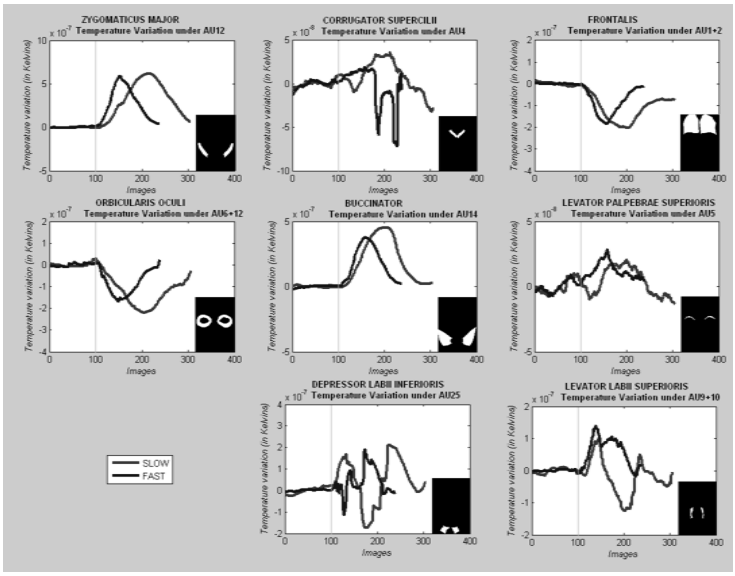
SLOW AUs correlations with MAP AU in time



MORE ANATOMICAL RESULTS

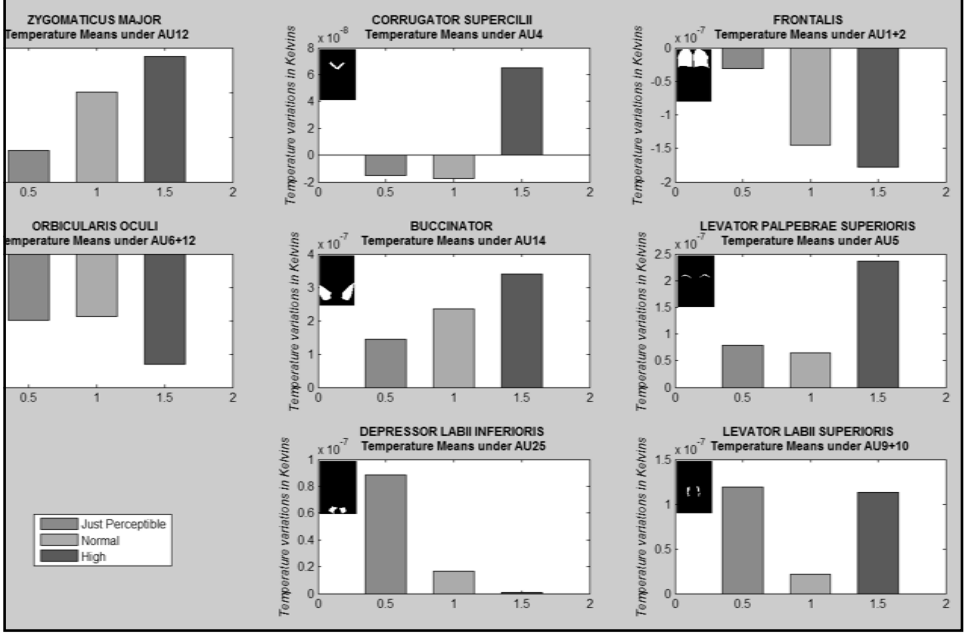
Anatomically-based approach

Is thermography sensible to kinetics?



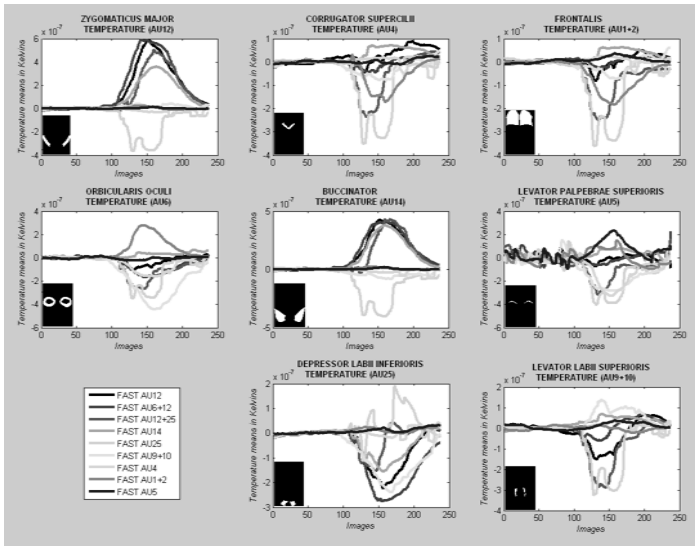
Anatomically-based approach

Is thermography sensible to intensities?



Principal Component Analysis

FAST AUs temperature means in time



Anatomically-based approach

Is thermography sensible to muscles specificities?

Pattern recognition on APEX phase SLOW AUs

	ROI AU12	ROI AU6	ROI AU25	ROI AU14	ROI AU9+10	ROI AU4	ROI AU1+2	ROI AU5
AU12	**4.2412e-007 n.s**	-9.1929e-008 p<0.001	-2.0823e-007 p<0.001	**3.281e-007 p<0.20**	-1.1016e-007 p<0.001	-1.2945e-008 p<0.001	-3.416e-008 p<0.001	-3.4516e-008 p<0.001
AU6+12	5.501e-007 p<0.001	**-1.5754e-007 n.s**	-2.6391e-007 p<0.001	3.7226e-007 p<0.001	1.2472e-010 p<0.01	-1.5115e-008 p<0.001	-2.5071e-008 p<0.001	-3.2215e-008 p<0.001
AU12+25	**4.599e-007 p<0.20**	-1.1031e-007 p<0.001	-9.6377e-008 p<0.001	3.9802e-007 p<0.001	-1.1117e-007 p<0.001	-4.399e-008 p<0.001	-9.7992e-008 p<0.001	-7.0252e-008 p<0.001
AU25	-3.0819e-007 p<0.001	-2.5609e-007 p<0.001	**3.7819e-008 n.s**	-3.8039e-007 p<0.001	-2.7202e-007 p<0.001	-2.5446e-007 p<0.001	-2.8226e-007 p<0.001	-2.7753e-007 p<0.001
AU14	2.6404e-007 p<0.001	-4.03e-008 p<0.001	-2.8005e-007 p<0.001	**3.0407e-007 n.s**	2.8429e-008 p<0.001	-2.3351e-008 p<0.001	1.0036e-008 p<0.001	-3.3308e-008 p<0.001
AU9+10	1.1579e-008 p<0.001	-3.7976e-007 p<0.001	-2.4601e-007 p<0.001	-8.2207e-008 p<0.001	**-1.9168e-008 n.s**	-6.1722e-008 p<0.001	-9.1063e-008 p<0.001	-3.108e-007 p<0.001
AU4	-3.3665e-008 p<0.001	-1.3629e-007 p<0.001	1.1402e-008 p<0.05	-3.1385e-008 p<0.001	4.8753e-008 p<0.001	**1.7595e-008 n.s**	-1.8942e-008 p<0.001	-3.279e-007 p<0.001
AU1+2	-7.3719e-009 p<0.001	1.5081e-007 p<0.001	8.7891e-009 p<0.05	-1.8058e-008 p<0.001	**-1.0417e-008 p<0.20**	-5.0716e-008 p<0.001	**-1.4696e-007 n.s**	-1.7727e-007 p<0.001
AU5	1.219e-008 p<0.001	-1.226e-008 p<0.001	1.4944e-008 p<0.10	7.6387e-009 p<0.001	4.2704e-008 p<0.001	2.5083e-008 p<0.001	2.2122e-008 p<0.001	**2.7824e-007 n.s**

Mean temperatures and significative differences between AUs

Permutation 1000x

FONT
Red significative difference with AU map
Black no significative difference
FILL
Brown muscles from upper part of the face
Orange muscles from lower part of the face

Principal Component Analysis

SLOW AUs temperature means in time