Personality gaze patterns unveiled via automatic relevance determination

Vittorio Cuculo, Alessandro D'Amelio, Raffaella Lanzarotti and Giuseppe Boccignone

PHuSe Lab - *Department of Computer Science, Università degli Studi di Milano, Italy*

PHUSE Lab
Perceptual computing and HUman SEnsing

7th International Symposium
"From Data to Models and Back (DataMod)"
25-26 June 2018, Toulouse, France

Perceptual computing and HUman SEnsing Lab

↓

Social Signal Processing

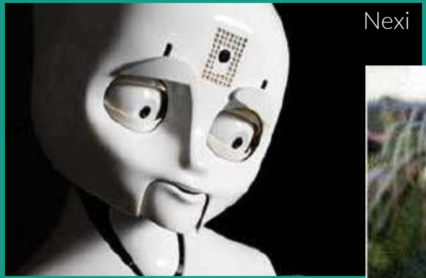
↓

Affective Computing

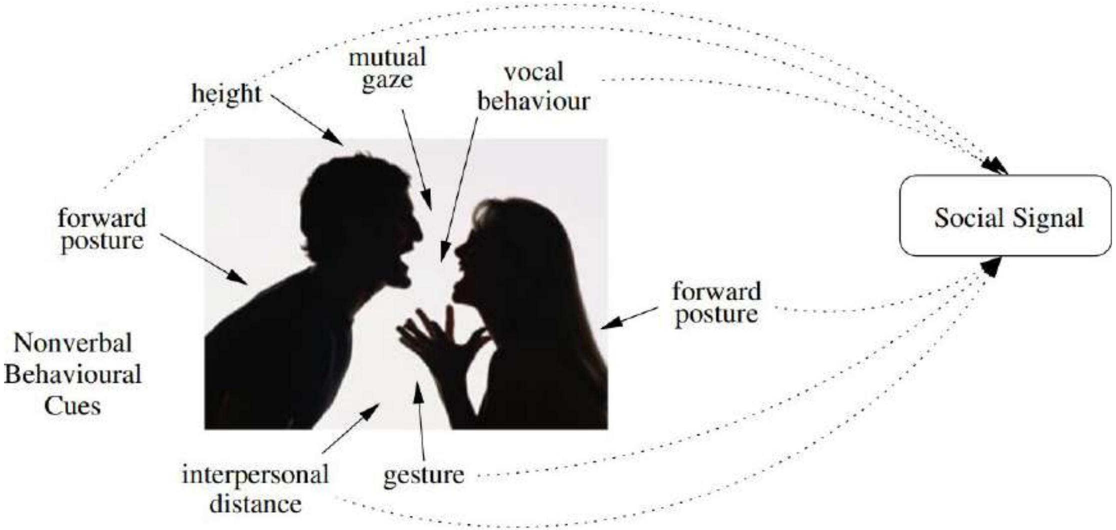
Affective Computing

is a multidisciplinary topic, with the aim to give computers the ability to:

- ➔ recognize emotions,
- ➔ express emotions,
- ➔ “have” emotions.



Social Signal Processing



	Example Social Signals						
Social Cues	emotion	personality	status	dominance	persuasion	regulation	rapport
Physical appearance							
height			√	√			
attractiveness		√	√	√	√		√
body shape		√		√			
Gesture and posture							
hand gestures	√				√	√	√
posture	√	√	√	√	√	√	√
walking		√	√	√			
Face and eyes behaviour							
facial expressions	√	√	√	√	√	√	√
gaze behaviour	√	√	√	√	√	√	√
focus of attention	√	√			√	√	√
Vocal behaviour							
prosody	√	√			√		
turn taking			√	√		√	√
vocalizations	√	√		√	√	√	√
silence							√
Space and Environment							
distance		√	√		√		√
seating arrangement				√			√

Vinciarelli, Alessandro, et al. "Social signals, their function, and automatic analysis: a survey." Proceedings of the 10th ICMI. ACM, 2008.

Gaze

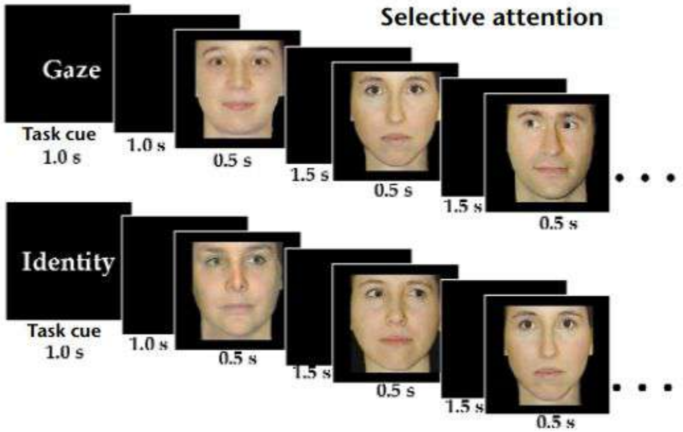
*is an important component of **social interaction***
*and a crucial signal of **non-verbal communication***

Kingstone, A., et al. "Cognitive Ethology and Social Attention." *On Human Nature*. 2017. 365-382.

Context

In the course of a typical face-to-face interaction:

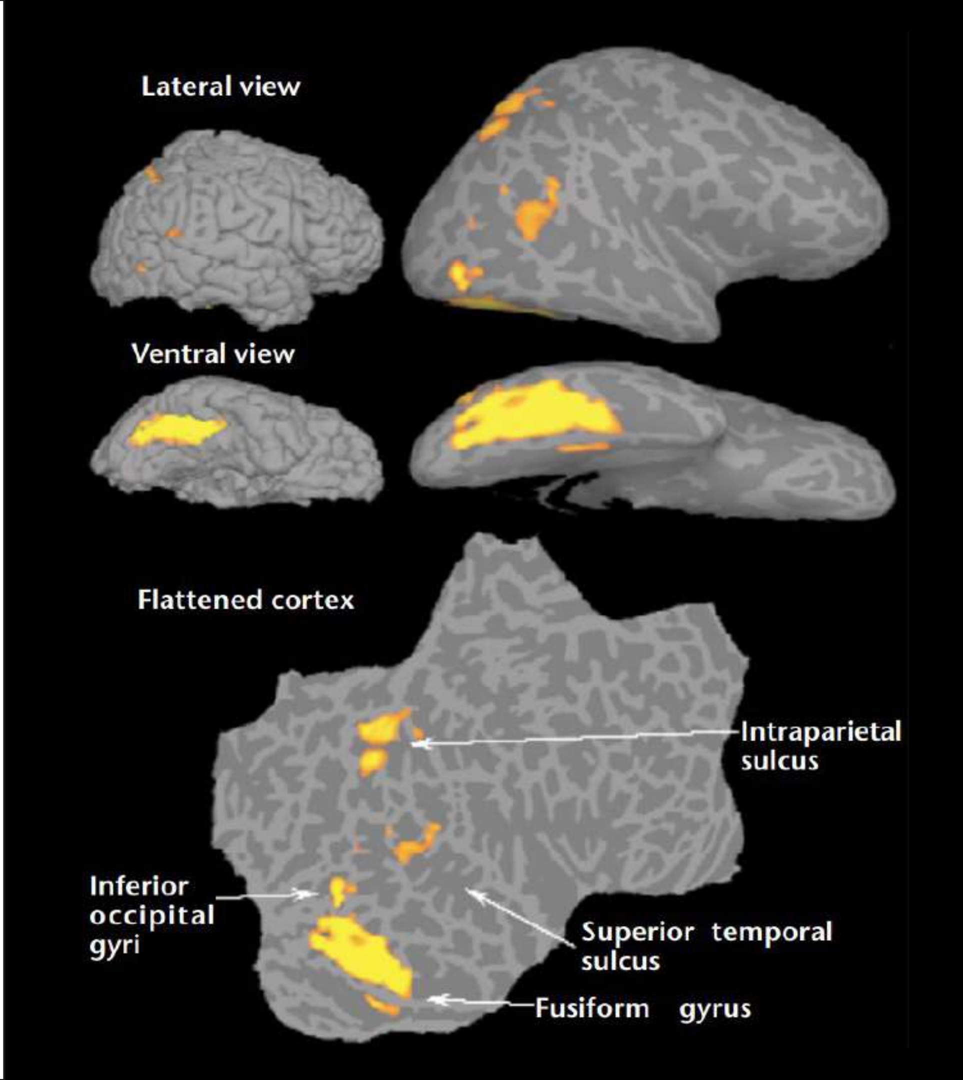
- eye contact is an indicator of **trustworthiness**
- although a long direct gaze could be interpreted as a **threat**.



Direct eye contact activates **specific brain areas** involved in human interaction and face processing.

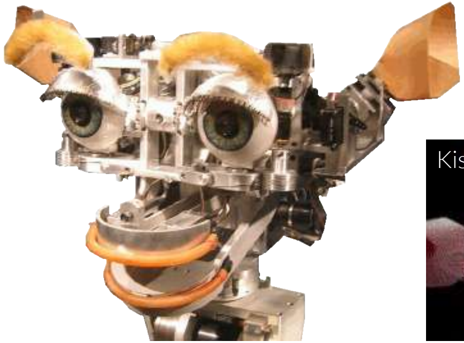
Therefore, person perception is increased when gaze is directed toward the viewer.

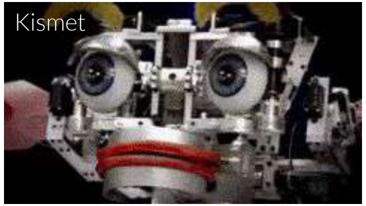
Hoffman, Elizabeth A., and James V. Haxby. "Distinct representations of eye gaze and identity in the distributed human neural system for face perception." Nature neuroscience 3.1 (2000): 80.

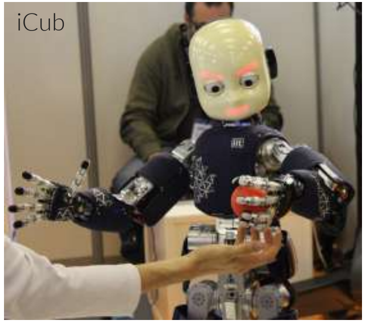


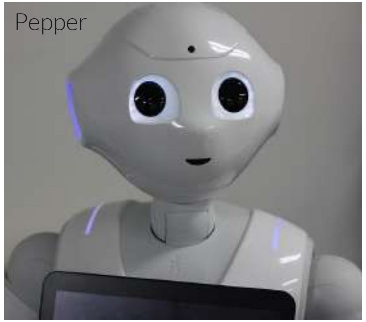
Looks obvious that...

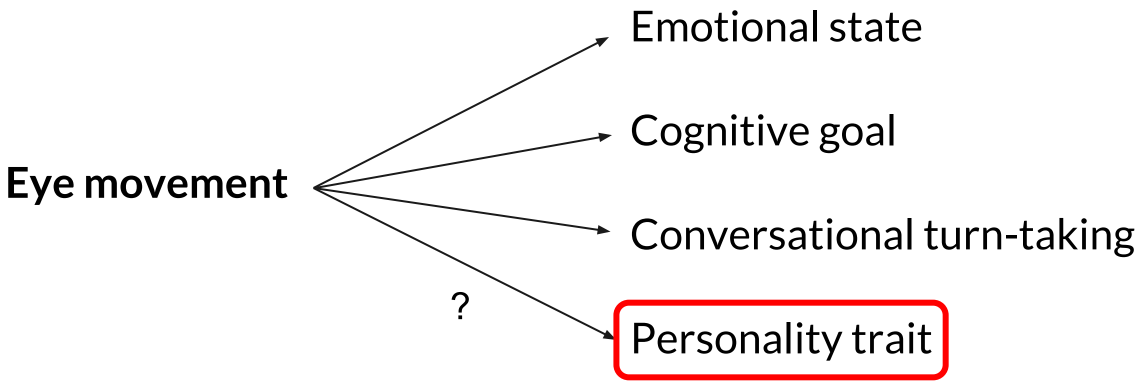
in order to realise effective and **empathic** computational systems that naturally interacts with humans (**HCI**) it is necessary to model the processes behind **human gaze** deployment.







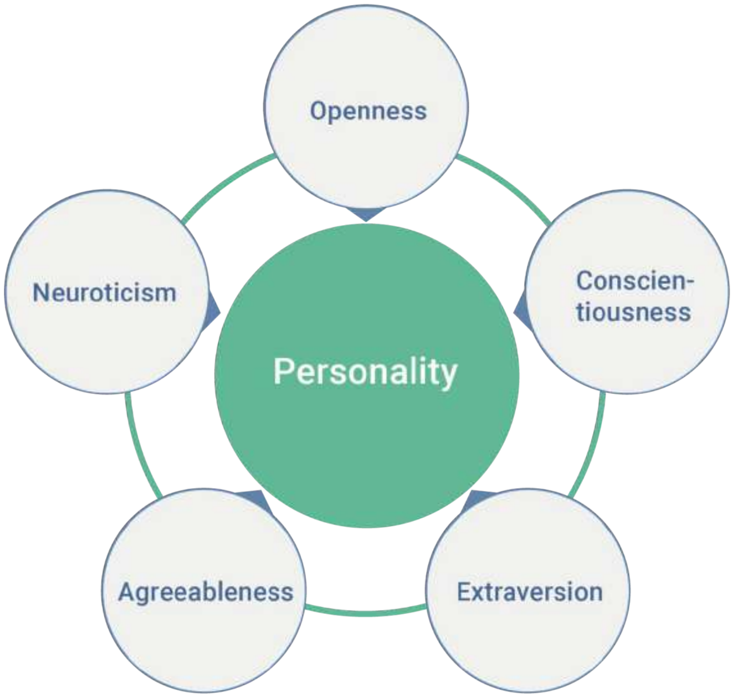



Eye movement
Emotional state
Cognitive goal
Conversational turn-taking
?
Personality trait

Personality

Big Five personality traits, also known as the **five factor model** (FFM).

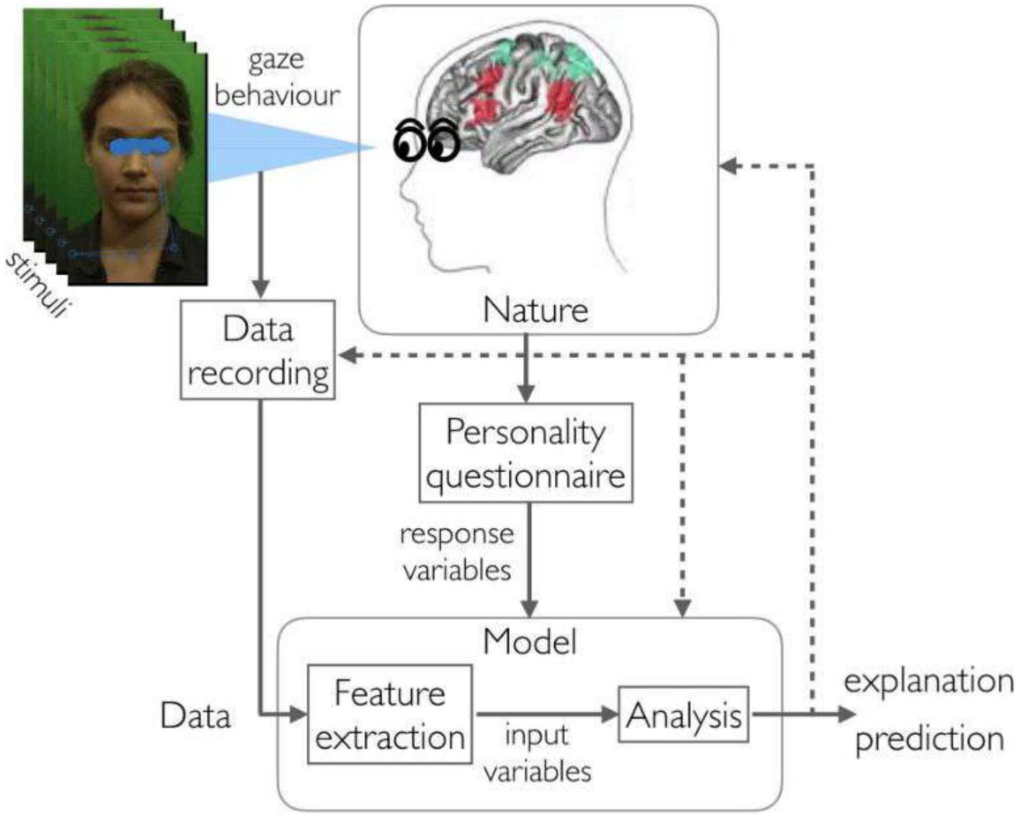
Typically assessed via standard psychological tests (eg. NEO-PI-R, BFI-44, BFI-10).



Previous works

- small datasets
    - (~40 recordings) Broz, F., Lehmann, H., Nehaniv, C.L., Dautenhahn, K.: Mutual gaze, personality, and familiarity: Dual eye-tracking during conversation. Proceedings - IEEE International Workshop on Robot and Human Interactive Communication pp. 858–864 (2012)
- focus on very specific personality traits
    - (optimist/pessimist) Isaacowitz, D.M.: Motivated Gaze: The View From the Gazer. Psychological Science 15(2), 68–72 (2006)
- adoption of non-natural stimulus
    - (non-meaningful, abstract stimuli) Rauthmann, J.F., Seubert, C.T., Sachse, P., Furtner, M.R.: Eyes as windows to the soul: Gazing behavior is related to personality. Journal of Research in Personality 46(2), 147–156 (2012)

Overview



stimuli
gaze behaviour
Nature
Data recording
Personality questionnaire
response variables
Model
Data
Feature extraction
input variables
Analysis
explanation
prediction

1. Eye tracking
DATA RECORDING

Recording scenario:

- Task based/**Free viewing**
- Static/**dynamic stimulus**
- **Screen based**/Glasses

Eye tracking data

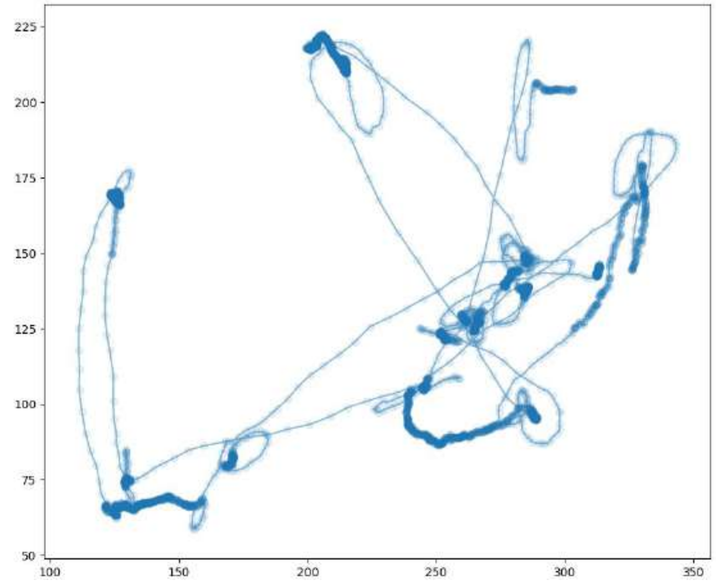
Analysis conducted on a **LARGE** (403 participants) dataset of people watching videos of another person.

A **10-item personality questionnaire** based on the Big Five personality inventory has been submitted.

Coutrot, Antoine, et al. "Face exploration dynamics differentiate men and women." Journal of Vision 16.14 (2016): 16-16.

As always... raw data is a mess

Timestamp	Number	GazePointXLeft	GazePointYLeft	CamXLeft	CamYLeft	DistanceLeft	PupilLeft	ValidityLeft	GazePointXRight	GazePointYRight	CamXRight	CamYRight	DistanceRight	PupilRight
95														
117	0	400.617	261.2175	0.7510002	0.6374704	648.1987	3.773164	0	400.9024	291.1999	0.5961173	0.6521371	636.4001	3.661053
133	1	398.393	264.365	0.7516774	0.6375181	648.2229	3.838122	0	418.6802	288.9396	0.5964973	0.6518696	636.5583	3.64993
150	2	396.2955	273.9963	0.7519954	0.6374961	647.8473	3.77234	0	393.907	301.2133	0.5968071	0.6517037	636.8112	3.675684
167	3	402.125	265.7434	0.7523934	0.6374515	648.0519	3.798069	0	399.3078	284.1953	0.5971763	0.6513929	636.6243	3.675363
183	4	414.2168	251.4495	0.7526376	0.6372757	648.2616	3.804291	0	430.813	272.5971	0.5972841	0.6511323	636.9761	3.629609
200	5	423.9691	256.5654	0.7527826	0.6372169	648.3549	3.810735	0	440.9916	264.9081	0.597564	0.6509658	636.6009	3.630603
216	6	423.9865	246.771	0.7531196	0.6373391	648.2988	3.817439	0	426.7016	274.3867	0.5979909	0.6507218	636.7742	3.65217
233	7	428.22	254.2387	0.7534257	0.6373549	648.2095	3.75736	0	426.7341	262.5856	0.5983127	0.6505361	637.0329	3.608105
250	8	427.502	235.5433	0.7537678	0.6372564	648.4797	3.747368	0	430.5061	257.4155	0.5986091	0.6503124	636.6136	3.607278
266	9	435.1046	242.4257	0.7538775	0.6371354	648.0962	3.729871	0	442.2343	254.1002	0.5988012	0.6500627	637.0001	3.587219
283	10	423.2355	261.5999	0.7541869	0.6370122	648.5149	3.7557	0	423.743	269.3259	0.5989991	0.6499335	636.6961	3.627606
300	11	433.2017	254.8062	0.7542553	0.6368436	648.4285	3.748498	0	421.663	262.8049	0.5990345	0.6497296	636.5421	3.588275
316	12	418.2851	253.153	0.7542648	0.6367035	648.2444	3.760934	0	423.6463	278.318	0.5990194	0.6495155	636.5278	3.576233
333	13	434.9374	248.5142	0.7542472	0.6363662	648.1369	3.736739	0	426.3913	273.6594	0.5989965	0.6492424	636.5372	3.573587
350	14	422.3765	290.4351	0.7540954	0.6367216	647.9678	3.742778	0	429.8147	309.0193	0.5990117	0.6495135	636.341	3.591557
366	15	418.8178	377.8113	0.753844	0.6371816	647.6741	3.709197	0	421.1444	391.3314	0.5990075	0.6500124	636.3063	3.590875
383	16	423.7291	365.6831	0.7537999	0.6368101	647.6413	3.717006	0	412.6543	375.5868	0.5986618	0.6498465	636.2288	3.577973
400	17	417.3529	375.5499	0.7536264	0.6365098	647.4266	3.706932	0	415.1166	374.7715	0.5984939	0.6496119	636.0198	3.570415
416	18	409.0251	369.9335	0.7534955	0.6363221	647.1501	3.723507	0	423.0077	365.2895	0.5982617	0.6494093	635.5084	3.535203
433	19	411.9613	366.2759	0.7534091	0.636264	647.0694	3.723622	0	417.2931	381.453	0.5981212	0.6494195	635.6729	3.55276
450	20	420.4647	372.6575	0.7533571	0.6363819	646.9561	3.710667	0	412.9641	375.7278	0.5980012	0.6496475	635.6643	3.553964
466	21	418.5887	366.1626	0.7533312	0.6367543	646.6282	3.744948	0	417.0449	370.9076	0.5998514	0.6495544	645.8091	3.641268
500	22	448.1517	426.7739	0.7534814	0.6373928	646.251	3.728234	0	425.8824	357.3699	0.5980758	0.6505944	634.8305	3.528945
516	23	425.5454	366.0304	0.7536324	0.6375493	646.0886	3.677925	0	424.6074	420.3143	0.5981955	0.6506779	634.6333	3.661961
533	24	407.2442	382.1979	0.7539406	0.6375214	646.032	3.724841	0	362.4283	369.4	0.5989246	0.6505076	634.9312	3.545217
550	25	382.0437	376.647	0.7543342	0.6372661	645.9999	3.73122	0	346.7462	378.2516	0.5996398	0.6500002	634.6049	3.559673
566	26	370.777	371.6201	0.7546184	0.637073	645.6644	3.765136	0	326.4905	386.1813	0.5997646	0.6495686	634.5554	3.610301
583	27	360.62	362.2698	0.7550178	0.6368808	645.6926	3.770904	0	345.1357	379.1794	0.6001299	0.6490359	634.3461	3.595069
600	28	371.0418	361.1357	0.7553933	0.636552	645.5532	3.764081	0	333.3999	379.6402	0.6004177	0.6485349	634.0368	3.59077
616	29	352.739	377.1207	0.7557038	0.6364966	645.5299	3.792601	0	327.5732	374.5496	0.6007568	0.6482773	634.3557	3.644621
633	30	364.7997	378.6232	0.7559824	0.6365534	645.6616	3.81726	0	331.7	389.1884	0.6010883	0.6481026	634.0649	3.648695
650	31	353.9612	370.7148	0.7562348	0.6367001	645.4138	3.871641	0	348.1435	390.4786	0.6013653	0.648073	633.7674	3.653214
666	32	358.9431	359.4175	0.7565078	0.6369652	645.5173	3.876763	0	337.5291	386.1313	0.6016595	0.6480598	634.0399	3.663415
683	33	359.6321	369.5832	0.7568166	0.6370528	645.5229	3.863067	0	343.475	381.1053	0.6019519	0.6480272	633.6067	3.694201
700	34	353.5806	366.2641	0.7569903	0.6370781	645.6316	3.89461	0	346.4277	379.5706	0.6021955	0.6477951	634.029	3.689347
716	35	357.3749	368.0299	0.7571286	0.6369992	646.3062	3.907702	0	336.7175	406.1323	0.6023462	0.6476824	633.6699	3.730237
733	36	353.7257	374.9613	0.7573475	0.6370568	645.4896	3.918049	0	330.6978	388.4258	0.6024583	0.6477064	633.4949	3.735837
750	37	352.0519	379.0789	0.7575161	0.637355	645.4671	3.929201	0	340.0563	371.7014	0.6026729	0.6479211	634.0341	3.73941
766	38	351.5531	366.0008	0.7575136	0.6377777	645.552	3.9707	0	360.0239	400.5162	0.6023819	0.6483929	633.5637	3.770778
783	39	449.1368	350.6203	0.7569316	0.6393128	645.7051	3.990263	0	490.351	398.9582	0.6014163	0.6489247	633.8975	3.796376
800	40	476.1451	336.3235	0.7566356	0.6389554	645.7972	3.981491	0	503.899	390.5497	0.6012101	0.6494787	634.3527	3.814618
816	41	482.7939	350.1748	0.7566625	0.6394882	645.7811	3.990834	0	487.8269	396.0803	0.6013822	0.6498792	634.0419	3.818946



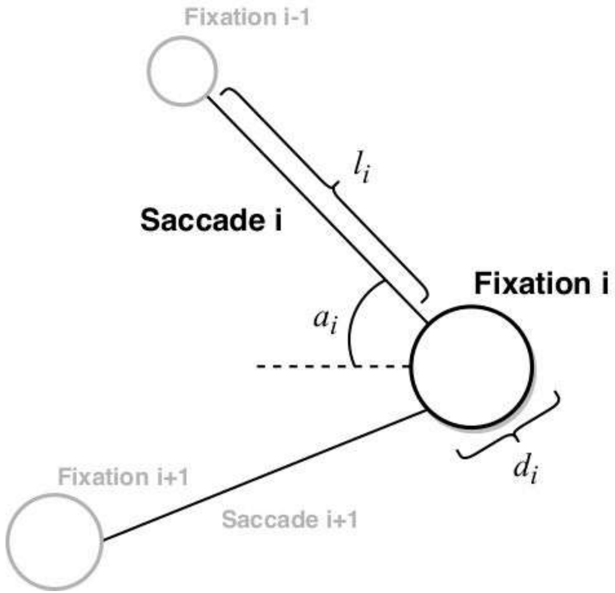
Gaze actions

FIXATIONS

are concerned with bringing onto the fovea salient objects of a scene

SACCADES

rapid transitions of the eye that permit to jump from spotting one location of the viewed scene to another



Gaze actions

SMOOTH PURSUIT

(in the presence of moving objects) typically associated with fixations since the focus remain on the same stimulus, but in this case a movement of the eyes is required.

POST SACCADIC OSCILLATION

recent research has shown that the pupil signal contains an additional event (PSOs) that influence fixation and saccade durations by at least 20 ms.

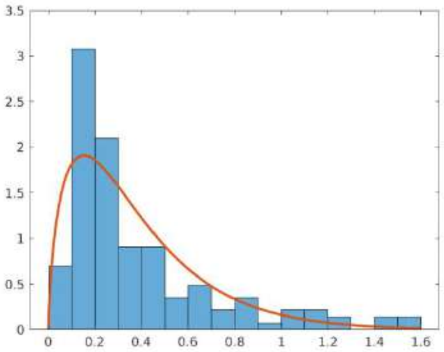
2. Feature extraction

Feature extraction

Considering a recorded scan path $\mathcal{W} = \{(\mathbf{f_i}, \mathbf{s_i}, \mathbf{p_i}, \mathbf{o_i})\}_{i=1}^{N}$ we derive:

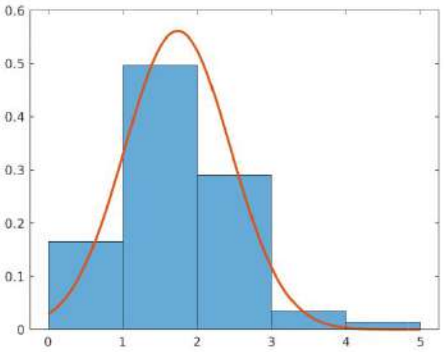
- Fixation duration

$$D \sim f(d \mid a, b) = \frac{1}{b^a \Gamma(a)} d^{a-1} \exp\left(\frac{-d}{b}\right)$$



- Saccade amplitude

$$L \sim f(\xi; \alpha, \beta, \gamma, \delta)$$



Feature extraction

- Saccade direction

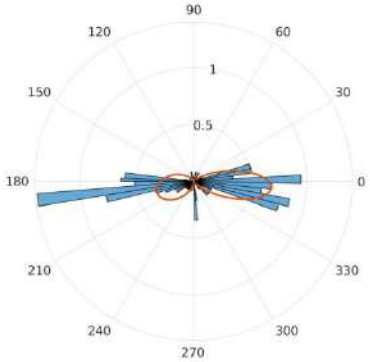
$$A \sim f(a \mid \mu, \kappa) = \frac{\exp(\kappa \cos(a-\mu))}{2\pi I_0(\kappa)}$$

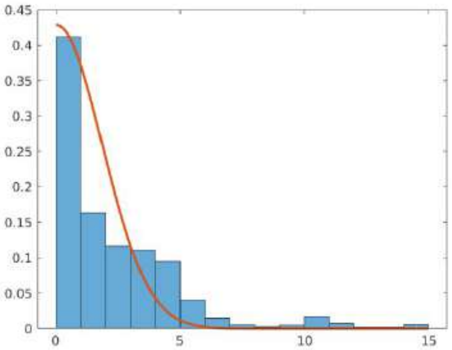
- Event frequency

$$E_j = \frac{e_j}{(e_1 + \cdots + e_4)}$$

- Pupil dilation

$$V \sim f(v \mid \sigma) = \frac{\sqrt{2}}{\sigma\sqrt{\pi}} \exp\left(-\frac{v^2}{2\sigma^2}\right)$$





$$\mathcal{X} = [D_a, D_b, L_\gamma, L_\delta, A_\mu, A_\kappa, E, V_\sigma]$$

2. Classification model

GP model learning and prediction

Find a nonlinear mapping between a subset of **features** $\mathcal{X}$ and the levels of **personality traits** $\mathcal{Y}$.

probit regression

$$p(y_i \mid \mathcal{X} = \mathbf{x}_i) = \Phi(y_i f(\mathbf{x_i})),\ y_i \in \{-1, 1\}$$

$$\Phi(z) = \int_{-\infty}^{z} \mathcal{N}(x \mid 0, 1) dx$$

$$f \sim \mathrm{GP}\left(\cdot \mid 0, k\right)$$

kernel function $\mathbf{K}_{ij} = k(\mathbf{x}_i, \mathbf{x}_j; \theta)$, being θ the hyperparameters of the kernel function.

Rasmussen, C. E., & Williams, C. K. (2006). Gaussian processes for machine learning (Vol. 1). Cambridge: MIT press.

ARD kernel

The adopted **automatic relevance determination** (ARD) kernel is a more general form of the squared exponential kernel for multi-dimensional inputs, that can be defined as

$$k(\mathbf{x}, \mathbf{x}'; \theta) = \sigma^2 \exp\left[-\frac{1}{2}\sum_{d=1}^{D}\left(\frac{x_d - x_{d'}}{w_d}\right)^2\right],$$

scale

weights

with hyperparameters

$$\theta = \{\sigma^2, w_1 \cdots w_D\}$$

x_d is not relevant if $1/w_d$ is small.

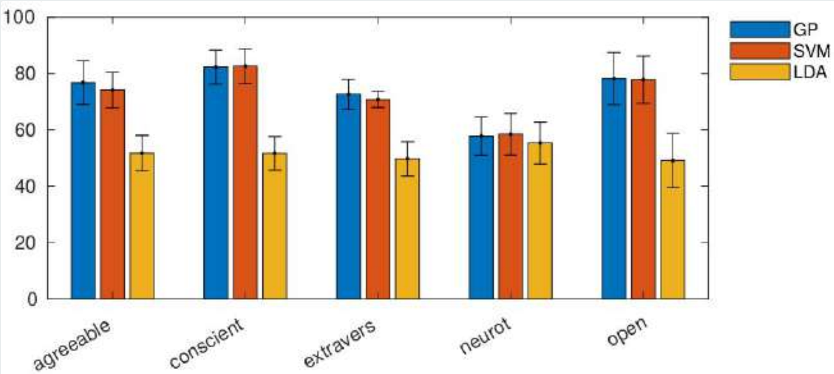
3. Analysis and results

Analysis

INGREDIENTS

1. **Binary classification** model for each personality trait (5),
2. k-fold **cross-validation** (k=10),
3. classes made up by **highest** ($C_1 = \{2 \leq p \leq 5\}$) and **lowest** ($C_2 = \{7 \leq p \leq 10\}$) levels of each trait,
4. unbalanced classes treated using **ADASYN** oversampling technique inside each fold of the cross-validation, in order to avoid possible overfitting problems

Results



chance level: 50%

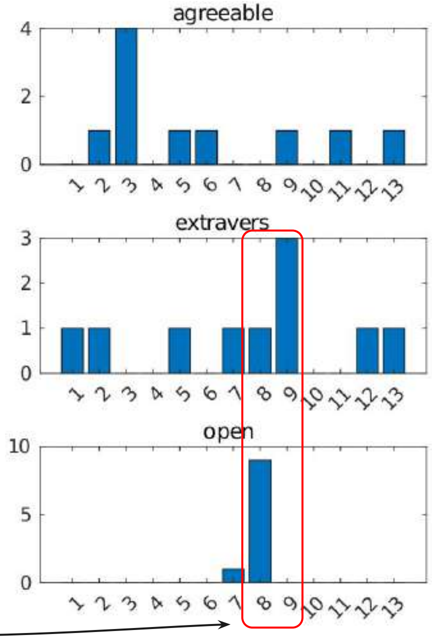
Personality trait	Accuracy	Precision	Recall	F-measure	
agreeableness	0.77 ± 0.08	0.79	0.96	0.87	GP
	0.74 ± 0.06	0.78	0.93	0.85	SVM
	0.52 ± 0.06	0.78	0.54	0.64	LDA
conscientiousness	0.82 ± 0.06	0.86	0.94	0.90	GP
	0.82 ± 0.06	0.86	0.94	0.90	SVM
	0.52 ± 0.06	0.86	0.53	0.65	LDA
extraversion	0.73 ± 0.05	0.74	0.96	0.84	GP
	0.71 ± 0.03	0.75	0.92	0.82	SVM
	0.50 ± 0.06	0.71	0.54	0.62	LDA
neuroticism	0.58 ± 0.07	0.48	0.44	0.45	GP
	0.58 ± 0.07	0.45	0.14	0.22	SVM
	0.55 ± 0.07	0.45	0.53	0.49	LDA
openness	0.78 ± 0.09	0.82	0.95	0.88	GP
	0.78 ± 0.08	0.82	0.93	0.87	SVM
	0.49 ± 0.10	0.78	0.53	0.63	LDA

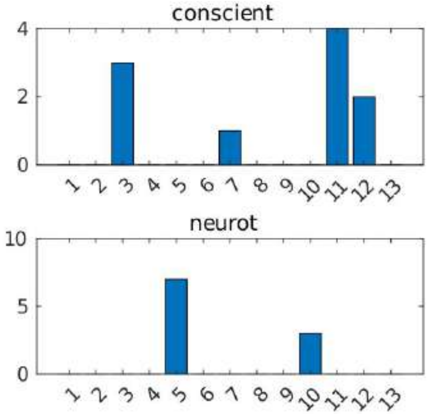
(probably) sneaky definition of neuroticism

ARD weights

number of *wins*
in the cross-validation

typically overlooked feature





ARD weights

1	Dilation (V_σ)	8	Saccade direction (A_{κ_1})
2	Fixation duration (D_a)	9	Saccade direction (A_{κ_2})
3	Fixation duration (D_b)	10	Number of fixations
4	Saccade amplitude (L_γ)	11	Number of saccades
5	Saccade amplitude (L_δ)	12	Number of PSOs
6	Saccade direction ($A_{\mu 1}$)	13	Number of smooth pursuits
7	Saccade direction ($A_{\mu 2}$)		

Thanks

vittorio.cuculo@unimi.it
http://phuselab.di.unimi.it/

P
HU
SE Lab
Perceptual computing
and HUman SEnsing