

Supplementary Materials

Archetypes in human cognition defined by time preference for reward and their brain correlates: an evolutionary trade-off approach

**Giorgia Cona^{1,6,\$}, Loren Koçillari^{2,6,\$}, Alessandro Palombit^{3,6},
Alessandra Bertoldo^{3,6}, Amos Maritan^{2,6†},
Maurizio Corbetta^{4,5,6†*}**

Departments of General Psychology¹, Physics², Information Engineering³
Neuroscience, University of Padua, Italy⁴.

Departments of Neurology, Radiology, Neuroscience
Washington University School of Medicine, Saint Louis, USA⁵
Padova Neuroscience Center (PNC), University of Padua, Italy⁶

\$ equal contribution first author

†equal contribution senior author

***Corresponding author:**

Maurizio Corbetta M.D.
Department of Neuroscience
Clinica Neurologica Azienda Ospedaliera
University of Padua
Via Giustiniani 5
35128 Padova, Italy
maurizio.corbetta@unipd.it

SI Materials and Methods

HCP Database: behavioural dataset. The behavioral database consists of tests that are part of the NIH Toolbox battery and of several Non-Toolbox behavioral measures. They are collected in the following main domains:

- Demographics: Gender, Age by Year, Race, Ethnicity, Handedness, Self-Reported demographics on education, income, relationship status from SSAGA.
- Health and Family History: Body Mass Index, Blood Pressure, Parental Psychiatric or Neurological Illnesses.
- Alertness: Cognitive Status, Sleep
- Cognition: Episodic memory (Picture sequence and Verbal), Executive Function (Cognitive Flexibility and Inhibition), Fluid Intelligence, Language (Reading decoding and Vocabulary comprehension), Processing Speed, Self-regulation/Impulsivity (Delay Discounting), Spatial Orientation, Sustained Attention, Working Memory.
- Emotion: Emotion recognition, Psychological Well-being, Social Relationships, Stress and Self-Efficacy.
- Motor: Endurance, Locomotion, Dexterity, Strength.
- Personality: Five Factor Model (NEO-FFI).
- Psychiatric and Life Function: Achenbach Self-Report of Life function and Psychiatric Clinical Symptoms, Self-reported Psychiatric Clinical Symptom measures from SSAGA.
- Sensory: Audition, Olfaction, Pain, Taste, Contrast Sensitivity, Color Vision, Visual Acuity.
- Substance Use: Urine Drug Screen, Seven-day Alcohol and Tobacco Use Retrospective, Self-Reported Substance Use and Abuse measures from SSAGA.

Supplementary Figures

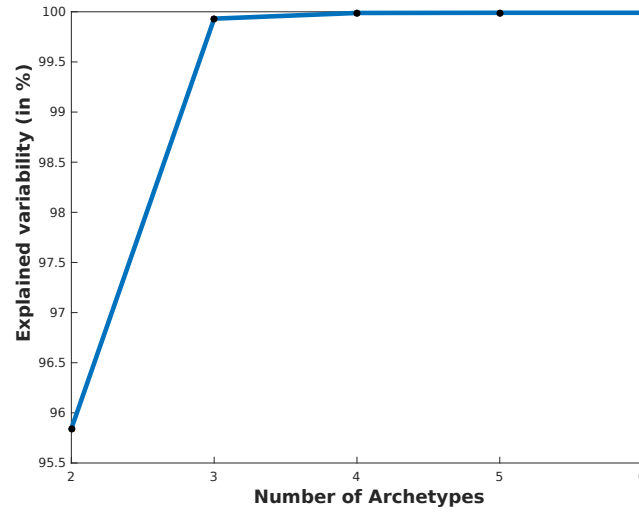


Figure S1: Optimal number of vertices of the Pareto Front. This figure shows that three is the optimal number of vertices that explains the largest amount of variance (in percentage) of the data point, which are plotted in the two dimensional space of AUC \$200 and AUC \$40,000. We made the analysis by varying the number of vertices from two to six. The vertices were found by using PCHA algorithm, as developed by (1). The slope of the blue curve describes the increment of the explained variance as increasing the number of vertices. It results that three is a stationary point, after which the explained variance increases negligibly.

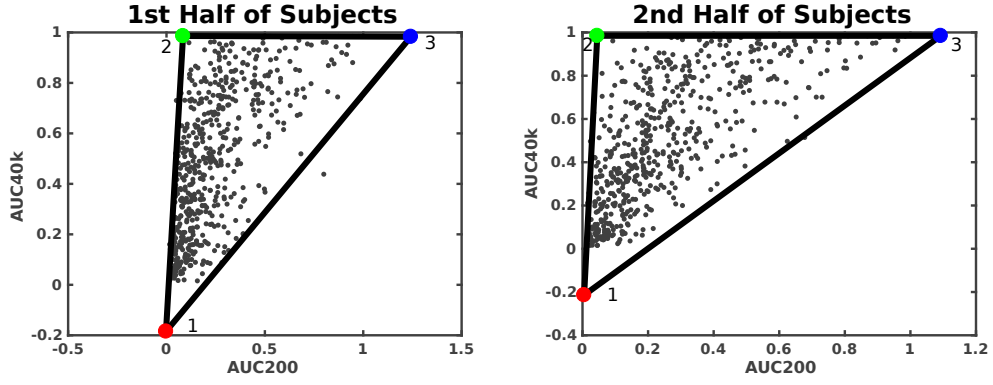


Figure S2: Robustness of the Pareto Front-Test 1. This figure shows the robustness of our triangular front when we randomly split in two sub-samples of equal population the original sample of 1206 subjects and then we made for both the triangularity test. It results that the p-values are $< 10^{-4}$.

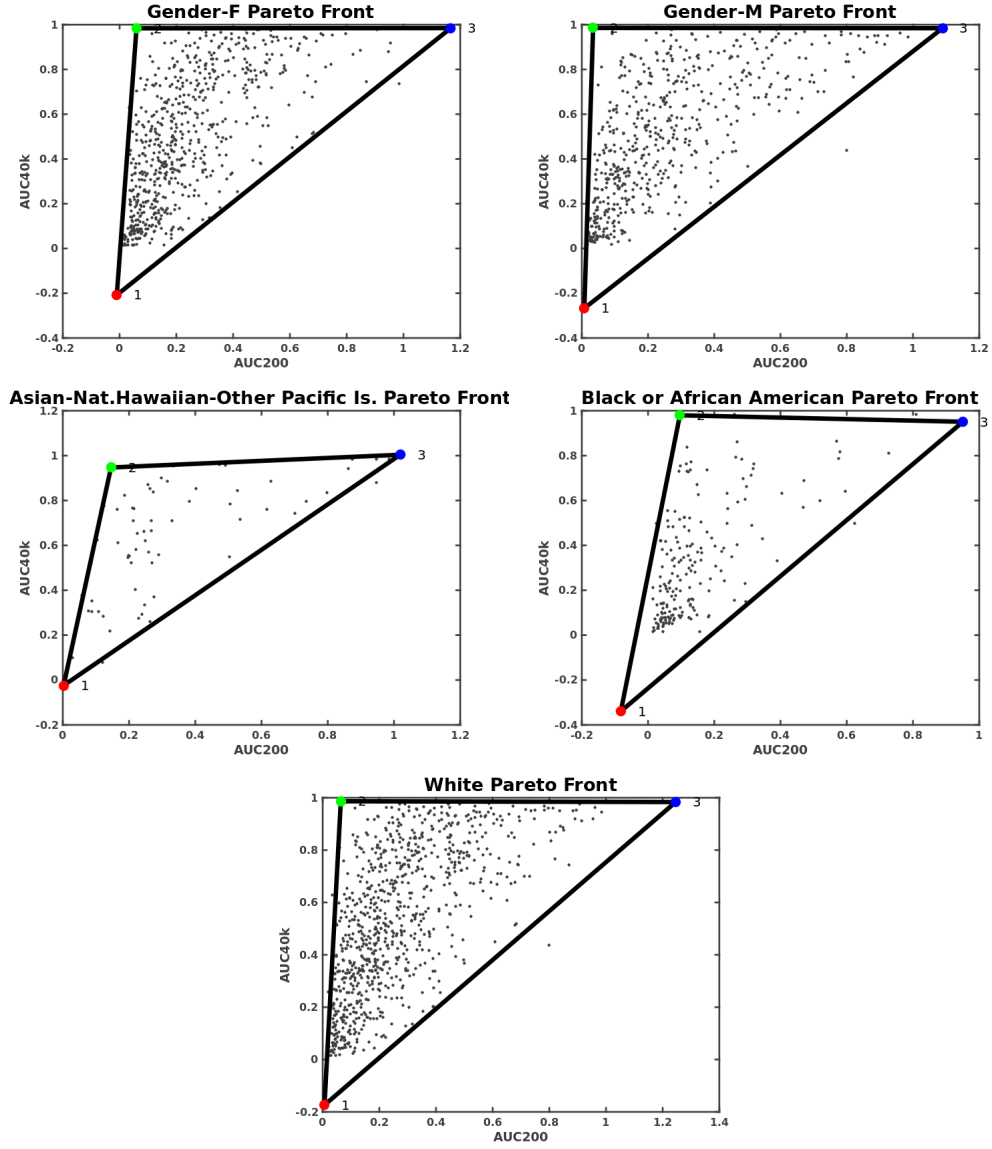
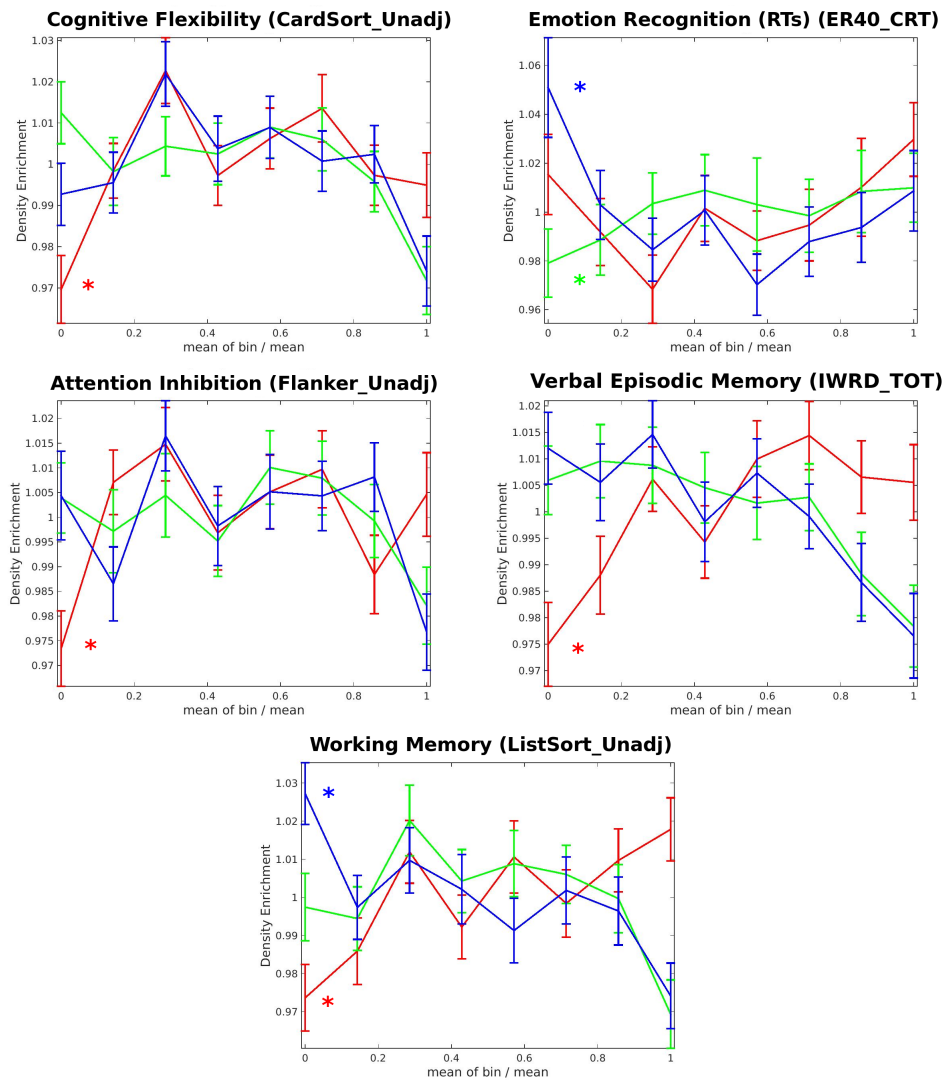


Figure S3: Robustness of the Pareto Front-Test 2. This figure shows the robustness of our triangular front. We considered many sub-samples of the data points (1206 subjects) and made for each of them the triangularity test. We analyzed separately samples of only female/male subjects and the different race (Asian-Nat.Hawaiian-Other Pacific, Black or African American, White). It results that the triangular shape is robust to gender and race labels, meaning that the properties of the triangle are not related to them.

Enrichment Analysis

Cognitive



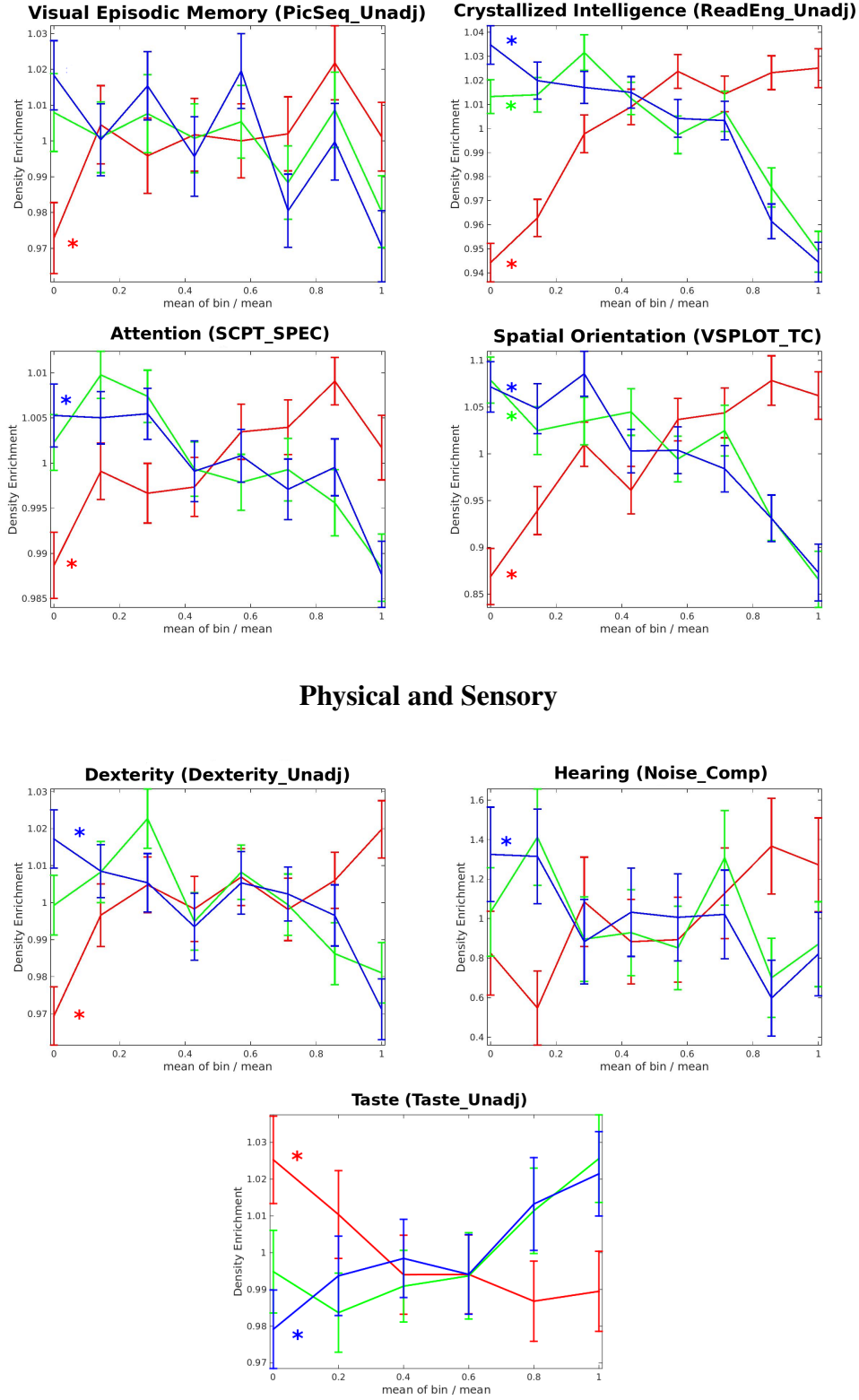
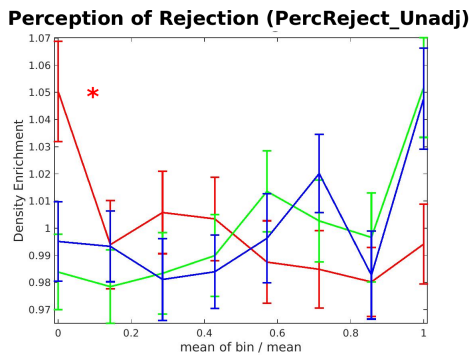
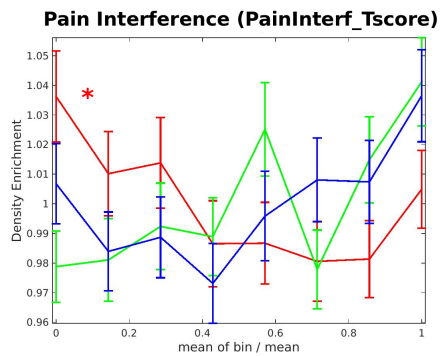
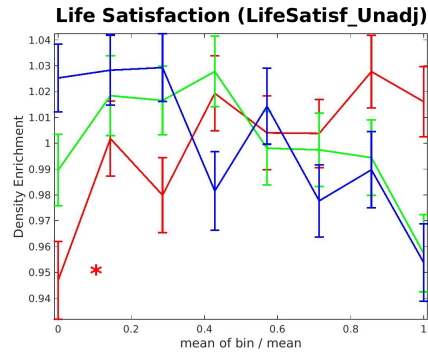
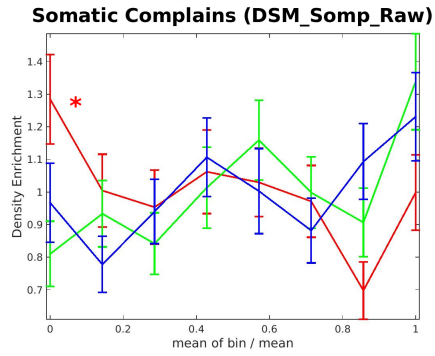
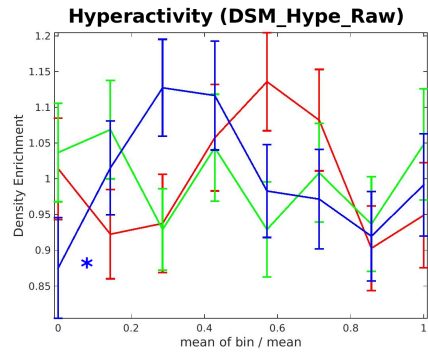
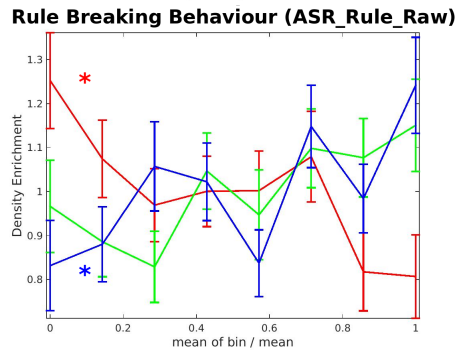
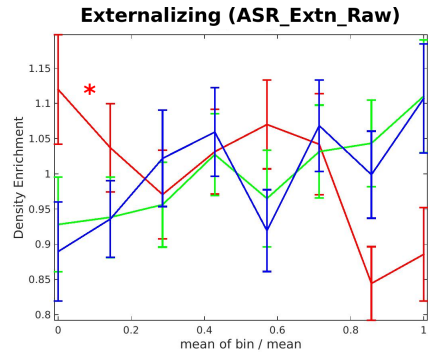
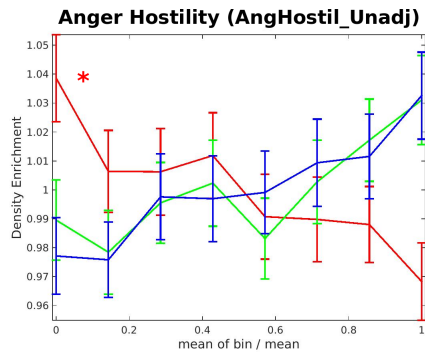
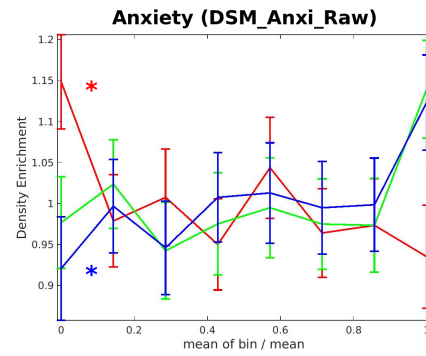
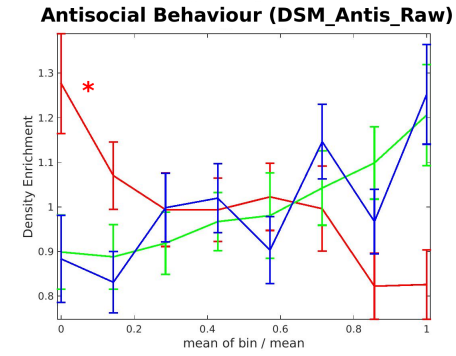
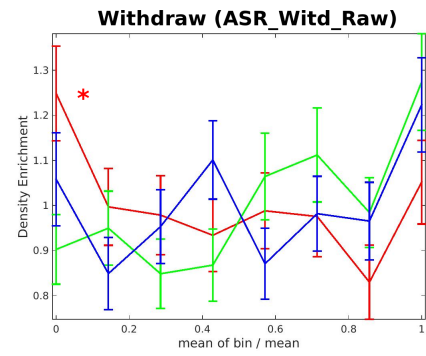
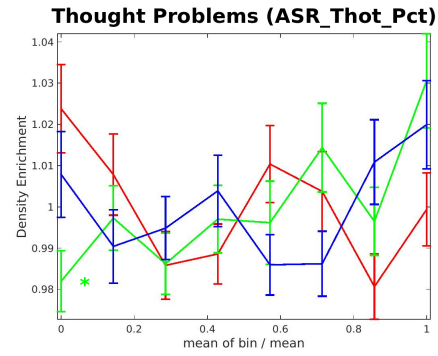
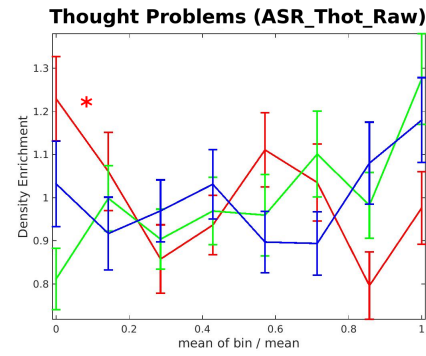
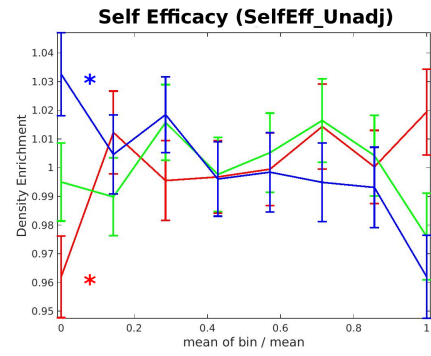
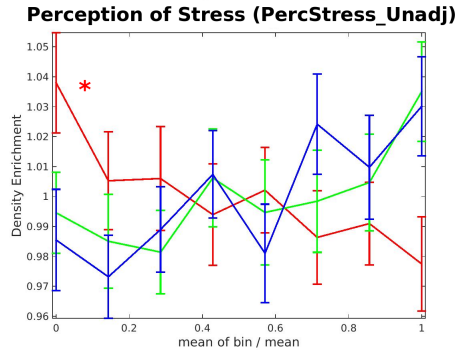


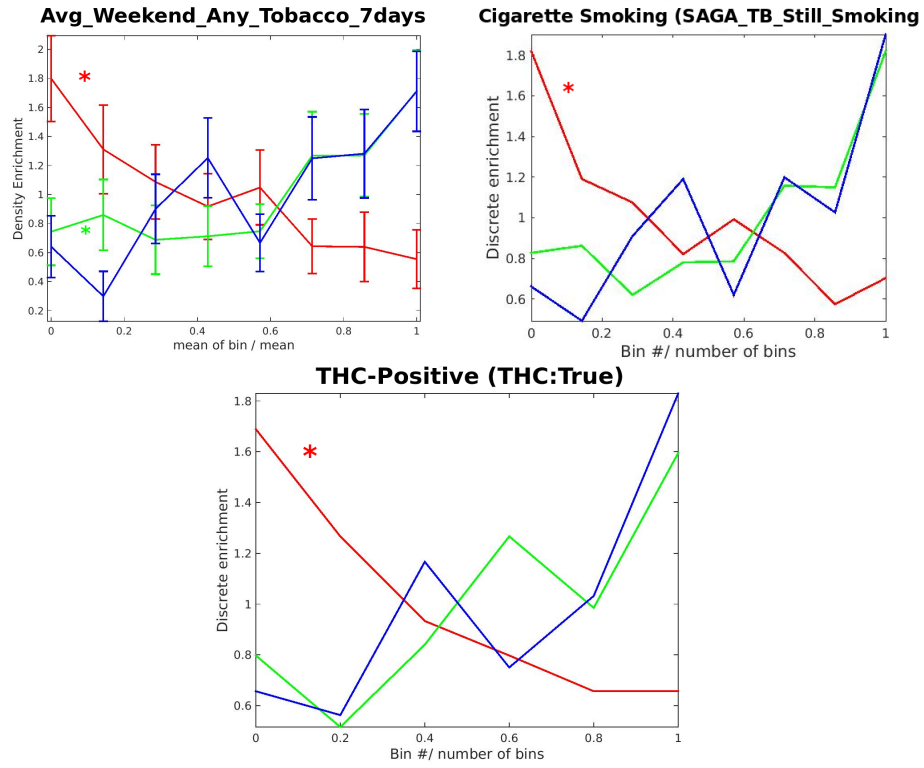
Figure S4: Enrichment analysis of Cognitive, Physical and Sensory traits. We plotted all the enriched features of the Cognitive, Physical and Sensory traits, which result from the density analysis of the archetypes, in the case of 8 bins.

Personality





Substance use



Socio-demographic

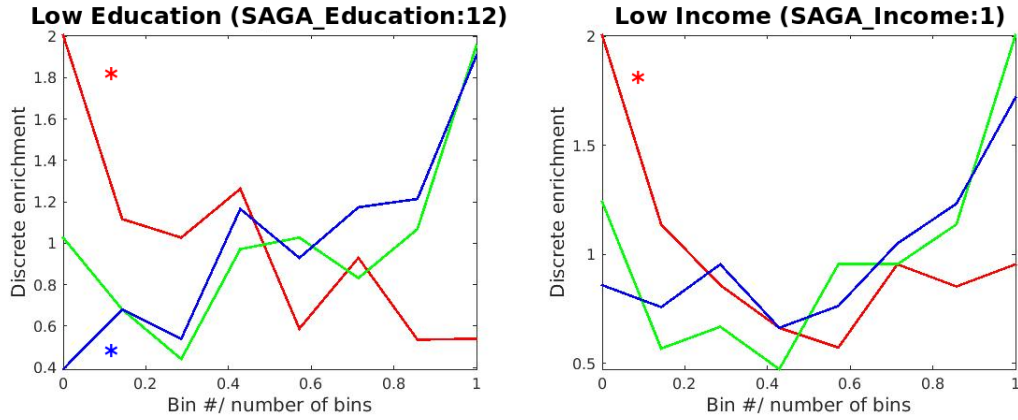


Figure S5: Enrichment analysis of personality, Substance use and socio-demographic traits. We plotted all the enriched features of the personality, Substance use and socio-demographic group, which result from the density analysis of the archetypes, in the case of 8 bins.

References

1. Mørup, M., & Hansen, L. K. (2012). Archetypal analysis for machine learning and data mining. *Neurocomputing*, 80, 54-63.