Psychology 405: Psychometric Theory
Further topics

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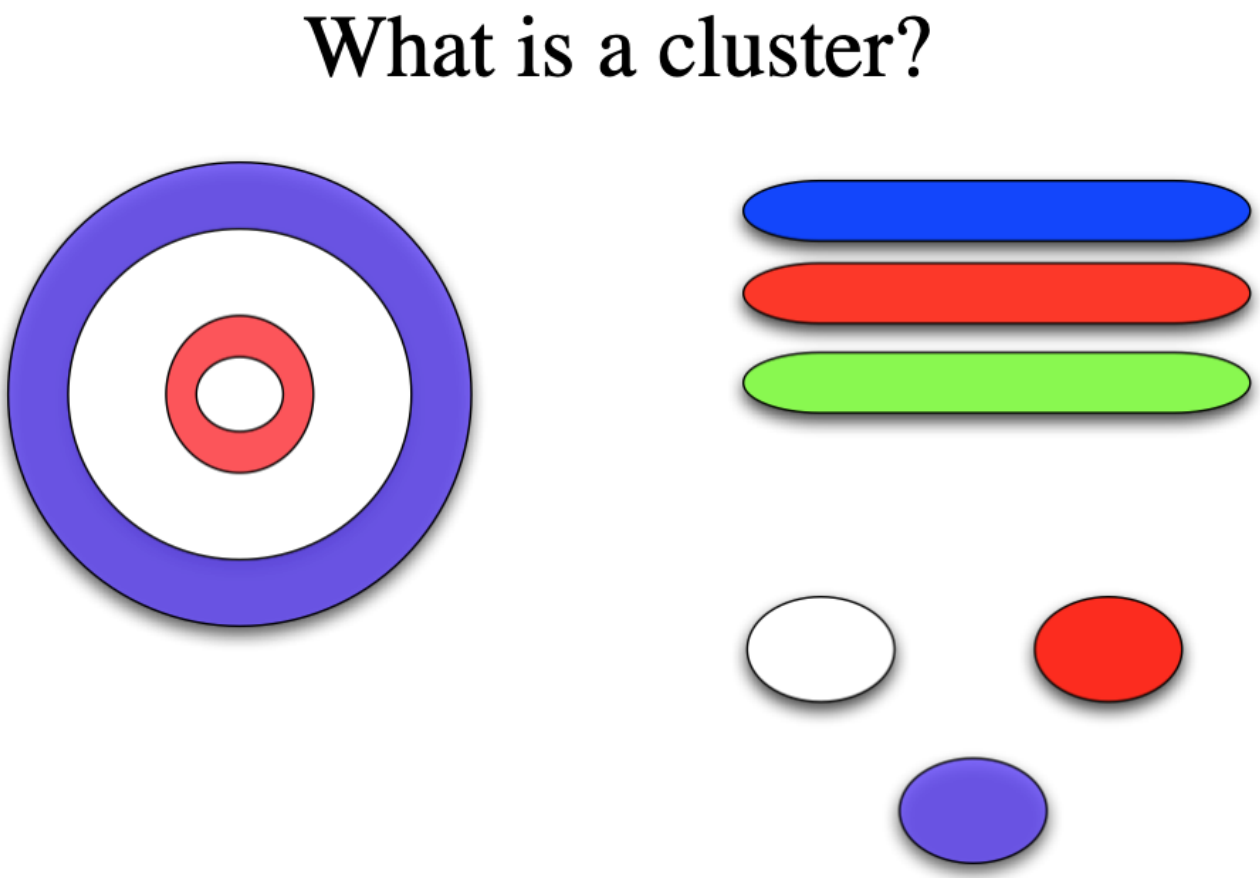
Outline

Cluster analysis as a reduction procedure

1. Cluster analysis is used in many different fields to group objects
2. Cluster analysis of galaxies in astronomy
3. Cluster relationships of viruses in biology
4. Clusters of dna in genetics
5. Clusters of “projectile points" in anthropology
6. Clusters of zipcodes in marketing
7. What is a a cluster?

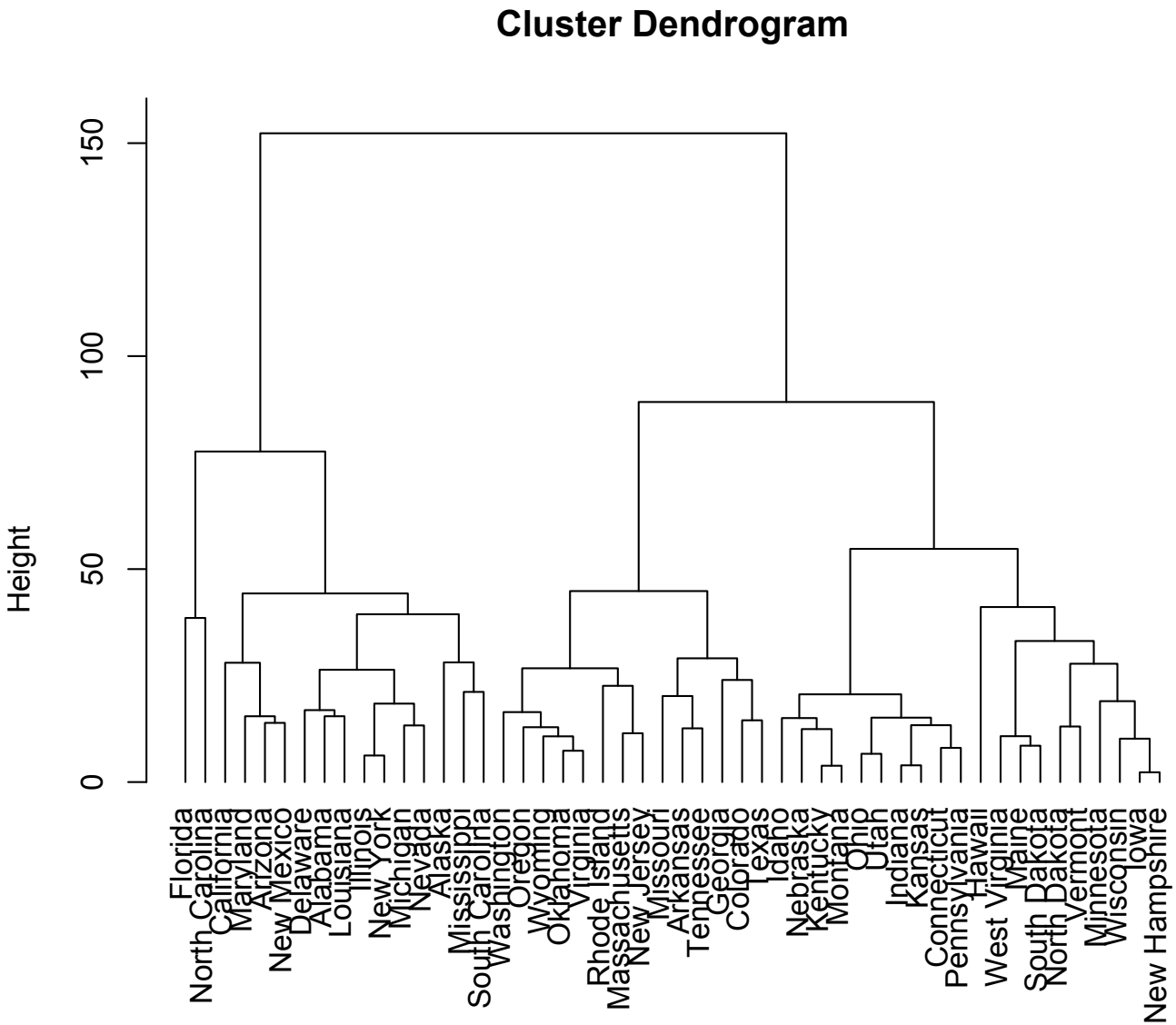
What is a cluster?



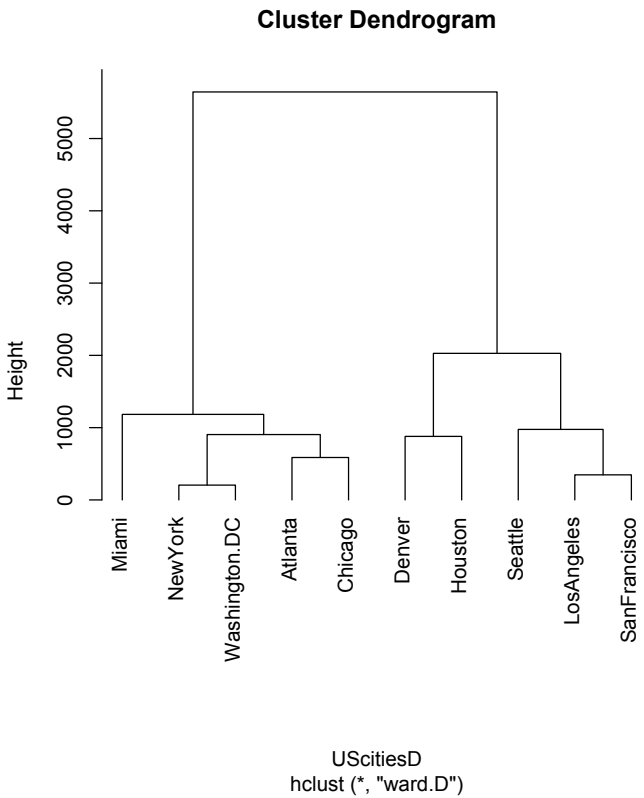
Clustering rules

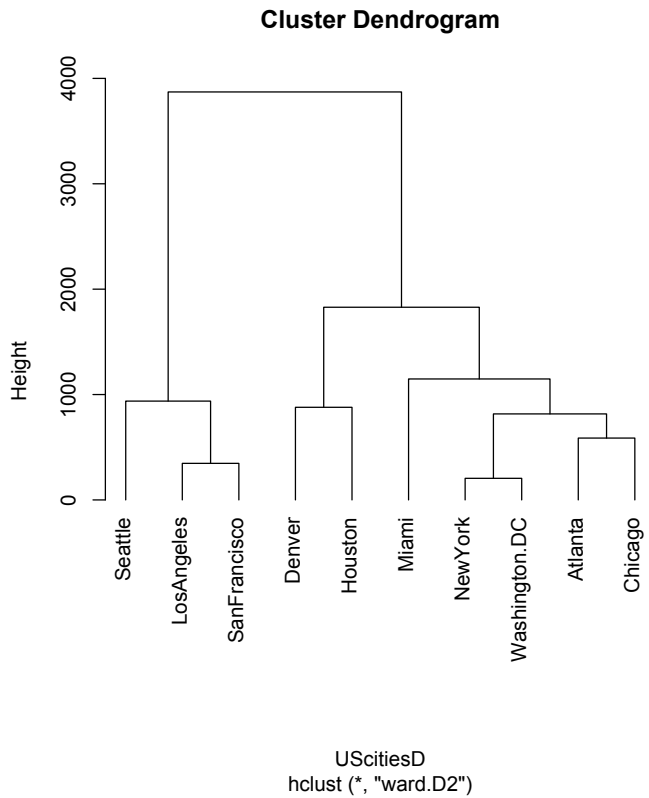
1. What is the measure of distance between clusters?
   - Nearest neighbor
   - Farthest neighbor
   - Centroid distance
2. Methods
   - Hierarchical
     - Agglomerative (e.g., hc or iclust)
     - Divisive(e.g., diana)
   - Non-hierarchical (e.g., k-means)

hclust of arrests

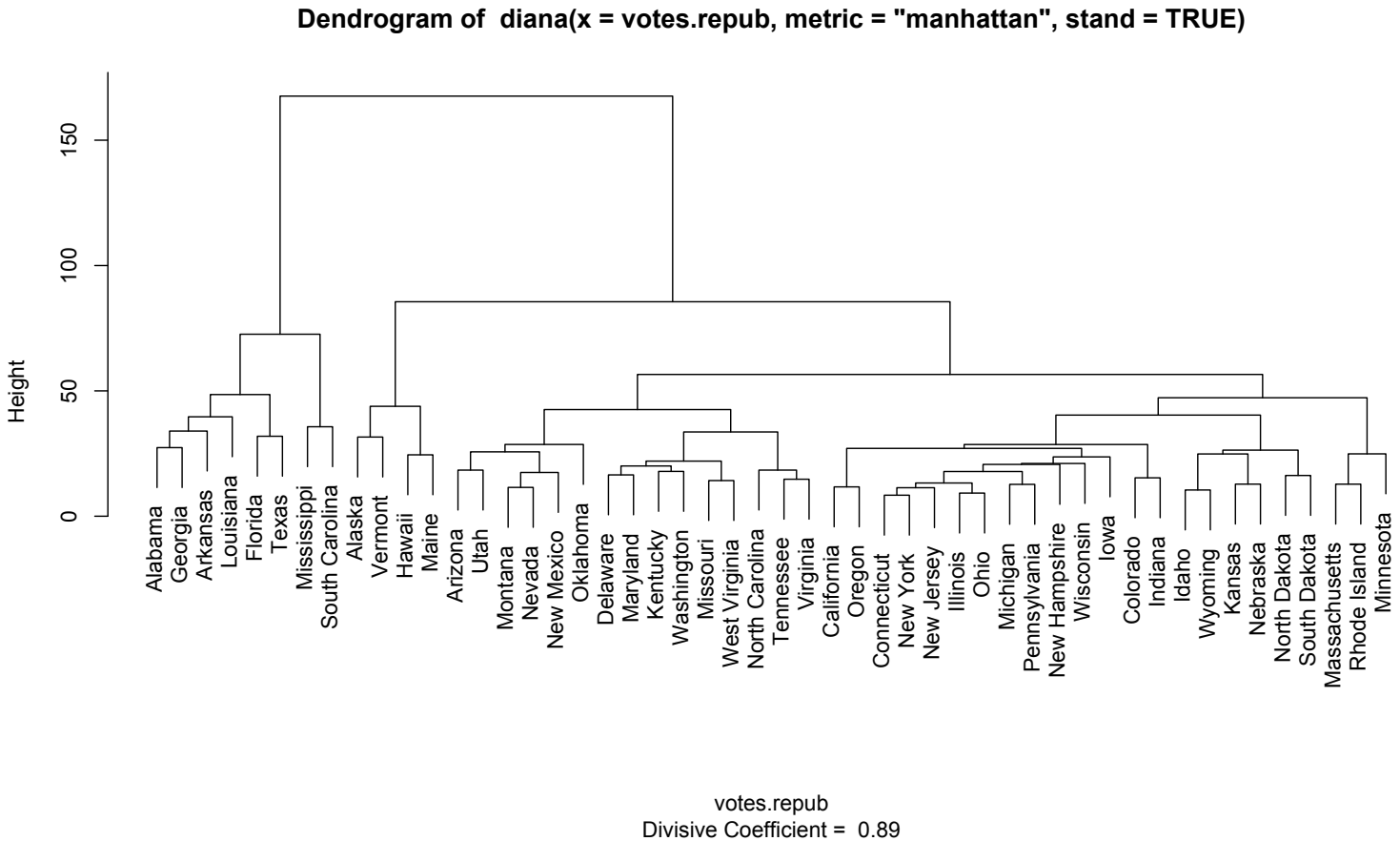


Wards method for cities based upon distances





DIvisive ANAlysis using diana of voting by states



Clustering issues

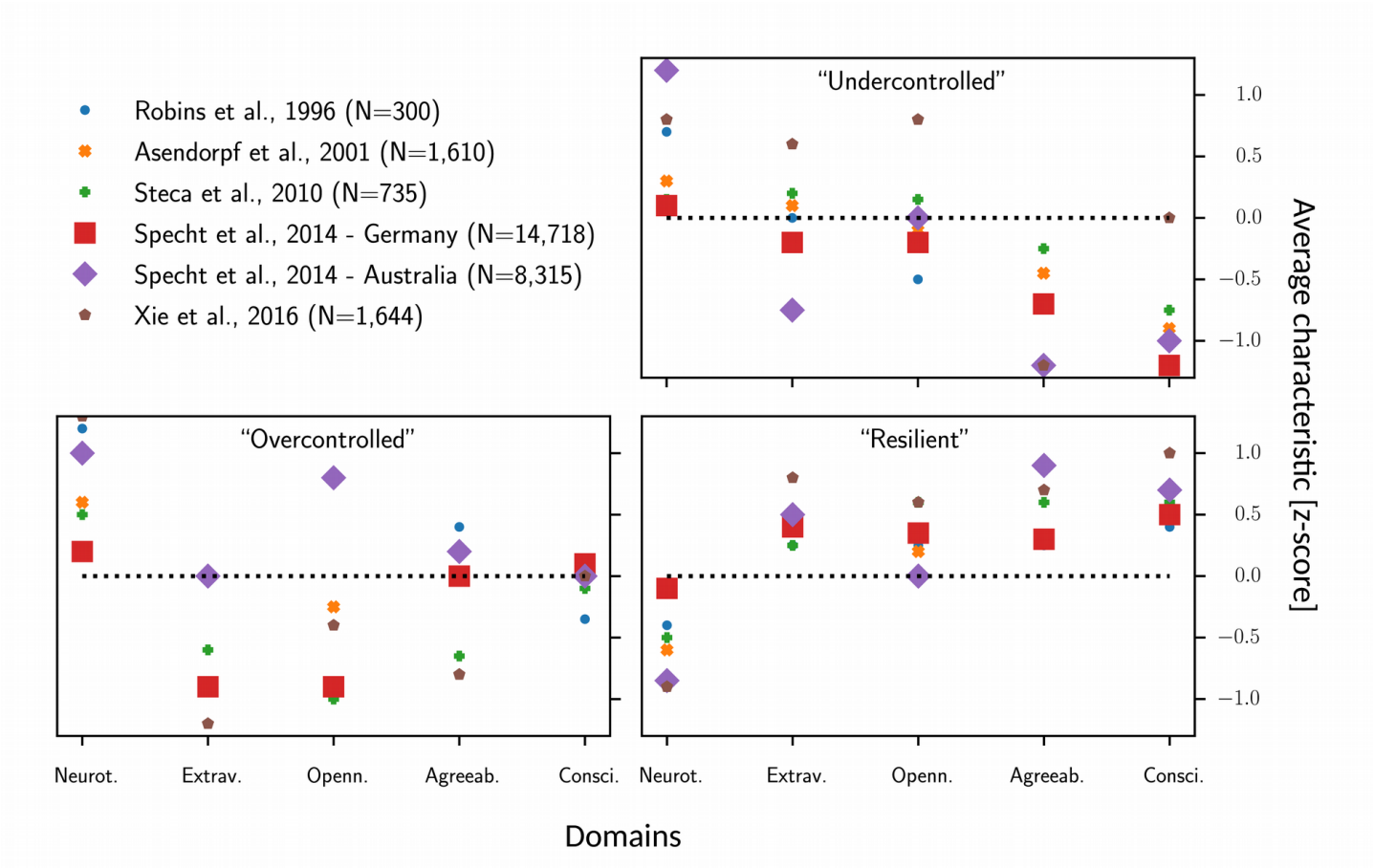
1. Cluster Objects/people
   - similarities or distances?
   - can objects be reversed? (not usually)
2. Cluster items (unusual, but see ICLUST)
   - can be reversed (-happy)
   - results are similar to factor analysis
3. Stopping rules for cluster
4. number of cluster problem

Do people form clusters

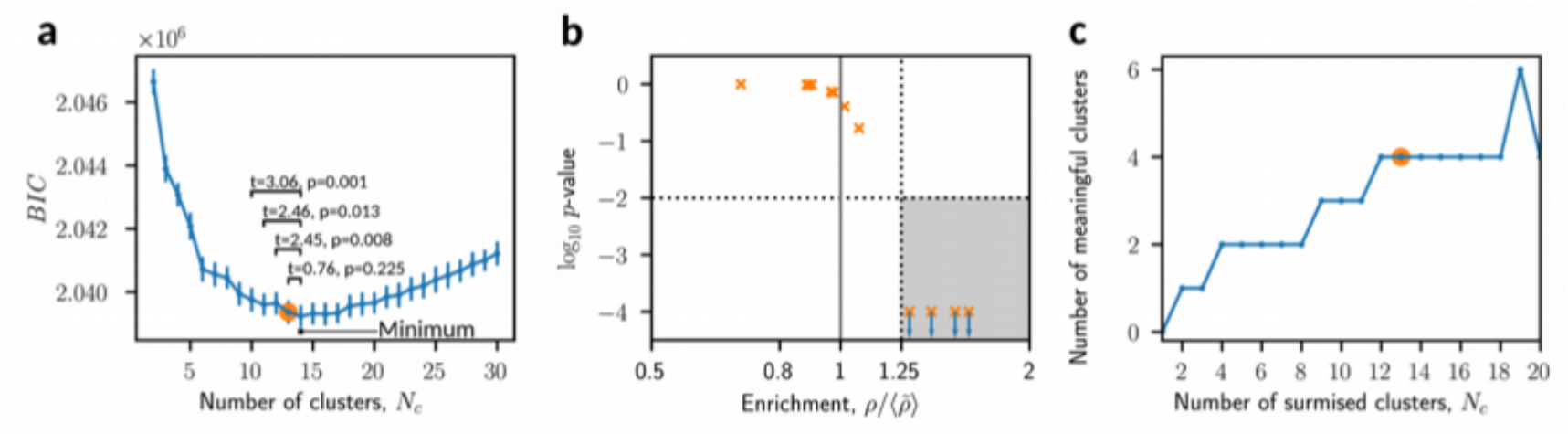
1. The types of Theophrasus (Theophrastus, 1909)
2. Galen's Typology of the four temperaments (Stelmack and Stalikas, 1991)
3. Asendorf, Robbins, and Caspi (ARC) model (Asendorf et al., 2001)
4. Gerlach with modern clustering (Gerlach et al., 2018)

The ARC model

Figure 1



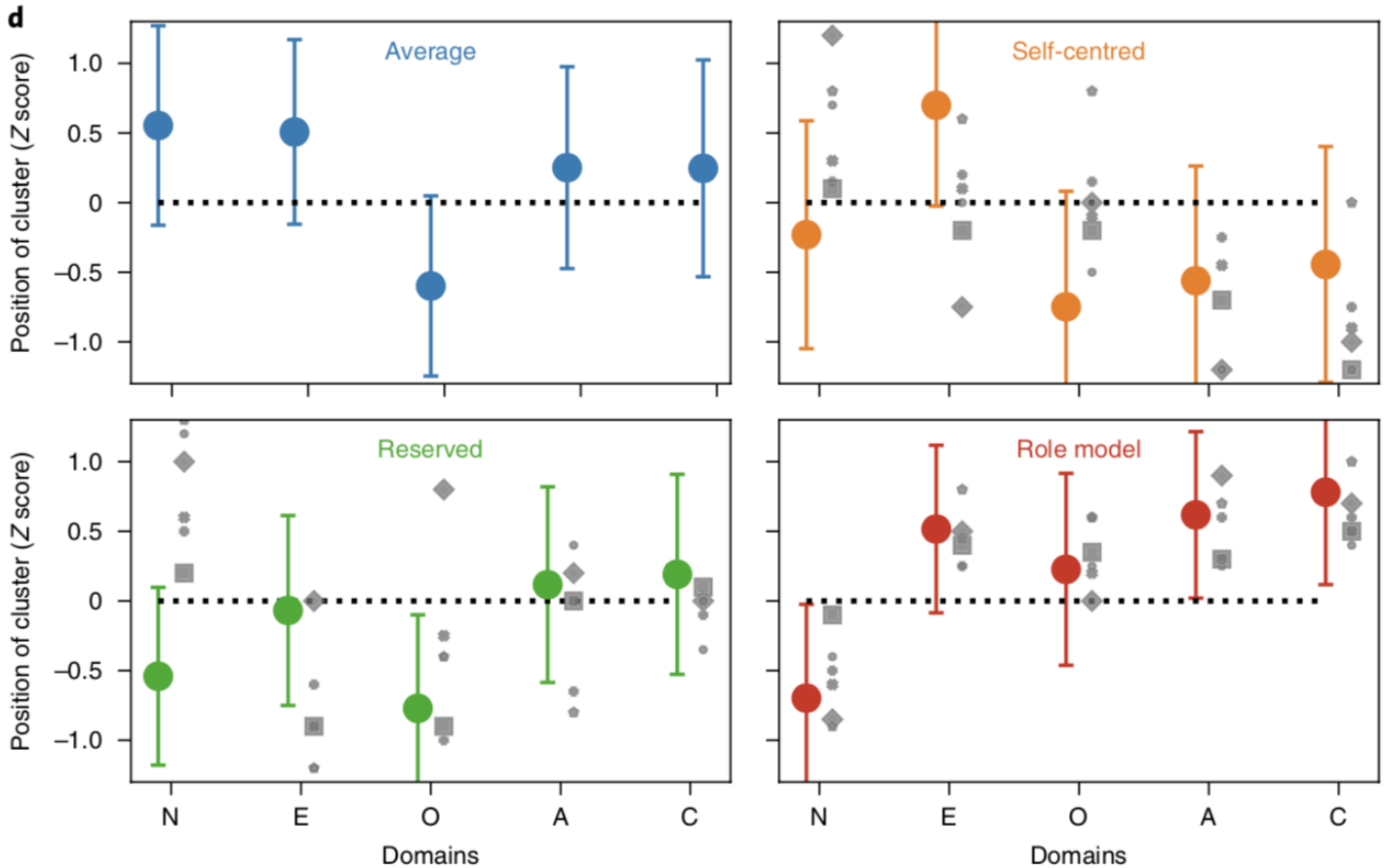
Gerlach et al, 2018 the cluster problem



(Gerlach et al., 2018, 2019)

The need for random cross validation.

Gerlach et al, 2018



(Gerlach et al., 2018, 2019)

Problems with types

1. Multidimensional space is amazingly empty (Del Giudice, 2021)
2. It is normal to be abnormal
3. It is unusual to be average

Types as “lumps in the batter"

1. Although people like to think in terms of discrete types, this is probably a mistake
2. High dimensional space is remarkably empty and we should think of them as mere lumps in the batter
3. Think about the distribution of people in the US.
4. Although there are increases in density in NY, Chicago, Houston, and LA, to say all Americans live in one of 4 cities is clearly wrong.

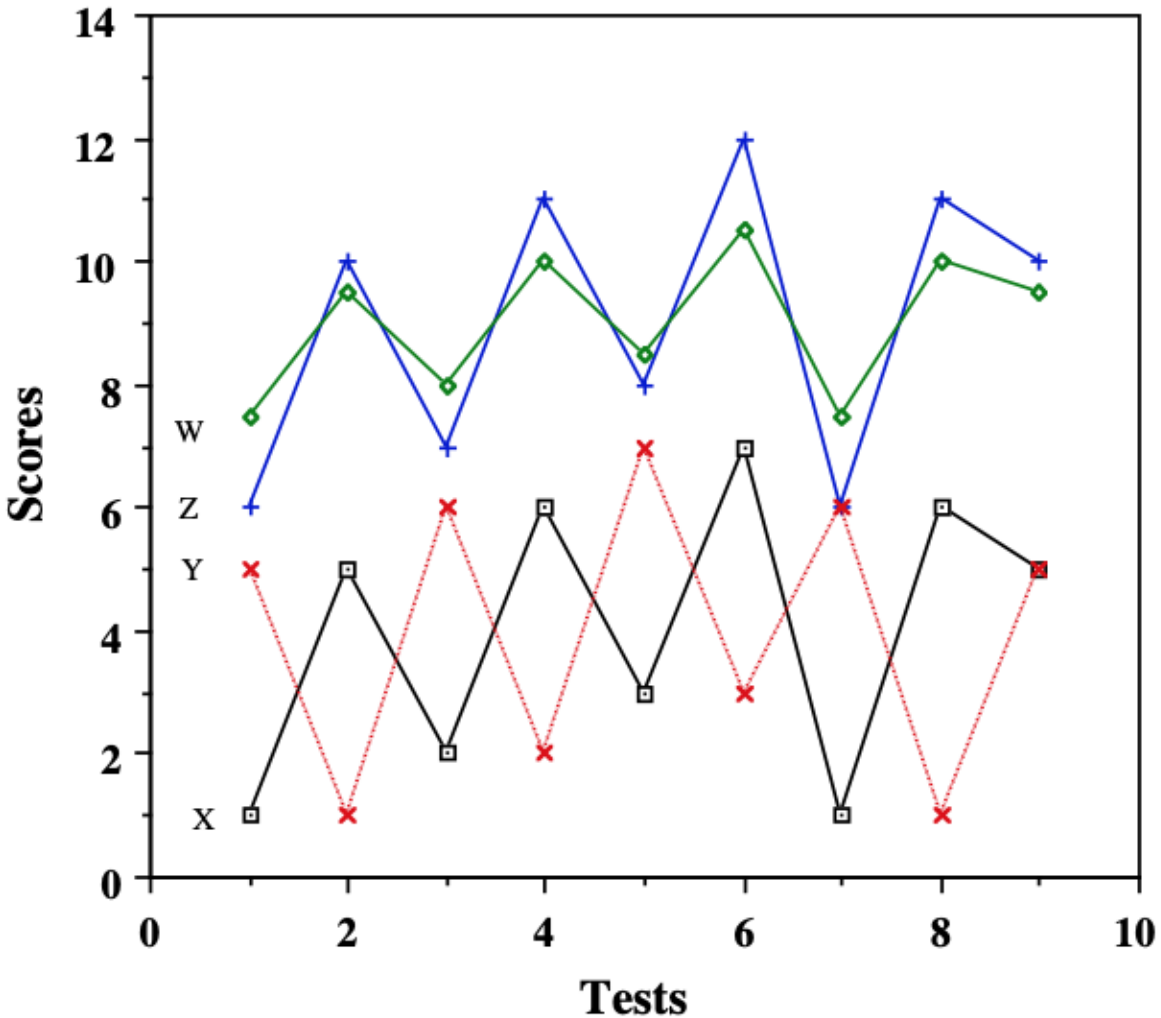
Similarity and distance

1. Given a set of scores on multiple tests (a subject profile) how should we measure similarity between different profiles?
2. What does it mean to have a similar profile?
3. What metric to use?
4. Minkowski distances $D_M = (\Sigma(X_i - Y_i)^r)^{1/r}$
   - If r = 2 that is the normal Euclidian distance (diagonals are shorter than sums)
   - if r =1 that is a city block distance (all distances are equally important)
   - if $r > 2$ is non-Euclidean (emphasizes the biggest difference
   - if $r = \infty$, non-Euclidean (distance is the biggest dififference)
   - The central square in Stockholm (Sergels square) designed by Piet Hein is a “super ellipse" with r =2.5

Similarity and correlation

1. $D = \sqrt{\Sigma(X_i - Y_i)^2}$
2. let $M_x = mean(X), M_y = mean(Y) \qquad L = M_x - M_y$
3. $x = X - M_x \qquad y = Y - M_y$
4. $D = \sqrt{\Sigma(X_i - Y_i)^2} = \sqrt{\Sigma((X_i - M_x) - (Y_I - M_y) + L)^2}$
5. $D = \sqrt{(x - y_L)}^2 = \sqrt{\sigma_x^2 + \sigma_y^2 - 2\sigma_{xy} + L^2}$
6. Level is distance of the means
7. Scatter is variances of x and y
8. Patten is covariance of x and y
9. For standardized variables, then distance is a function of the correlation between two profiles. $D^2 = 2(1 - r_{xy})$

Profile similarity



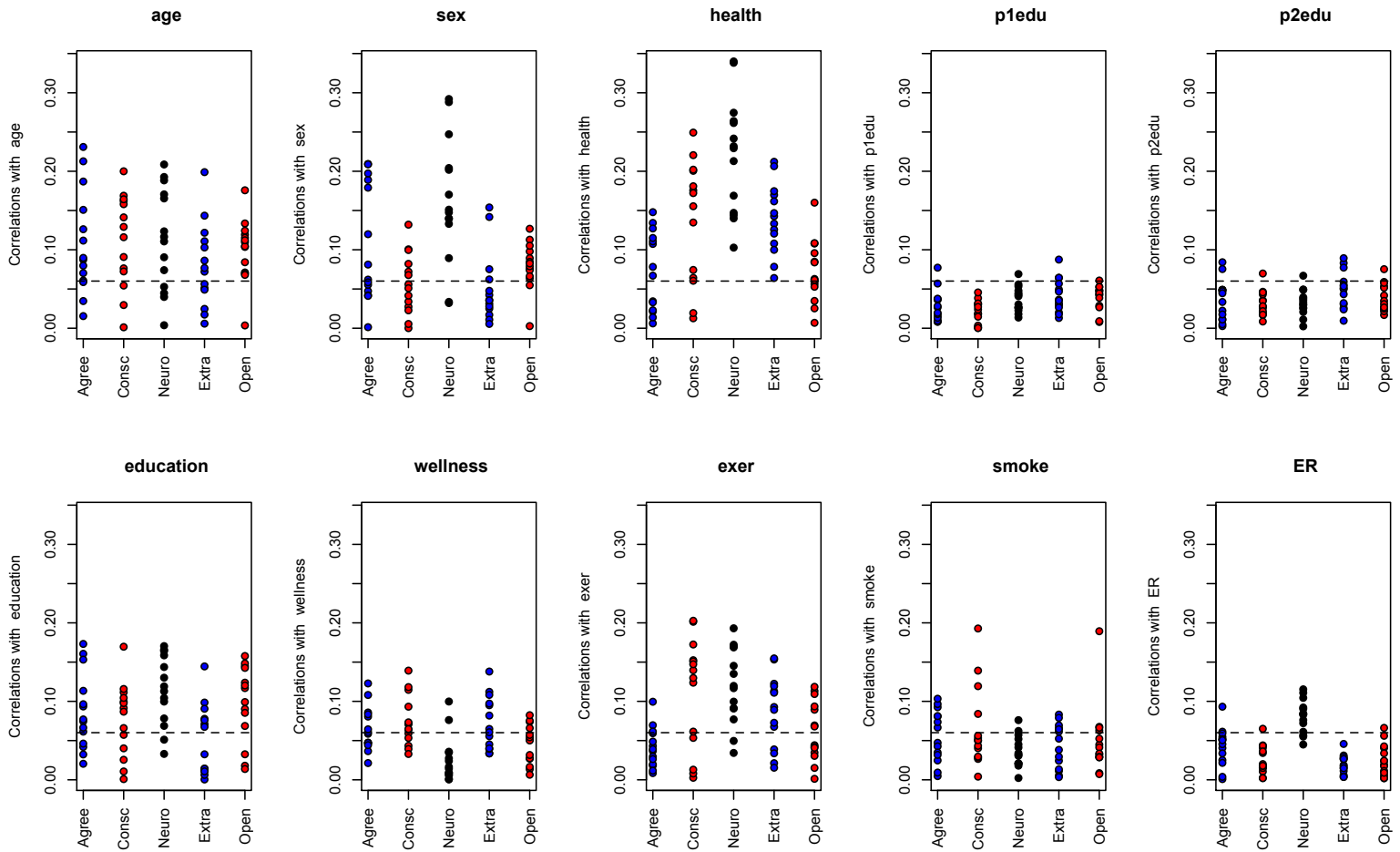
How useful are items?

1. Common observation is that items have low correlations with other items.
2. From a classical reliability perspective: Item variance = general + group + specific + error.
3. The “gospel" is that items are mainly error variance.
4. This is true from a latent variable perspective, but less true if we actually examine item variance.
5. Perhaps 20% of an item is general factor variance, another 10-20% group variance but about 40% is specific and reliable variance.
6. We can see this by doing a variance decomposition of items that are repeated across time.
7. So what?
8. Lets look at the correlates of items.

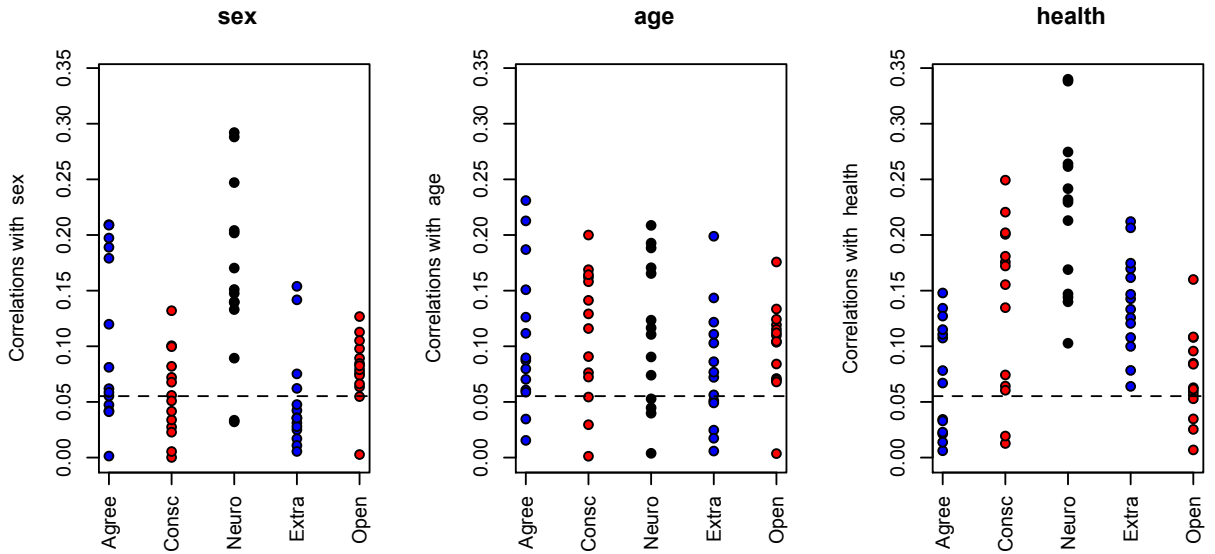
Items as analogous to SNPs in GWAS studies

1. In Genome Wide Association Studies one examines phenotypic variation as it correlates with differences in SNP frequencies across the genome.
2. Do the same by examining phenotypic variation and correlation across the persome (Möttus et al., 2019)
3. A typical approach is to show the correlations and their probability values (corrected for multiple tests)
   - Typically displayed in “Manhattan Plots" across the genome. We do this across the “Persome".
4. First show plots for an open source data set (spi) available in the *psych* package.
   - This is a set of 135 temperament items with 10 criteria for 4,000 subjects.
5. Then do the same for items from the Big 5, then an extend set (the little 27), then for a bigger data set with even more items.

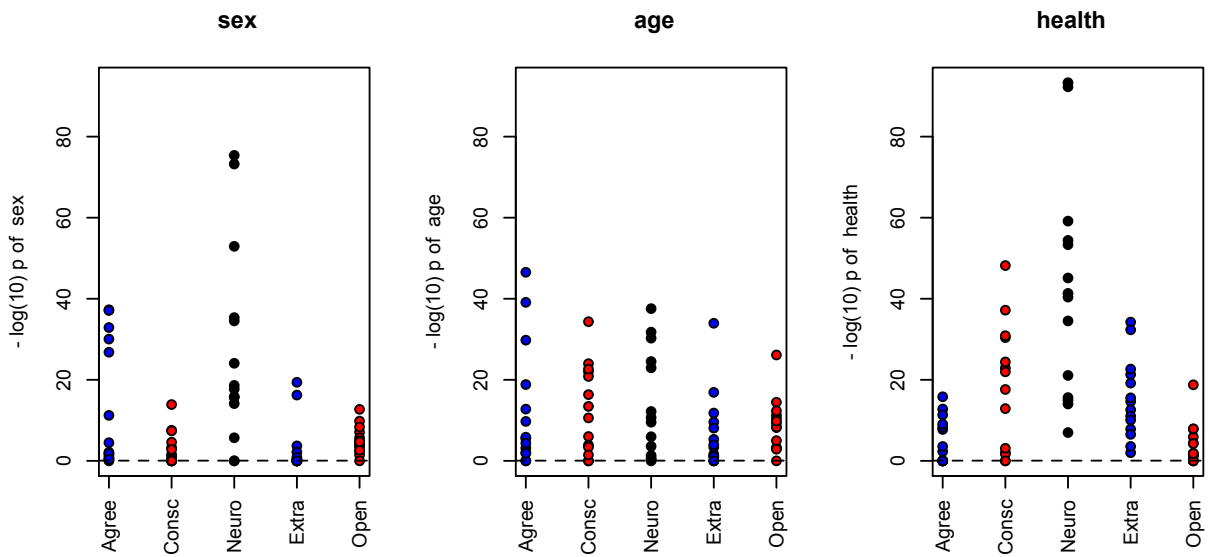
A “Manhattan plot" of the spi items on the big 5 for 10 criteria



A "Manhattan plot" of the spi items for 3 criteria big 5

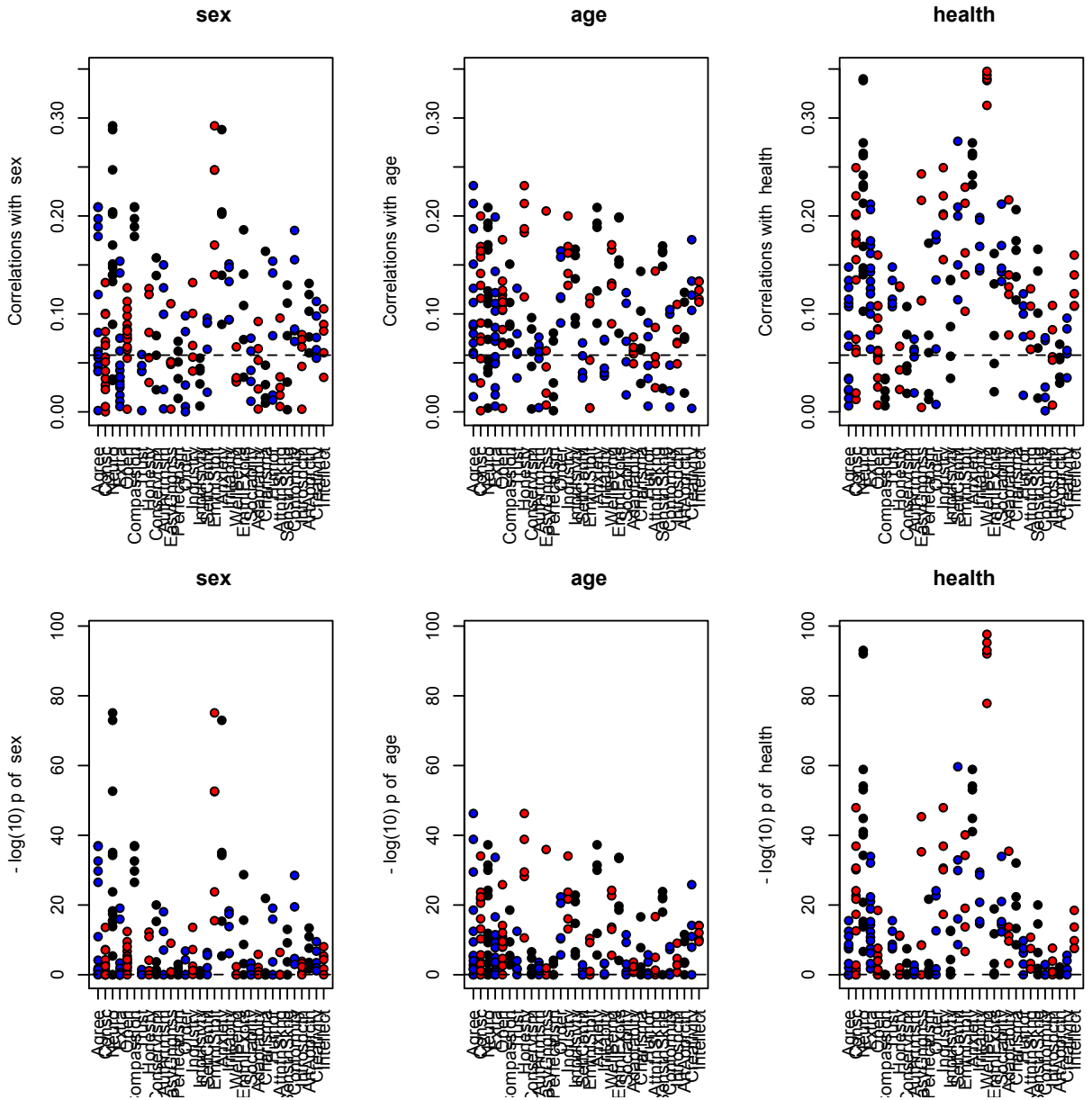


Correlations (absolute values)



Log p values (Holm corrected for multiple tests)

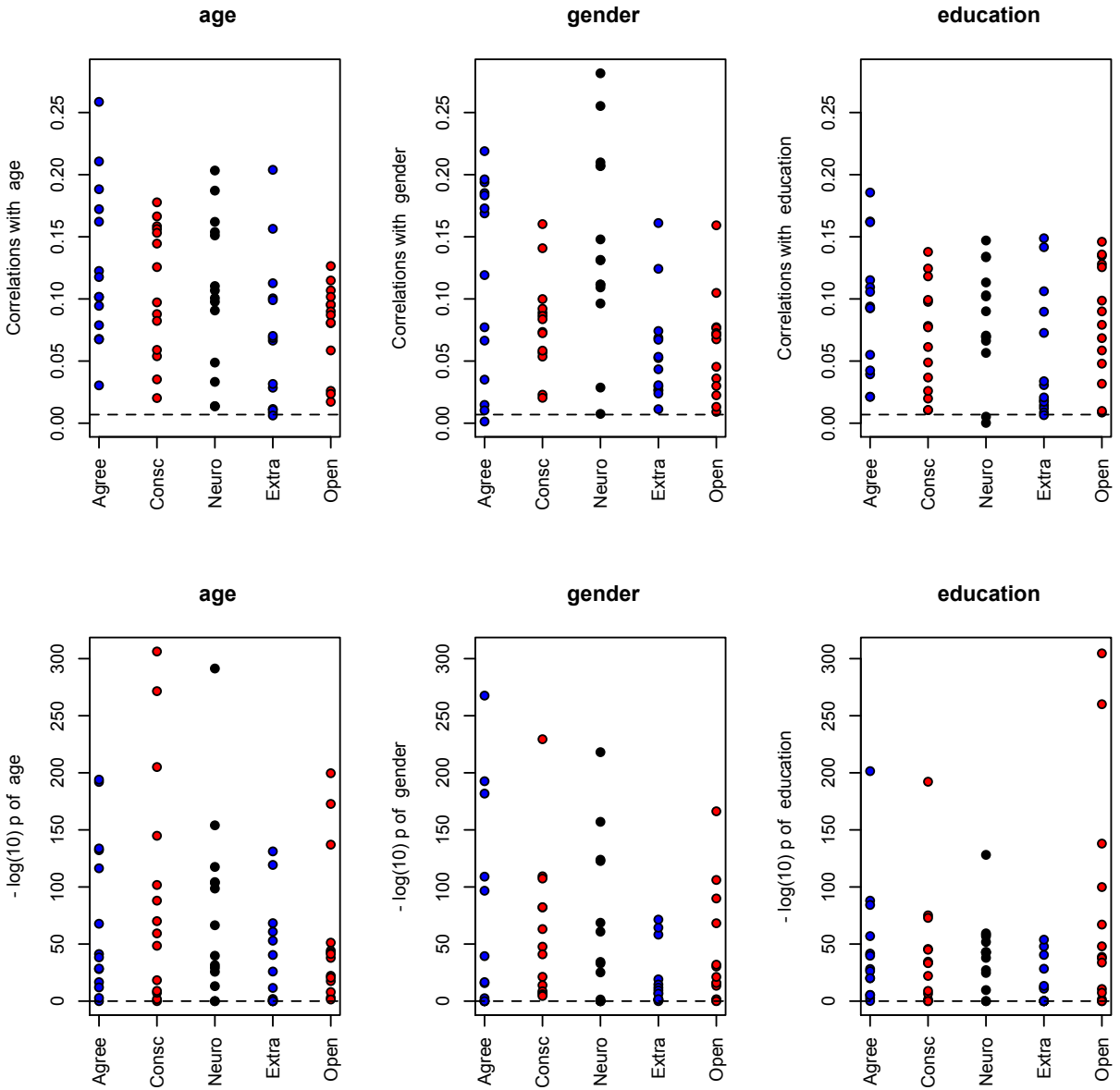
More predictors: 3 criteria big 5 + spi 27, N =4000



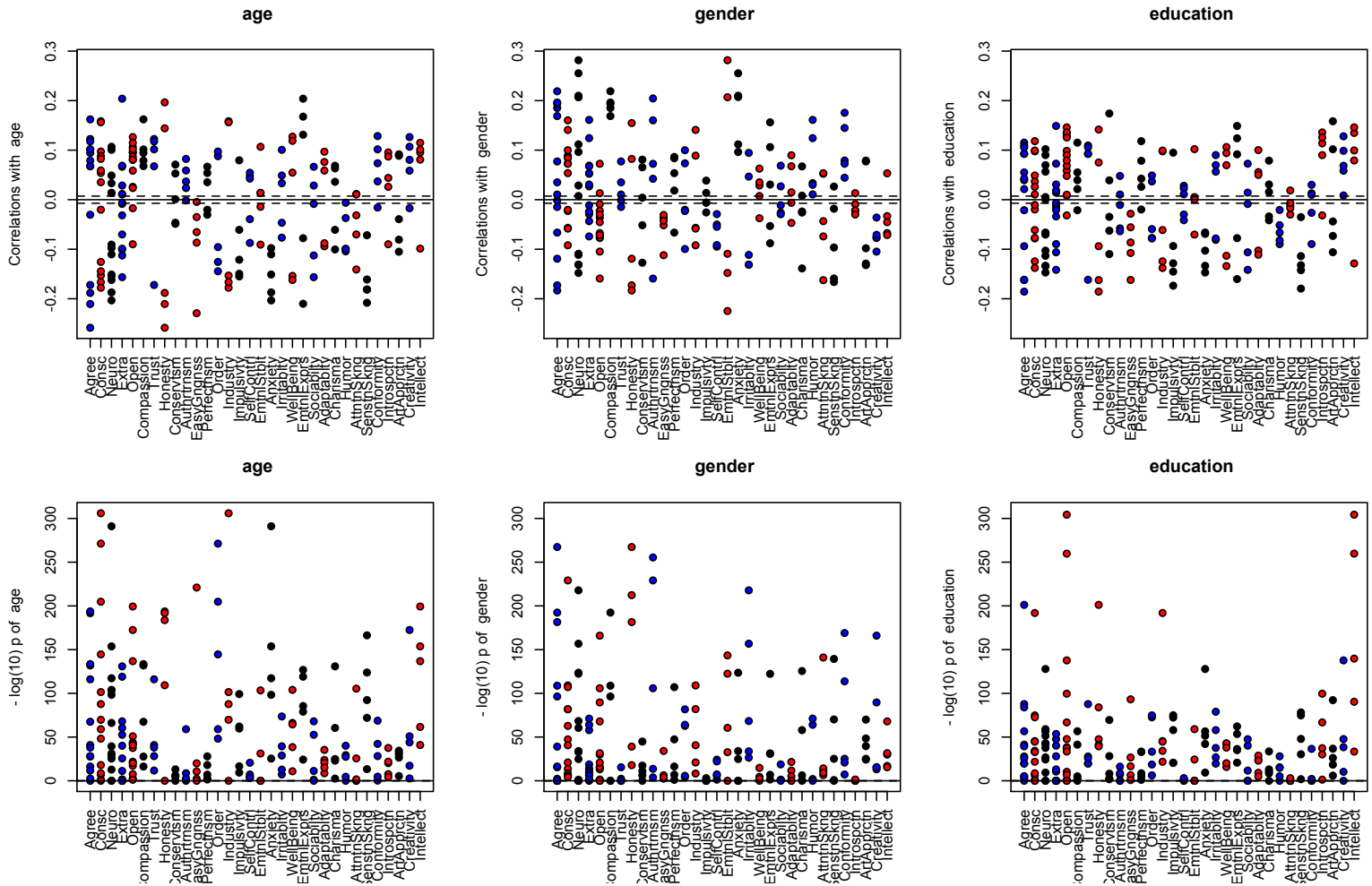
Correlations (absolute values)

Log p values (Holm corrected for multiple tests)

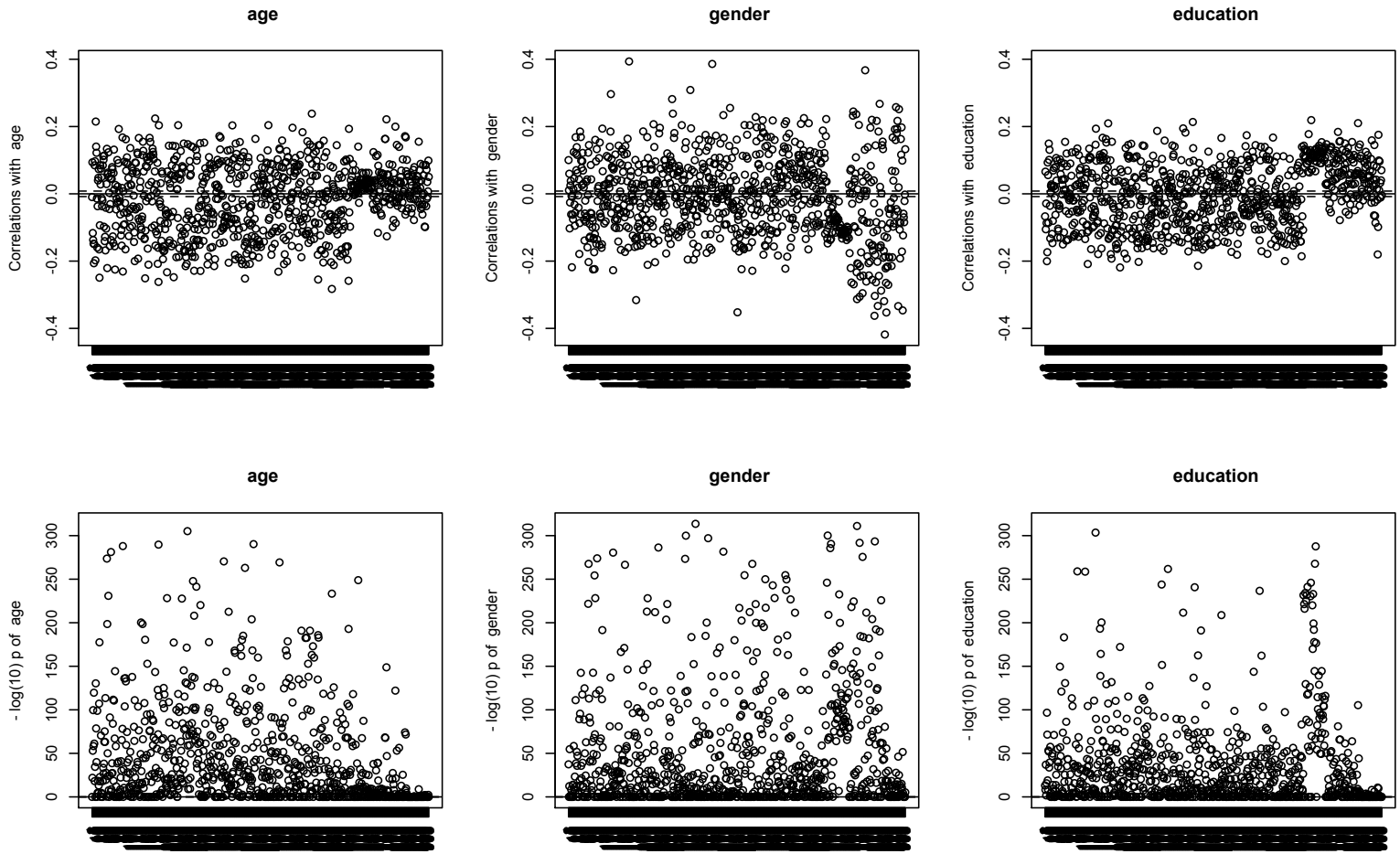
More subjects: 3 criteria big 5, N = 255,000



More subjects: 3 criteria - Big 5 + little 27 items, N = 255,000



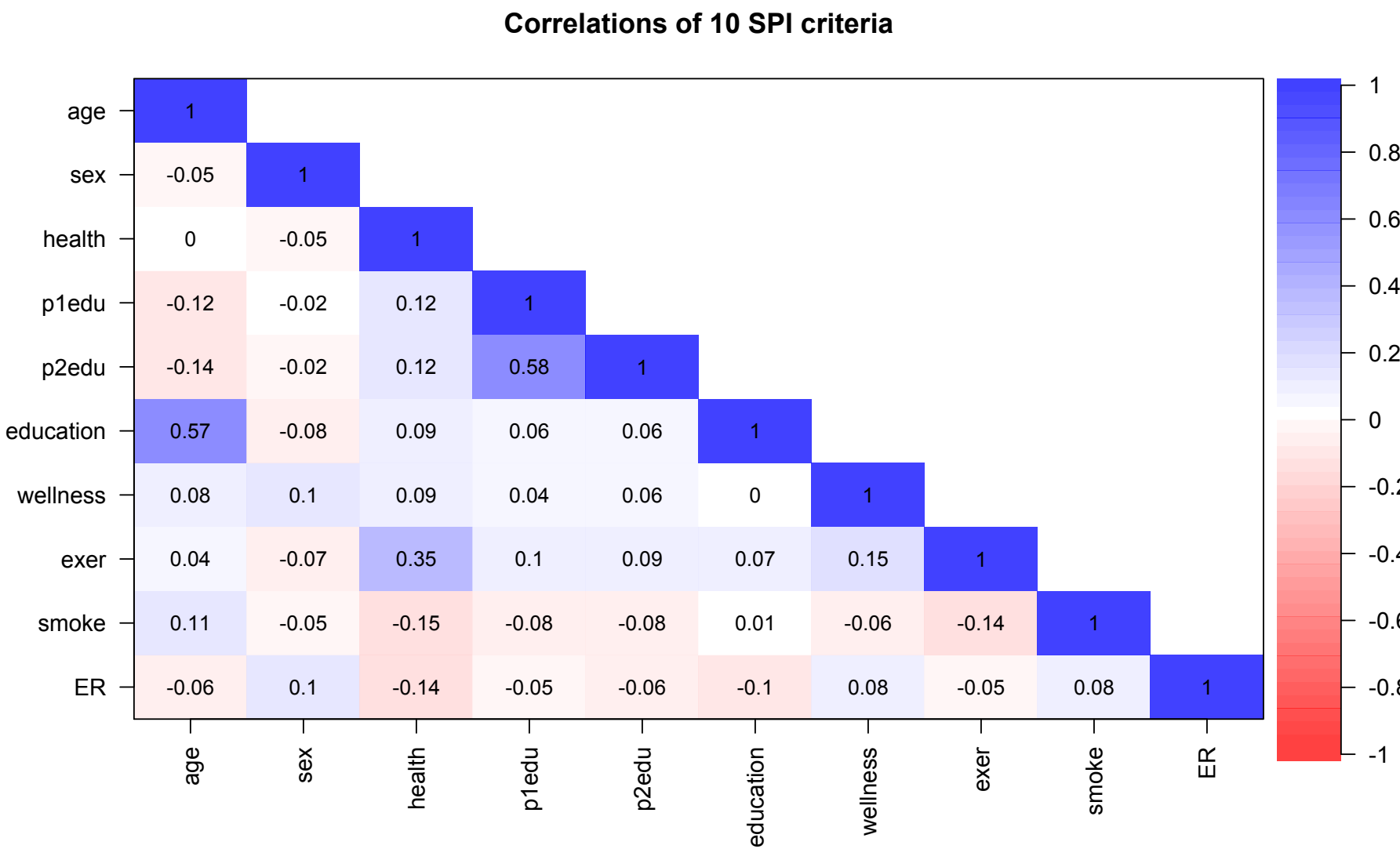
More subjects: 3 criteria - 904 items (temperament, abilities, interests)



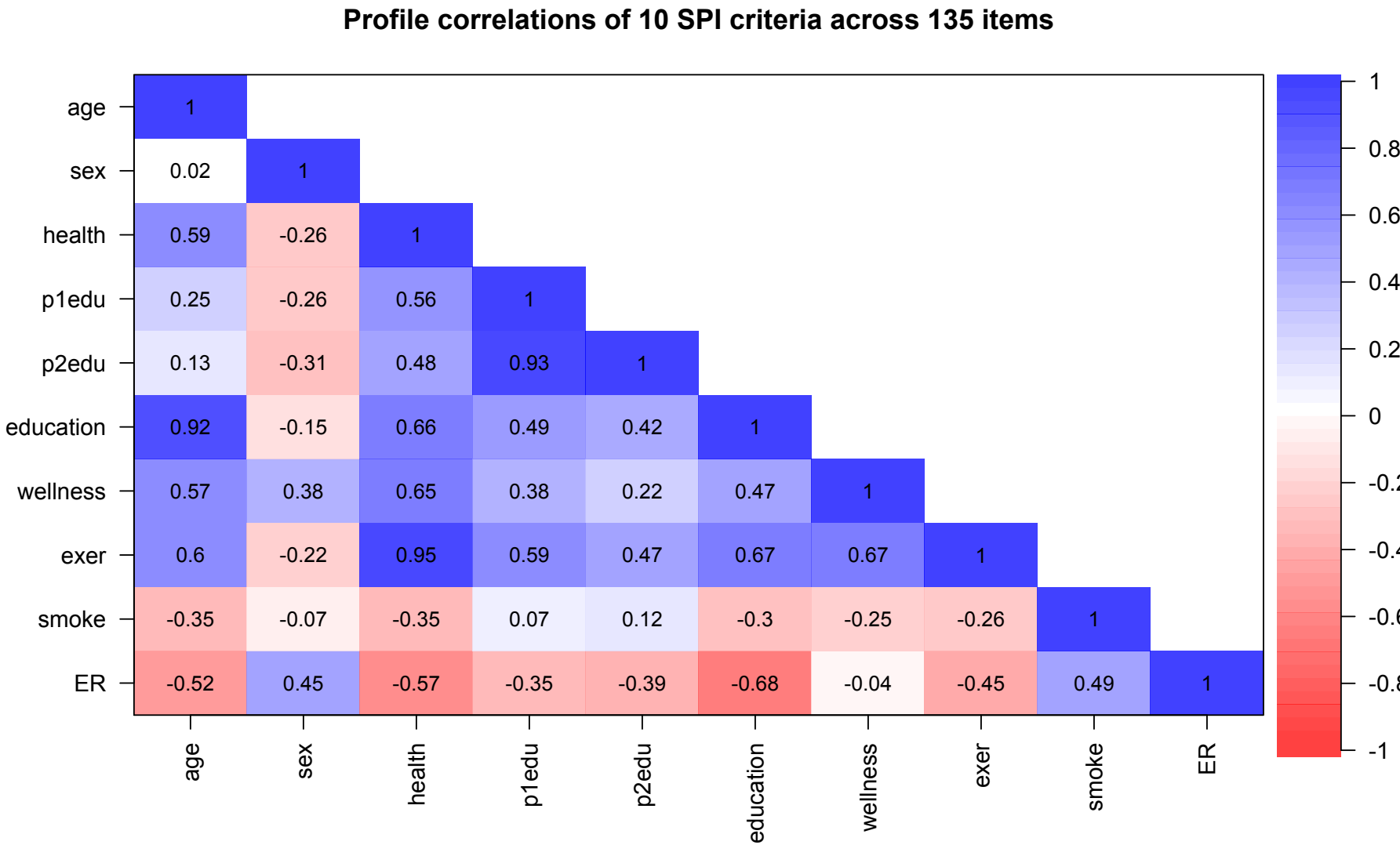
Profile correlations are analogous to the “genetic correlation"

1. For any set of criteria or grouping variables we can find a vector of validity correlations across our predictor set.
2. We can then correlate these vectors. This is analogous to the genetic correlation across SNPs.
3. Basically, we are correlating the profiles of the Manhattan plots
4. I show this using the 10 criteria in the `spi` data set
5. First the raw correlations, then the profile correlations

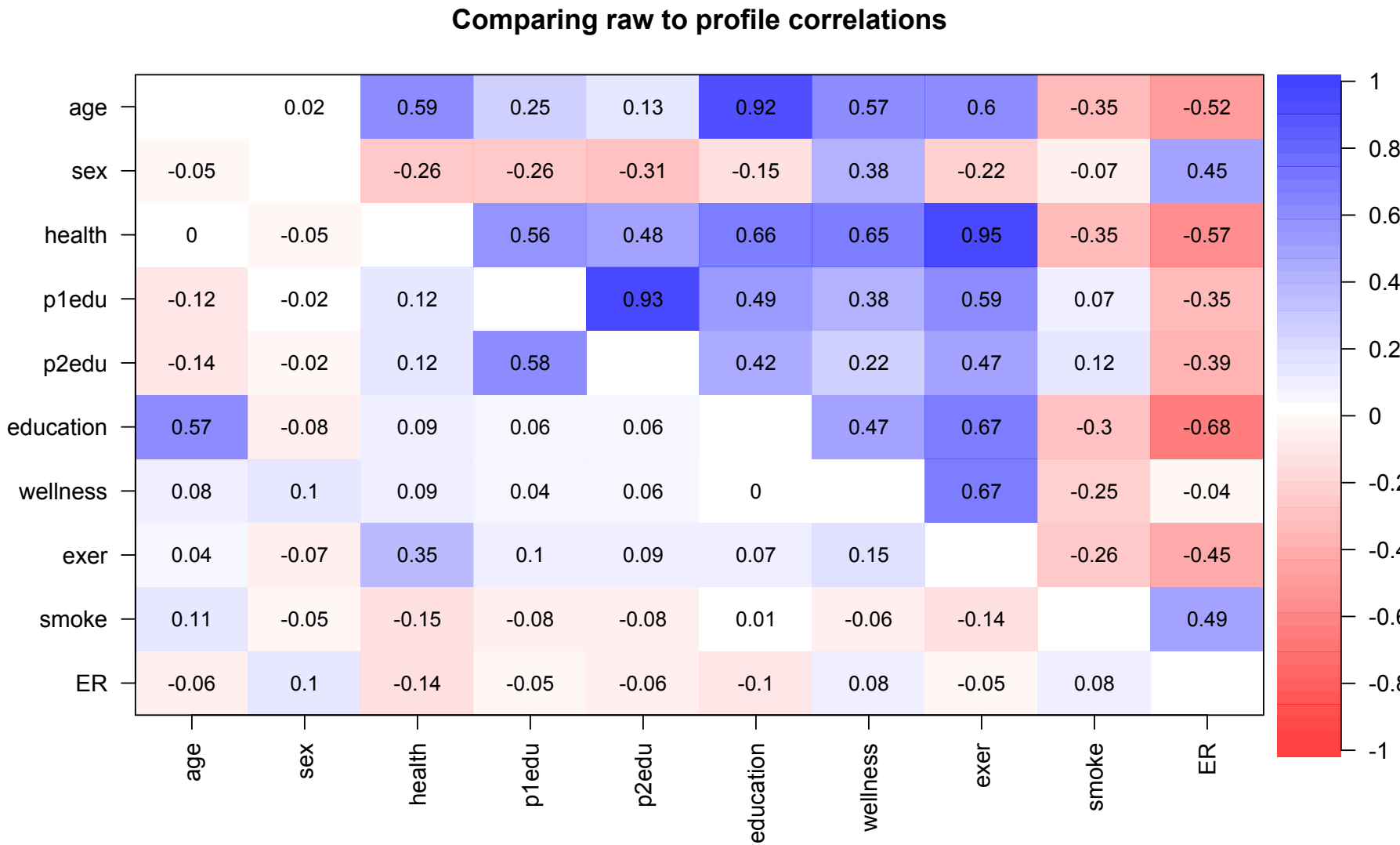
10 criteria from the SPI data set, raw correlations



10 criteria from the SPI data set, profile correlations



Comparing raw and profile correlations from the SPI dataset



Recent paper demonstrating the power of items

1. Hofmann et al. (2025) used several large data sets of items.
2. Examined the items that correlated with sex/gender.
3. No clear structure, but strong benefit of using items over facets over trait (big Few) dimensions

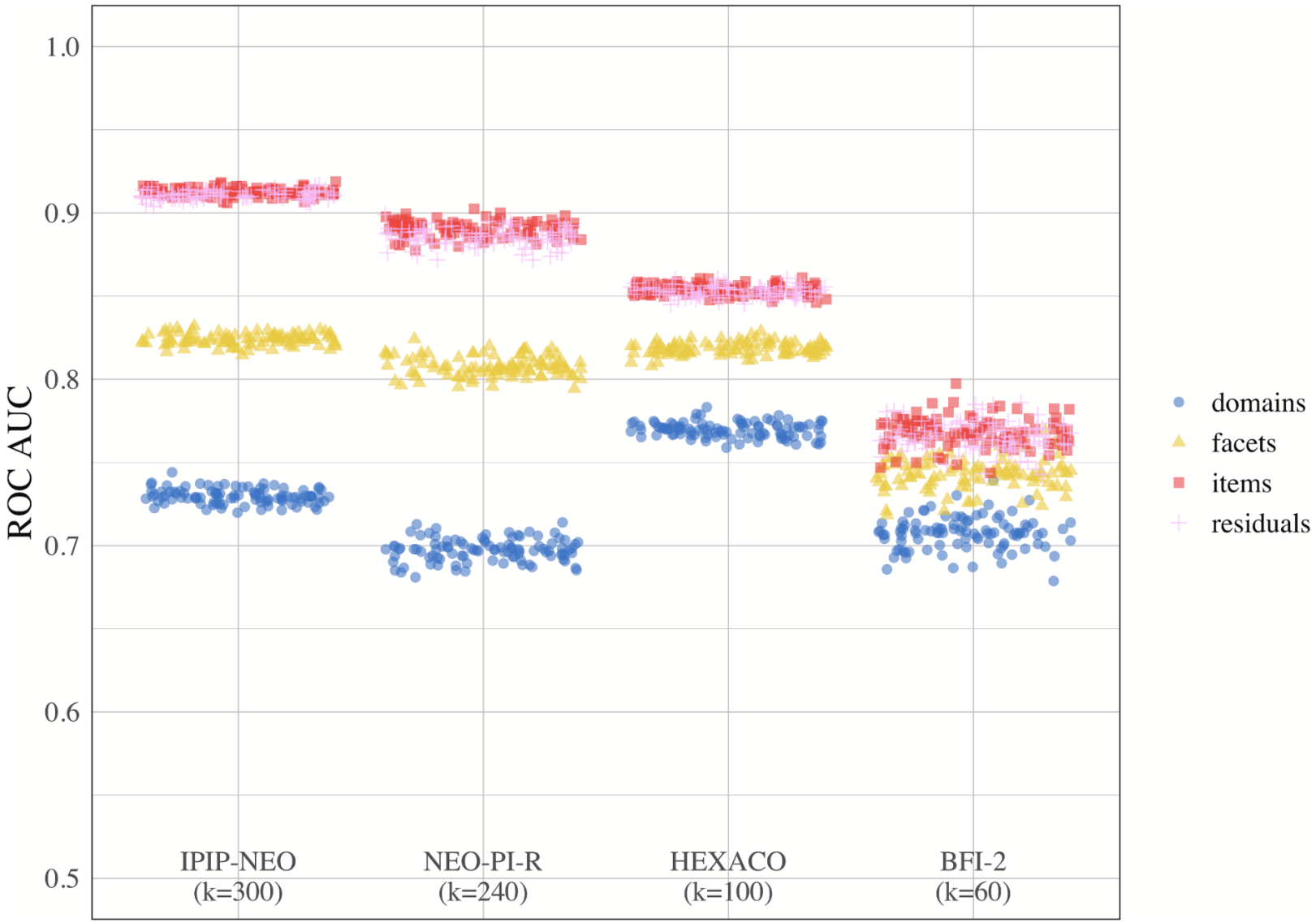
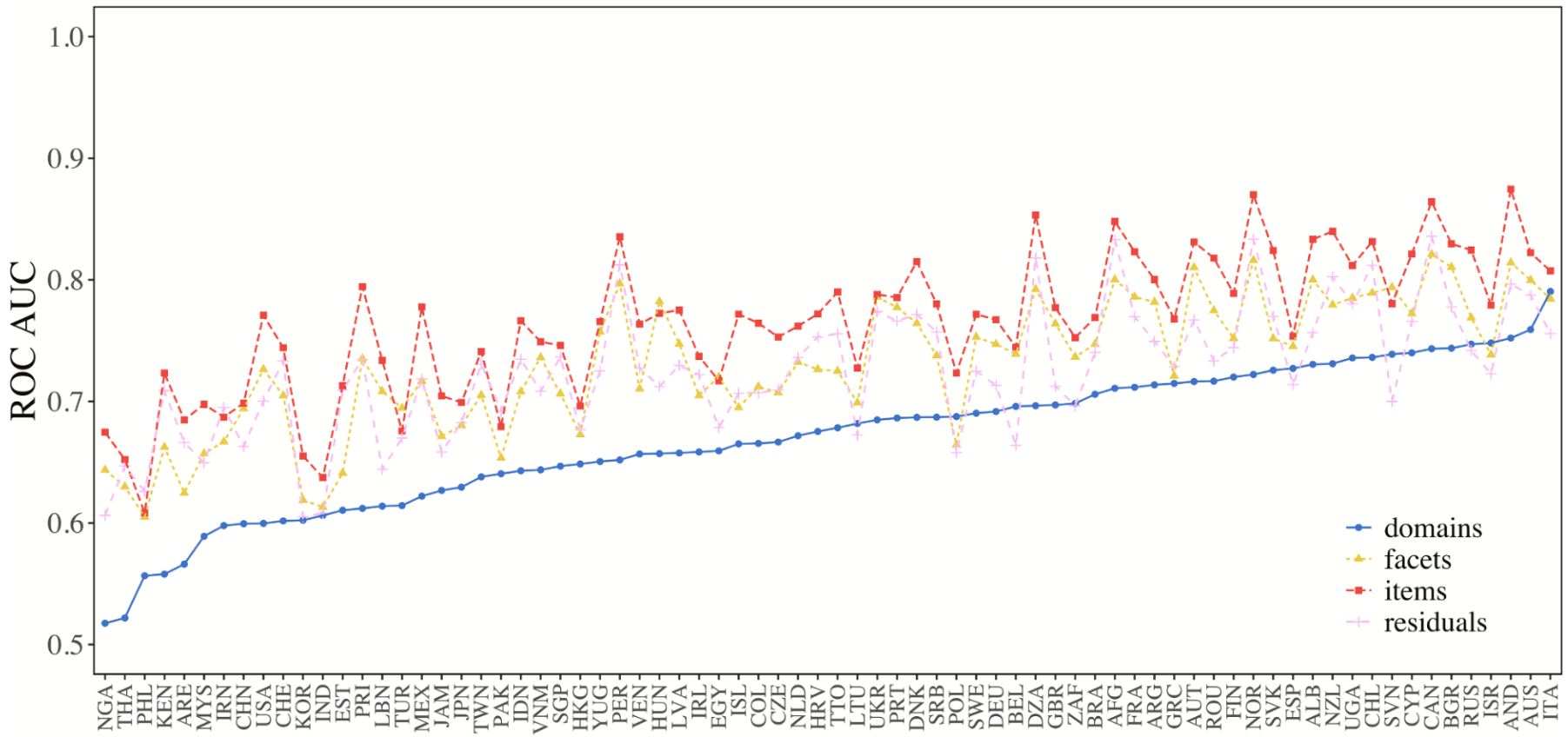
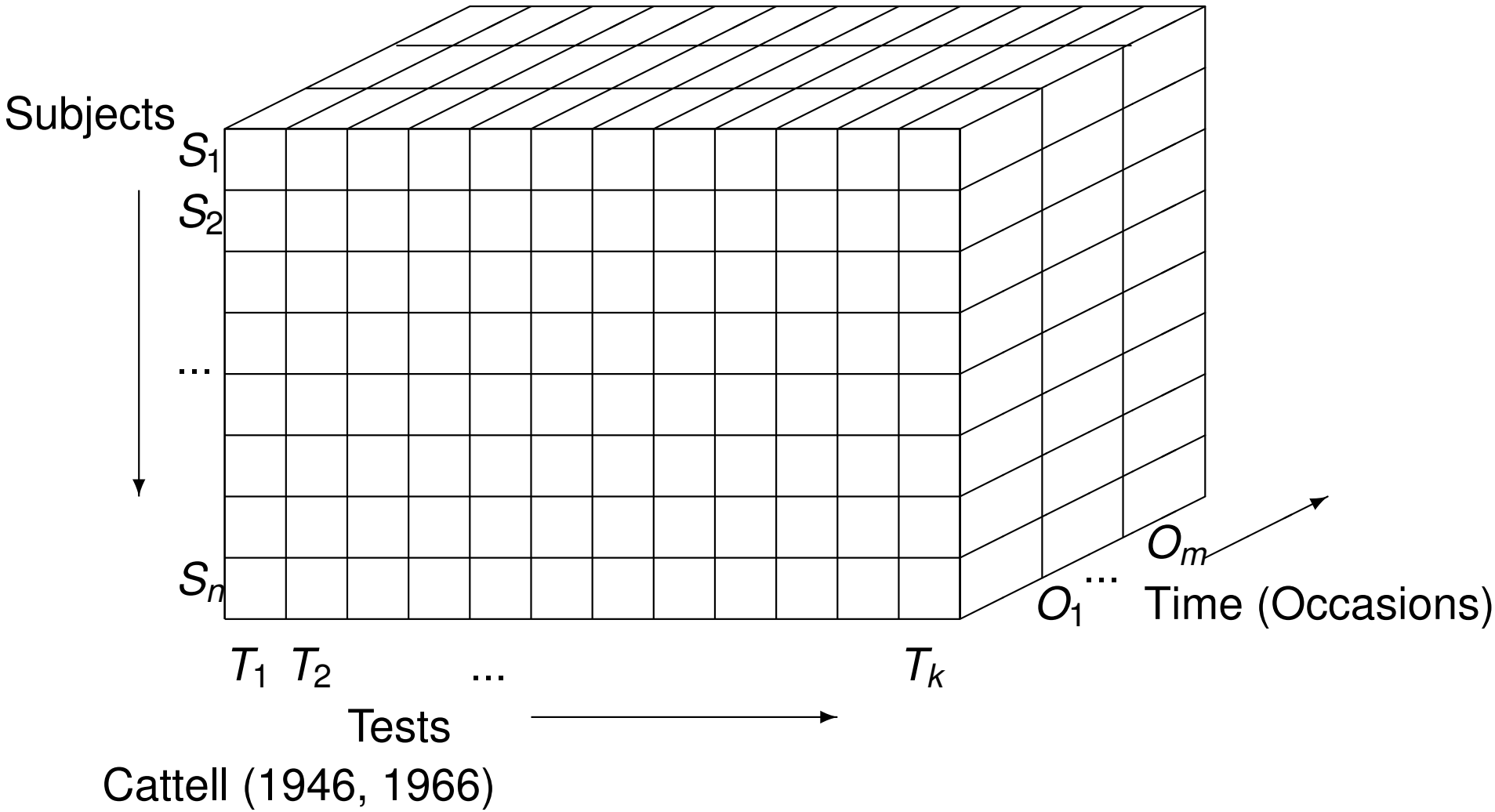


Fig. 1. *Area Under the Curve estimates across personality levels and inventories. Note.* ROC AUC = Area Under the Receiver Operating Curve. The 300-item version of the IPIP-NEO only included participants who identified with an English-speaking country. Colours and point shapes represent trait levels. Residuals represent item scores after removing facet-specific variance.

Predicting gender by country by method



Cattell and the data box: Subjects x Measures x Time



Cattell (1946, 1966)

Cattell and the Data Box

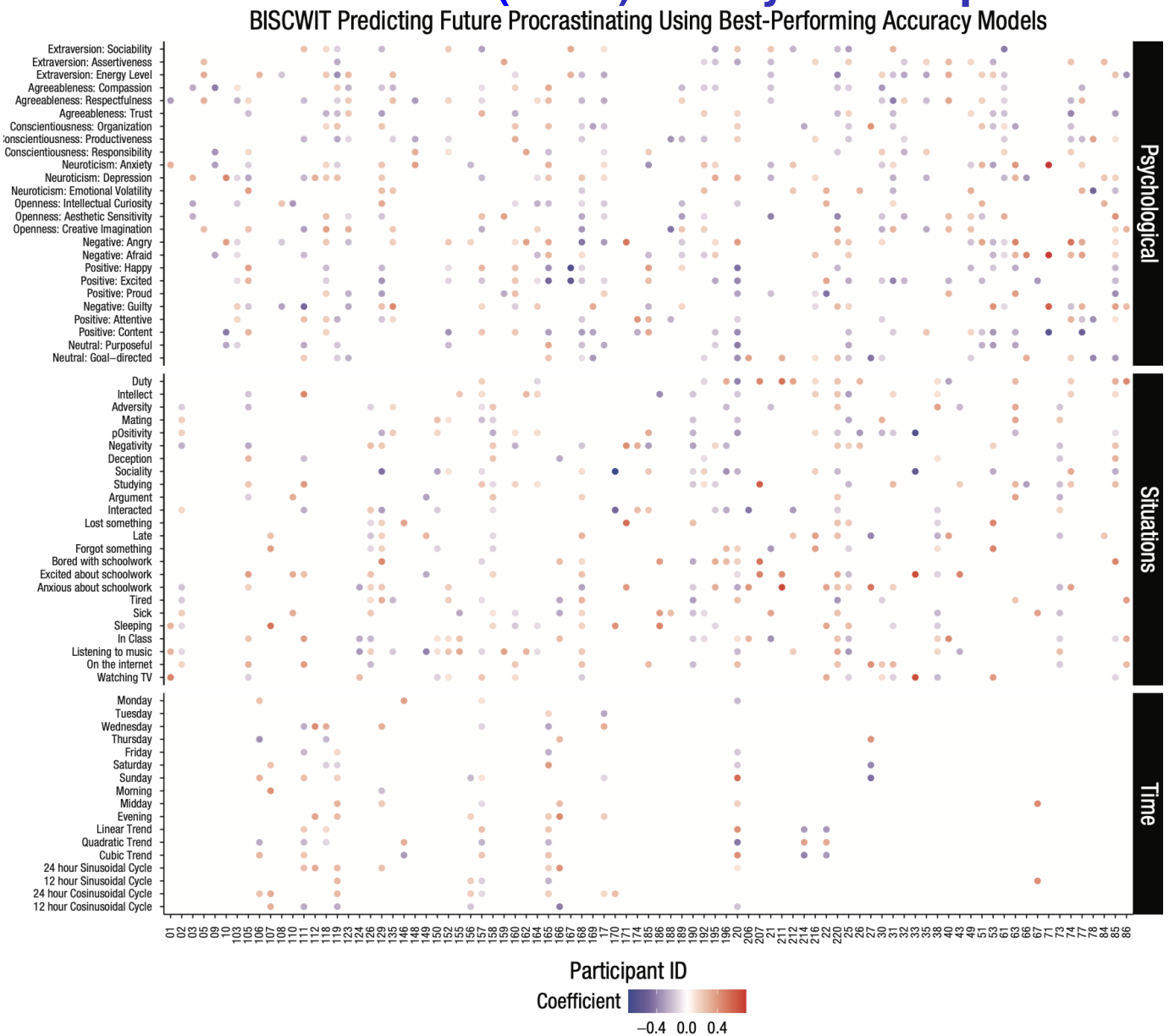
1. One occasion
   - R: Correlate measures across persons : standard personality traits
   - Q: Correlate Persons across measures: Personality typology
2. One Person
   - P: Correlate Measures across Occasions; Individual personality structure
   - O: Correlate Occasions across measures: Individual psychological environment
3. One Measure
   - T: Correlate Occasions across Persons: Anxiety arousing situations
   - S: Correlate Persons across Occasions: Anxious person types

Cattell (1946, 1966b,a); Revelle (2009, 2015) (Note that Cattell changed his notation from paper to paper).

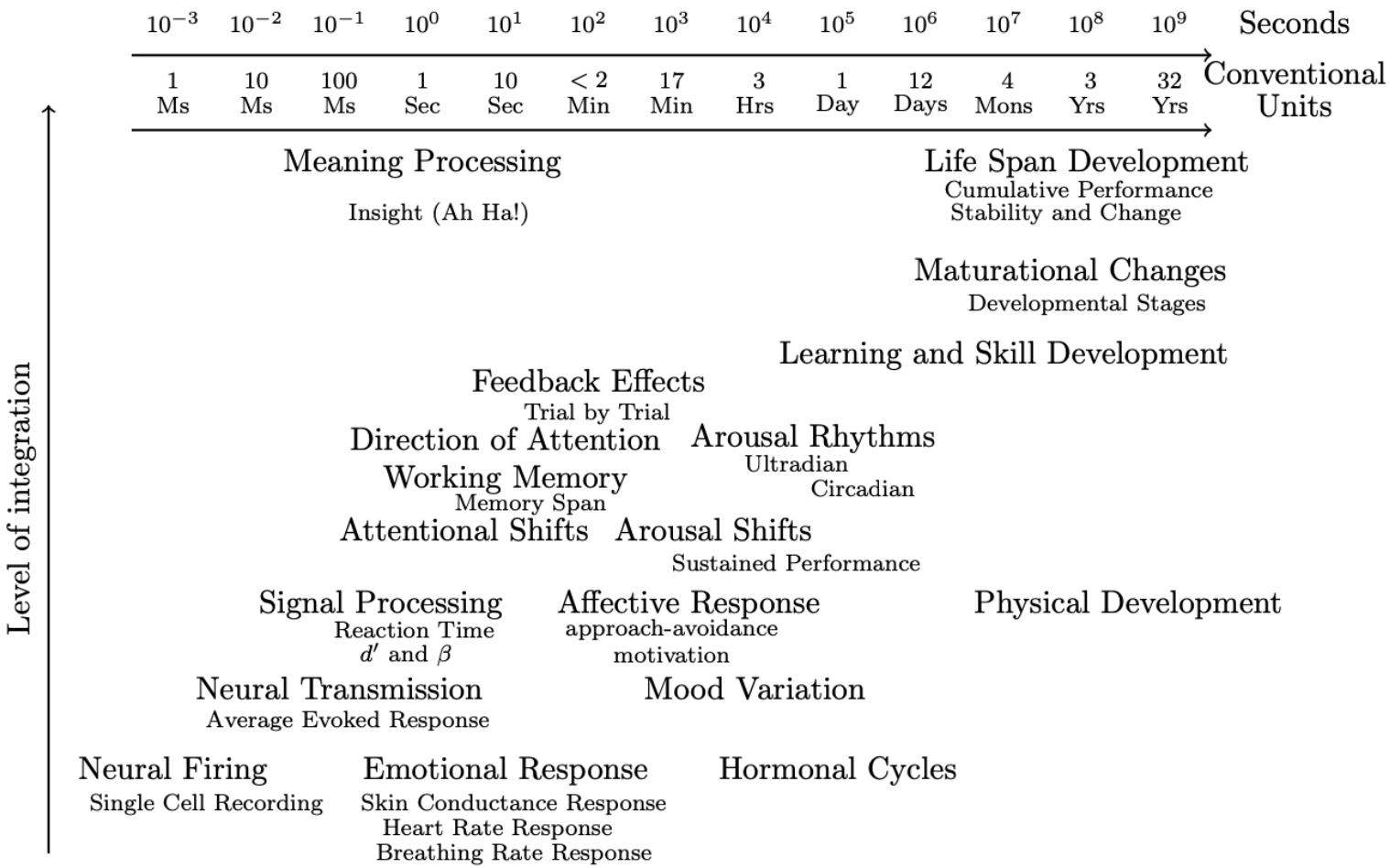
Taking Cattell seriously

1. Is personality ergodic?
   - No (Nesselroade and Molenaar, 2016)
   - Every person has a different measurement model
2. Revelle and Wilt (2016)
   - Same factors, different structural relations
3. The power of within subject measurement across time: Experience Sampling Method/ Event based sampling methodology (ESM) as a powerful within subject tool.
   - Beck and Jackson, 2021, 2020, 2022)
   - Revelle and Wilt (2019a,b); Wilt and Revelle (2019)

Beck and Jackson (2022) Idiosyncratic prediction models

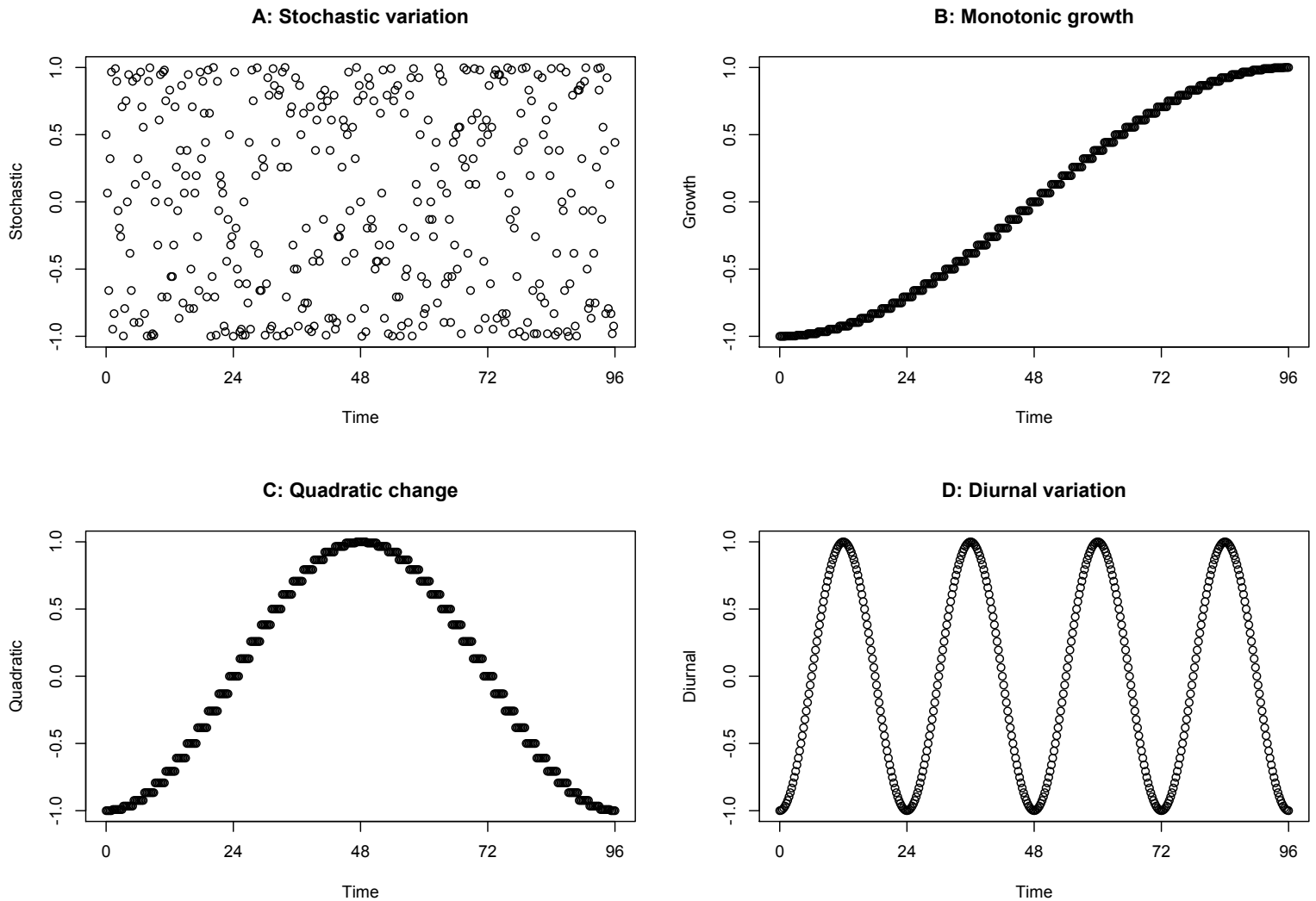


The psychological spectrum



(Revelle, 1995; Revelle and Wilt, 2019a)

Stochastic ≠ dynamic



Methods of data collection

1. Self report of identiy – how do you *normally* feel, act, think, want (The ABCDs)
   - Traits/states (normally versus in the moment)
   - adjectives/sentences/narratives
2. Other reports of reputation (peer, supervisor, subordinate)
3. Ability tests – what is the *best* you can do
4. Behavioral observation - what is the subject doing?
5. Physiology
   - above the neck EEG/MRI/fMRI/PET
   - below the neck HR/SC/BP/blood/urine
6. Telemetric
   - active: web/big EAR/text messaging
   - passive: appearance of webpages, facebook
7. Large scale national and international surveys
8. Animal – lesion/drug/observation

Methods of data collection

1. Self Report
   - Direct subjective
     - empirical scales: MMPI/Strong-Campbell
     - factorial scales: EPI/16PF/NEOPI-R
     - rational scales: PRF
2. Indirect/projective (access to subconscious?)
   - TAT
   - Rorschach
3. Indirect/objective
   - Cattell objective test battery
   - Implicit Attitudes Test (RT measures)
   - Emotional “Stroop”
4. Indirect/other
   - Kelly Construct Repetory Grid (Kelly, 1955)
   - Carroll INDSCAL (Carroll and Chang, 1970)

George Kelly and the theory of personal constructs

Kelly (1955)

1. People as scientists:
2. “each man contemplates in his own personal way the stream of events upon which he finds himself so swiftly borne"
3. “Man looks at his world through transparent patterns or templates which he creates and then attempts to fit over the realities of which the world is composed. The fit is not always very good. Yet without such patterns the world appears to be such an undifferentiated homogeneity that man is unable to make any sense out of it. Even a poor fit is more helpful to him than nothing at all.

George Kelly (1955) and the theory of personal constructs

1. Fundamental postulate:
   “A person’s processes are psychological channelized by the ways in which he anticipates events."
2. Measurement:
   The role construct repertory test (REP test).
3. Analysis:
   What are the fundamental constructs with which one views the world? This can be the entire set of constructs elicited by the REP test, or some clustering or grouping of these constructs.

A Kelly Rep test

self	O		O				
lover	O						
mother		O					
father				O			
sib	O						
teacher			O				
Best friend		O		O			
Boss			O				
coworker		O		O			
construct							

Problems with the Rep Test

1. Completely idiosyncratic. There is no concern with any fundamental dimensions.
2. However, it is possible to apply same group space and still detect individual construct dimensions
3. But consider a similar model: individuals as having unique distortions of shared space.
4. The INDSCAL and ALSCAL algorithms are available to solve for joint and individual spaces.

Multidimensional Scaling

1. Application of metric or non-metric scaling
2. Metric scaling:
3. Find dimensional representation of observed distances (e.g., latitude and longitude)
4. Strong assumption of data and metric
5. Non-metric scaling
6. Scaling to minimize a criterion insensitive to ordinal transformations

Multidimensional Scaling: ($|o_i - o_j| < |o_k - o_l|$)

$$Distance_{xy} = \sqrt{\sum_{i=1}^{n} (x_i - y_i)^2}. \quad (1)$$

Consider the `cities` data set of airline distances.

```
> cities
```

	ATL	BOS	ORD	DCA	DEN	LAX	MIA	JFK	SEA	SFO	MSY
ATL	0	934	585	542	1209	1942	605	751	2181	2139	424
BOS	934	0	853	392	1769	2601	1252	183	2492	2700	1356
ORD	585	853	0	598	918	1748	1187	720	1736	1857	830
DCA	542	392	598	0	1493	2305	922	209	2328	2442	964
DEN	1209	1769	918	1493	0	836	1723	1636	1023	951	1079
LAX	1942	2601	1748	2305	836	0	2345	2461	957	341	1679
MIA	605	1252	1187	922	1723	2345	0	1092	2733	2594	669
JFK	751	183	720	209	1636	2461	1092	0	2412	2577	1173
SEA	2181	2492	1736	2328	1023	957	2733	2412	0	681	2101
SFO	2139	2700	1857	2442	951	341	2594	2577	681	0	1925
MSY	424	1356	830	964	1079	1679	669	1173	2101	1925	0

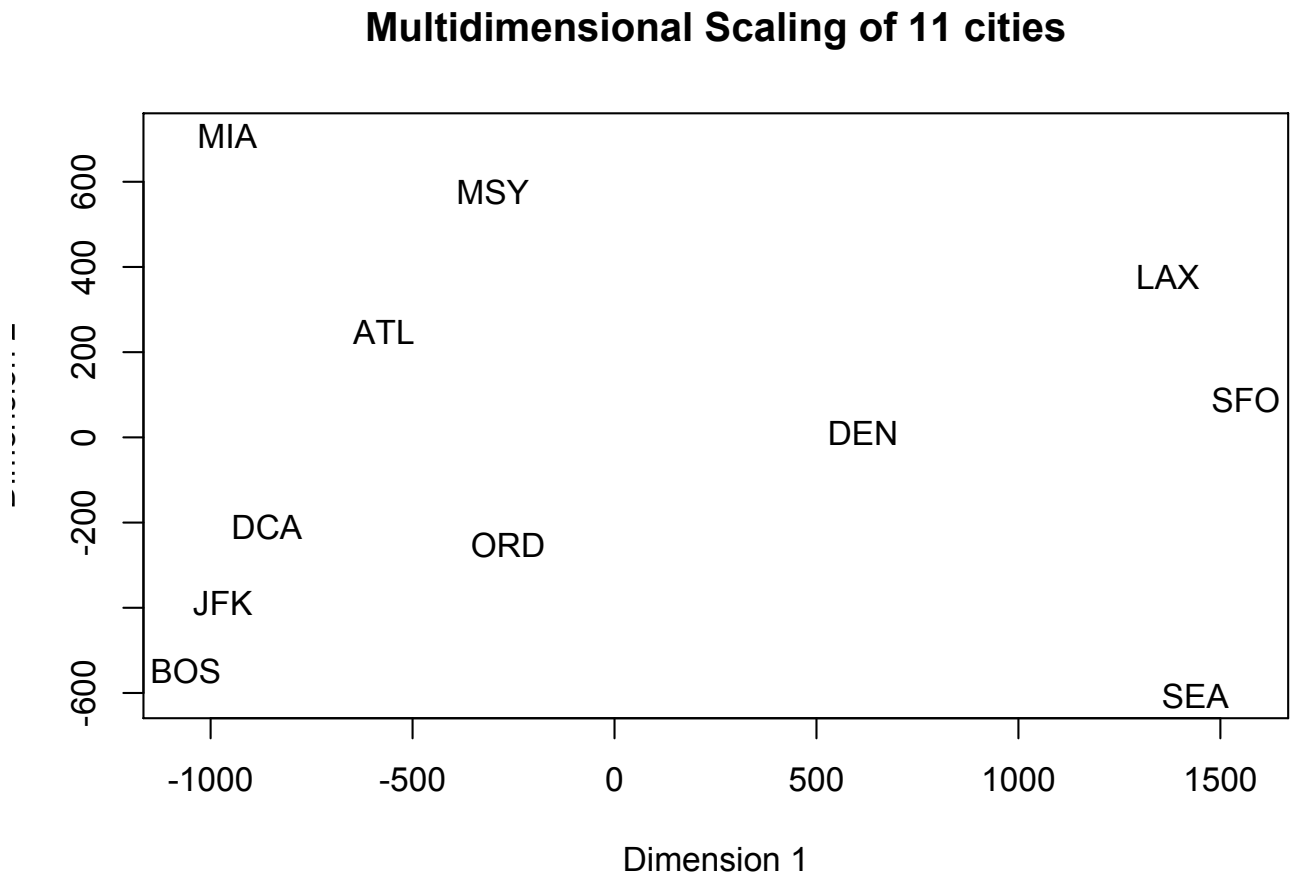
A two dimensional solution of the airline distances

```
> city.location <- cmdscale(cities, k=2)
> plot(city.location,type="n", xlab="Dimension 1",
    ylab="Dimension 2",main ="cmdscale(cities)")
> text(city.location,labels=names(cities))
> round(city.location,0)
```

```
     [,1] [,2]
ATL  -571  248
BOS -1061 -548
ORD  -264 -251
DCA  -861 -211
DEN   616   10
LAX  1370  376
MIA  -959  708
JFK  -970 -389
SEA  1438 -607
SFO  1563   88
MSY  -301  577
```

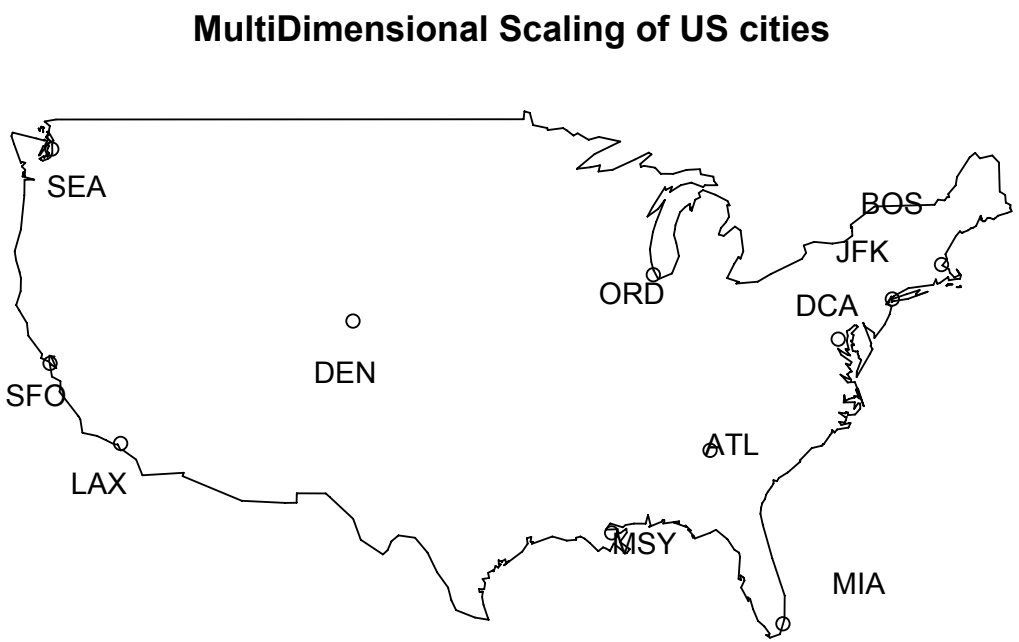
1. Use the `cmdscale` function to do multidimensional scaling, ask for a 2 dimensional solution
2. Plot the results (don't actually show the points)
3. Add the names of the cities
4. Show the numeric results

Original solution for 11 US cities. What is wrong with this figure? Axes of solutions are not necessarily directly interpretable.



Revised solution for 11 US cities after making `city.location <- -city.location` and adding a US map.

The correct locations of the cities are shown with circles. The MDS solution is the center of each label. The central cities (Chicago, Atlanta, and New Orleans are located very precisely, but Boston, New York and Washington, DC are north and west of their correct locations.



Individual differences in multidimensional scaling

1. Add individual differences to the basic MDS equation:

$$Distance_{xy} = \sqrt{\sum_{i=1}^{n} (x_i - y_i)^2}. \quad (2)$$

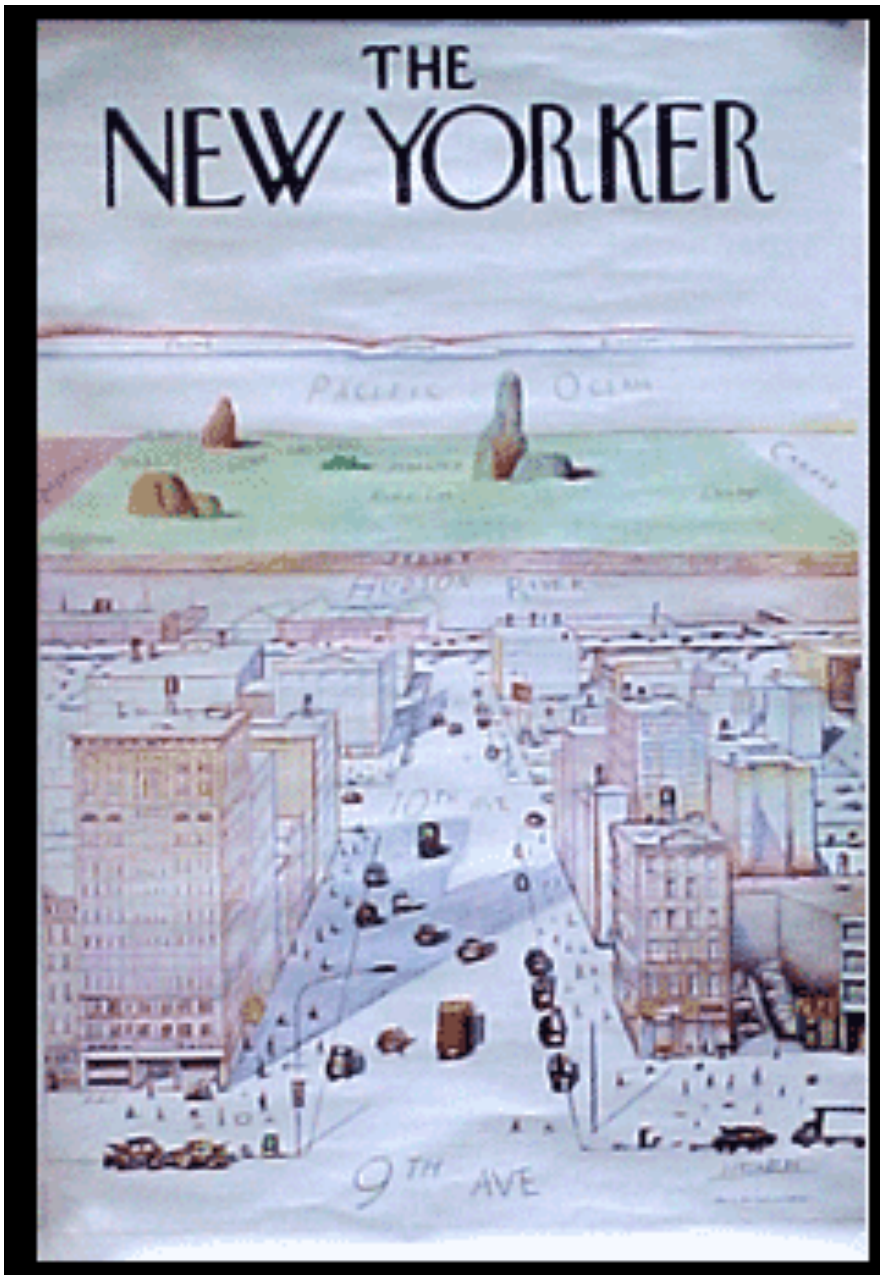
2. There exists a group space for everyone, and an individual set of weights (w) for each person

$$Distance_{pxy} = \sqrt{\sum_{i=1}^{n} w_{ip}(x_i - y_i)^2}. \quad (3)$$

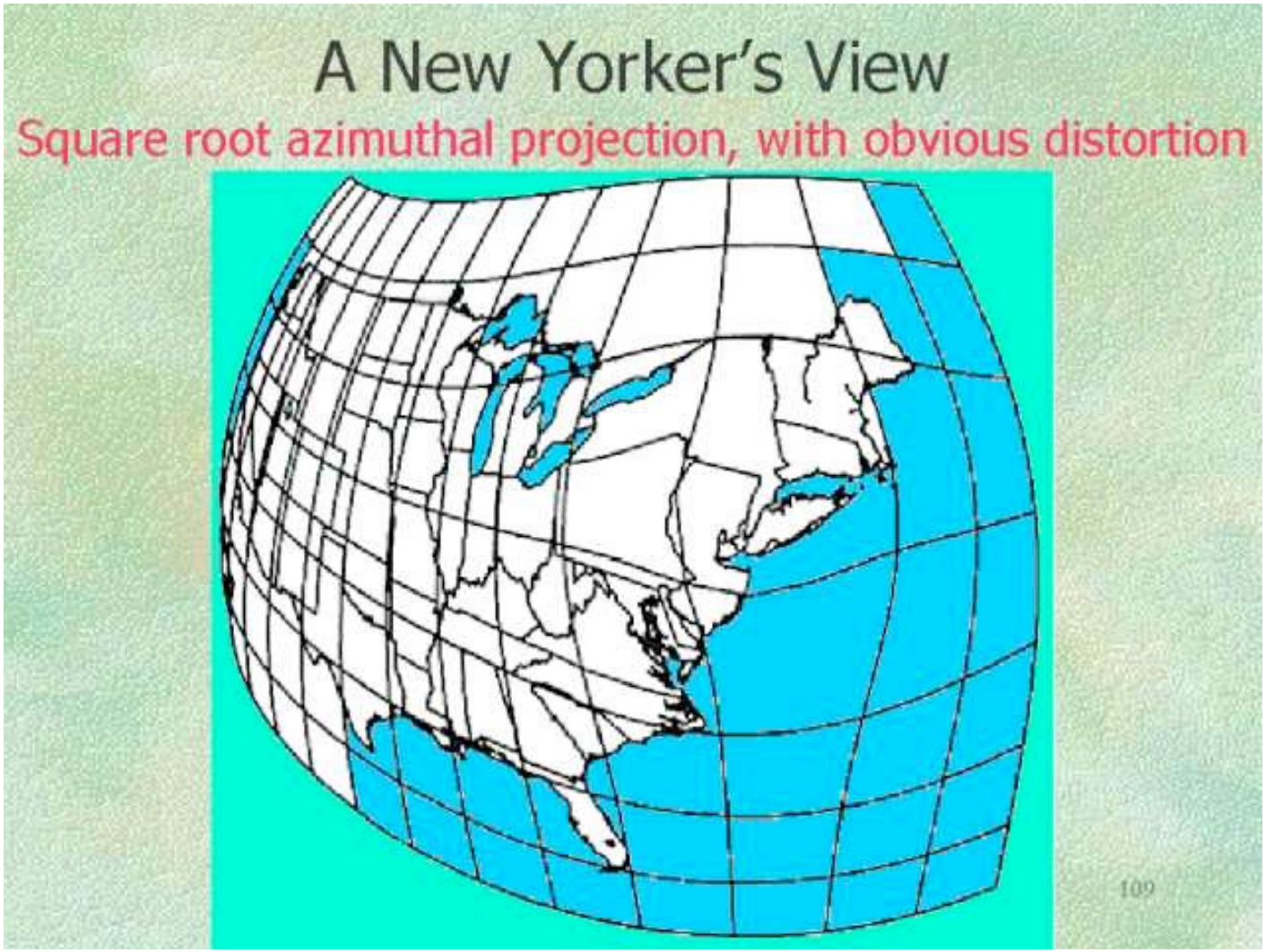
3. People differ in they way they see the world
4. Most classic is how New Yorkers see the world

(Carroll and Chang, 1970)

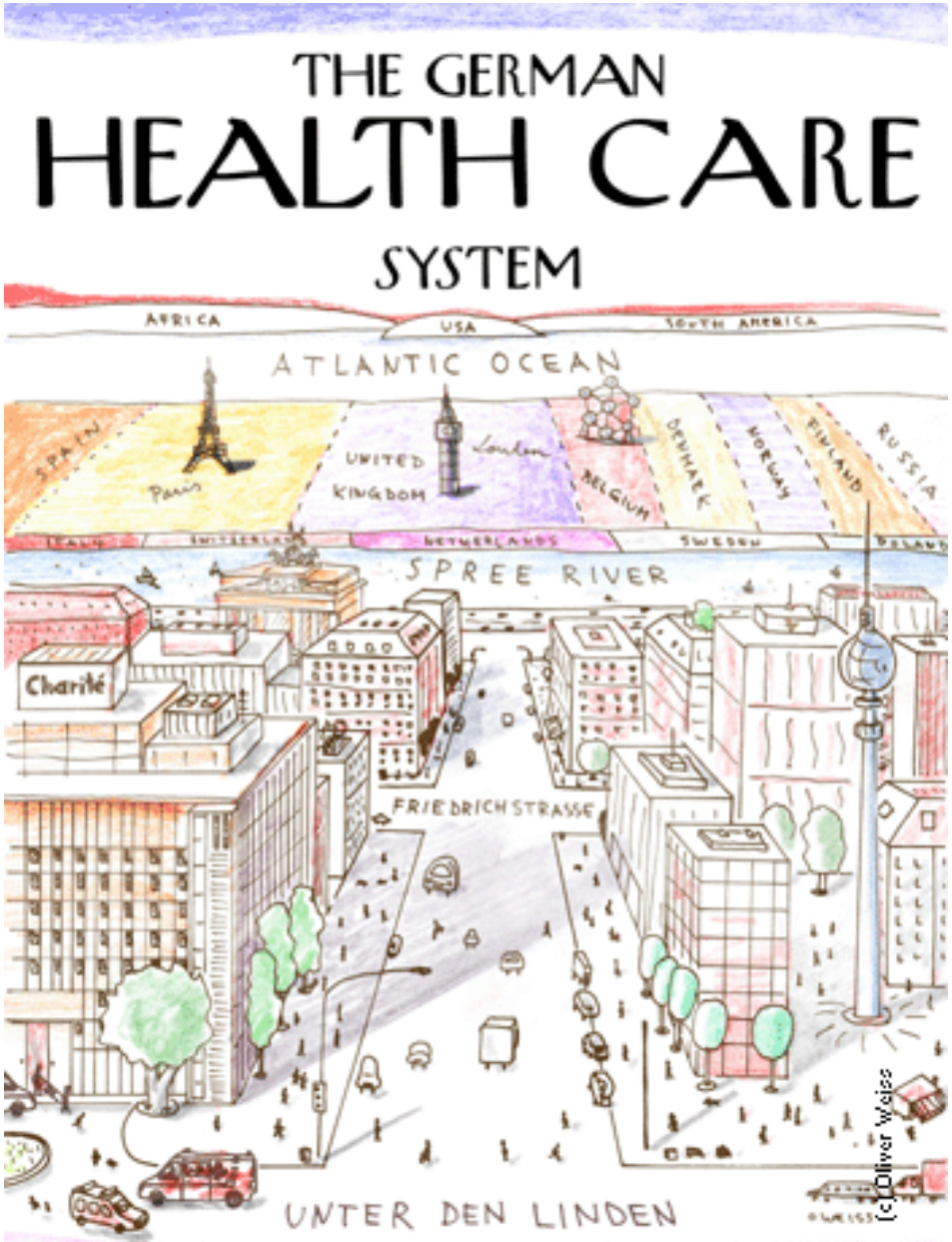
How New Yorkers distort the world



How mathematiciians distort the world



The German Health care system view



Myron Wish and the perceptions of nations

1. How do people view other countries (Wish et al., 1970; Kruskal and Wish, 1978)
2. A four dimensional solution at the group level
3. Asked attitudes towards the Viet Nam War
4. Could reproduce attitudes from the weights applied to two of the world view dimensions.

Wish and the structure of nations

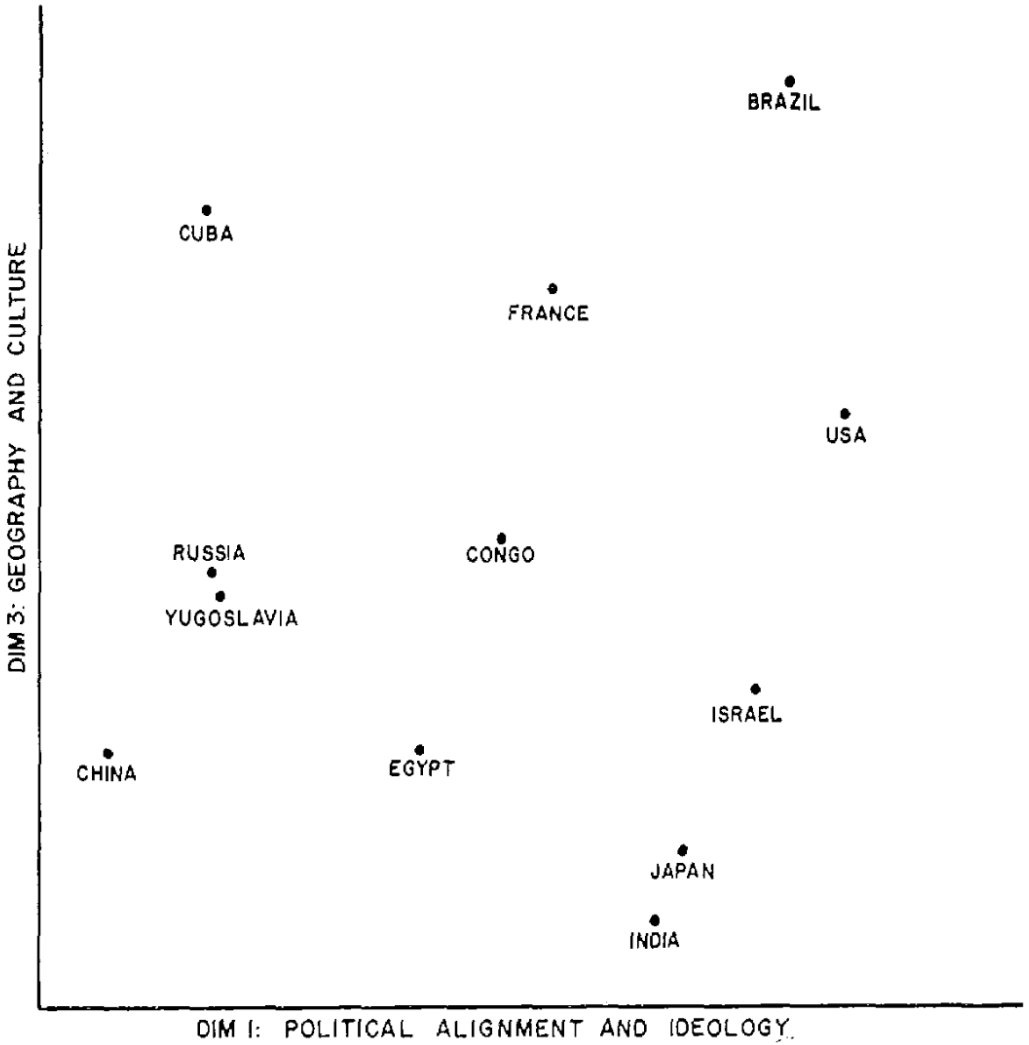


FIG. 2. Dimensions 1 and 3 of three-dimensional INDSCAL configuration for 12 nations.

Individual weights

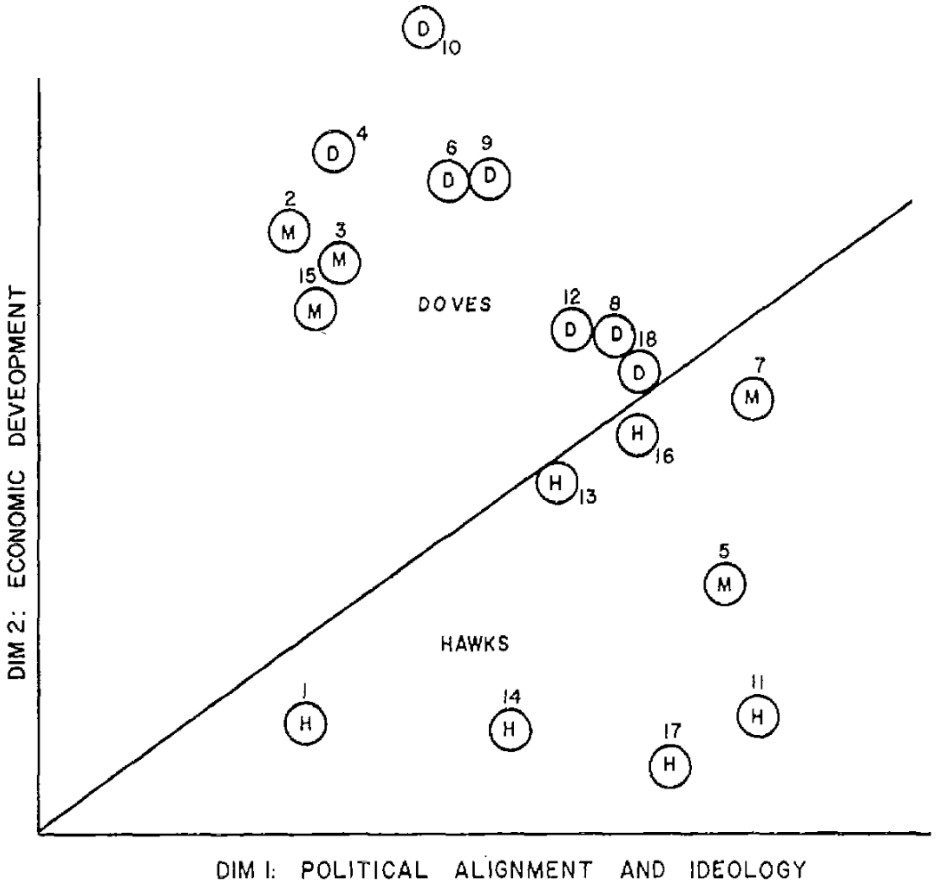


FIG. 3. Plot of subjects' weights on Dimensions 1 and 2 of three-dimensional INDSCAL configuration for 12 nations.

21 countries

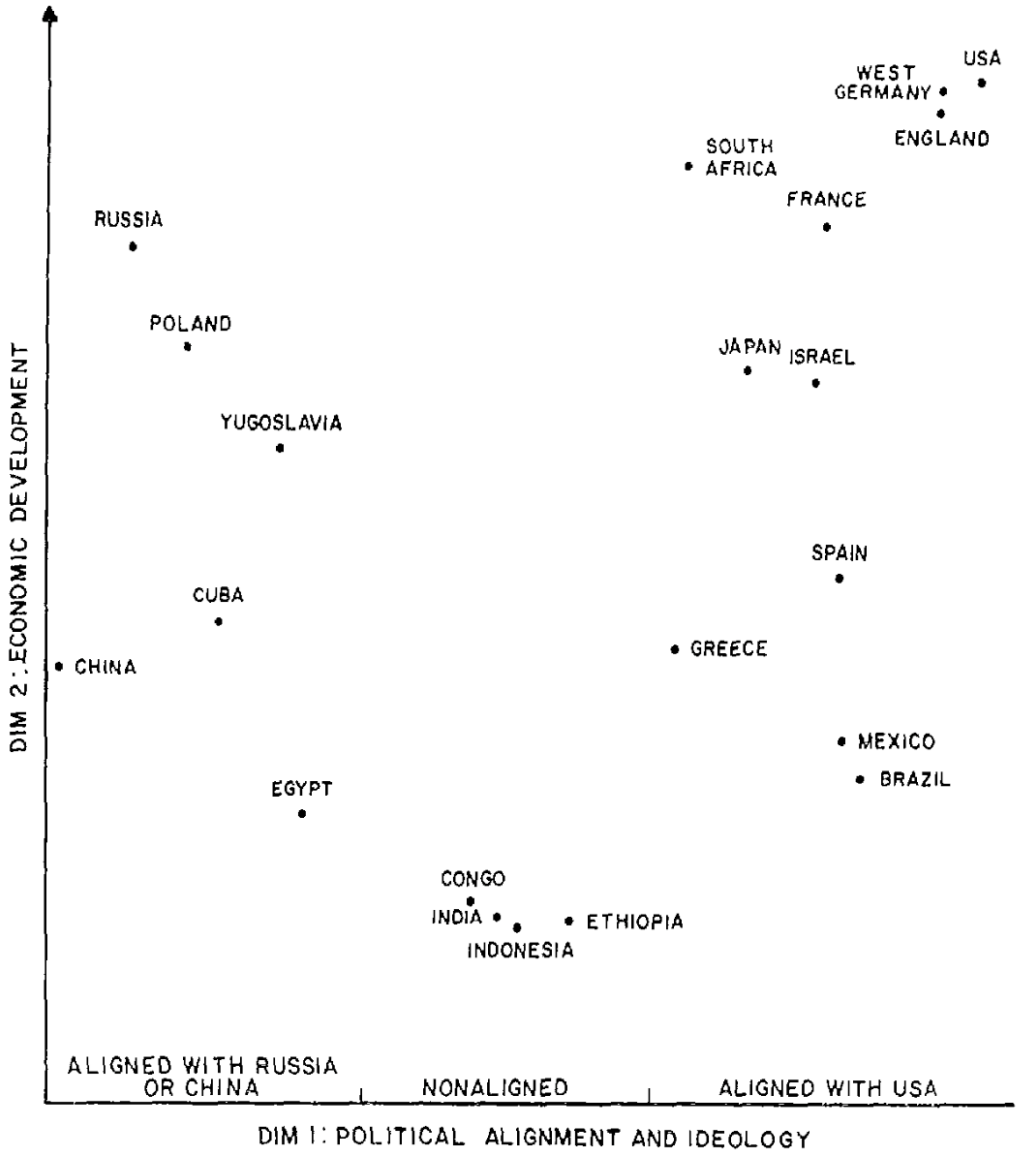


FIG. 5. Dimensions 1 and 2 of four-dimensional INDSCAL configuration for 21 nations.

Even more sources of data

1. Performance tests
   - OSS stress tests
   - New faculty job talks
   - Clinical graduate applicant interviews Internships
   - Probationary Periods
2. Web based instrumentation
   - self report
   - indirect (IAT) (Greenwald and Banaji, 1995; Schimmack, 2021)
3. Archival and Longitudinal data sets
   - MIDUS (Mroczek, 2007)
   - Project Talent (Damian et al., 2019; Major et al., 2012; Spengler et al., 2018)
   - Large public domain data sets (Hofmann et al., 2025)

But all need evidence for reliability and valildity.

Using time as a variable: the measurement of mood

1. Between subjects at one time
2. Within subjects over time

The example of introversion-Extraversion in affective space

1. Personality trait description
   - Introversion/Extraversion
   - Neuroticism Stability
2. Affective Space (moods)
   - Positive Affect
   - Negative Affect
3. Behavior
   - Activation and Approach
   - Inhibition and Avoidance

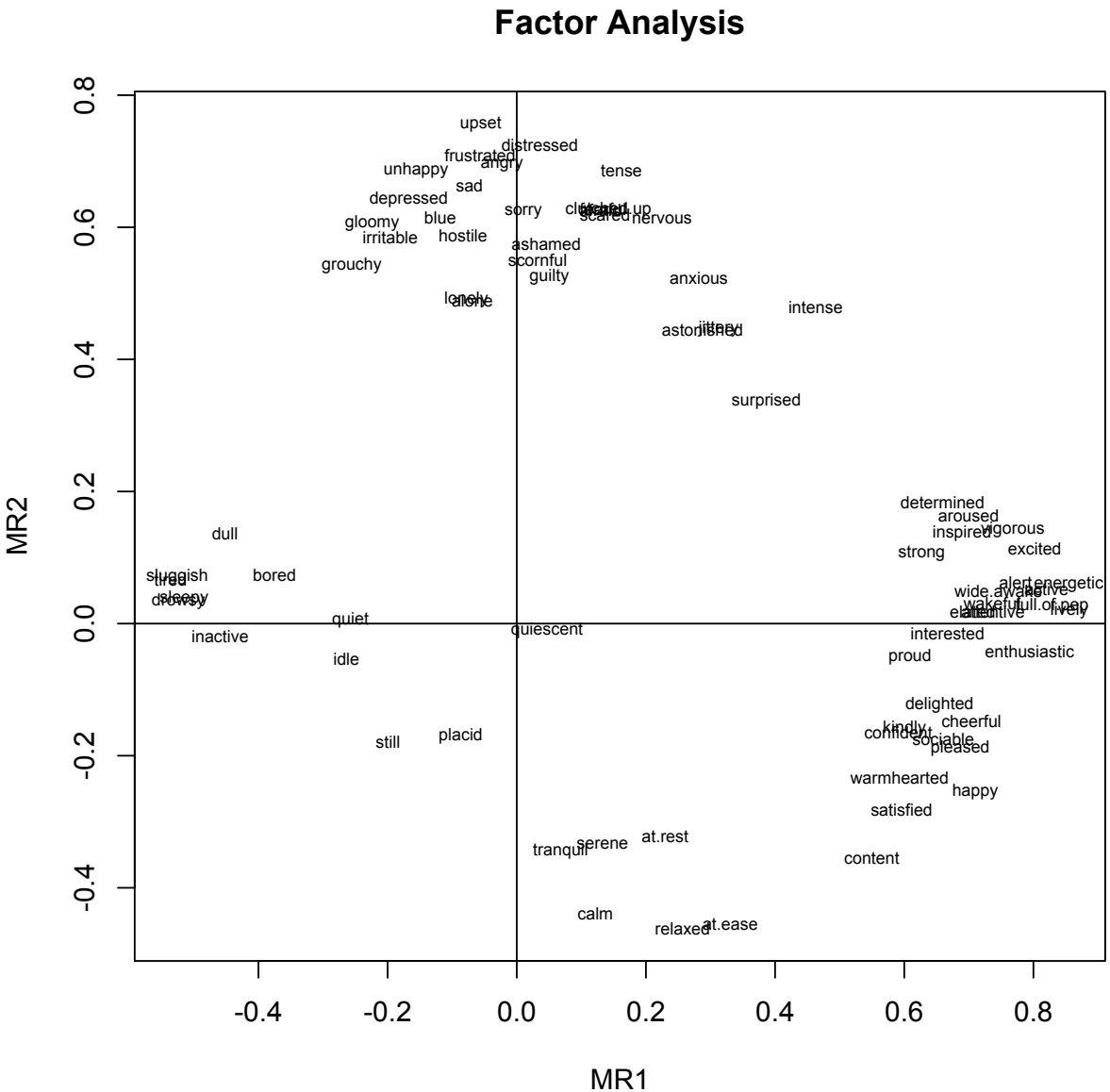
Standard model of personality and emotions

1. Dimensional model of personality Particularly Extraversion and Neuroticism
2. Dimensional model of emotions
3. Positive Affect and Negative Affect
4. Dimensional congruence
5. Extraversion and Positive Affectivity
6. Neuroticism and Negative Affectivity

Measuring the dimensions of affect

1. Motivational state questionnaire (MSQ) 70-72 items given as part of multiple studies on personality and cognitive performance item Items taken from
   - Thayer's Activation-Deactivation Adjective Check list (ADACL) (Thayer, 1970, 1978, 1989)
   - Watson and Clark Positive Affect Negative Affect Scale (PANAS) (Watson et al., 1988)
   - Larsen and Diener adjective circumplex (Diener and Larsen, 1984; Larsen and Ketelaar, 1989)
   - MSQ given before and after various mood manipulations (Revelle and Anderson, 1998)
2. Structural data is from before
3. Structural results based upon factor analyses of correlation matrix to best summarize data

Between subjects: the MSQ-R

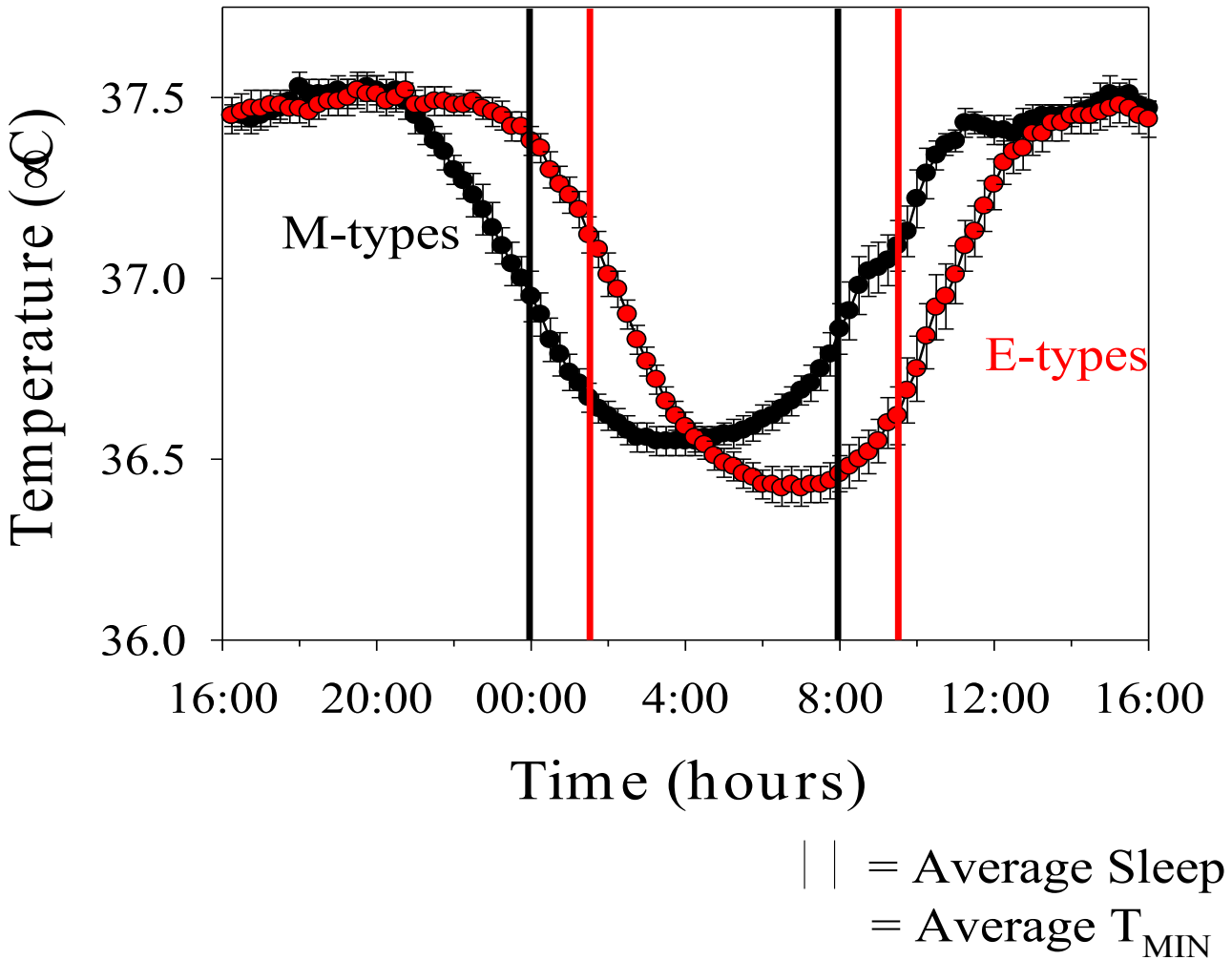


Personality Measurement: snapshot or movie

1. Cross sectional measurement of a person is similar to a photograph– a snapshot of a person at an instant.
2. Appropriate measurement requires the integration of affect, behavior, and cognition across time

Personality and affect: within subject measurement

1. High frequency sampling: physiology
   - Physiological assays
   - Cortisol
   - Body temperature
     - Core body temperature collected for 2 weeks
     - Data taken by aggregating subjects from multiple studies conducted by Eastman and Baehr on phase shifting by light and exercise (Baehr et al., 2000)
2. Low frequency sampling: cell phone sampling of affect (Wilt et al., 2016a,b)


Temperature (°C)
37.5
37.0
36.5
36.0
M-types
E-types
16:00
20:00
00:00
4:00
8:00
12:00
16:00
Time (hours)
| | = Average Sleep
= Average T_{MIN}

Within subjects: diary studies

1. Measures
2. Check lists
3. Rating scales
4. High frequency sampling <– – Multiple samples per day
5. Low frequency sampling – Once a day
6. Sometimes at different times

High frequency measures of affect

1. Measures taken every 3 hours during waking day for 6-14 days
2. Paper and pencil mood ratings
3. Short form of the MSQ – Visual Analog Scale – Sampled every 3 hours
4. Portable computer (Palm and later cell phone) mood ratings <– – Short form of the MSQ
5. Sampled every 3 hours

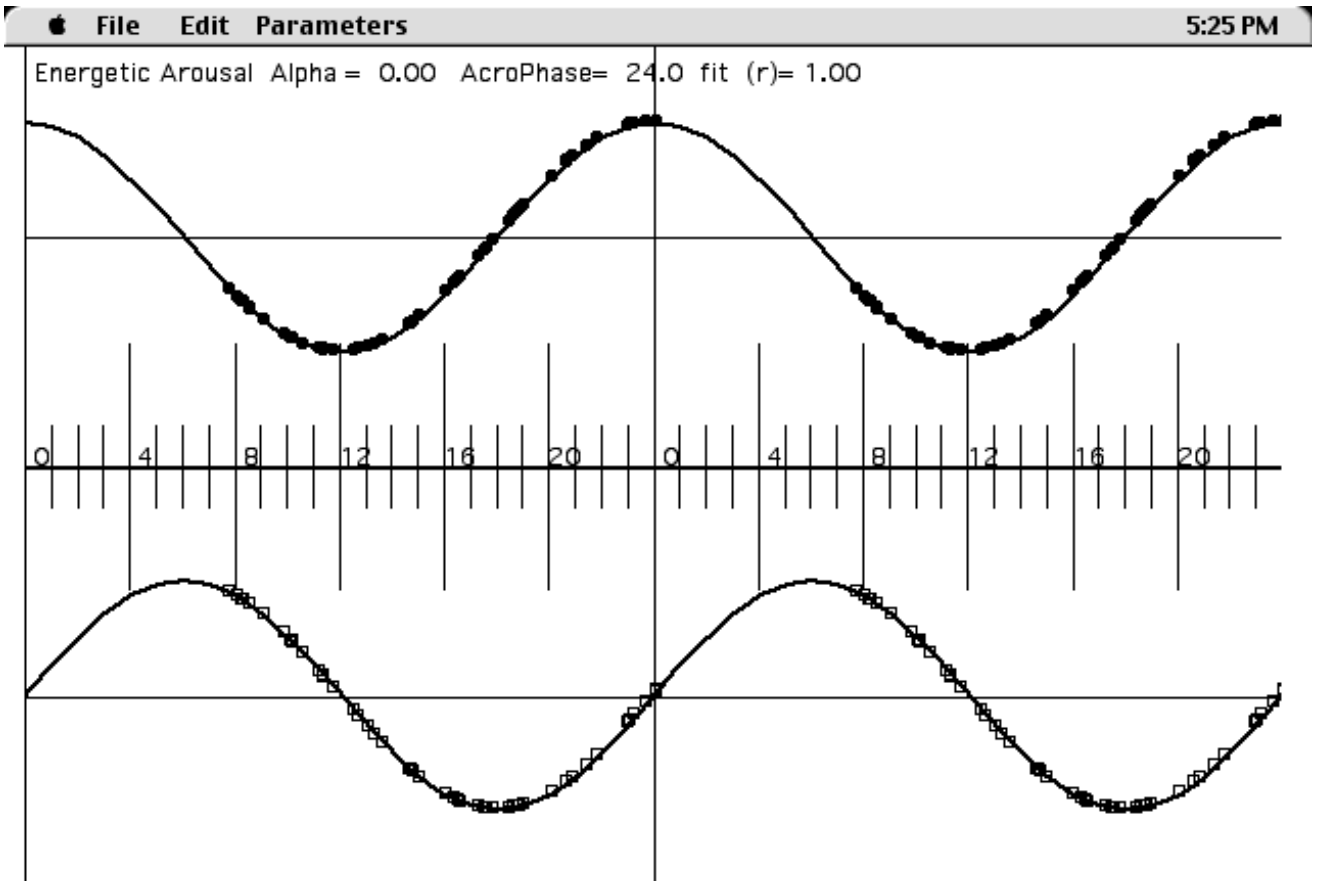
Traditional measures

1. Mean level
   - Energetic arousal
   - Tense arousal
   - Positive affect
   - Negative affect
2. Variability
3. Correlation across measures (Synchrony)

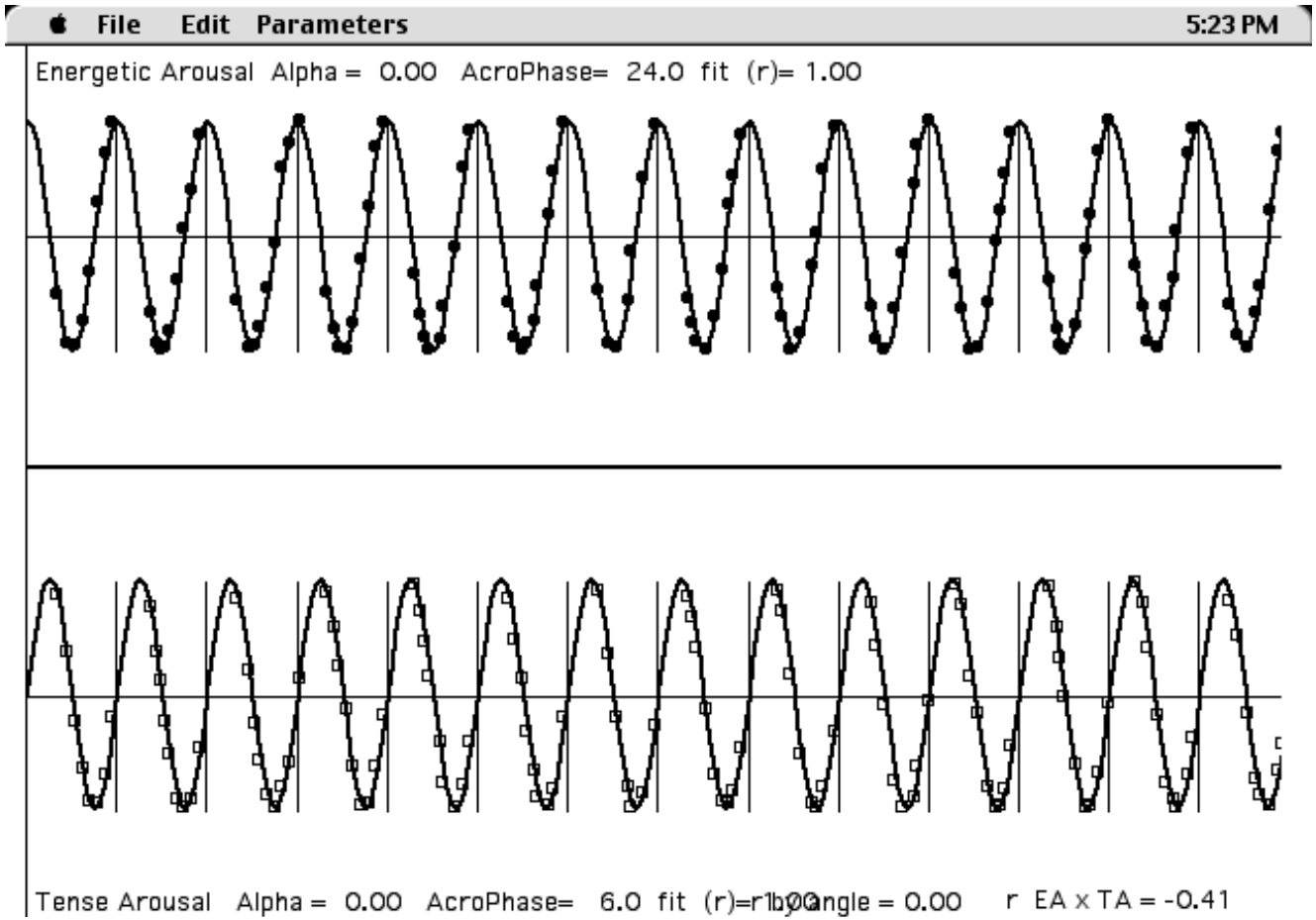
Phasic measures of affect

1. Fit 24 hour cosine to data
   - Iterative fit for best fitting cosine
   - Permutation test of significance of fit
2. Measure
   - Fit (coherence)
   - Amplitude
   - Phase

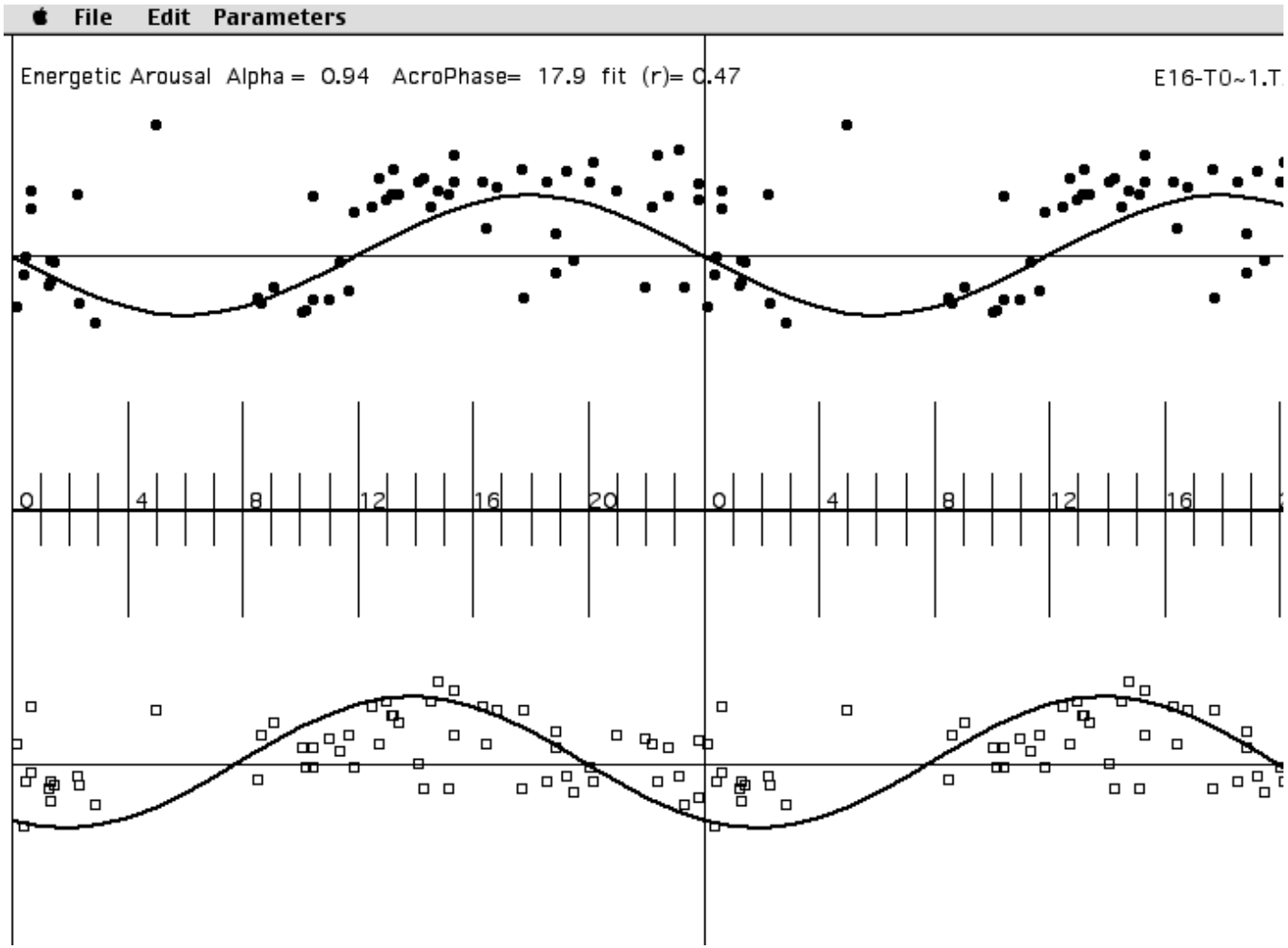
Simulating mood



Simulating mood across 2 weeks



Fitting mood



Personality as coherence over time and space

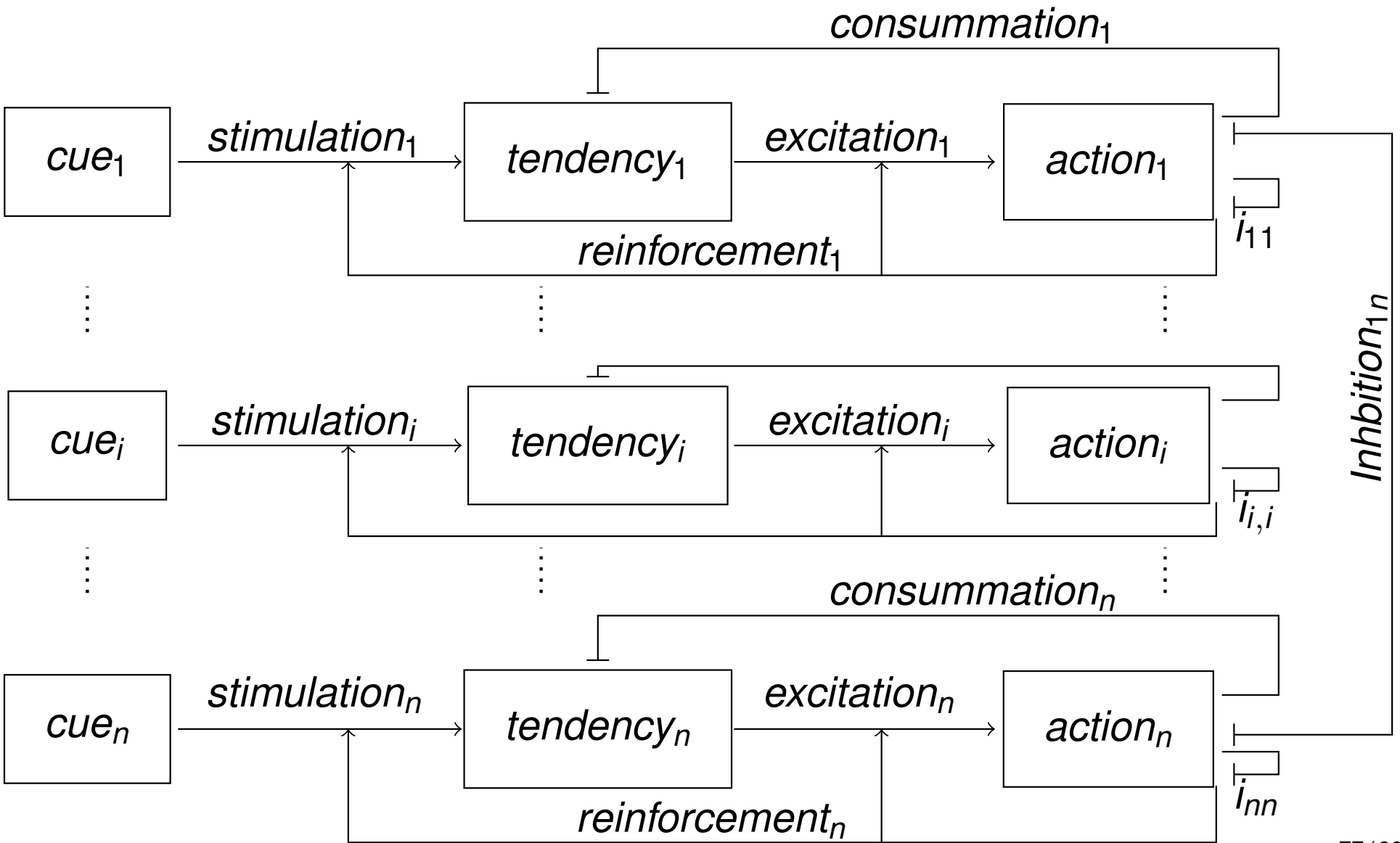
1. Personality is an abstraction used to describe and explain the coherent patterning over time and space of affect, cognition, and desire as they result in behavior for an individual.
   - Reputation: How others see our behavior.
   - Identity: How we interpret our behavior as the result of our affects and our cognitions.
2. This unique patterning or individual signature reflects a complex set of dynamic processes that can be described at three levels of analysis: within individuals, between individuals, and between groups of individuals.
3. It can be measured at different levels of temporal resolution and different levels of specificity.

Observing and explaining the stream of behavior

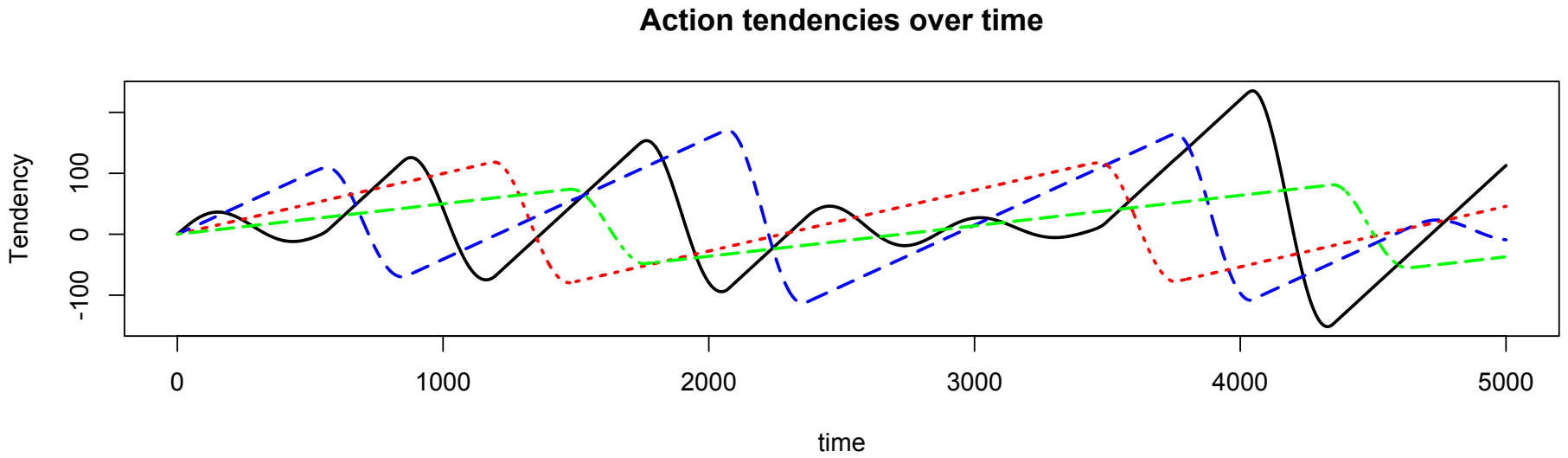
- To all observers, the dynamic processes of the stream of feelings, thoughts, motives and behavior show a unique temporal signature for each individual.
- To an individual differences theorist, the how and why individuals differ in their patterns is the domain of study.
- To a biologically minded psychologist, these dynamic processes reflect genetic bases of biological sensitivities to the reinforcement contingencies of the environment.
- To a mathematically oriented psychologist, these dynamic processes may be modeled in terms of the differential equations of the Dynamics of Action and its reparameterization (Atkinson and Birch, 1970; Revelle and Condon, 2015).

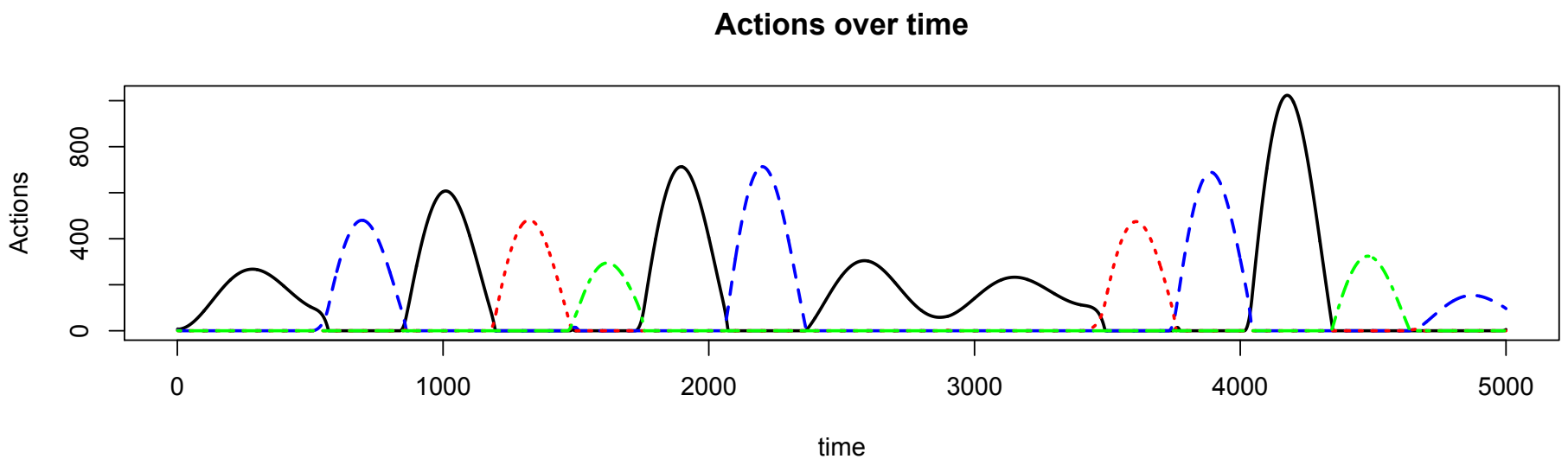
A more complicated model

$dt = Sc - Ca$ $dA = Et - Ia$



Simulation of four individuals in a conversation





Multilevel analysis can yield surprising results

Although it is well known that the structure within a level does not imply anything about the structure at a different level, this distinction is frequently forgotten.

1. Various names for the phenomena:
   - Yule-Simpson paradox (Simpson, 1951; Yule, 1903)
   - The fallacy of ecological correlations (Robinson, 1950)
   - The within group–between group problem (Pedhazur, 1997)
   - Ergodicity (Molenaar, 2004)
2. This distinction will be important as we consider models of coherency and differences within-individuals, between-individuals, and between groups of individuals.

Thinking by analogy

1. Anna Baumert and colleagues considered the many theoretical problems facing those of us who want to propose integrative theories (Baumert et al., 2017).
2. In a commentary on that article David Condon and I have suggested that it useful when searching for explanations at these multiple levels to consider the physical analogy of weather, climate, and climate change which are all driven by the same underlying cause (the balance of solar radiation and re-radiation) but have complex lower level drivers that have larger immediate effects (Revelle and Condon, 2017).
3. We argued that weather:climate:climate change :: emotion:personality:personality development
4. Thus we search for general models that can be applied at these multiple levels.
5. One such model is the Dynamics of Action (Atkinson and Birch, 1970; Revelle and Condon, 2015)

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