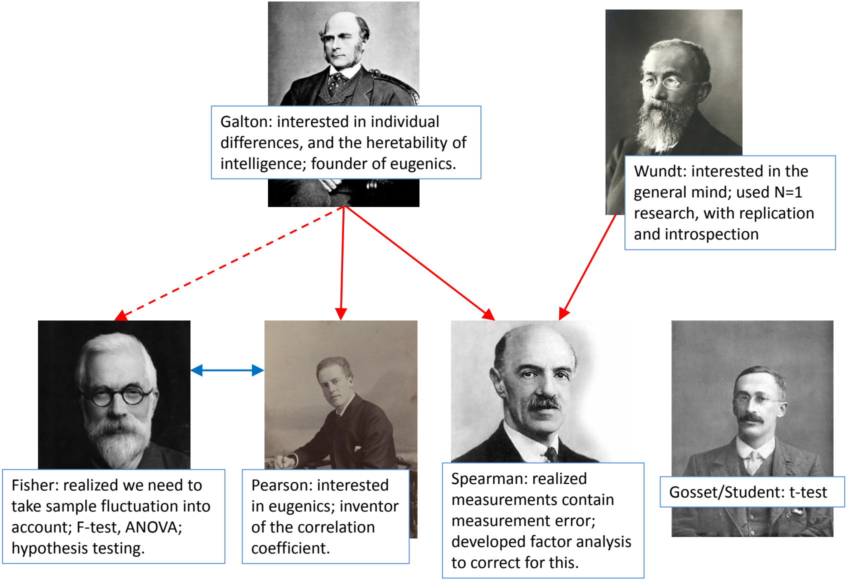
A brief history of dynamic modeling in psychology

Ellen L. Hamaker

Utrecht University

July, 2017

Founders of statistics



A brief history of our statistics

Natural selection operates at the level of the **population**; **statistical techniques** that were developed to study this are **necessarily concerned with the population**.

Pearson (1895, p. 225): On inheritance

[...] we must definitely free our minds [...] of any hope of reaching a mathematical relation expressing the degree of correlation between individual parent and individual offspring.

Galton and his followers assumed they were studying **traits**; Hence, all situational and other temporal effects were considered **irrelevant** (i.e., random measurement error).

Trait versus processes

Focusing on **traits** using cross-sectional research is extremely useful for **selection purposes**. But how is it related to **processes** that operate **within** individuals?

McCrae and John (1991, p. 199):

Personality processes, by definition, involve some change in thoughts, feelings and action of an individual; all these **intra-individual changes seem to be mirrored by inter-individual differences** in characteristic ways of thinking, feeling and acting.

Epstein (1980, p.803):

Too often the **highly questionable assumption** is made that correlations derived from **nomothetic studies** of groups of individuals are applicable to **processes within individuals**.

Outline

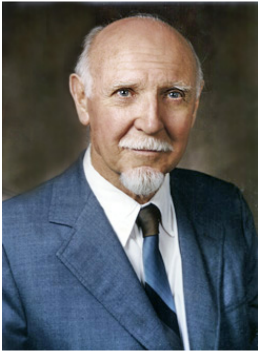
- **Idiographic versus nomothetic research**
- Bringing in the dynamics
- Idiographic versus nomothetic revisited
- 2017

Cattell on unique (idiographic) traits

Cattell was inspired by Allport, who said (1937, p. 297): "Strictly speaking, no two persons ever have precisely the same trait".

Cattell (1943, p. 562):

Actually the mathematical psychologist can claim that unique traits are measurable in units unique to the individual, but this is rather a Pyrrhic conquest for measurement.



Cattell's P-technique

DECEMBER, 1947
PSYCHOMETRIKA—VOL. 12, NO. 4

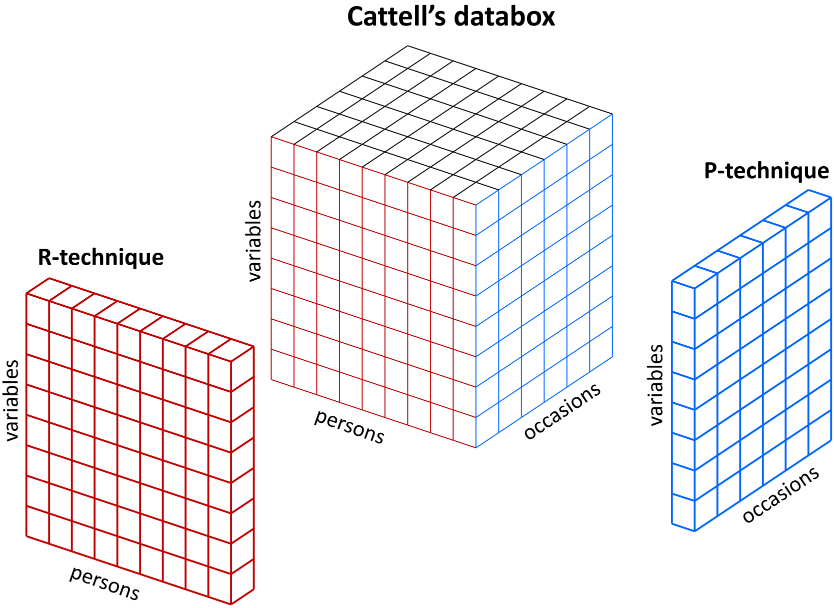
P-TECHNIQUE DEMONSTRATED IN DETERMINING PSYCHO-PHYSIOLOGICAL SOURCE TRAITS IN A NORMAL INDIVIDUAL

R. B. CATTELL, A. K. S. CATTELL, AND R. M. RHYMER
UNIVERSITY OF ILLINOIS

First application of Cattell's P-technique analysis using **46 variables** measured on **54 occasions**, resulted in **9 factors**.

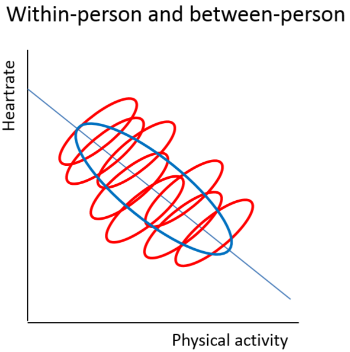
It took a full-time assistant **2 months** to preform this analysis (cf. Luborsky, 1995).

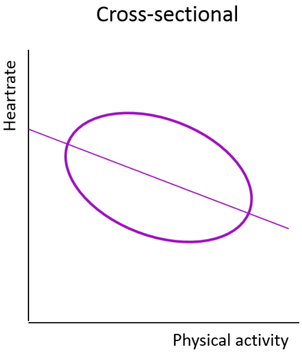
Different kinds of data



Idiographic versus nomothetic research

The question posed by Cattell is: How are the factors obtained from **R-technique** analysis related to those obtained from **P-technique** analysis?





Traits vs. states is like mountains vs. waves

Cattell (1967, p. 170): Cross-sectional research is

[...] an instantaneous snapshot, and, as such, it catches people at differen state levels as well as at their different trait levels. In statistical terms it includes both across-people and across-occasion variance.

The Great Wave by Hokusai

Outline

- Idiographic versus nomothetic research
- **Bringing in the dynamics**
- Idiographic versus nomothetic revisited
- 2017

Time series data is like a movie



Dynamics

An important feature of repeated measures is the **sequential dependency** (i.e., **autocorrelation**) in the data.

It forms a portal into the **underlying dynamics**, that is, how past states and external influences give rise to the current state of a system.

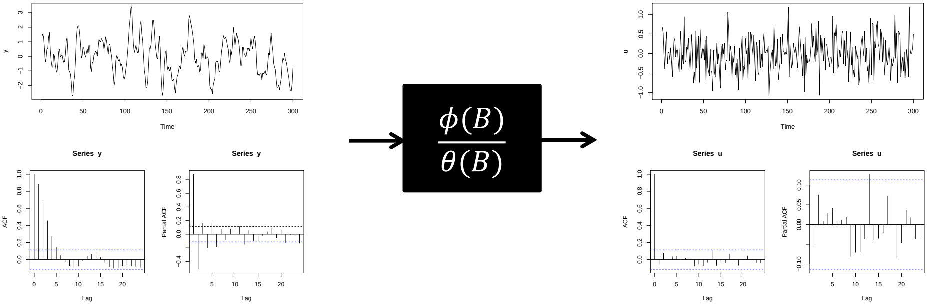
Three ways in which dynamics can be investigated:

- time series analysis in the time domain (econometrics)
- time series analysis in the frequency domain (signal processing)
- dynamical systems modeling (classical mechanics)

TSA in the time domain

A cornerstone here is the ARMA model:

$$y_t = \phi_0 + \phi_1 y_{t-1} + \cdots + \phi_p y_{t-p} + u_t - \theta_1 u_{t-1} - \cdots - \theta_q u_{t-q} = \frac{\theta(B)}{\phi(B)} u_t$$



Applications of ARMA-based models in psychology:

- dynamic factor analysis (DFA): Molenaar, Browne, Nesselroade, and McArdle
- VAR(1) model as a dynamic network: Bringmann, Tuerlinckx, Borsboom, Epskamp
- time varying autoregressive (TVAR): Bringmann

Outline

- Idiographic versus nomothetic research
- Bringing in the dynamics
- **Idiographic versus nomothetic revisited**
- 2017

Empirical study on nomothetic $\neq$ idiographic

Schmitz and Skinner (1993) studied academic performance in children.

Cross-sectionally:

- children who experience more control, put in more effort
- children who put in more effort, perform better
- children who perform better, experience more control

Does this **reflect** the process at the within-person level?

Process (over time within a child):

- Does experiencing more control lead to putting in ore effort?
- Does putting in more effort lead to better performance?
- Does a better performance lead to the experience of more control?

Using TSA on individual data S&S concluded that:

- some children have a pattern similar to the cross-sectional results
- some children have very different patterns (e.g., performing well leads to less effort)

Beyond N=1

The major question is: How can we study **processes**

and at the same time get

general knowledge of processes?

This requires time series ($T > 20$) from multiple subjects ($N > 1$); this allows for:

- bottom-up approach: replicated time series analysis
- top-down approach: dynamic multilevel modeling

Outline

- Idiographic versus nomothetic research
- Bringing in the dynamics
- Idiographic versus nomothetic revisited
- **2017**

Dynamic Structural Equation Modeling in Mplus

DSEM in Mplus **allows** for:

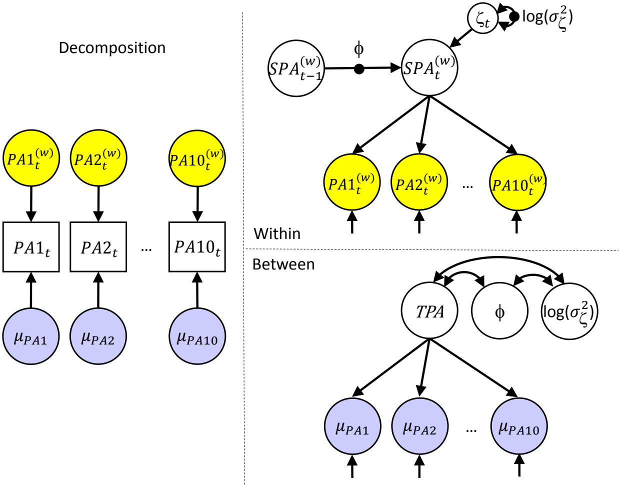
- N=1 and dynamic multilevel models
- within-person: a time series model with lagged relationships
- between-person: individual differences in the means and dynamics (slopes)

Particular strengths of DSEM in Mplus:

- can handle missing data
- can handle unequal intervals between the observations
- can include latent variables
- can handle multivariate models
- uses uninformative priors
- can include level 2 outcomes (not only predictors)
- can include random variances
- includes individual standardization of parameters

Multilevel AR factor model

Using the 10 indicators of PA from the COGITO study, we can specify a multilevel factor model:



Multilevel latent AR(1) model

Decomposition

$$\mathbf{y}_{it} = \boldsymbol{\mu}_i + \mathbf{y}_{it}^{(w)}$$

Within level: State positive affect

$$\mathbf{y}_{it}^{(w)} = \boldsymbol{\Lambda}^{(w)} SPA_{it}^{(w)} + \boldsymbol{\epsilon}_{it}^{(w)} \qquad \boldsymbol{\epsilon}_{it}^{(w)} \sim MN(\mathbf{0}, \boldsymbol{\Theta})$$

$$SPA_{it}^{(w)} = \phi_i SPA_{i,t-1}^{(w)} + \zeta_{it}^{(w)} \qquad \zeta_{it}^{(w)} \sim N(0, \sigma_{\zeta,i}^2)$$

Between level: Trait positive affect

$$\boldsymbol{\mu}_i = \nu + \boldsymbol{\Lambda}\, TPA_i + \boldsymbol{\epsilon}_i$$

$$\begin{bmatrix} TPA_i \\ \phi_i \\ log(\sigma_{\zeta,i}^2) \end{bmatrix} = \begin{bmatrix} \gamma_{TPA} \\ \gamma_{\phi} \\ \gamma_{logVar} \end{bmatrix} + \begin{bmatrix} u_{TPA,i} \\ u_{\phi,i} \\ u_{logVar,i} \end{bmatrix}$$

Thank you!

e.l.hamaker@uu.nl