PENN STATE
1855
Max Planck Institute for Human Development

CILVR Longitudinal
June 17, 2010
University of Maryland

Intraindividual Variability & Change:

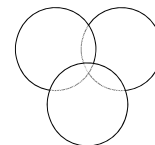## *Tools for Examining the Development of Dynamic Constructs*

Nilam Ram

Pennsylvania State University
Max Planck Institute for Human Development

PENN STATE
1855
Max Planck Institute for Human Development

Developmental Theory, Method & Data

- Aligning, developing, & adapting *"stuff"* to the study of *"biopsychosociocultural"* change

Theory　Data
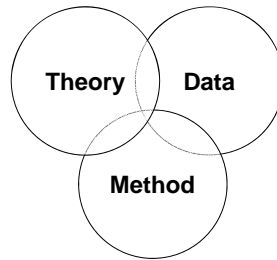
Method

E. Muybridge, *Dancing Waltz,* 1887

A Theory / Method / Data *"Tethering"*
of Intraindividual Variability

1. IntraVar Constructs
– Dynamic Characteristics & Dynamic Processes
- Naming constructs – Defining constructs

2. IntraVar Measures & Models
– Time-Structured IntraVar & Net IntraVar
- Assumptions (iid = independently and identically distributed)

3. IntraVar Data
– Multi-Time-Scale "Burst" Designs
- Development of Dynamic Characteristics & Processes

A Lifespan Developmental Perspective
(Baltes & Nesselroade, 1979)

(Meta)Theory:

"Interest in the description, explanation, prediction, and modification of *processes* that lead to a given outcome or *sequence* of outcomes"

(Meta)Methods & Data:

"Longitudinal methodology involves repeated, time-ordered observation of <u>an individual</u> or individuals with the goal of identifying *processes* and *causes* …"

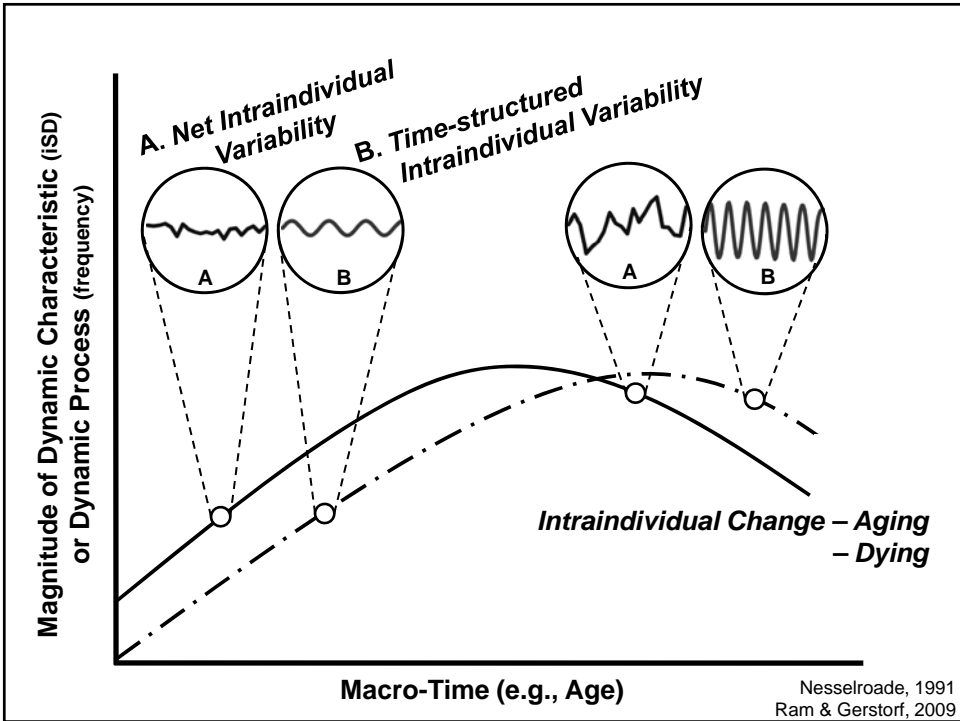## Movement, Change, Development, Dynamics
Traces of Behavior

R. Long, *Walking a Circle in Mist, Scotland 1986*
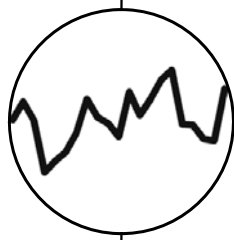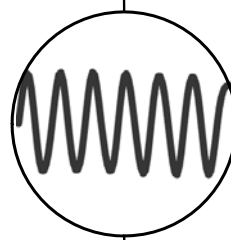
INTRAINDIVIDUAL VARIABILITY & CHANGE

Nesselroade, 1991
Ram & Gerstorf, 2009

Tethering IntraVar Theory to Method
Constructs ←→ Measures & Models

Dynamic Characteristics

Dynamic Processes

Net Intraindividual Variability

Time-Structured Intraindividual Variability

Dynamic Characteristics
"Traits"

- **Capacities or Potentials for Change**

  - *Plasticity*
    - Capability of, or susceptibility to, being molded, shaped, modified, or otherwise changed (Baltes, 1987; Gottlieb, 1998; Lerner, 1984)
  - *Lability / Rigidity*
    - Proneness to or inability to change across contexts (Cattell, 1966)
  - *Robustness*
    - Ability to maintain function across a wide range of conditions, stresses, or pressures (Hammerstein et al., 2006)
  - *Reactivity*
    - Ability to be responsive or to react to stimuli (Bolger et al., 1989)

  - *Poignancy, Complexity, Diversity, Connectivity, etc…*

Dynamic Processes
"Functions"

- **Transactions or activities that connect prior states to future states (behavioral transformations)**

  – *Regulation, adaptation, accommodation, differentiation, learning, metamorphosis, transition*

  a. *Stability Maintenance*
     - Restoration of the system's organizational and functional unity (equilibrium) after endogenous or exogenous perturbation.
  b. *Incremental Change*
     - Refinement, elaboration, growth or loss of a characteristic
  c. *Transformational Change*
     - Reorganization of an existing state or pattern into a qualitatively different state or pattern

  Ford, 1987; Ford & Lerner, 1992

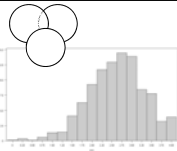# Dynamic Characteristic vs. Dynamic Process

Flexibility   **Process of Dance**

A Collection of States   **Moving from One State to the Next**

Net (*Time-Independent*) *IntraVar*   *Time-Structured IntraVar*
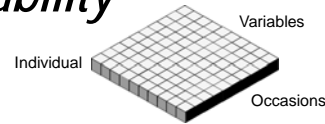
Intraindividual Variability

- *A methodological definition:*
  - variation in scores over repeated measurements of a single individual

- *Descriptions*:
  - *Measures* and *models* of intraindividual variability
    - iMean, iVariance, iSkew, iKurtosis
    - iCovariance (iRegression, iSEM, iEtc…)

Total IntraVar = Time-Structured IntraVar + Net IntraVar

Observed Behavior = Dynamic Processes + Dynamic Characteristics

---

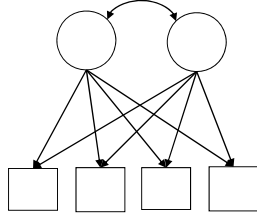# *Time-Structured IntraVar*
Dynamic Processes

- *Objective: construct a statistical <u>model</u> that adequately describes systematic time-dependent structures in the data (iPrediction of future behavior)*

  - *Univariate:* time-series in the time domain (ARMA) or frequency domain (spectral analysis), linear & nonlinear dynamic systems, …

  - *Multivariate:* vector ARMA, multivariate spectral analysis, coupled differential equations (e.g. Lotka-Volterra), state-space models, …

  Total IntraVar = Time-Structured IntraVar + Net IntraVar

Time-Structured IntraVar
Across Occasions – Growth/Diffusion Curves or Functions

Growth Curve Analysis (Meredith & Tisak, 1990; Banks, 1994)

$$Y_{ti} = \beta_{0i} + \beta_{1i}time_{ti} + e_{ti}$$

$$\beta_{0i} = \gamma_{00} + u_{0i}$$

$$\beta_{1i} = \gamma_{10} + u_{1i}$$

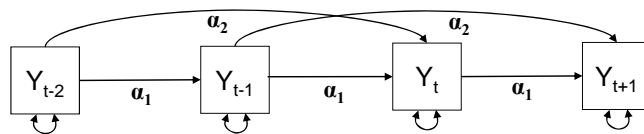**Functional Data Analysis** (Ramsay & Silverman, 2005)

$$y_i(t) = \sum_{k=1}^{K} c_k \phi_k(t) + e_i(t)$$

Time-Structured IntraVar
Between Occasions – Lags, Cyclicity

Time-Series Analysis (Shumway & Stoffer, 2006)

$$Y_t = \alpha_1[Y_{t-1}] + \alpha_2[Y_{t-2}] + ... + \alpha_k[Y_{t-k}] + \varepsilon_t$$

Spectral Analysis (Warner, 1998)

$$Y_{ti} = R_i[\cos(\omega \cdot time_{ti} + \phi_i)] + \varepsilon_{ti}$$
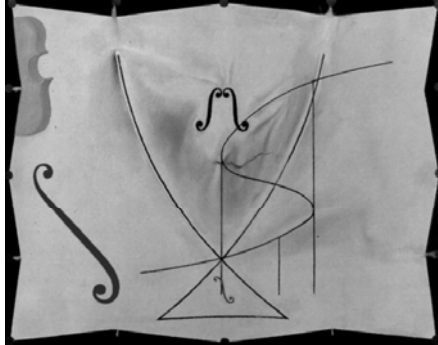
Time-Structured IntraVar
Between Occasions – Linear & Non-linear Dynamics

Linear & Non-linear Dynamic Systems (Boker, 2001; Gottman et al., 2002; Shumway & Stoffer, 2006; Tong, 1993; van der Maas & Molenaar, 1992)

$$\frac{dy}{dt}(t) = A \cdot y(t) + e(t)$$

$$\eta(t) = A + B\,\eta(t-1) + v(t)$$

$$y(t) = \Lambda\,\eta(t) + e(t)$$

S. Dalí, *The Swallow's Tail*, 1983

Net IntraVar
Dynamic Characteristics

– *Objective: <u>measure</u> the extent or range of behaviors manifest in the data (iDescription)*

- *Univariate: intraindividual* standard deviation (iSD), min, max, range (iRange), coefficient of variation, signal-to-noise ratio, MSSD, coefficient of dispersion, entropy, …
  - Continuous, count, categorical variables (shape of distribution)

- *Multivariate: intraindividual* covariance/correlation (icorr), regression, odds-ratios, multivariate moments (variance, skew, kurtosis), Mahalanobis distance, principal components, P-technique factor-analysis, …
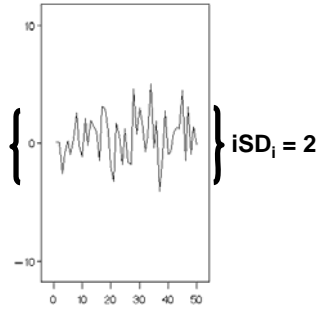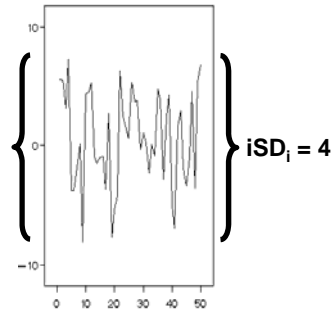
Total IntraVar = Time-Structured IntraVar + Net IntraVar

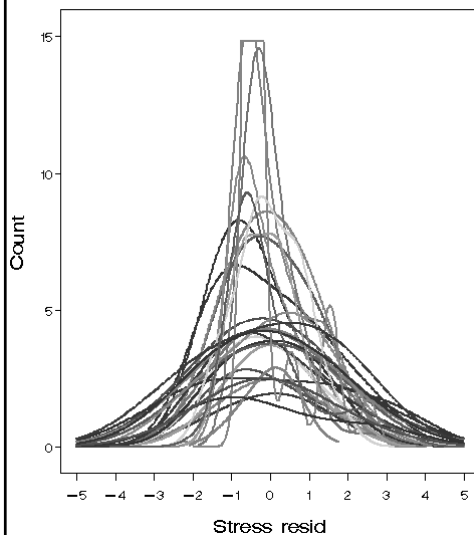# (Net) Intraindividual Standard Deviation
Continuous Variable

$$iSD_i = \sqrt{Variance_i} = \sqrt{\sigma_i^2} = \sqrt{\frac{1}{T-1}\sum_{t=1}^{T}\left(y_{ti} - \overline{y_i}\right)^2}$$

where y_{ti} are
*independent and identically distributed (**iid**)*

iSD$_i$ = 4

iSD$_i$ = 2

(Net) Intraindividual Density Distributions
"Generalized" Univariate – with Interindividual Differences

- **Dynamic Characteristics described by Distributions**
  - *iMean*
  - *iVariance*
  - *iSkew*
  - *iKurtosis*

  - *Formal distributions*
    - *normal, maximum value, minimum value, exponential, Poisson, etc.*
  - *Kernel distributions*

(Net) Entropy
Categorical Variable

- Degree of 'disorder' or 'uncertainty' in a system
  - How observations in the data set are distributed across various categories, *assuming iid*

$$Entropy_i = -\frac{1}{\ln m} \sum_{j=1}^{m} p_j \ln p_j$$
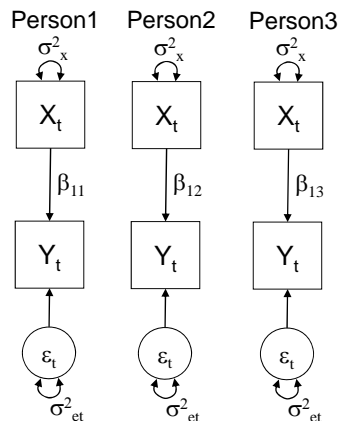
$m = 4$	A	B	C	D
p_j	.25	.25	.25	.25

Entropy = 1.0

$m = 4$	A	B	C	D
p_j	--	--	1.0	--

Entropy = 0.0

Interindiv. Differences in
(Net) Intraindivual Covariation/Coupling

- Interindividual differences in the relationship between two distributions of scores

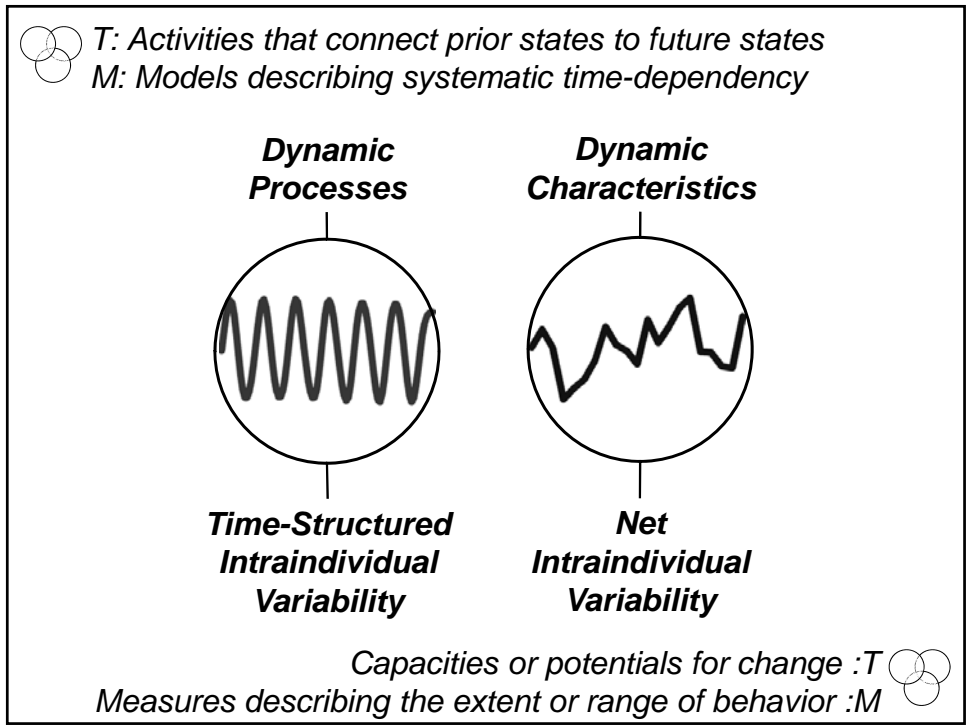**Multilevel Regression:**
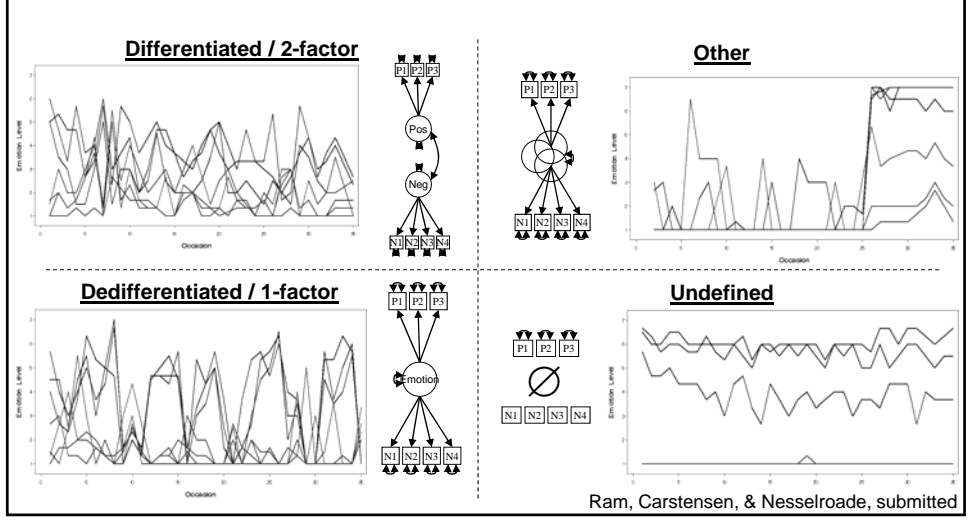
(occasions nested within persons)

$$Y_{ti} = \beta_{0i} + \beta_{1i}X_{ti} + \varepsilon_{ti}$$
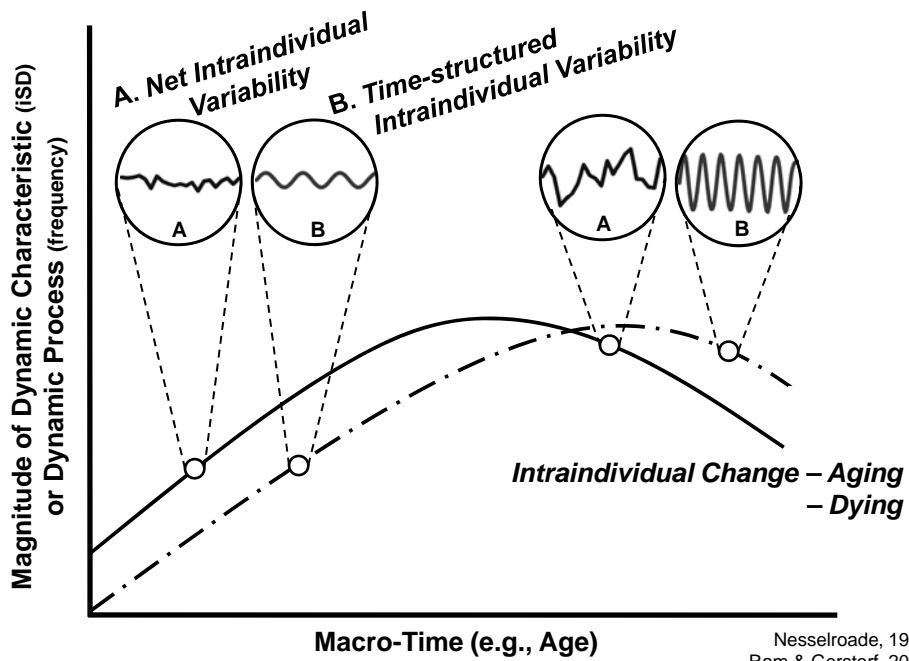$$\beta_{0i} = \gamma_{00} + u_{0i}$$
$$\beta_{1i} = \gamma_{01} + u_{1i}$$

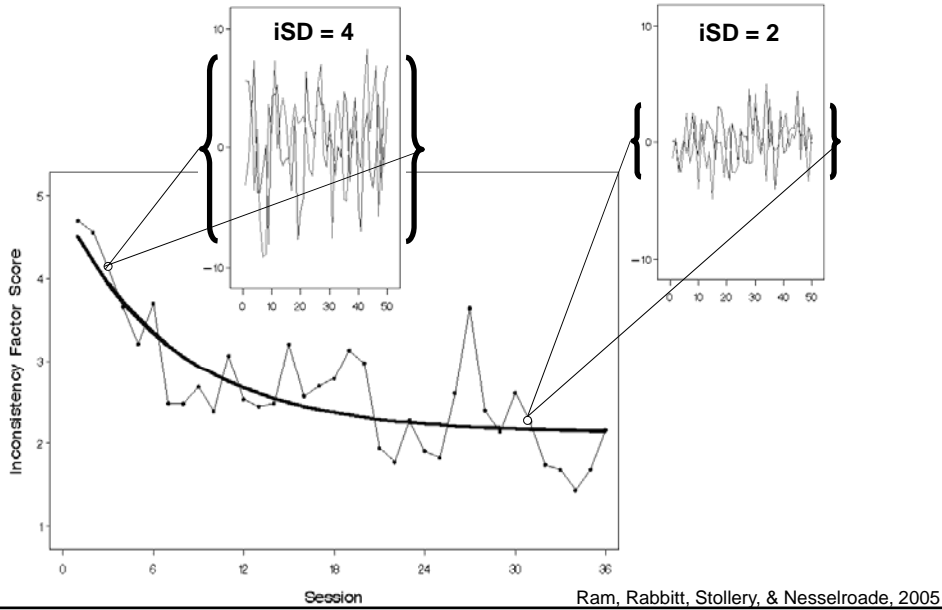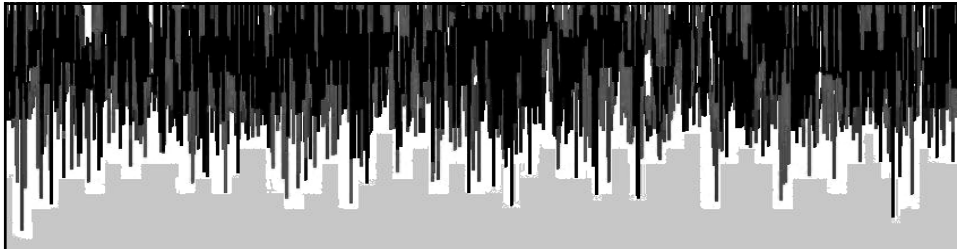*where e_{ti} are assumed **iid***

11

Interindiv. Differences in
(Net) Intraindivual Covariation/Coupling
"Generalized" P-Technique

Differentiated / 2-factor

Other

Dedifferentiated / 1-factor

Undefined

Ram, Carstensen, & Nesselroade, submitted

T: Activities that connect prior states to future states
M: Models describing systematic time-dependency

Dynamic Processes

Dynamic Characteristics

Time-Structured Intraindividual Variability

Net Intraindividual Variability

Capacities or potentials for change :T
Measures describing the extent or range of behavior :M

Intraindiv. Change in Intraindiv. Variability
Multi-Time-Scale Design

Ram, Rabbitt, Stollery, & Nesselroade, 2005

A. Net Intraindividual Variability

B. Time-structured Intraindividual Variability

Intraindividual Change – Aging – Dying

Macro-Time (e.g., Age)

Magnitude of Dynamic Characteristic (iSD) or Dynamic Process (frequency)

Nesselroade, 1991
Ram & Gerstorf, 2009
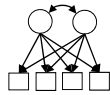
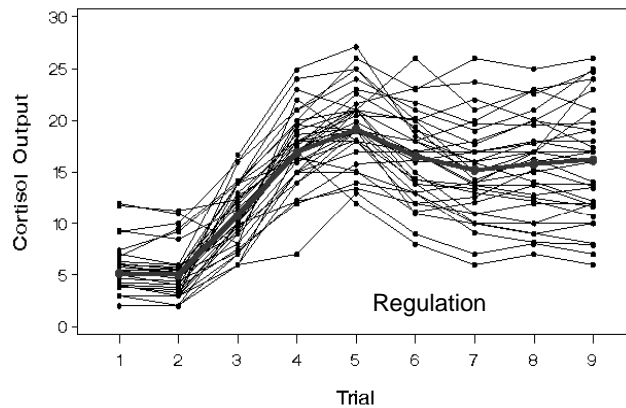# INTRAINDIVIDUAL VARIABILITY & CHANGE
DYNAMIC CHARACTERISTICS & DYNAMIC PROCESSES

Time-Structured Change
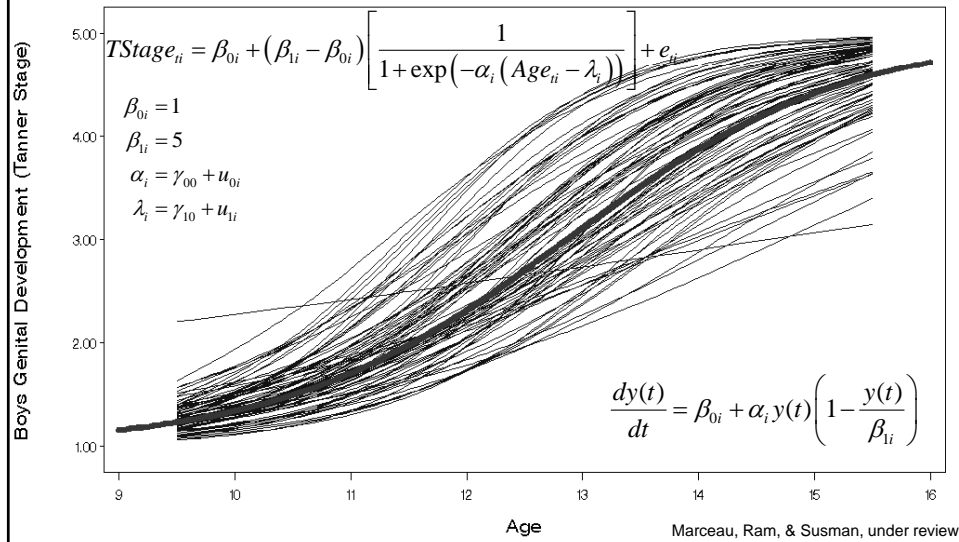### *Across Occasions – Growth/Diffusion Curves or Functions*

Non-linear Growth Curves & Growth Mixtures

Regulation

Ram & Grimm, 2007
Grimm & Ram, 2009a
Ram & Grimm, 2009
Grimm & Ram, 2009b

Pubertal Development
Transformations to Examine Timing of Developmental Landmarks

$$TStage_{ti} = \beta_{0i} + (\beta_{1i} - \beta_{0i})\left[\frac{1}{1+\exp(-\alpha_i(Age_{ti} - \lambda_i))}\right] + e_{ti}$$

$\beta_{0i} = 1$

$\beta_{1i} = 5$

$\alpha_i = \gamma_{00} + u_{0i}$

$\lambda_i = \gamma_{10} + u_{1i}$

$$\frac{dy(t)}{dt} = \beta_{0i} + \alpha_i y(t)\left(1 - \frac{y(t)}{\beta_{1i}}\right)$$

Boys Genital Development (Tanner Stage)

Age

Marceau, Ram, & Susman, under review

Dynamic Processes
"Functions"

- **Transactions or activities that connect prior states to future states (behavioral transformations)**

  - *Regulation, adaptation, accommodation, differentiation, learning, metamorphosis, transition*

  a. *Stability Maintenance*
     - Restoration of the system's organizational and functional unity (equilibrium) after endogenous or exogenous perturbation.
  b. *Incremental Change*
     - Refinement, elaboration, growth or loss of a characteristic
  c. *Transformational Change*
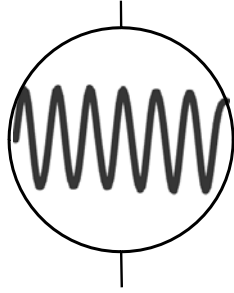   - Reorganization of an existing state or pattern into a qualitatively different state or pattern

  Ford, 1987; Ford & Lerner, 1992

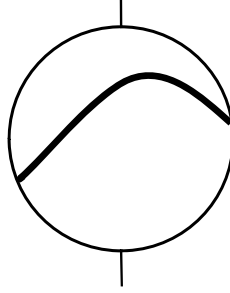## Tethering IntraVar Theory to Method
Constructs ←→ Models

Stability Maintenance

Incremental Change

Transformational Change

$$\frac{d^2 y(t)}{dt^2} = \beta\, y(t)$$

Oscillatory/Control

$$\frac{dy(t)}{dt} = \alpha\, y(t)\left[1 - \frac{y(t)}{k(t)}\right]$$

Growth/Diffusion
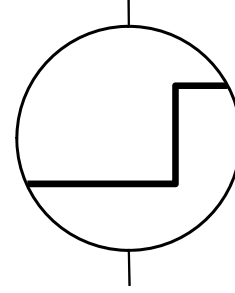
$$\frac{dy(t)}{dt} = \alpha + \beta\, y(t) - y(t)^3$$

Catastrophe

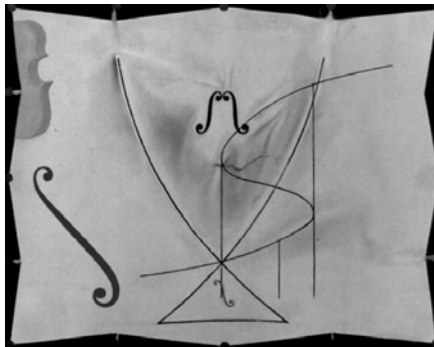
Time-Structured IntraVar/Change
Between Occasions – Linear & Non-linear Dynamics

Linear & Non-linear Dynamic Systems (Boker, 2001; Gottman et al., 2002; Shumway & Stoffer, 2006; Tong, 1993; van der Maas & Molenaar, 1992)
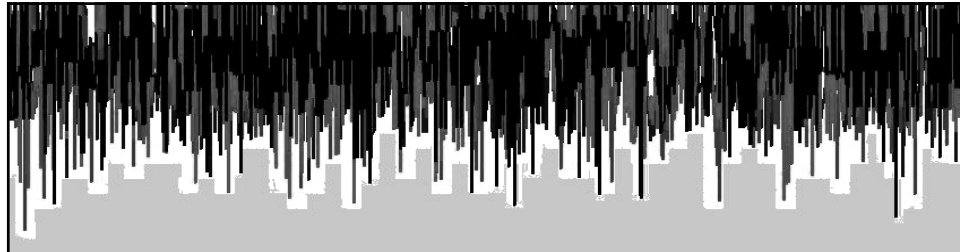
$$\frac{dy}{dt}(t) = A \cdot y(t) + e(t)$$

$$\eta(t) = A + B\,\eta(t-1) + v(t)$$

$$y(t) = \Lambda\,\eta(t) + e(t)$$

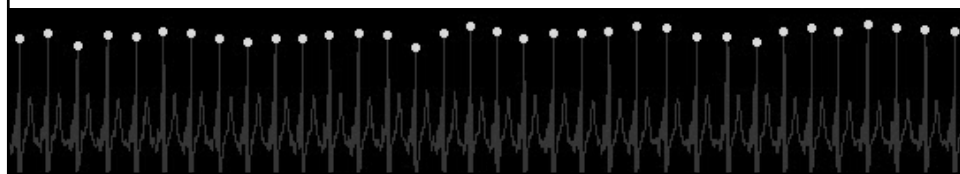S. Dalí, *The Swallow's Tail*, 1983

Theoretical Precision of Systems 'Features': equilibria, carrying capacities, cost functions, sequencing and timing of turning points, etc.
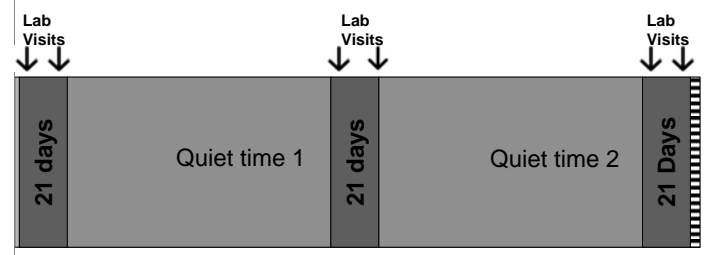
REMOTE AND INTENSIVE DATA

DYNAMIC CHARACTERISTICS & DYNAMIC PROCESSES

http://vimeo.com/12570097

---

iSAHIB

NIA RC1–AG035645

- Participants:
  - ~125 adults, age 18-90 years
    - Recruited from Penn State University and surrounding community

- Multi-Time Scale "Burst" Design:
  - Three 21-day bursts of measurement at 4.5 month intervals

Lab Visits		Lab Visits		Lab Visits	
21 days	Quiet time 1	21 days	Quiet time 2	21 Days	

R.A.I.D Tools
Remote And Intensive Design and Data Analysis

)))iSAHIB

- Web-based Questionnaire:
  - Initial + Pre-burst + Post-burst assessments
    - 6 lab visits (~ 300/100 items each)

- Electronic Diary:
    - Initiated during a 1 hr training session
  - Social Interactions + End of Day
    - Event contingent +*plus*
    - Reminders every 2-hours (8am-8pm) if no reports
    - ~ 6 social interactions/day (27 items)
    - + 1 daily "before bed" questionnaire (52 items)

Method
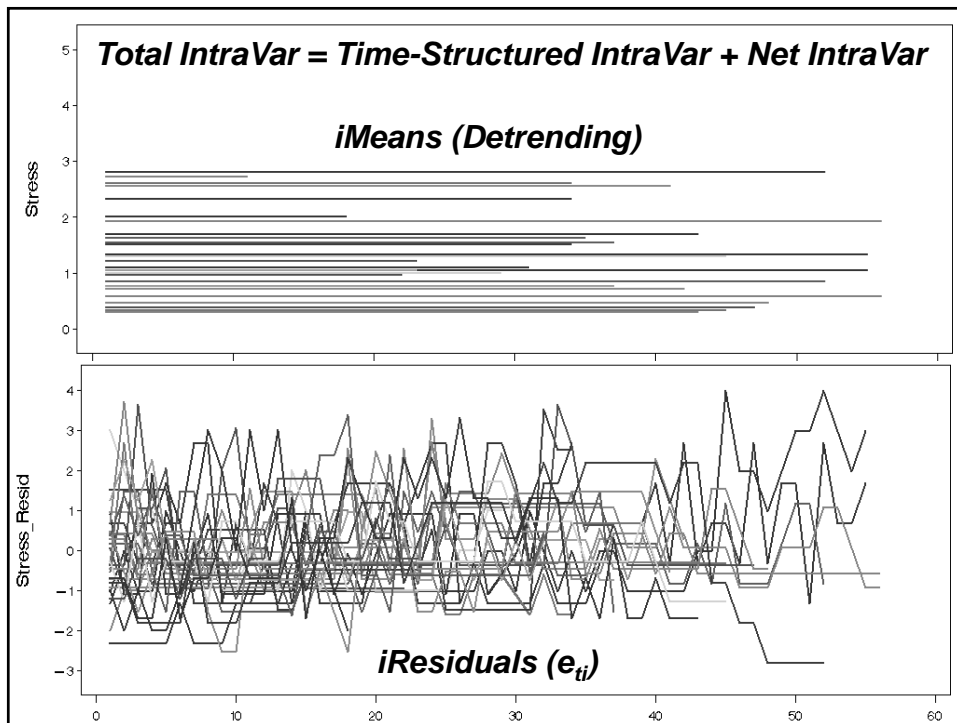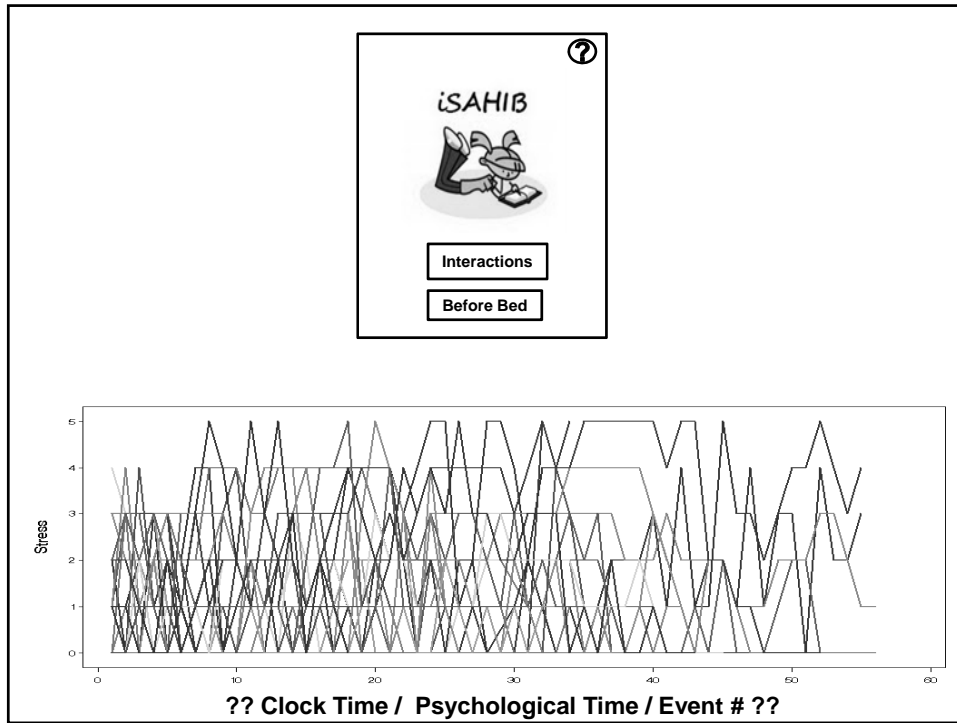*Measures of Change (4 Levels – speed of process)*

)))iSAHIB

1. Dispositions – Stable Traits (1 occasion):
   - Demographics:
   - Personality:
   - Motivation:
   - Emotion: Emotion Regulation, Trait Pride/Shame/Guilt

2. Person/Context Characteristics – Developmental Change (6 occasions):
   - Physical &Mental Health, Well-Being (Life Satisfaction)
   - Personality (Big 5 + Perceived Control)
   - Life Events

3. Daily Experiences – Daily Variability (3 x 21 = ~63 occasions):
   - Affect, Control, Stress, Satisfaction with Life, Self-esteem
   - Physical Activity, Health Behaviors
   - Time Use, Sleep

4. Social Interactions – Situational Variability (3 x 21 x 6 = ~378 occasions):
   - Context, Social Ecology (Utility)
   - Emotion, Emotion Regulation
   - Motivation, Self-esteem, Perceived Control
   - Interpersonal Perceptions (of other) and Behavior (self)

?? Clock Time / Psychological Time / Event # ??

Total IntraVar = Time-Structured IntraVar + Net IntraVar

iMeans (Detrending)

iResiduals (e_{ti})

Intraindividual Density Distributions
### Dynamic Characteristics

- *Does the distribution (quantifications of variance) hold Dynamic Process information?*
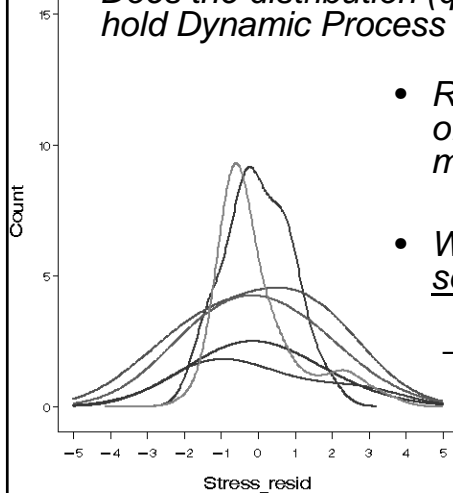
  - *Requires a precise conception of the "generating or selection mechanisms"*

  - *What are possible generating or <u>selection</u> mechanisms?*

    – *Structural affordances or constraints*

      • *Notion of a filter or sieve*

Intraindiv Change in Intraindiv Distribution
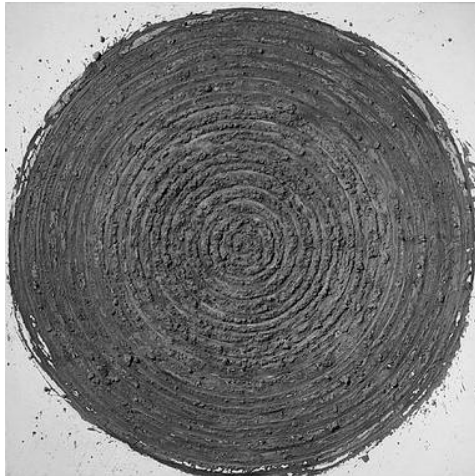### The 'Products' of a Dynamic Process
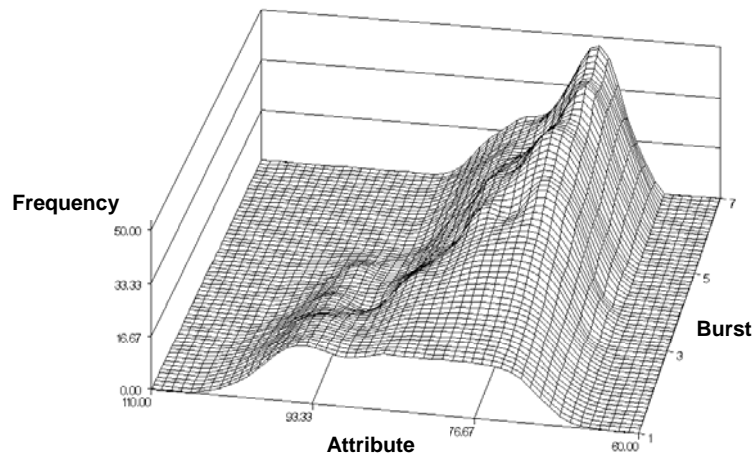
Tracking 'Moments' across Time: <u>variance</u>, skew, kurtosis, 'fat tails' etc.

Development in Ecological Context
Change in Ecological Momentary Assessment
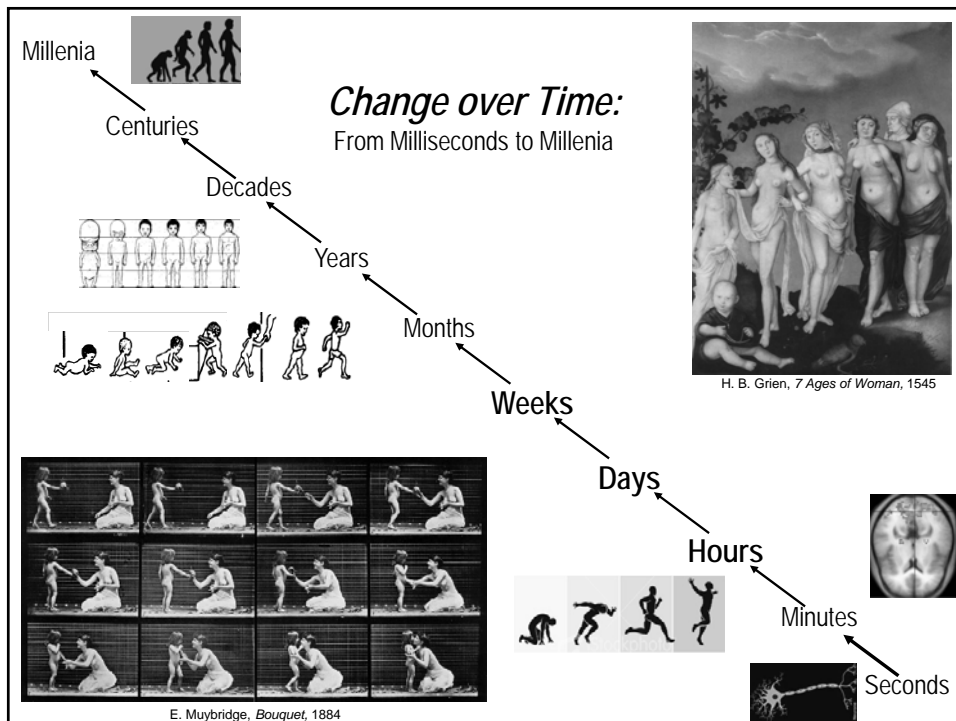
- *Individuals*
- *Families*
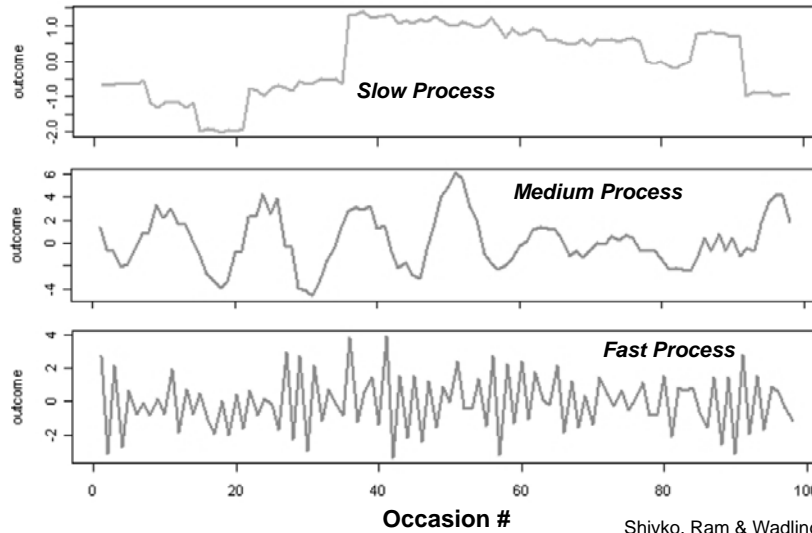- *Neighborhoods*
- *Social Structures*
                    …

- *Micro-Time*
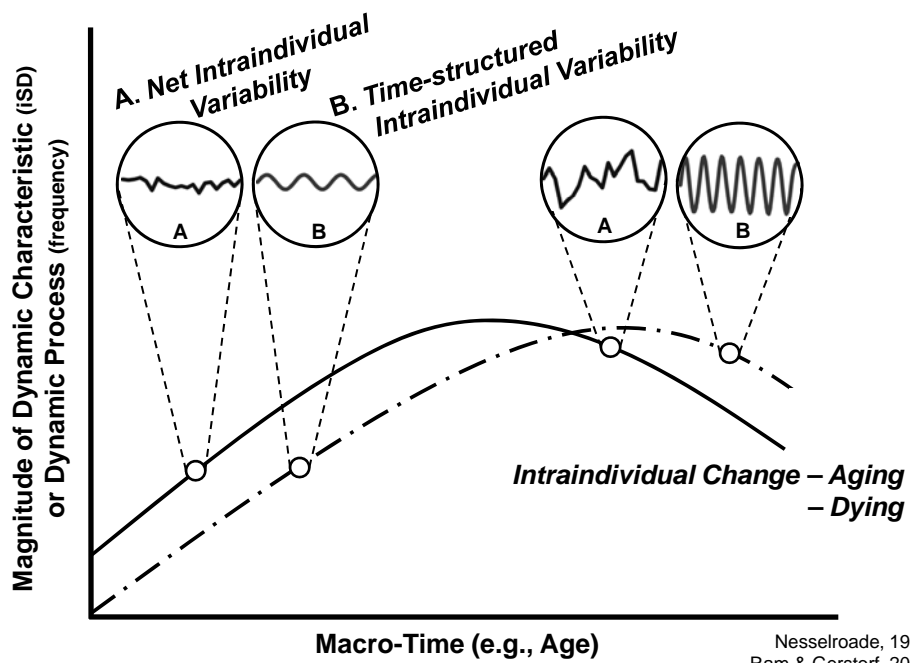- *Meso-Time*
- *Macro-Time*
- *Mega-Time*
                    …

G. Uecker, *Aschekreis*, 1987

Millenia

Centuries

Decades

Years

Months

Change over Time:
From Milliseconds to Millenia

H. B. Grien, *7 Ages of Woman*, 1545

Weeks

Days

Hours

Minutes

Seconds

E. Muybridge, *Bouquet*, 1884

Speed of Process
"Natural" or "Artificial" Variance Decomposition (EMA Data)

Slow Process

Medium Process

Fast Process

outcome

Occasion #

Shiyko, Ram & Wadlinger, in prep

A. Net Intraindividual Variability

B. Time-structured Intraindividual Variability

A B A B

Magnitude of Dynamic Characteristic (iSD) or Dynamic Process (frequency)

Intraindividual Change – Aging – Dying

Macro-Time (e.g., Age)

Nesselroade, 1991
Ram & Gerstorf, 2009

Aligning Theory, Method, & Data
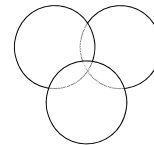### *Some Current Thoughts … (Boker, Molenaar, & Nesselroade, 2009)*

- **Theory** – logically self-consistent framework explaining behavior
  - Hypotheses regarding the <u>specifics</u> of change are somewhat sparse (stability maintenance, incremental, transformational processes)

- **Models** – mathematical/formal structure for making inferences
  - Models, often borrowed from other fields, are able to articulate <u>complex</u> patterns of changes

- **Data** – set of observations describing individuals & environments
  - Need for greater <u>density</u> of observations (in time)

REMOTE AND INTENSIVE DATA

DYNAMIC CHARACTERISTICS &
DYNAMIC PROCESSES