PIRE: Inferences involving time-scales in intensive longitudinal data

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June 6, 2016
Support & Collaborators

- The American Cancer Society, for financial support of aspects of this work
- Paper collaborators, Barta, Hofer, Stawski, & Collyer
- Recent papers on mHealth and exercise with graduate student Daniel Smith
Time-Dependent Longitudinal Designs

- Critical Idea: the fact that phenomena exist at varying timescales needs more emphasis as a central design consideration, with analytical consequences and opportunities.

- Dealing with time involves more than just choosing the metameter (the counter variable), term, number and spacing of measurements.

- TDLD are used when there is reason to believe that (ostensibly related) processes reside at more than one time scale (such as, generally, clock time, calendar time, over epochs).

- Increases design efficiency, power, 'time locus' of the phenomena.

- Dictates analytical options, such as possibility of upward generality (sometimes aggregation).
Typical Considerations: Measurement Timing

- Evenly Spaced Time Measurements at One Time Scale
- Irregularly Spaced Measurements on One Time Scale
- Varying Number of Measurements at One Time Scale
Stationary Processes

- Useful for processes that have characteristic patterns, like diurnal processes, day of week effects, monthly cycles, etc.
- At times difficult in humans to get the measurement at exactly the right time. Can be crucial.
- Many processes reside at multiple time scales
- Almost all behavioral processes have 'blackout periods' during which we are constrained from the behavior (e.g. smoking in restaurants)
Nonstationary Processes (often event driven)

- Comes up in case of event contingent or context limited data, for example
- Smoke a cigarette and be tracked for x period; Locate yourself in a bar and be tracked for x period.
- Irregularity can actually be the process more often than not.
- More difficult for time graded analyses like time series, but not impossible (can bin data, or run in continuous time)
Time dependent longitudinal designs (TDLD) need to be in the design reference framework.

- Revisit Campbell and Stanley’s typology
- \[O1 \ O2 \ O3\] DELAY \[O1 \ O2 \ O3\] DELAY \[O1 \ O2 \ O3\]
- Example, measurements during a period of violence, between earthquakes, among developmental periods.
Time-Dependent Longitudinal Designs Schematic

- R G1 [O1 O2 O3] DELAY [O1 O2 O3] X DELAY [O1 O2 O3]
- G2 [O1 O2 O3] DELAY [O1 O2 O3] DELAY [O1 O2 O3]
Elaborated Time-Dependent Longitudinal Design

- $[O_1 \times O_2 \ O_3 \ ] \ \text{DELAY} \ [O_1 \times O_2 \ O_3 \ ] \ \text{DELAY} \ [O_1 \times O_2 \ O_3 \ ]$
- $[O_{1\ldots\ldots\ldots} \times O_{2\ldots\ldots\ldots} \ O_{3\ldots\ldots\ldots} \ ] \ \text{DELAY} \ ETC. \ \text{REWRITE \ AS:}$
- $[O_1(o^5) \times O_2(o^5) \ O_3(o^5)] \ldots (2 \text{weeks}) \ldots [O_1(o^{10}) \times O_2(o^{10}) \ O_3(o^{10})]$
Combining Signal and Event Contingent Studies

Example:
- Mood when smoking vs. not smoking

KEY:
- = Event report = cigarette, sampled (c)
- = Signal-based, random non-smoking assessment
- EOD = End of Day report, stressful events
- = Sleep

Case-control design
Background: Trend toward technology use in measurement 80s-present

- Idiographic conceptions; Lamiell, Allport, Molenaar (see 2004 manifesto; see also Hamaker chapter in Conner & Mehl, 2012)
- Measurement through technology; ability to measure many of these influences over time for one or more individuals
- Diary studies, Beeper studies, EMA, on-line tailored programs, text programs, etc.
- Recent emergence of mHealth as nomenclature for technology serving health-care needs
Background: Trend toward interest in regulation 80s-2000

- Experimental to ecological observation
- Theories suggesting dynamics that evolve; Lewin, Gottlieb, Carver & Scheier, to name a few
- Predominantly cross-sectional to frequent longitudinal studies
- Naturalistic time series designs may help to establish baseline patterns of health over time prior to intervention.
Background: Measurement burst design

- Nesselroade 1991, "longitudinal research designs need to be planned around successive bursts of measurement rather than merely successive ones'.
- A special case of the interrupted time-series design, Campbell and Stanley, 1963
- Benefits include cost-saving, placing measurements at time scale of the phenomenon, and ability to compare burst to burst change.
- Diverse history of design emergence. Inadvertent occurrence in ABAB designs, psychophysical research, and as a cost-saving measure recently.
- ABAB designs involve assessment at baseline (A), following treatment (B), upon return to baseline (A), and again following treatment (B).
Conceptual Example: Hypothetical Burst Data

Multiple Burst Design with Intervention

Time

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Conceptual Example: Measurement Burst Design

Longitudinal Micro-genetic Models of Self-regulation

- Contextual influence (I)
- Action in response (A)
- Change in State (C)
- Feedback (F)

Micro-level

Motivation

School Outcomes

Molar-level

Conceptual Example: Intentionality

Early Life-span Intentionality

Age in years: 0.3, 0.7, 1.5, 2.5, 3.5, 4, ..., 7, 10+

- Encodes representations
- Exhibits novel intentions
- Apprehends others' intentions
- Experience with intention-action sequences
- Explains other's intentions
- Inception of joint assessments of affective and cognitive experience
- Differentiation of beliefs about one's agency
- Development of lasting global beliefs about one's agency
- Manages intentions through metacognition
- Inception of joint assessments of affective and cognitive experience

Micro-level

Molar-level

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Intentionality as even lower level processes

Infant Intentionality

Micro-level

Molar-level

R = Representation
E = Encoding
I = Intention
A = Intention-Action Sequence

0 Seconds
4.5 Seconds

Time in Years

Metacognition ~ Agentic Personality Traits

Agency

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Hoffman & Hofer

Cognition, Health, & Aging Project
PI: Martin Sliwinski, Syracuse University

- 106 adults age 65 – 95 years ($M = 80$)
- Within-burst: 6 occasions over 10 days
- Between-bursts: 6 bursts at 6-month intervals
- Simple & complex versions of 3 RT tasks:
  - Attention Switching $\rightarrow$ N-Count
    - Running count of 1 or 2 shapes
  - Processing Speed $\rightarrow$ Number-Match
    - Number strings of 3 or 5 digits same?
  - Working Memory $\rightarrow$ N-Back
    - Does current digit match that shown 1 or 2 back?
Conceptual Example: Hoffman and Hofer Burst Diagram

Hoffman & Hofer

Measurement Burst Designs: Distinguishing Retest & Change

Long-Term Change (6 bursts so far)

Burst 1
  Session 1 2 3 4 5 6
  6-10 Days

Burst 2
  Session 1 2 3 4 5 6
  6-10 Days

Burst 3
  Session 1 2 3 4 5 6
  6-10 Days

Short-Term Change

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Could it be that certain phenomena inherently reside at various timescales, and is this lawful? (Newell, formerly at Carnegie Mellon)

<table>
<thead>
<tr>
<th>Scale (sec)</th>
<th>Time Units</th>
<th>System</th>
<th>World (theory)</th>
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<tbody>
<tr>
<td>$10^7$</td>
<td>Months</td>
<td></td>
<td>SOCIAL BAND</td>
</tr>
<tr>
<td>$10^5$</td>
<td>Weeks</td>
<td></td>
<td></td>
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<tr>
<td>$10^6$</td>
<td>Days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$10^4$</td>
<td>Hours</td>
<td>Task</td>
<td>RATIONAL BAND</td>
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<td>$10^3$</td>
<td>10 min</td>
<td>Task</td>
<td></td>
</tr>
<tr>
<td>$10^2$</td>
<td>Minutes</td>
<td>Task</td>
<td></td>
</tr>
<tr>
<td>$10^1$</td>
<td>10 sec</td>
<td>Unit task</td>
<td>COGNITIVE BAND</td>
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<td>100 ms</td>
<td>Deliberate act</td>
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</tr>
<tr>
<td>$10^{-2}$</td>
<td>10 ms</td>
<td>Neural circuit</td>
<td>BIOLOGICAL BAND</td>
</tr>
<tr>
<td>$10^{-3}$</td>
<td>1 ms</td>
<td>Neuron</td>
<td></td>
</tr>
<tr>
<td>$10^{-4}$</td>
<td>100 μs</td>
<td>Organelle</td>
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</table>
Could our cognitions about time be limited—do we even perceive certain levels or is time reconstructed automatically. Which is more important? Perceived time of an experience or actual? When? (Yaacov Trope, NYU)

Is memory encoding of events differential at different time scales (see Mehl volume, pp. 232-246). Are remarkable events at low time scales recorded better than unremarkable ones.

Many processes reside at multiple time scales…and on each time scale, monitoring can be varied.
Epistemological Aspect: Reactivity

- The Active-Passive continuum
- Movement toward more passive may not always be necessary, sometimes active may be good
- Device approach may have its own forms of reactivity
- Self-report seems very prone to reactivity.
TDLD Design Basics—Things to think through in Study Planning

- How many time points are needed to capture the dynamics of a phenomenon?
- Need to know something about the processes and to have a defined target model
- Possible approach for delayed effects such as booster programs, long-term decrement, etc.
TDLD Design Basics—Things to think through in Study Planning

- Do the phenomena naturally exist at varying time scales?
- Does the theory or previous results suggest that looking for information at other time scales is needed?
- Will analytical models support integration of information from multiple time scales?
- Can you NOTATE your design as shown earlier and develop a resource justification for it?
Analytical Options

- Multilevel model can be flexibly employed for this kind of study
- School stress example in Walls and Schafer 2006, chapter 1
- Pain data example in Walls, Barta, Stawski, Collyer and Hofer, 2013
- Two exercise science examples in Smith and Walls (under review)
Multilevel Concept in Practice

Cont./Choice relations

Variable by day mean levels
### Example Output

#### Type 3 Tests of Fixed Effects

<table>
<thead>
<tr>
<th>Effect</th>
<th>Num DF</th>
<th>Den DF</th>
<th>F Value</th>
<th>Pr &gt; F</th>
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<td>98</td>
<td>5.51</td>
<td>0.0200</td>
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<td>0.0200</td>
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Burst Effects in Pain

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Clustered components of person specific functional forms

Device based studies—smoking, alcohol, and...toothbrushing

Connecting with "Quantified Self" movement in the US

Pushing ahead with interdisciplinary center—looking for collaborative options—two international post-docs completed stays recently.