

Intensive Longitudinal Methods

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Intensive Longitudinal Methods: Mixed Models for Ecological Momentary Assessment (EMA) Data

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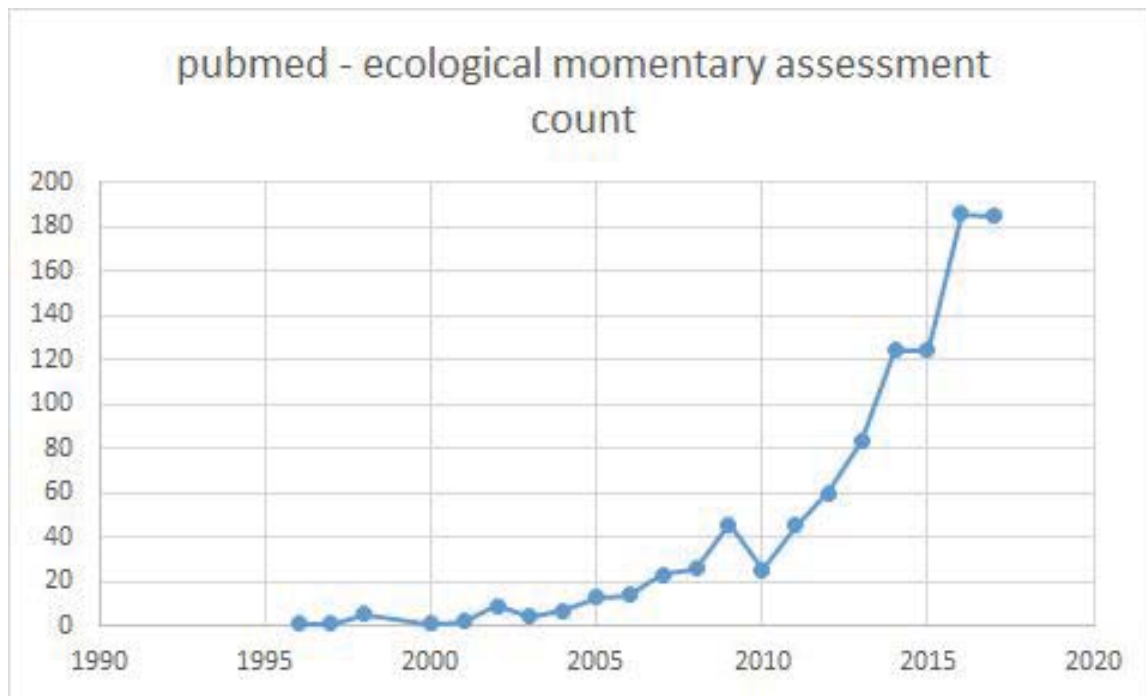
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Ecological Momentary Assessment (EMA) data

aka experience sampling and diary methods

- Subjects provide frequent reports on events and experiences of their daily lives (*e.g.*, 30-40 responses per subject collected over the course of a week or so)
- electronic diaries: palm pilots, personal digital assistants (PDAs), interactive voice response (IVR) systems, cell phones, actigraphs, web-based
- Capture particulars of experience in a way not possible with more traditional designs
e.g., allow investigation of phenomena as they happen over time
- Reports could be time-based, following a fixed-schedule, randomly triggered, event-triggered

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Per year counts of articles from a pubmed search

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Data are rich and offer many modeling possibilities!

- person- and occasion-level effects on occasion-level responses
 ⇒ potential influence of context and/or environment
e.g., subject response might vary when alone vs with others
- data are inherently multilevel
 - occasions (level-1) within subjects (level-2)
 - occasions (level-1) within days (level-2) within subjects (level-3)
 - occasions (level-1) within waves (level-2) within subjects (level-3)
- References for mixed model analysis of EMA data
 - Schwartz, J.E. & Stone, A. (2007). The analysis of real-time momentary data: A practical guide. In: A.A. Stone, S.S. Shiffman, A. Atienza, and L. Nebeling, editors, *The science of real-time data capture: Self-report in health research*. Oxford, England: Oxford University Press, p. 76-113.
 - Walls, T.A., Jung, H., & Schwartz, J.E. (2006). Multilevel models for intensive longitudinal data. In: Walls, T.A. and Schafer, J.L., editors, *Models for intensive longitudinal data*. New York: Oxford University Press, p. 3-37

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Mixed model applications

- To produce summary statistics, accounting for clustering of data
- Examine within-subject effect of time-varying covariates
- Examine why subjects differ in mean level as well as variability
 - between-subjects variance
 - e.g.*, subject heterogeneity could vary by gender or age
 - within-subjects variance
 - e.g.*, subject degree of stability could vary by gender or age
- To examine intercept and slope heterogeneity in terms of covariates
- Modeling of the timing of event reports
 - Time until first event in a day
 - Event times during and across days

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Ecological Momentary Assessment (EMA) Study of Adolescent Smokers (Mermelstein)

- 461 students completed the baseline measurement wave
- participants were in either 9th or 10th grade at baseline
- 55.1% female
- reported on a screening questionnaire 6-8 weeks prior to baseline that they had smoked at least one cigarette in their lifetime
- 57.6% smoked at least one cigarette in the past month at baseline
- written parental consent and student assent were required
- 57% were white, 20% hispanic, 16% black, and 7% of other race

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Random prompts and Smoking events

- Carry PDA for a week, answer questions when prompted
average = 30 answered prompts (median = 30, range = 7 to 71)
 $\sum_i^N n_i = 14,105$ total number of random prompts
- Subjects trained to to event record smoking episodes
234 subjects provided at least one smoking event
average = 4.9 smoking events (median = 3, range = 1 to 42)
 $\sum_i^N n_i = 1,142$ total number of smoking events
- Mutually exclusive
- $N = 234$, Spearman corr of n(random) with n(smoke) = -.08 (ns)

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Dependent Variables - Random prompt versions

- Positive Affect mood scale (mean=6.797 and sd=1.935)
 - Before signal: I felt Happy
 - Before signal: I felt Relaxed
 - Before signal: I felt Cheerful
 - Before signal: I felt Confident
 - Before signal: I felt Accepted by Others
- Negative Affect mood scale (mean=3.455 and sd=2.253)
 - Before signal: I felt Sad
 - Before signal: I felt Stressed
 - Before signal: I felt Angry
 - Before signal: I felt Frustrated
 - Before signal: I felt Irritable

⇒ items rated on 1 (not at all) to 10 (very much) scale

For smoking events, subjects rated mood before and after smoking

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Summary statistic for the outcomes

y_{ij} = affect level of subject i at occasion j

which mean do you report?

- $\bar{y}_{..}$ = mean ignoring clustering of data
- mean of $\bar{y}_{i.}$ = mean of subject-level means

are they different?

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suppose that there are two subjects with values

- 1
- 10, 10, 10, 10, 10, 10, 10, 10

- $\bar{y}_{..} = 9$
- mean of $\bar{y}_{i.} = 5.5$

⇒ Equal only if the number of obs is the same for all subjects
(which usually doesn't happen with EMA)

which to use?

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Neither!

Want some kind of estimate that takes into account

- clustering of data within subjects and correlation of the clustered observations
- varying numbers of observations per subject

Mixed model ($i = 1, 2, \dots, N$ subjects, and $j = 1, 2, \dots, n_i$ obs)

$$y_{ij} = \beta_0 + v_i + \epsilon_{ij} \quad \text{where } v_i \sim N(0, \sigma_v^2) \text{ and } \epsilon_i \sim N(0, \sigma_\epsilon^2)$$

$\hat{\beta}_0$ is such an estimate

\Rightarrow intercept in a mixed model with no covariates

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$$\hat{\beta}_0 = \frac{\bar{y}_{..} - \frac{1}{N^*} \sum_{i=1}^N n_i \rho_i \bar{y}_i}{1 - \frac{1}{N^*} \sum_{i=1}^N n_i \rho_i}$$

where

- $\rho_i = n_i r / [1 + (n_i - 1)r]$ = Spearman-Brown reliability
- $r =$ intraclass correlation $r = \frac{\sigma_v^2}{\sigma_v^2 + \sigma_\epsilon^2}$
- $N^* =$ total number of observations $= \sum_{i=1}^N n_i$

note,

$$\hat{\beta}_0 = \bar{y}_{..} \text{ if } n_i = n \text{ or } r = \rho_i = 0$$

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SAS MIXED syntax

```
PROC MIXED COVTEST;  
CLASS id;  
MODEL NegAff = / SOLUTION;  
RANDOM INTERCEPT / SUBJECT=id;
```

`id` = subject id variable

`NegAff` = negative affect (occasion-varying) score

⇒ mean, accounting for clustering, is intercept estimate

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Does it matter?

Random prompts ($N = 461, \sum n_i = 14105$)

	NA	PA
$\bar{y}_{..}$	3.455	6.797
Avg($\bar{y}_{i.}$)	3.485	6.777
mixed model $\hat{\beta}_0$	3.483	6.779

Smoking events, mood rating BEFORE smoking
($N = 234, \sum n_i = 1141$)

	NA	PA
$\bar{y}_{..}$	3.493	6.604
Avg($\bar{y}_{i.}$)	3.984	6.384
mixed model $\hat{\beta}_0$	3.908	6.411

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SAS example: MoodMeans.sas

```
DATA one; INFILE 'U:\Data\Robin\PreMoods\MoodRanPreSmk.dat';
INPUT id PosAff NegAff SmkE;
PROC FORMAT;
    VALUE SmkE 0 = 'Random' 1 = 'Smoke';

PROC SORT; BY SmkE;

/* raw mood means for random and smoking events */
PROC MEANS; VAR PosAff NegAff;
BY SmkE; FORMAT Smke Smke.;
RUN;
```

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----- SmkE=Random -----					
The MEANS Procedure					
Variable	N	Mean	Std Dev	Minimum	Maximum
PosAff	14105	6.7969656	1.9346636	1.0000000	10.0000000
NegAff	14105	3.4548458	2.2528845	1.0000000	10.0000000

----- SmkE=Smoke -----					
Variable	N	Mean	Std Dev	Minimum	Maximum
PosAff	1141	6.6036810	2.1001806	1.0000000	10.0000000
NegAff	1141	3.4934268	2.3633460	1.0000000	10.0000000

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```

/* means of subject mood means for random and smoking events */
PROC SORT; BY SmkE id;
PROC MEANS NOPRINT; BY SmkE id; VAR PosAff NegAff;
OUTPUT OUT = summdat MEAN(PosAff NegAff) = MPosAff MNegAff;
PROC MEANS DATA=summdat; VAR MPosAff MNegAff;
BY SmkE; FORMAT Smke Smke.;
RUN;

```

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----- SmkE=Random -----

The MEANS Procedure

Variable	N	Mean	Std Dev	Minimum	Maximum
MPosAff	461	6.7774679	1.2355936	2.3882353	9.8160000
MNegAff	461	3.4849921	1.5255682	1.0190476	8.1833333

----- SmkE=Smoke -----

Variable	N	Mean	Std Dev	Minimum	Maximum
MPosAff	234	6.3840328	1.7822418	1.5000000	10.0000000
MNegAff	234	3.9839033	2.1026653	1.0000000	9.8000000

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```

/* mixed model estimates of means - random prompts */
DATA random; SET one; IF SmkE=0;
PROC MIXED COVTEST;
CLASS id;
MODEL PosAff = / SOLUTION;
RANDOM INTERCEPT / SUBJECT=id;

PROC MIXED COVTEST;
CLASS id;
MODEL NegAff = / SOLUTION;
RANDOM INTERCEPT / SUBJECT=id;
RUN;

/* mixed model estimates of means - smoking events */
DATA smoke; SET one; IF SmkE=1;
PROC MIXED COVTEST;
CLASS id;
MODEL PosAff = / SOLUTION;
RANDOM INTERCEPT / SUBJECT=id;

PROC MIXED COVTEST;
CLASS id;
MODEL NegAff = / SOLUTION;
RANDOM INTERCEPT / SUBJECT=id;
RUN;

```

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The Mixed Procedure

Dimensions

Subjects	461
Max Obs Per Subject	71

Number of Observations

Number of Observations Used	14105
-----------------------------	-------

Covariance Parameter Estimates

Cov Parm	Subject	Estimate	Standard Error	Z Value	Pr > Z
Intercept	id	1.4451	0.1006	14.36	<.0001
Residual		2.3028	0.02788	82.60	<.0001

Solution for Fixed Effects

Effect	Estimate	Standard Error	DF	t Value	Pr > t
Intercept	6.7793	0.05756	460	117.78	<.0001

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Stata example: MoodMeans.do

```
cd "U:\Data\Robin\PreMoods"
log using MoodMeans.log, replace
infile id PosAff NegAff SmkE using MoodRanPreSmk.dat, clear

label define SmkElabel 0 "random prompt" 1 "smoke event"
label values SmkE SmkElabel

* get subject mood means for random and smoke
sort id SmkE
egen MPosAff = mean(PosAff), by(id SmkE)
egen MNegAff = mean(NegAff), by(id SmkE)

* get one mean per subject for random and smoke
bys id SmkE: replace MPosAff = . if _n>1
bys id SmkE: replace MNegAff = . if _n>1

local myvars "PosAff NegAff MPosAff MNegAff"
* raw mood means and mean of subject mood means for random and smoke
sort SmkE
by SmkE: summ `myvars'
```

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-> SmkE = random prompt

Variable	Obs	Mean	Std. Dev.	Min	Max
PosAff	14,105	6.796966	1.934664	1	10
NegAff	14,105	3.454846	2.252885	1	10
MPosAff	461	6.777468	1.235594	2.388235	9.816
MNegAff	461	3.484992	1.525568	1.019048	8.183333

-> SmkE = smoke event

Variable	Obs	Mean	Std. Dev.	Min	Max
PosAff	1,141	6.603681	2.100181	1	10
NegAff	1,141	3.493427	2.363346	1	10
MPosAff	234	6.384033	1.782242	1.5	10
MNegAff	234	3.983903	2.102665	1	9.8

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```

* mixed model estimates of means - random prompts
mixed PosAff if SmkE==0 || id:
mixed NegAff if SmkE==0 || id:
* mixed model estimates of means - smoking events
mixed PosAff if SmkE==1 || id:
mixed NegAff if SmkE==1 || id:

```

```
log close
```

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```

Mixed-effects ML regression          Number of obs   =   14,105
Group variable: id                  Number of groups =     461

Obs per group:
    min =          7
    avg =         30.6
    max =          71

Wald chi2(0)   =          .
Prob > chi2    =          .

Log likelihood = -26580.659

```

```

-----+-----
      PosAff |      Coef.   Std. Err.      z    P>|z|    [95% Conf. Interval]
-----+-----
      _cons |   6.779296   .0575026   117.90   0.000   6.666593   6.891999
-----+-----

```

```

-----+-----
Random-effects Parameters |      Estimate   Std. Err.    [95% Conf. Interval]
-----+-----
id: Identity              |
      var(_cons) |   1.442183   .1003463   1.258329   1.652899
-----+-----
      var(Residual) |   2.302813   .0278801   2.248813   2.358111
-----+-----

```

```
LR test vs. linear model: chibar2(01) = 5482.66      Prob >= chibar2 = 0.0000
```

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Why are the smoking means so different?

NA: $\bar{y}_{..} = 3.493$ $\text{Avg}(\bar{y}_{i.}) = 3.984$ $\hat{\beta}_0 = 3.908$ mixed model
PA: $\bar{y}_{..} = 6.604$ $\text{Avg}(\bar{y}_{i.}) = 6.384$ $\hat{\beta}_0 = 6.411$ mixed model

⇒ subjects with many smoking events have lower NA and higher PA

Consider $\mathbf{n_smk}_i$ (# of smoking events) as a regressor in a model of mood before smoking:

$$\text{Mood}_{ij} = \beta_0 + \beta_1 \mathbf{n_smk}_i + v_i + \epsilon_{ij}$$

NA: $\hat{\beta}_1 = -.0661$, $se = .019$, $z = -3.48$, $p < .0005$

PA: $\hat{\beta}_1 = .0311$, $se = .017$, $z = 1.87$, $p < .062$

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SAS example: MoodMeans.sas

```
/* get number of smoking events per subject */
PROC SORT DATA=one; BY id;
PROC MEANS NOPRINT; BY id; VAR SmkE;
    OUTPUT OUT = nummdat    SUM(SmkE) = NSmkE;
/* Select smoking events for subjects with smoking events */
DATA two; MERGE one nummdat; BY id;
IF NSmkE > 0 AND SmkE=1;
/* mixed model analysis of NegAff with NSmkE */
PROC MIXED COVTEST;
CLASS id;
MODEL NegAff = NSmkE / SOLUTION;
RANDOM INTERCEPT / SUBJECT=id;
RUN;
```

Stata example:MoodMeans.do

```
* mixed model analysis of NegAff with NSmkE
sort id
egen NSmkE = sum(SmkE), by (id)
mixed NegAff NSmkE if SmkE==1 || id:
```

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Example for exercises (Mermelstein et al, 2002)

- 8th or 10th graders carried hand-held computers during a seven consecutive day data collection period
- 17,514 random prompts from 515 students; average of 34 prompts per student (range = 3 to 58).
- Outcome is measure of the subject's positive mood (`posmood` mean=6.733, sd=2.117)
- Of interest is the degree of heterogeneity in positive mood in both WS and BS variation
- Covariates: `genderf` coded 0 for males and 1 for females; `alone` a prompt-varying covariate coded 0 if the subject was alone or 1 if with others

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`posmood_example.dat` (`id`, `posmood`, `alone`, `genderf`)

```
posmood_example.dat - Notepad
File Edit Format View Help
1 9.6667 0 1
1 10.0000 1 1
1 9.0000 0 1
1 7.3333 0 1
1 8.6667 0 1
1 10.0000 0 1
1 7.6667 1 1
1 5.6667 0 1
1 8.0000 0 1
1 6.6667 1 1
1 8.3333 1 1
1 7.6667 1 1
1 4.0000 1 1
1 8.0000 1 1
1 5.0000 1 1
1 9.3333 0 1
1 8.3333 0 1
1 7.6667 1 1
1 6.3333 1 1
1 7.3333 0 1
1 8.3333 1 1
1 7.0000 0 1
1 7.3333 1 1
1 6.6667 0 1
1 6.6667 1 1
1 4.3333 0 1
2 10.0000 0 1
2 9.3333 0 1
2 9.0000 0 1
2 3.6667 0 1
2 9.6667 0 1
2 10.0000 0 1
2 10.0000 1 1
2 10.0000 1 1
2 10.0000 0 1
2 10.0000 0 1
2 7.0000 0 1
2 10.0000 0 1
2 10.0000 0 1
2 10.0000 0 1
2 9.3333 0 1
2 10.0000 0 1
2 10.0000 1 1
2 7.0000 0 1
```

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Exercise

Using `posmood_example.dat` and either SAS or Stata

- Obtain raw means of `posmood` for with others and alone prompts
- Obtain mean of subject means of `posmood` for with others and alone prompts
- Obtain mixed model estimates of `posmood` means for with others and alone prompts

Do they differ?

need help?

syntax examples: `MoodMeans_posmood_example.sas`
and `MoodMeans_posmood_example.do`

Time-varying Covariates - WS and BS effects

Section 4.5.2 in Hedeker & Gibbons (2006), *Longitudinal Data Analysis*, Wiley.