Ecological Momentary Assessment and Active Living Research

Genevieve F. Dunton, PhD, MPH
Department of Preventive Medicine
University of Southern California
Workshop Outline

• Introduction to EMA

• Research questions that EMA can address

• How to design and conduct an EMA study

• EMA data management, processing, analysis

• Challenges and limitations with EMA research

• How EMA can inform the design of programs and policies to prevent childhood obesity
FUNDING:
Robert Wood Johnson Foundation-Active Living Research Program #RWJF 65837 (Dunton, PI).
National Cancer Institute #R01-CA-123243 (Pentz, PI).

PROJECT PERIOD:
Limitations of Recall and Observational Methods

Recall Instruments
- Memory errors and biases
- Not completed in the environment in which the behavior occurs

Observational Methods
- Often limited to a single setting
- Do not measure mood or subjective perceptions
Limitations of Objective Methods

Accelerometer
- Difficulty measuring activity type, load bearing, incline, bicycling, swimming

GPS
- Difficulty differentiating some modes of travel (scooter chair, wheel chair, stroller)
- Do not measure mood or subjective perceptions.
Ecological Momentary Assessment (EMA)

- Real-time responses in naturalistic settings
- Can simultaneously measure:
  1) Activity type (soccer, watching TV)
  2) Where (playground, trail, sidewalk)
  3) With whom (alone, friends, siblings)
  4) Perceived characteristics (safety, traffic, etc)
  5) Mood (positive affect, negative affect, stress)
Benefits of Electronic EMA

• Reduced memory errors and biases
• Multiple observations across the day
• Ecological validity
• Time-stamped
• No manual data entry
Objective 1: Measure Physical Activity and Sedentary Behavior

• How frequently?
• When?
• What intensity?
• What duration?
• What type?
• Weight bearing?
• Incline?
Validity of EMA Activity Responses
(30-min. before EMA prompt)

Objective 2: Describe the Contexts of PA and Sedentary Behavior

- Where?
- With whom?
- Do these patterns differ according to?
  - Demographic factors (sex, age, ethnic, income)
  - Temporal factors (time of day, day of the week, seasons)
Outdoor Location of Physical Activity

Age and Income Differences in Physical Activity Contexts

Objective 3: Examine Differences in PA Across Contexts

• How do physical activity levels (e.g., intensity, duration) differ across physical and/or social contexts?

• How do physical activity experiences (e.g., enjoyment, positive and negative affect) differ across physical and/or social contexts?
Physical Activity Level by Social Context
(30-min. before EMA prompt)

![Bar chart showing physical activity levels by social context.]

Physical Activity Level by Physical Context
(30-min. before EMA prompt)

Objective 4: Investigate Antecedents, Concomitants, Consequences of PA Episodes

- Is the likelihood of participating in a physical activity bout related to prior or current mood, stress, pain, fatigue, etc?

- Does participating in a physical activity bout influence subsequent predict subsequent mood, stress, pain, fatigue, etc?
Conceptual Model of Temporal Relationships

7:45am MVPA
SE
PA
NA
Energy
Fatigue
Demand
Control

11:45am MVPA
SE
PA
NA
Energy
Fatigue
Demand
Control

3:45pm MVPA
SE
PA
NA
Energy
Fatigue
Demand
Control

7:45pm MVPA
SE
PA
NA
Energy
Fatigue
Demand
Control

Lagged Effects
Objective 5: Examine Daily and Within-Daily Variability in PA

- Do some people have stable patterns of activity across the day whereas other people’s patterns are variable?

- Does day-to-day variability in physical activity change during an intervention?

- Are patterns of daily and within-daily variability in physical activity related to health outcomes?
Electronic EMA
Equipment/Technology

- Mobile phone
- Personal Digital Assistant (PDA)
- Internet (Laptop, Desktop, iPad)
Mobile Phone Options

• Purchase new with voice/data plan
• Purchase new without voice/data plan
• Purchase unlocked and upload software
  - eBay or Tiger Direct
  - need to purchase separate warranty
• Use participants’ SIM cards on research phone (AT&T or T-Mobile)
• Use participants’ phones
EMA Data Collection Platforms

Electronic Surveys (written text)
1. Internal Programs/Applications (resident on a mobile device)
2. External Programs/Applications (web resident that a web-accessing mobile device connects to)
3. SMS (text-messaging)

Interviews (spoken word)
1. Live phone calls from trained research staff
2. Automated Interactive Voice Response (IVR) software (SpeechMaster; Speechsoft)
EMA Data Collection Platforms - Electronic Surveys

Internal Programs/Applications

- iPAQ PDA- Context-Aware Experience Sampling (CAES) (open source) ([http://web.mit.edu/caesproject/CAES/design.htm](http://web.mit.edu/caesproject/CAES/design.htm))
- Palm Zire or Palm Zire 21- Transactional Electronic Diary (TED) software ([Vahabzadeh et al. 2004](http://vahabzadeh.com/)).
- Hire programmer to develop new program
MyExperience is a context-aware data collection platform for capturing objective and subjective data as it's experienced.
self-report surveys

The beta version of MyExperience provides fourteen separate survey response widgets (a selection of which are shown below) from radio button lists and text fields to widgets that allow the subject to take pictures, video, or even to record their responses audibly. This response data is stored in a local database on the mobile device which can be synchronized wirelessly via WiFi or the cellular networks to the research team’s servers.

Figure 2. MyExperience allows researchers to specify a variety of self-report response widgets to gather both closed-form (e.g., likert scale) and open-form data (e.g., audio recordings). Click on a screenshot above to get a larger resolution version.
The XML file below demonstrates how a researcher would program MyExperience for a study relating heart rate and perceived levels of pain. Note that the file is only around 50 lines long (including comments) and collects both sensor and user response data. Here, two sensors are used: a GPS sensor and a heart rate sensor. A trigger is constructed to invoke a "pain survey" whenever the subject’s heart rate exceeds 150 beats per minute. The pain survey involves two questions: the first asks if the subject is currently experiencing pain and, if so, the follow-up question asks for a verbal description of this pain. The heart rate, location data, and survey responses are automatically recorded to a SQL database on the phone that can be automatically synchronized with a server-side database.

```xml
<?xml version="1.0" encoding="utf-8"?>
<myexperience name="PainStudy" version="1.0">
<sensor name="LocationSensor" type="GpsSensor"/>
<sensor name="HeartSensor" type="HeartRateSensor"/>
</sensor>
<actions>
<property name="EntryQuestionId">PainLocation</property>
</actions>
<triggers>
<trigger name="HeartRateTrigger" type="Trigger">
<script>
hrSensor = GetSensor("HeartSensor");
if(hrSensor.StateEntered > 150) {
    painSurveyAction = CreateAction("PainSurvey");
}
</script>
```
EMA Data Collection Platforms

**SMS Messaging**

- GSM Mobile Phone- Frontline SMS (open source) ([http://www.frontlinesms.com/](http://www.frontlinesms.com/))

Data Transfer and Storage Options

• Store on phone’s internal hard drive or SIM card and download after phone is returned
  - Needs to be secure
  - Potential for data loss
  - Need turn-around time

• Transfer wirelessly to secure research server
  - Real-time info and feedback
  - Need mobile data coverage
  - Security issues
EMA Sampling Schedule

- **Event-contingent** - information recorded during or after a pre-determined behavior.
- **Context-contingent** – information recorded when a context or environment is sensed (GPS, heart rate, etc).
- **Interval-contingent** - information recorded according to a specific pre-set time frames (e.g., at 8am and 12noon everyday).
- **Signal-contingent** – information recorded when prompted, often at random times throughout the day.
Example EMA Sampling Schedule (Interval-Signal Contingent Hybrid)

- Monitoring occurred across 4 days (Fri-Mon) for each wave.
- No prompts during school hours on Friday or Monday.

<table>
<thead>
<tr>
<th>Day</th>
<th>8:30-10am</th>
<th>10am-12pm</th>
<th>12-2pm</th>
<th>2-4pm</th>
<th>4-6pm</th>
<th>6-8pm</th>
<th>8-8:30pm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Friday</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Saturday</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Sunday</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Monday</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Question sequences were prompted at a random time within each interval.
EMA Items

- Current Activity
- Mood
- Fatigue/Energy
- Physical Context (i.e., location)
- Social Context (i.e., company)
- Posture (sitting, standing)
- Perceived Exertion
- Enjoyment of Current Activity
- Duration of Current Activity
- Intrinsic Motivation
- Perceived Vegetation, Safety, Traffic
Please stop what you are doing for a survey. Press the button under the word BEGIN to get started.

What were you DOING right before the beep went off? (Choose your main activity)
1. Reading, Computer, or Homework
2. Watching TV/Movies
3. Playing video games
4. Active Play, Sports, or Exercising
5. Other

What was this OTHER activity?
1. Eating/Drinking
2. Talking/On the phone
3. Chores
4. Riding in a car
5. Something else

WHERE were you just before the beep went off?
1. Home
2. School
3. Car/Van/Truck
4. Outdoors
5. Other

Were you ALONE just before the beep went off?
1. Yes
2. No

Were you with your MOM or DAD just before the beep went off?
1. Yes
2. No
EMA Items

Survey
How STRESSED were you feeling just before the beep went off?
1. ◯ Not at all
2. ◯ A little
3. ◯ Quite a bit
4. ◯ Extremely

Survey
How did you get here?
1. ◯ Walked
2. ◯ Rode my bike
3. ◯ Car/Van/Truck
4. ◯ Bus/Subway/Train

Survey
How many TREES AND PLANTS are there in the area where you are right now?
1. ◯ No trees or plants
2. ◯ Some trees and plants
3. ◯ A lot of trees and plants

Survey
How much TRAFFIC is on the closest street to where you are right now?
1. ◯ No traffic
2. ◯ A little traffic
3. ◯ A lot of traffic

Survey
How SAFE do you feel where you are right now?
1. ◯ Unsafe
2. ◯ Somewhat safe
3. ◯ Very safe

That's it! Thank you.
You have earned $1 for doing this survey.
Issues to Consider with EMA Items

• Time frame
  - Right now, before the signal, in the past few hours

• Order (mood items first)

• Length of question

• Number of response options (no more than 5)

• Skip sequences and branching

• Assessed every time or on a pre-programmed schedule
Practical Issues

- Reminder prompts for unanswered and unfinished entries
- Phone requires nightly charging
- Contact call and/or reminder text to encourage compliance and assess problems
- Study hotline available for technical problems
- Monetary compensation to promote compliance
Complementary Assessments

- Accelerometer/Heart Rate
- GPS
- Photographs/videos
- Audio recording
- UV assessments
- Air pollution monitoring
Data Linking

- Use internal electronic time stamps
- One-to-one linking (if same epoch or interval)
- One-to-many linking (if different epochs or intervals)
  - Create windows surrounding/before/after the EMA prompt
  * Time only
  * Time and spatial
## Time-Matching of EMA and Accelerometer Data (+/- 15 min Window)

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity Ct.</th>
<th>MVPA</th>
<th>Steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>15:58:18</td>
<td>243</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td>15:59:18</td>
<td>2,541</td>
<td>1</td>
<td>166</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ID</th>
<th>Prompt Time</th>
<th></th>
<th>MVPA min</th>
<th>Tot Steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>12009</td>
<td>16:13:18</td>
<td></td>
<td>5</td>
<td>960</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time</th>
<th>Activity Ct.</th>
<th>MVPA</th>
<th>Steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>16:27:18</td>
<td>56</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>16:28:18</td>
<td>2,199</td>
<td>1</td>
<td>154</td>
</tr>
</tbody>
</table>
## Data Management

### Initial Structure of Data Set

<table>
<thead>
<tr>
<th>Participant ID</th>
<th>Time</th>
<th>Self-Efficacy</th>
<th>Stressful Events</th>
<th>MVPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID1</td>
<td>1 (7:45am)</td>
<td>X1</td>
<td>X1</td>
<td>Y1</td>
</tr>
<tr>
<td>ID1</td>
<td>2 (11:45am)</td>
<td>X2</td>
<td>X2</td>
<td>Y2</td>
</tr>
<tr>
<td>ID1</td>
<td>3 (3:45pm)</td>
<td>X3</td>
<td>X3</td>
<td>Y3</td>
</tr>
<tr>
<td>ID2</td>
<td>1 (7:45am)</td>
<td>X1</td>
<td>X1</td>
<td>Y1</td>
</tr>
<tr>
<td>ID2</td>
<td>2 (11:45am)</td>
<td>X2</td>
<td>X2</td>
<td>Y2</td>
</tr>
</tbody>
</table>
## Data Management

**Modified Data Structure for Lagged Analysis**

<table>
<thead>
<tr>
<th>Participant ID</th>
<th>Time (T)</th>
<th>Self-Efficacy (T-1)</th>
<th>Stressful Events (T)</th>
<th>MVPA (T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID1</td>
<td>1 (7:45am)</td>
<td>---</td>
<td>X1</td>
<td>Y1</td>
</tr>
<tr>
<td>ID1</td>
<td>2 (11:45am)</td>
<td>X1</td>
<td>X2</td>
<td>Y2</td>
</tr>
<tr>
<td>ID1</td>
<td>3 (3:45pm)</td>
<td>X2</td>
<td>X3</td>
<td>Y3</td>
</tr>
<tr>
<td>ID1</td>
<td>4 (7:45pm)</td>
<td>X3</td>
<td>X4</td>
<td>Y4</td>
</tr>
</tbody>
</table>
## Modified Data Structure

<table>
<thead>
<tr>
<th>Participant ID</th>
<th>Time (T)</th>
<th>Self-Efficacy (T-1)</th>
<th>Stressful Events (T)</th>
<th>MVPA (T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID1</td>
<td>1 (7:45am)</td>
<td>---</td>
<td>X1</td>
<td>Y1</td>
</tr>
<tr>
<td>ID1</td>
<td>2 (11:45am)</td>
<td>X1</td>
<td>X2</td>
<td>Y2</td>
</tr>
<tr>
<td>ID1</td>
<td>3 (3:45pm)</td>
<td>X2</td>
<td>X3</td>
<td>Y3</td>
</tr>
<tr>
<td>ID1</td>
<td>4 (7:45pm)</td>
<td>X3</td>
<td>X4</td>
<td>Y4</td>
</tr>
</tbody>
</table>

Lagged Effect  
Concurrent Effect
Data Analysis

Multilevel modeling - takes into account clustering of observations within people

- SAS (PROC Mixed/PROC NL Mixed)
- HLM (Bryk & Raudenbush)
- SPSS (Mixed Models)
- SUDAAN (SEMETHOD=zeger)
Multilevel Equations

Level 1 (Within-Person Level):

$$\pi_{0jk} (Y) = \beta_{00k} + \beta_{01k} (X) + r_{0jk} \quad \text{(separate equation for each person)}$$

Level 2 (Person Level):

$$\beta_{00k} = \gamma_{000} + \gamma_{001} \text{(age)} + \gamma_{002} \text{(gender)} + \mu_{00k}$$
$$\beta_{01k} = \gamma_{010} + \gamma_{011} \text{(age)} + \gamma_{012} \text{(gender)} + \mu_{01k}$$
Multilevel Equations

Level 1 (Within-Person Level):

\[ \pi_{0jk}(Y) = \beta_{00k} + \beta_{01k}(X) + r_{0jk} \]

Level 2 (Person Level):

\[ \beta_{00k} = \gamma_{000} + \gamma_{001}(\text{age}) + \gamma_{002}(\text{gender}) + \mu_{00k} \]
\[ \beta_{01k} = \gamma_{010} + \gamma_{011}(\text{age}) + \gamma_{012}(\text{gender}) + \mu_{01k} \]
Challenges and Limitations

- Missing data
- Disruptions
- Reactance
- Participant burden
- Costs
Available Data

**Initial Enrollment**
Level 2: 121 participants
Level 1: 2,420 survey prompts

Data Loss

- Removed from study due to missing memory card (Level 2: 1 participant, Level 1: 20 surveys)

**Surveys Programmed**
Level 2: 120 participants
Level 1: 2,400 survey prompts

- Participant received phone after 1st prompt on Fri. (Level 1: 12 surveys)
- Phone powered off or battery drain (Level 1: 90 surveys)
- Unknown technical issues (e.g., software crash) (Level 1: 34 surveys)

**Surveys Received**
Level 2: 120 participants
Level 1: 2,264 survey prompts

- Missing accelerometer data (e.g., initializing/downloading problems) (Level 2: 6 participants, Level 1: 120 surveys)
- Accelerometer non-wear (Level 2: 3 participants, Level 1: 376 surveys)

**Surveys Matched**
Level 2: 111 participants
Level 1: 1,768 survey prompts

- Unanswered prompts (e.g., did not hear signal, incompatible activity, chose not to answer) (Level 1: 326 surveys)

**Matched Surveys - Answered**
Level 2: 111 participants
Level 1: 1,442 survey prompts
EMA Survey Compliance

- Children answered 80% (range 7% – 100%) of EMA surveys that could be matched to accelerometer data.

- Unanswered surveys were less common among White/Caucasian children (11%) as compared with African-American (21%), Asian (22%), Mixed/Biracial (22%), and Other (25%).

- No differences by day of the week, time of day, sex, age, income or weight status.
Unanswered EMA Surveys
(30-min. before EMA prompt)

Extent to Which EMA Surveys Disrupted Activity
(15 min. before/after the EMA prompt)

Participant Reactance

Problem
- Multiple assessments may make participant more aware of behaviors, emotions, cognitions

Solutions
- Limit number of assessments
- Assess multiple type of behaviors
- Do not assess behavior-specific cognitions


Participant Burden

• Too many or too repetitive questions can lead to burden or boredom

Consequences
- Unanswered surveys
- Mindless answering of surveys
- Choosing first item response
- Having another person complete survey

Solutions
- Limit items
- Change order of questions
- Choose random subset of items for each survey
Costs

• Cost of equipment
  - Mobile phone: $50-$500

• Cost of voice/data plan (w/mobile provider)
  - $20-$100 per month per phone

• Cost of programming and maintenance
  - Modify existing program $1000+
  - New program $5000+

• Cost of research personnel
  - Project manager/assistants (nights/weekends)
Potential to Inform Obesity Prevention

- Identify emotional and motivational triggers
- Develop context-specific interventions and policies
- Inform Ecological Momentary Interventions (EMIs)
  - Real-time prompting to influence problem-solving, decision-making, and behavioral processes

Hurling R; Catt M; Boni MD; Fairley BW; Hurst T; Murray P; Richardson A; Sodhi JS. Using internet and mobile phone technology to deliver an automated physical activity program: randomized controlled trial. *Journal of Medical Internet Research*, 2007 9,7.

Further References

General EMA Research


EMA Research Specific to Physical Activity


• Rofey et al. Utilizing ecological momentary assessment in pediatric obesity to quantify behavior, emotion, and sleep. *Obesity*, 2010 18,1270-2.

Acknowledgments

• Co-Investigators: Mary Ann Pentz, Ph.D (USC)
  Donna Spruijt-Metz, Ph.D (USC)
  Jennifer Wolch, Ph.D (UCB)
• Consultant: Stephen Intille, Ph.D (MIT)
• Programming: Jennifer Beaudin (MIT)
• Ph.D Student: Yue Liao
• Project Manager: Keito Kawabata
• Active Living Research Rapid Response Grant (RWJF # 65837) (Dunton, PI)
• Active Living Research Accelerometer Loan Program
Thank You