# Understanding the dynamics of physical activity using ecological momentary assessment methods

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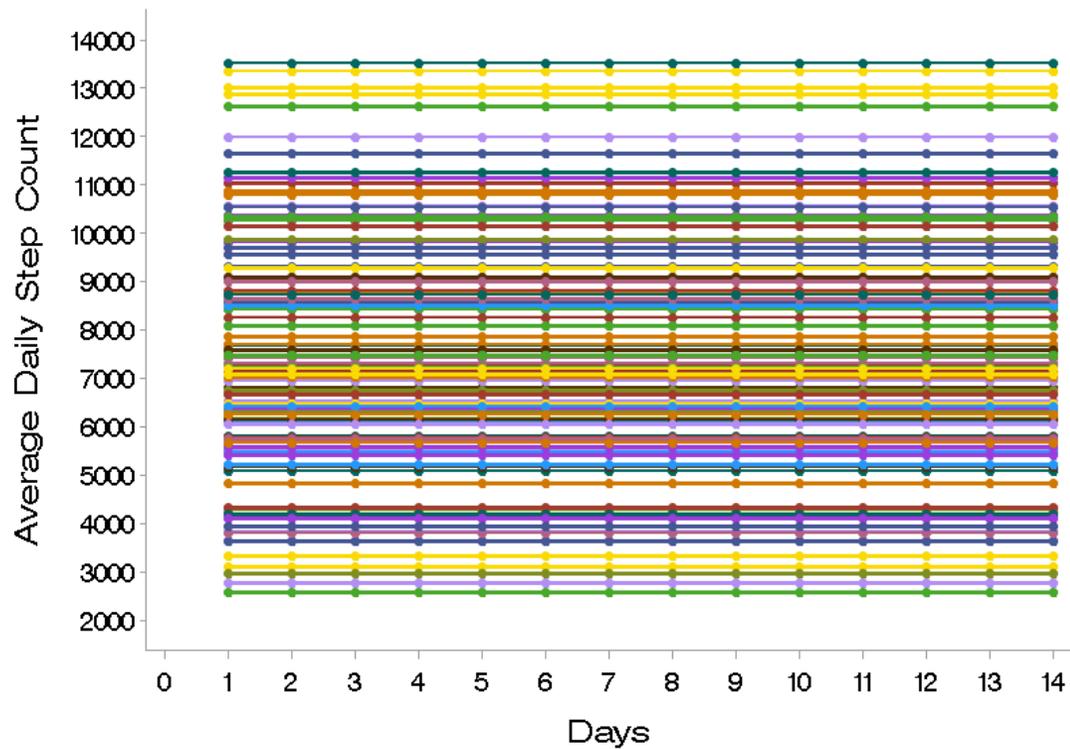
Differences between more or less active *people*
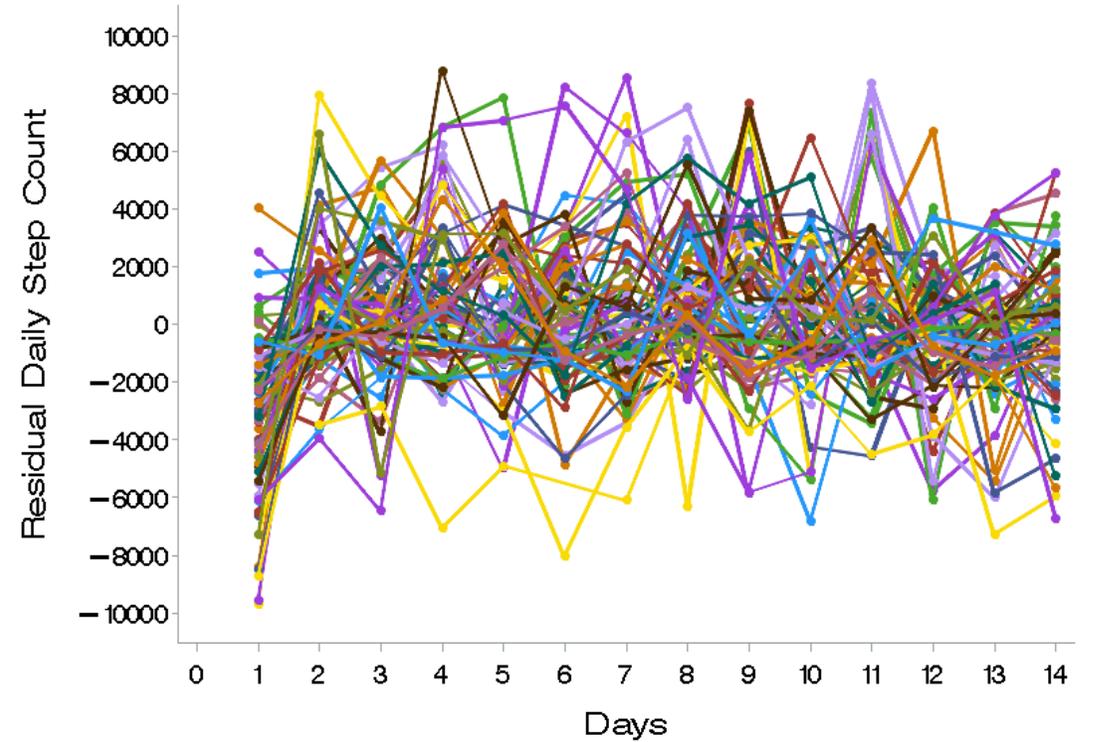
Differences between more or less active *days*

Physical activity is a repeated-occurrence health behavior but many of our popular health behavior theories were adapted from theories designed to explain limited-occurrence health behaviors.

Physical activity is performed on a frequent basis, for extended periods of time (ideally across the lifespan)

Ecological Momentary Assessment (EMA) is a real-time data capture strategy where participants are repeatedly assessed in the context of everyday life.

- Improves ecological validity of findings

- Reduces recall biases

- Allows for the analysis of processes over time

EMA encompasses a range of methods.
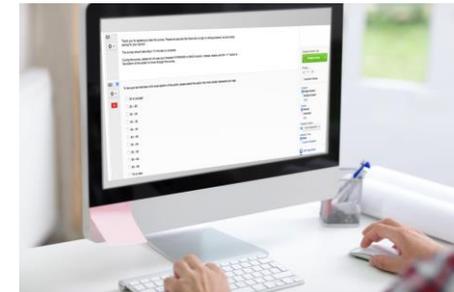
(Stone & Shiffman, 1994; Stone, Shiffman, & Hufford, 2008)

Ecological Momentary Assessment (EMA) is a real-time data capture strategy where participants are repeatedly assessed in the context of everyday life.

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EMA encompasses a range of methods.

(Stone & Shiffman, 1994; Stone, Shiffman, & Hufford, 2008)

A major motivation for EMA is to avoid the pitfalls and limitations of reliance on autobiographical memory.

Percent of adults who meet US Federal Physical Activity Guidelines

	8.1 - 18.9
	19.0 - 20.3
	20.4 - 22.7
	22.8 - 26.2
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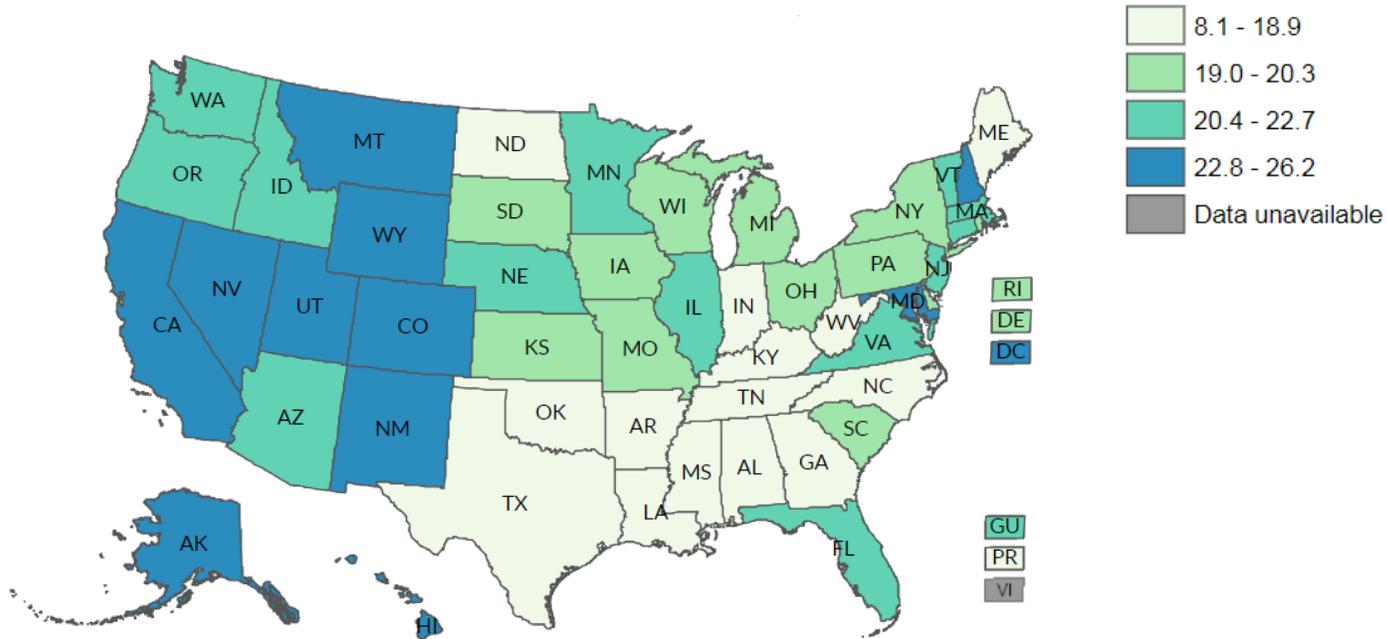
Behavior Risk Factor Surveillance System, 2015

- During the past month, other than your regular job, did you participate in any physical activities or exercises such as running, calisthenics, golf, gardening, or walking for exercise?

  o When you took part in physical activity, for how many minutes or hours did you usually keep at it?

- During the past month, how many times per week or per month did you do physical activities or exercises to STRENGTHEN your muscles?

Traditional research methods have participants aggregate and summarize their experiences.
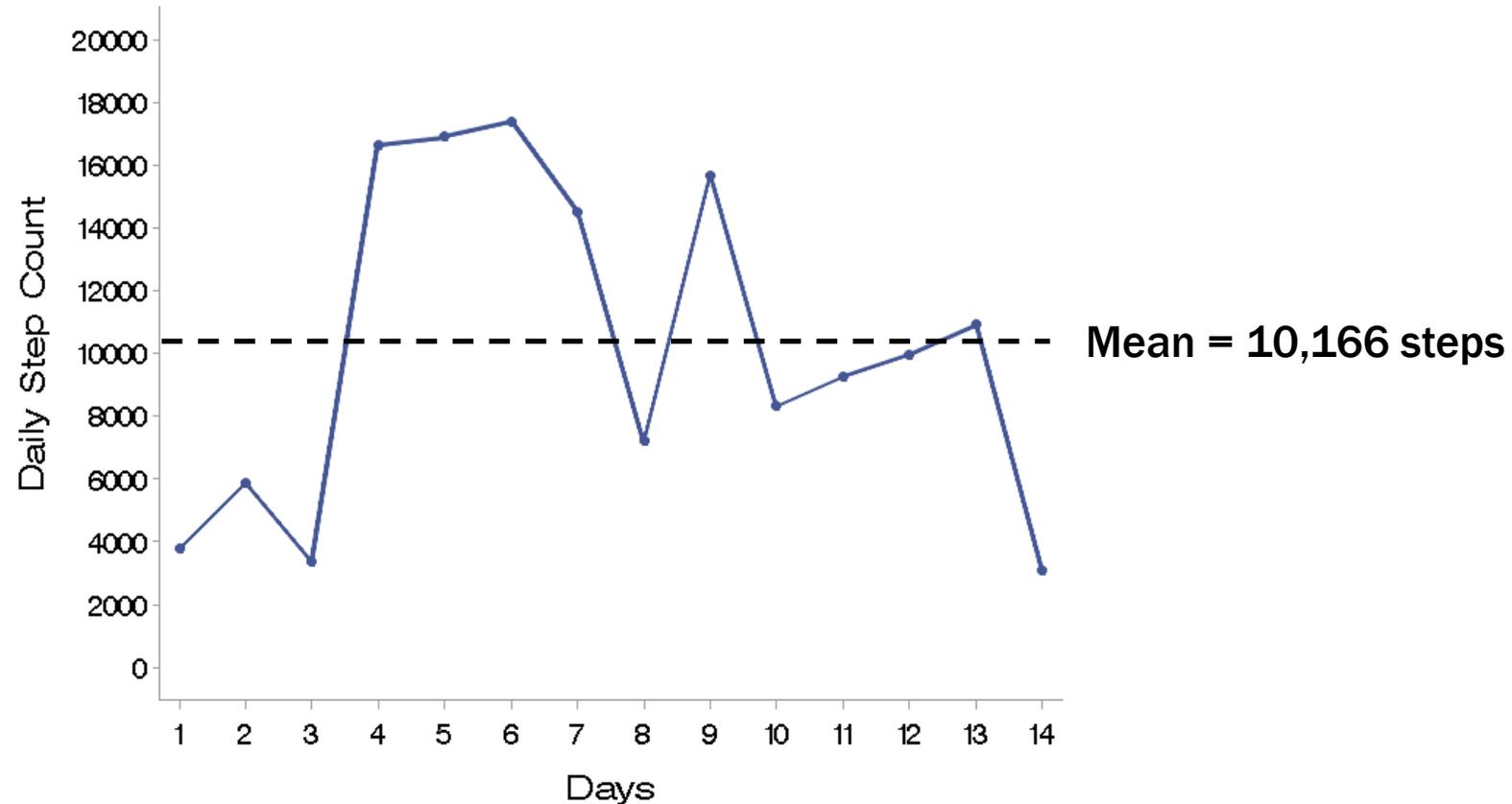
The mean doesn't accurately represent behavior on any given day.

The goal of EMA is to capture moments representative of subjects' experience, so how can the sampling scheme be designed to capture those moments?

Signal-contingent: aim to characterize experiences more broadly and inclusively without predefined focus on discrete events

Event-contingent: do not aim to characterize subjects' entire experience, but rather focus on particular discrete events or episodes

The most important influence on the design must be the aims of the study.

Three primary ways in which EMA can help us advance the field of physical activity research are:

I. **Sequentiality:** The temporal sequence of antecedents to and consequences of health behaviors.

II. **Synchronicity:** The extent to which explanatory factors co-occur in time and space with health behaviors.

III. **Instability:** Patterns of change and fluctuations in explanatory factors and health behaviors.

(Dunton, 2017)

What are the practical questions we can ask to advance our understanding of health behaviors?

I. Sequentiality

- What are the bi-directional relationships between momentary affective and physical feeling states and physical activity?

II. Synchronicity

- Does being alone or with others impact a person's affective experience during physical activity and sedentary behavior?

III. Instability

- Does subject-level variability in affective and physical feeling states impact adults odds of meeting physical activity guidelines?

Sequentiality: Research suggests bi-directional relations exist between affective and physical feeling states and activity-related behaviors.

The majority of work investigating these bi-directional relations has taken place in controlled laboratory settings.

EMA studies have investigated these bi-directional relations among adolescents and adults.

Objective: investigate acute bi-directional relationships between affective and physical feeling states and activity-related behaviors among older adults in the context of everyday life.

Older adults completed a 10-day ecological momentary assessment study.

N= 104 (72% Women, M age = 72, Range 60-98)

A 10-day EMA study with 6 prompts per day assessing current behavior and affective states.

8:00 AM · 8:23 AM · 11:09 AM · 12:44 PM · 2:27 PM · 5:31 PM · 6:04 PM · 8:00 PM
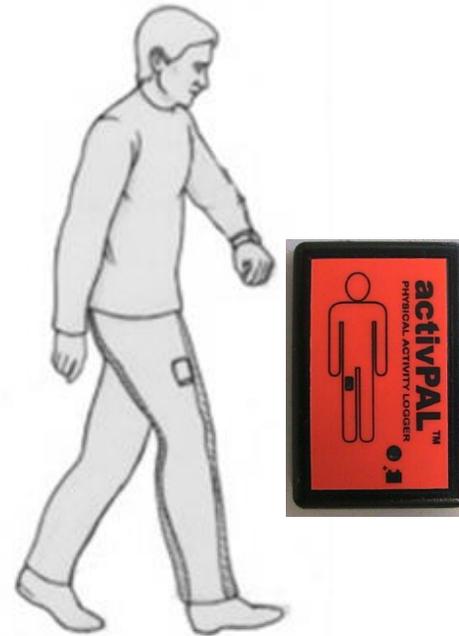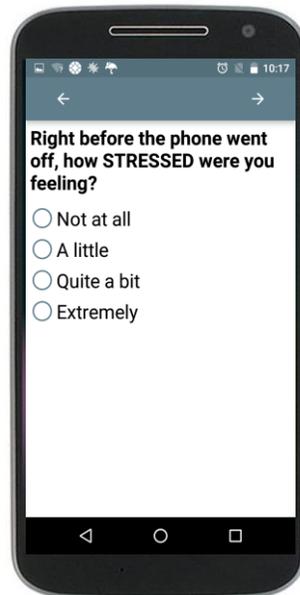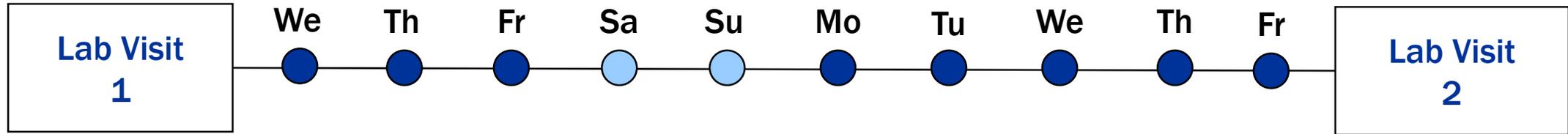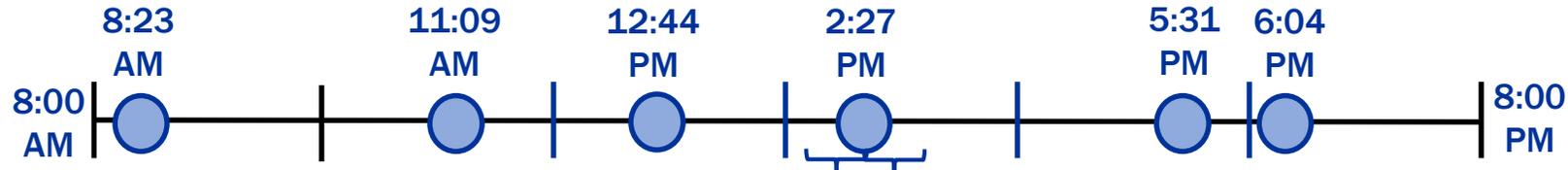
Physical Activity = total minutes of stepping in the 15 minutes before or after the prompt

Composite **positive affect** was averaged based on three items:
Happy
Cheerful
Calm/Relaxed

Right before the phone went off, how HAPPY were you feeling?
○ Not at all
○ A little
○ Quite a bit
○ Extremely

M = 2.65

Positive Affect

Right before the phone went off, how ENERGETIC/FULL OF PEP were you feeling?
○ Not at all
○ A little
○ Quite a bit
○ Extremely

M = 2.46

Feelings of Energy

Feelings of Energy was assessed using a single-item

On occasions when older adults engaged in more standing than was typical for them in the 15 minutes prior to the EMA prompt, they tended to report greater feelings of energy at the prompt.

	Positive Affect Estimate (SE)	Feelings of Energy Estimate (SE)
Intercept	1.81* (0.46)	2.07* (0.46)
BS Standing	0.02 (0.02)	0.05* (0.02)
WS Standing	0.01 (0.01)	0.01* (0.001)
Lag Affective/Physical Feeling State	0.26* (0.01)	0.23* (0.01)

On occasions when older adults engaged in more stepping than was typical for them in the 15 minutes prior to the EMA prompt, they tended to report greater feelings of energy at the prompt.

	Positive Affect Estimate (SE)	Feelings of Energy Estimate (SE)
Intercept	1.92* (0.51)	2.24* (0.52)
BS Stepping	-0.07 (0.19)	-0.06 (0.19)
WS Stepping	0.01 (0.01)	0.10* (0.01)
Lag Affective/Physical Feeling State	0.26* (0.01)	0.23* (0.01)

Momentary positive affect was unrelated to subsequent time spent stepping as well as time spent standing.

	Standing Estimate (SE)	Stepping Estimate (SE)
Intercept	3.54* (1.10)	1.23* (0.16)
BS Positive Affect	0.10 (0.17)	-0.01 (0.02)
WS Positive Affect	-0.03 (0.10)	0.02 (0.02)
Lag Standing/Stepping	0.53* (0.01)	0.33* (0.01)

On occasions when older adults reported greater feelings of energy than was typical for them, they engaged in more standing and more stepping in the 15 minutes following the EMA prompt.

	Standing Estimate (SE)	Stepping Estimate (SE)
Intercept	3.49* (1.08)	1.23* (0.16)
BS Energy	0.38* (0.17)	-0.02 (0.02)
WS Energy	0.22* (0.08)	0.04* (0.01)
Lag Standing/Stepping	0.52* (0.01)	0.33* (0.01)

Feelings of energy appear to be strongly linked to activity-related behaviors in older adults; however, this was not the case for positive affect.

These findings may indicate the optimal timing for the delivery of just-in-time intervention messaging to increase standing or moving

Content to increase activity may be most effective when older adults already feel more energetic or when they need to feel more energetic

What are the practical questions we can ask to advance our understanding of health behaviors?

I. Sequentiality

- What are the bi-directional relationships between momentary affective and physical feeling states and physical activity?

II. Synchronicity

- Does being alone or with others impact a person's affective experience during physical activity and sedentary behavior?

III. Instability

- Does subject-level variability in affective and physical feeling states impact adults odds of meeting physical activity guidelines?

Synchronicity: Affective response to physical activity and sedentary behavior may differ depending on the physical and social context.

To date few studies have examined affective-response to physical activity among older adults and those that have revealed inconsistent findings.

Physical Context   Social Context
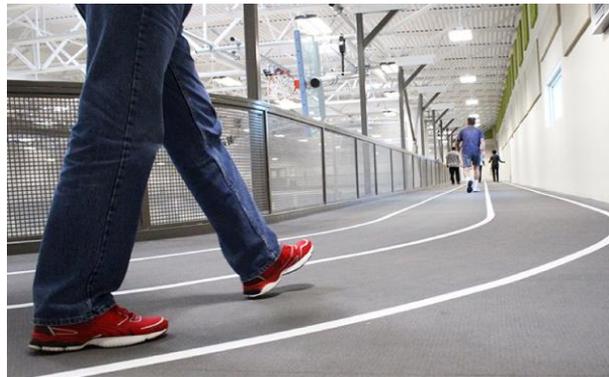
Indoors   Outdoors   Alone   With Others

Objective: examine social and physical contextual influences on older adults' momentary affective response to activity-related behaviors in naturalistic settings.

Older adults completed a 10-day ecological momentary assessment study.

N= 104 (72% Women, M age = 72, Range 60-98)

A 10-day EMA study with 6 prompts per day assessing current behavior and affective states.

Physical Activity = total minutes of stepping in the 30-min window (±15 min) around the prompt
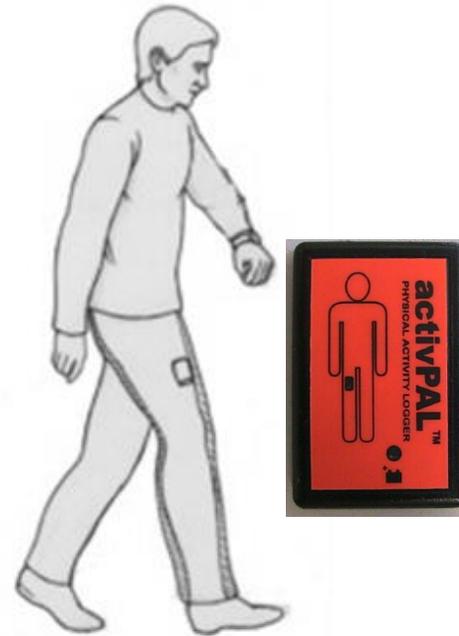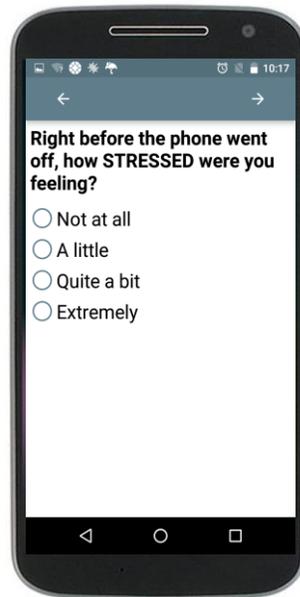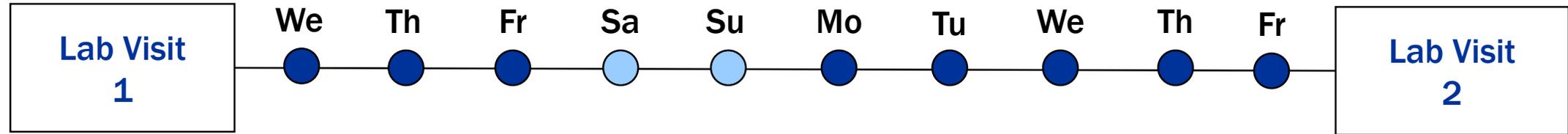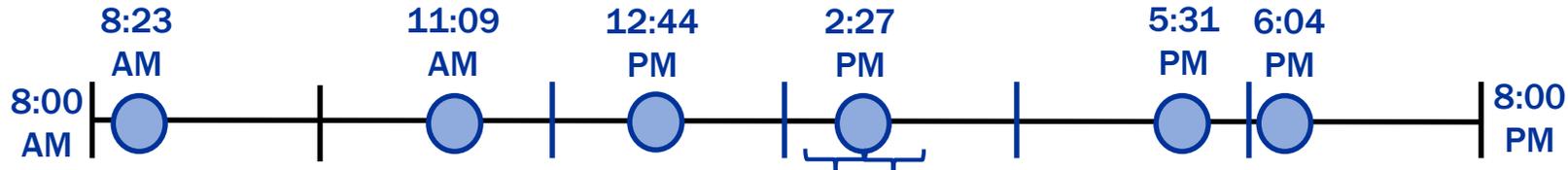
Sedentary Behavior = total minutes of sitting in the 30-min window (±15 min) around the prompt

Current Behavior		Social Context	Physical Context	Positive Affect	Negative Affect
What were you doing right before the phone went off? ○ Reading ○ Using Computer ○ Watching TV/Movies ○ Eating/Drinking ○ Socializing ○ Doing Hobbies ○ Physical Activity/Exercising ○ Other	**Were you sitting while doing that activity?** ○ Yes ○ No	**Who were you with just before the phone went off?** ☐ I was alone ☐ Spouse/Partner ☐ Child(ren) ☐ Other family members ☐ Friends ☐ Other types of acquaintances ☐ People I don't know	**Where were you just before the phone went off?** ○ Home (Indoors) ○ Home (Outdoors) ○ Shared Community Living Space (Indoors) ○ Work (Indoors) ○ Outdoors (not at home) ○ Car/Van/Truck ○ Other	**Right before the phone went off, how HAPPY were you feeling?** ○ Not at all ○ A little ○ Quite a bit ○ Extremely	**Right before the phone went off, how FRUSTRATED/ANGRY were you feeling?** ○ Not at all ○ A little ○ Quite a bit ○ Extremely
5% prompts	**63% prompts**	**55% prompts**		**M = 2.65**	**M = 1.21**

Affective response to physical activity did not differ depending on whether older adults were alone vs. not alone.

|	Positive Affect Estimate (SE)	Negative Affect Estimate (SE)
Intercept	2.59* (0.04)	0.18* (0.02)
BS Physical Activity	1.33 (0.91)	-0.27 (0.27)
WS Physical Activity	0.07* (0.02)	-0.01 (0.01)
BS Alone	-0.65* (0.26)	-0.04 (0.08)
WS Alone	-0.12* (0.01)	0.01 (0.01)
WS Physical Activity × Alone	0.01 (0.06)	0.01 (0.02)
BS Physical Activity Duration	-0.17 (0.16)	-0.03 (0.05)
WS Physical Activity Duration	0.01 (0.01)	0.01 (0.01)

Affective response to physical activity did not differ depending on whether older adults were outdoors vs. indoors.

	Positive Affect Estimate (SE)	Negative Affect Estimate (SE)
Intercept	2.58* (0.05)	0.18* (0.02)
BS Physical Activity	0.93 (0.93)	-0.25 (0.27)
WS Physical Activity	0.05 (0.03)	-0.01 (0.01)
BS Outdoors	0.61 (0.55)	-0.14 (0.16)
WS Outdoors	0.03 (0.02)	0.01 (0.01)
WS Physical Activity × Outdoors	0.01 (0.06)	-0.01 (0.02)
BS Physical Activity Duration	-0.19 (0.18)	-0.01 (0.05)
WS Physical Activity Duration	0.01 (0.01)	0.01 (0.01)

Affective response to sedentary behavior differed depending on whether older adults were alone vs. not alone.

	Positive Affect Estimate (SE)	Negative Affect Estimate (SE)
Intercept	2.59* (0.05)	0.18* (0.02)
BS Sedentary Behavior	0.27 (0.49)	-0.03 (0.14)
WS Sedentary Behavior	0.01 (0.01)	-0.01 (0.01)
BS Alone	-0.57* (0.27)	-0.06 (0.08)
WS Alone	-0.12* (0.01)	0.01 (0.01)
WS Sedentary Behavior × Alone	0.02 (0.03)	0.03* (0.01)
BS Sedentary Behavior Duration	-0.01 (0.01)	0.01 (0.01)
WS Sedentary Behavior Duration	-0.01 (0.01)	-0.01 (0.01)

Simple effects revealed older adults displayed greater negative affect during sedentary behavior when alone (vs. not alone).
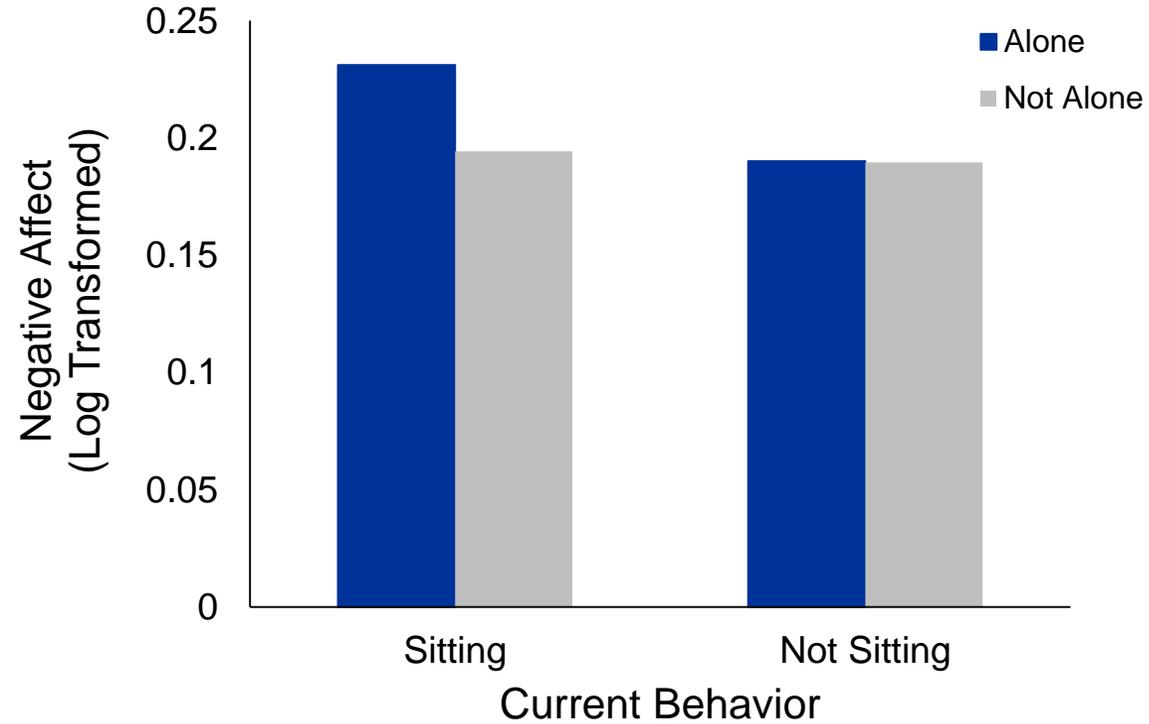
Affective response to sedentary behavior did not differ depending on whether older adults were outdoors vs. indoors.

	Positive Affect Estimate (SE)	Negative Affect Estimate (SE)
Intercept	2.57* (0.05)	0.19* (0.01)
BS Sedentary Behavior	0.31 (0.51)	0.01 (0.15)
WS Sedentary Behavior	0.01 (0.01)	0.01 (0.01)
BS Outdoors	0.44* (0.54)	-0.16 (0.16)
WS Outdoors	0.03* (0.03)	0.01 (0.01)
WS Sedentary Behavior × Outdoors	-0.05 (0.05)	0.03 (0.02)
BS Sedentary Behavior Duration	-0.01 (0.01)	0.01 (0.01)
WS Sedentary Behavior Duration	-0.01 (0.01)	-0.01 (0.01)

Being with other people may dampen negative affect response to sedentary behavior.

Interventions aiming to reduce sedentary behavior among older adults might target sedentary activities likely to be performed alone

What are the practical questions we can ask to advance our understanding of health behaviors?

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- What are the bi-directional relationships between momentary affective and physical feeling states and physical activity?

II. Synchronicity

- Does being alone or with others impact a person's affective experience during physical activity and sedentary behavior?

III. Instability

- Does subject-level variability in affective and physical feeling states impact adults odds of meeting physical activity guidelines?

Instability: Two individuals may have display a similar mean level of a particular feeling state but experience that feeling state in very different ways in the context of their everyday life.
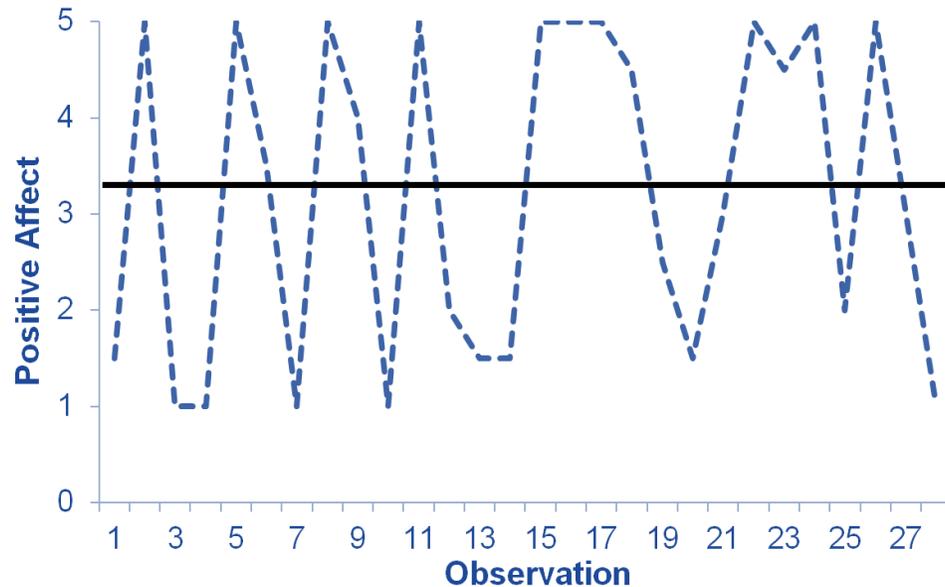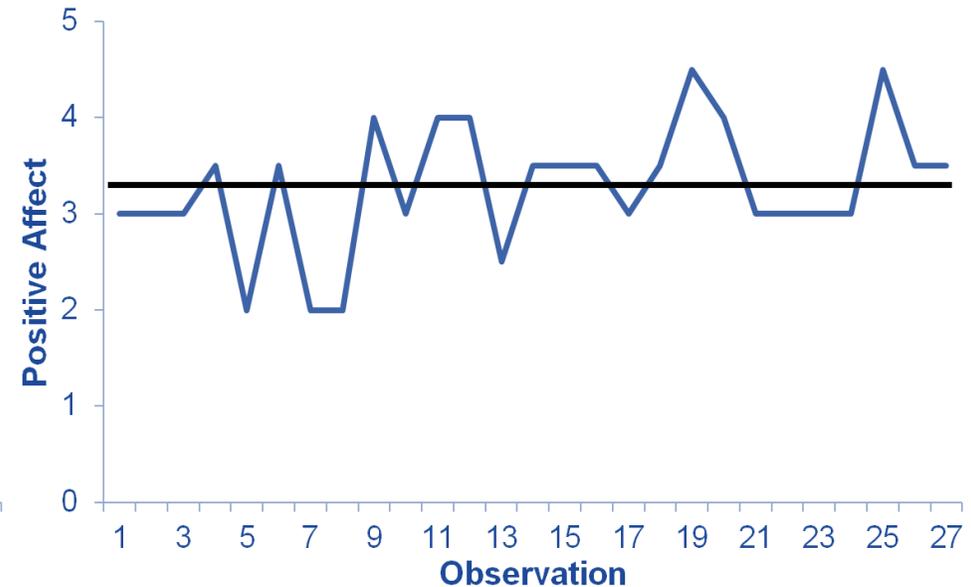


High Variability   Low Variability

Objective: Examine the extent to which within-person variability in positive affect and feeling energetic predicted participants' overall levels of physical activity.

# Data from four EMA studies with ambulatory monitoring were pooled to conduct this analysis.

Study	N	Mean Age	% Female
Mobile Healthy Places	122	11 years	48%
AsthEMA	21	14 years	43%
Project Mobile	116	40 years	72%
MATCH	404	41 years (Mothers) 10 years (Children)	100% (Mothers) 50% (Children)
Total	663	25 years	67%

Participants' affective and physical feeling states were assessed multiple times per day through EMA.

For positive affect items participants were asked about feeling HAPPY/JOYFUL/CHEERFUL/CALM right before the phone went off.
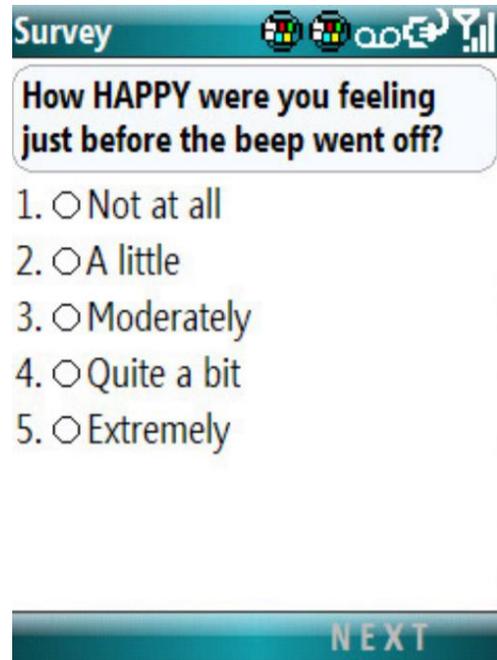
Project Mobile Sample Item
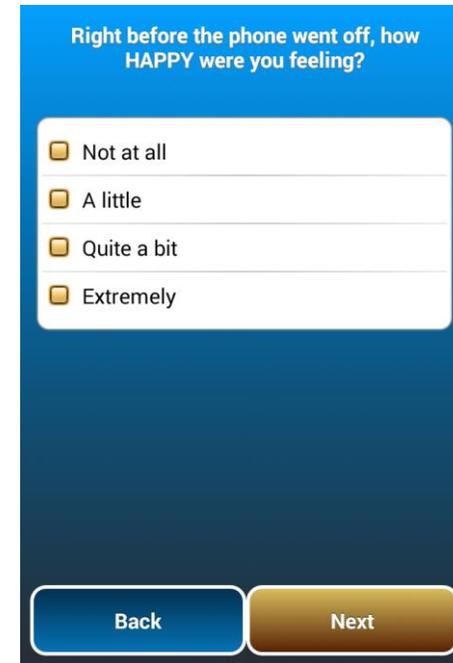
MATCH Sample Item

Participants' affective and physical feeling states were assessed multiple times per day through EMA.

For feelings of energy participants were asked about feeling ENERGETIC/FULL OF PEP right before the phone went off.

Project Mobile Sample Item

A waist-worn accelerometer was used to measure participants physical activity and sedentary time.

Physical activity

- Average daily minutes of MVPA
  - Children: ≥ 1770 to ≥ 2393 counts/min
  - Adults: ≥ 2020 counts/min

- Dichotomized into meeting US Federal guidelines for MVPA
  - Children: ≥ 60 min MVPA/day
  - Adults: ≥ 30 min MVPA/day

- Valid days considers 10+ hours of valid wear
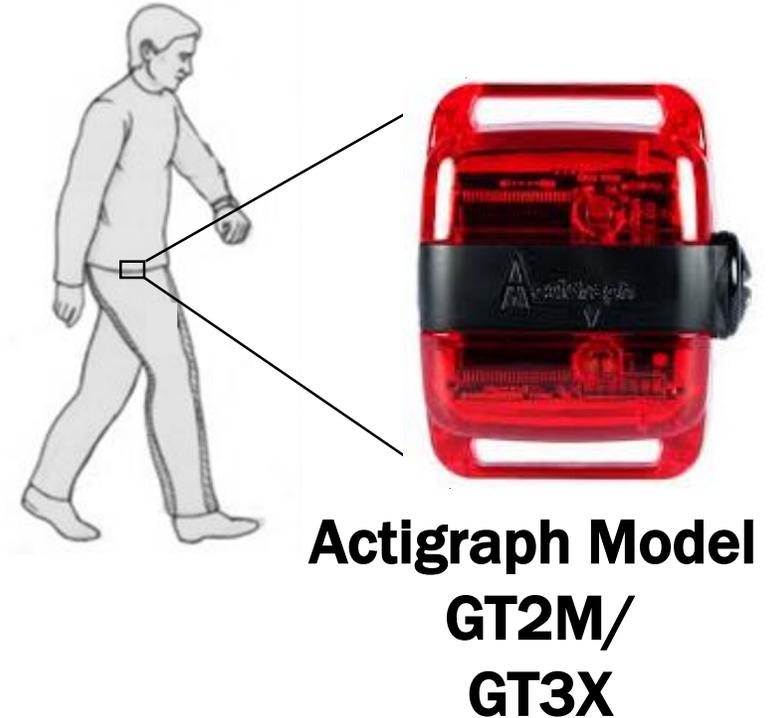
Actigraph Model GT2M/ GT3X

(Troiano et al., 2008)

A waist-worn accelerometer was used to measure participants physical activity and sedentary time.

Sedentary Time

- Average minutes of ST/valid hour
  - <100 counts/min for children and adults

- Adjusted for valid wear to account for differences in sedentary time as a result of more wear

Actigraph Model GT2M/ GT3X
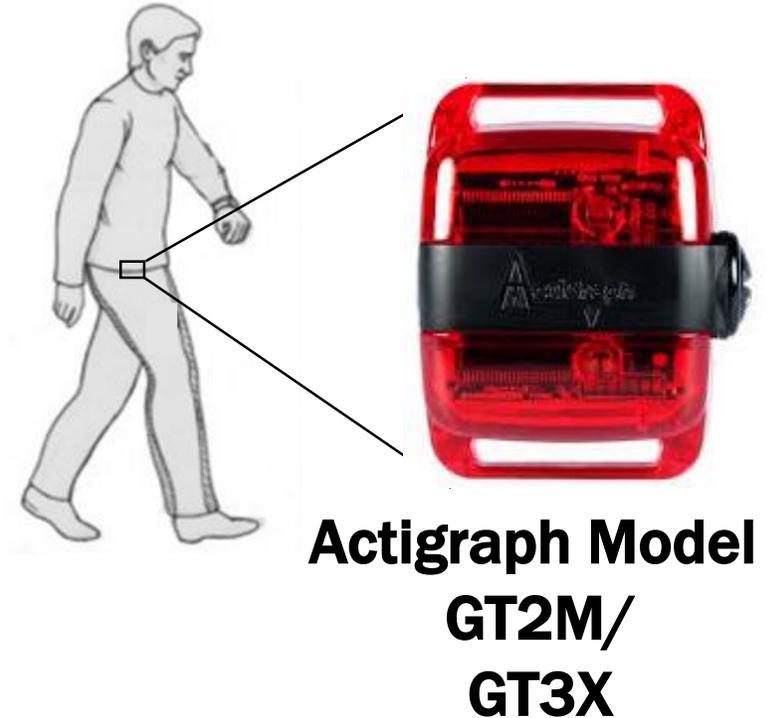
(Matthews et al., 2008)

A two-stage analytic approach was used to test the study objective.

First Stage: Uses Mixed-Effect Location Scale Modeling to decompose mean levels and variability in affective and physical feeling state.

Second Stage: Uses single-level regression to test associations between variability in EMA ratings of affective and physical feeling states and the behavioral outcome.

(Hedeker & Nordgen, 2013)

Second Stage: Behavioral outcome is regressed on mean level and variability in positive affect and covariates.

	Predicting Odds of Meeting Physical Activity Guidelines Estimate (SE)	Predicting Minutes of Sedentary Time Per Valid Hour Estimate (SE)
Intercept	-2.12** (0.49)	33.74** (0.68)
Mean Level of Positive Affect	-0.29 (0.19)	-0.01 (0.01)
Variability in Positive Affect	-0.16 (0.21)	0.16 (0.23)
Age	-0.01 (0.01)	0.11** (0.01)
Sex (Female)	1.23** (0.38)	1.04* (0.41)

Note. Single-level regression based on 617 participants. *p< 0.05. **p< 0.01.

Second Stage: Behavioral outcome is regressed on mean level and variability in feelings of energy and covariates.

	Predicting Odds of Meeting Physical Activity Guidelines Estimate (SE)	Predicting Minutes of Sedentary Time Per Valid Hour Estimate (SE)
Intercept	0.51 (0.55)	34.93** (1.03)
Mean Level of Energy	-0.09 (0.18)	-0.26 (0.30)
Variability in Energy	-0.43* (0.21)	0.15 (0.37)
Age	-0.01 (0.01)	0.07** (0.02)
Sex (Female)	-1.13** (0.36)	1.40* (0.58)

Note. Single-level regression based on 245 participants. *p< 0.05. **p< 0.01.

Fluctuations in feelings of energy may deplete self-regulatory resources involved in planning and implementing physical activity.

- Alternatively, being more physically active may stabilize one's perceived energy levels.

- Longitudinal studies are needed to untangle relations between variability in feelings of energy and physical activity levels.

- It is unclear if specific patterns of variability are more or less associated with maladaptive behaviors.

What are the practical questions we can ask to advance our understanding of health behaviors?

I. Sequentiality

- What are the bi-directional relationships between automatic affective evaluations and physical activity?

II. Synchronicity

- Does being alone or with others impact a person's affective experience during physical activity and sedentary behavior?

III. Instability

- Does subject-level variability in affective and physical feeling states impact adults odds of meeting physical activity guidelines?

EMA can provide novel insights into the prediction and modeling of physical activity behavior.
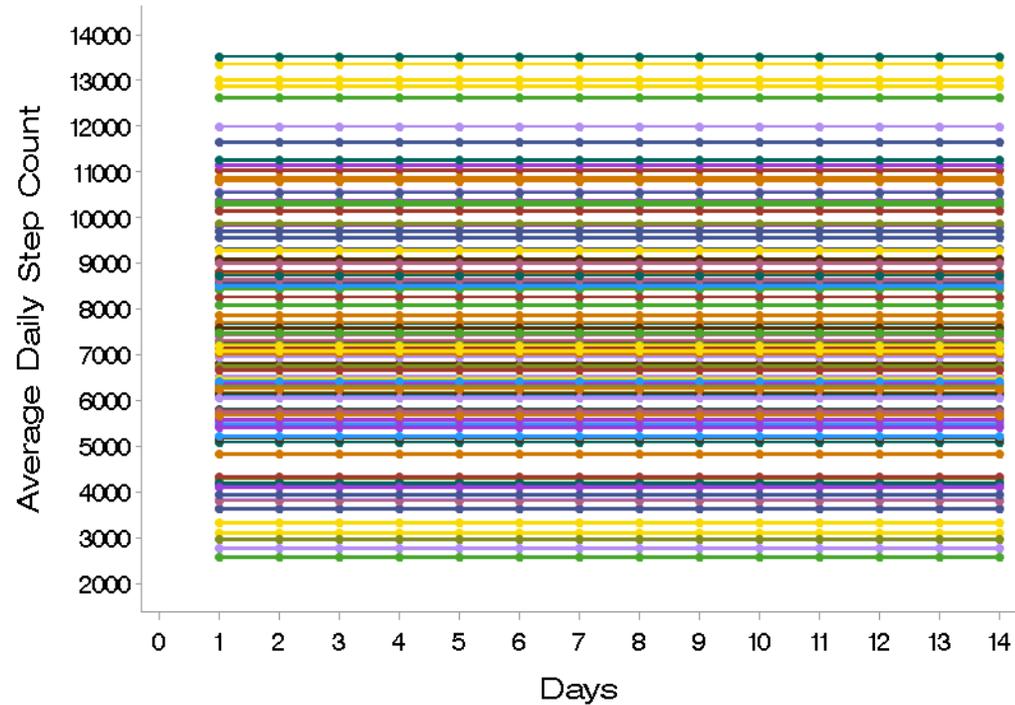
Differences between more or less active *people*
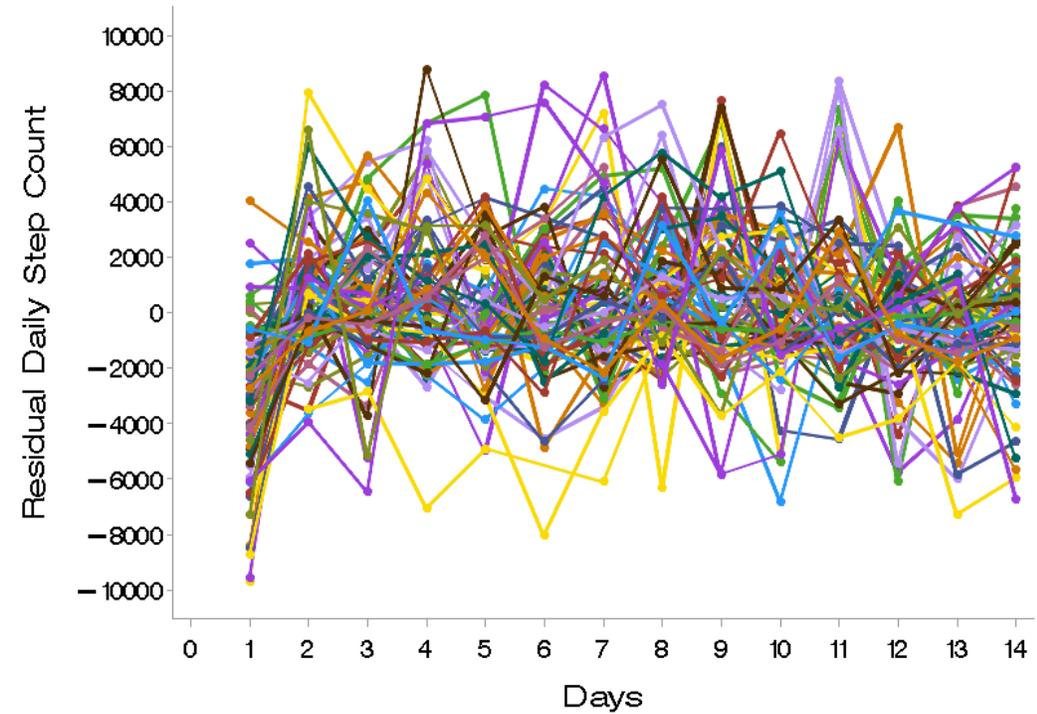
Differences between more or less active *days*

Thank you!

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