Leveraging Smartphones for the Detection of and Scalable Interventions for Depressive Symptoms in Adolescents

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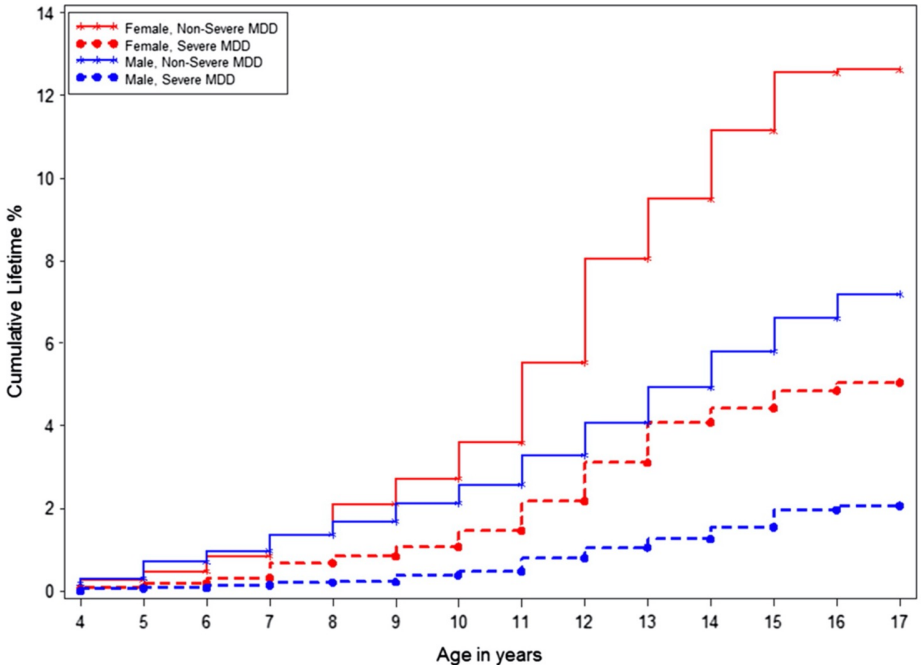
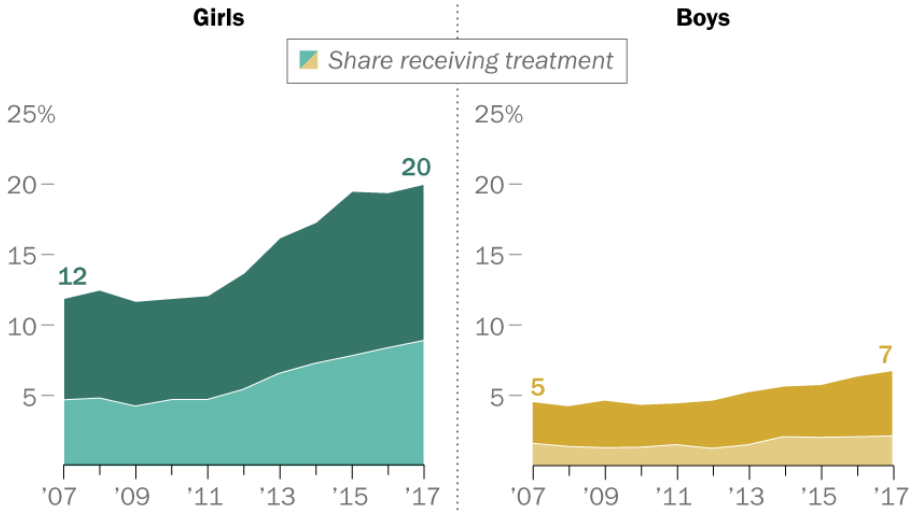
Depression in Adolescence



Avenevoli, 2015

% of teens ages 12-17 who have had at least one major depressive episode in the past year, 2007-2017



Pew Research Center, 2019

see also Griffith et al., 2021; Bailen et al., 2019; Borghuis et al., 2017

Rumination

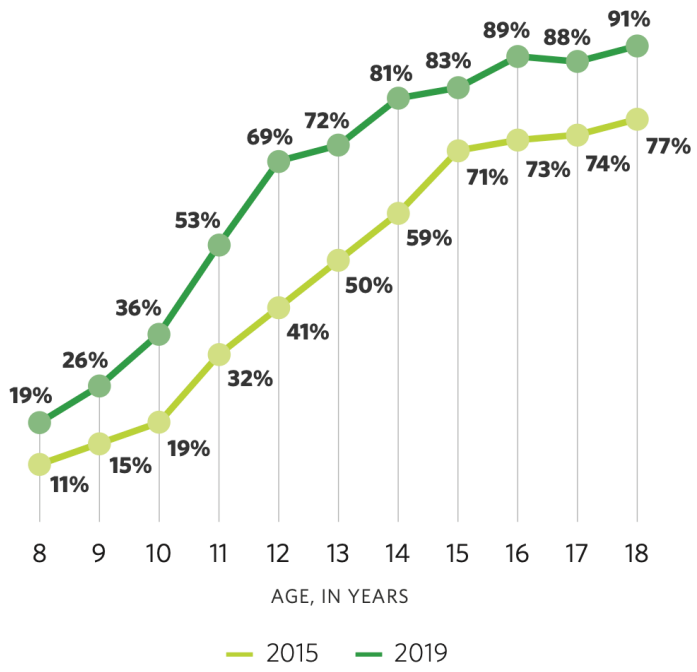
- Rumination (i.e., repetitive and negative self-focused thinking) is a transdiagnostic risk factor involved in the development of depression and anxiety (Aldao et al., 2010; Nolen-Hoeksema et al., 2008; Nolen-Hoeksema & Watkins, 2011; Watkins & Roberts, 2020).

- Rumination prospectively predicts the onset of depressive and anxiety symptoms in adolescents (e.g., McLaughlin & Nolen-Hoeksema, 2011; Muris et al., 2004; Gibb et al., 2012; Rood et al., 2009).

- Mindfulness training, with its emphasis on cultivating metacognitive awareness and present-moment attention, may be effective at reducing rumination in teens.

Youth Smartphone Ownership

FIGURE D. Smartphone ownership, by age, 2015 vs. 2019



Rideout & Robb, 2019

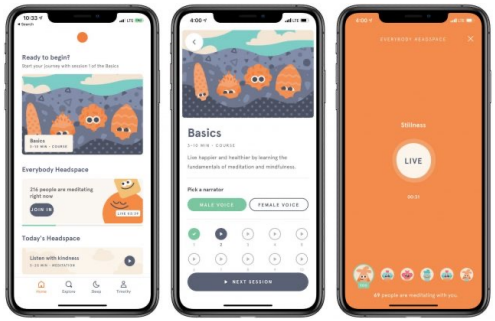
Table 1: Online health seekers
Among 14-22 year-olds, percent who have gone online for information about:

Fitness and exercise	63%
Diet and nutrition	52%
Stress	44%
Anxiety	42%
Depression	39%
Birth control	30%
Pregnancy	28%
Sleep disorders	27%
Sexually transmitted diseases	26%
Drug or alcohol abuse	24%

Rideout & Fox, 2018

Mindfulness Apps

- Most frequently used apps for depression (Headspace; 5 million monthly active users) and anxiety (Calm: 9 million monthly active users) are mindfulness apps
- > 260 mindfulness apps available on the Apple App store and Google Play
- Headspace > 42 million users and 250k downloads per month
- 11% teens use mindfulness apps
- 38% of teens w/ elevated stress or depressive sxs have reported using mental health apps (18% used a mindfulness app)

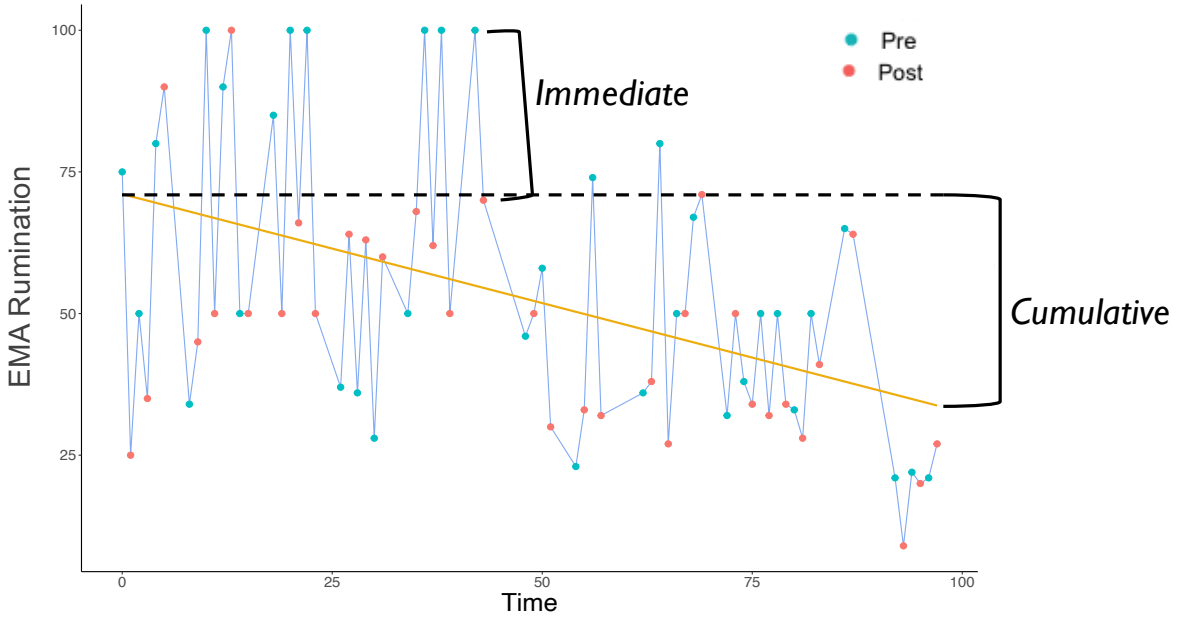


Rideout & Robb, 2019; Wasil et al., 2020

App-Based Mindfulness Training for Ruminating Adolescents

- Study 1: Single-arm trial of mindfulness app (Hilt & Swords, 2021; Webb et al., 2021)
- Study 2: RCT of mindfulness app vs. mood monitoring app (Webb et al., 2022)
- Mindfulness app for 3 weeks w/ a higher likelihood of receiving mindfulness exercise (1-12 mins in duration) if report higher sadness/anxiety
- Mean # of mindfulness exercises completed over 21 days
  - Study 1: 28.7 (avg 1.4/day)
  - Study 2: 33. 7 (avg 1.6/day)

"Immediate" vs. "Cumulative" Effects of Meditation on Rumination



Webb et al., *Mindfulness*, 2021

App-Based Mindfulness Training for Ruminating Adolescents

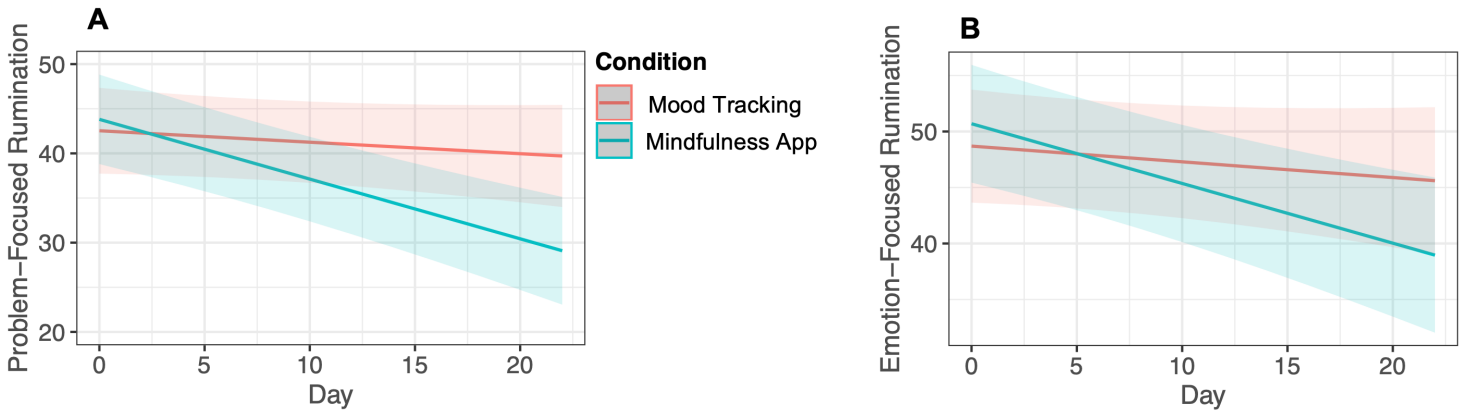
- Outcome is change in rumination (EMA)
  - Problem-focused and emotion-focused rumination
- <u>Study 1 (n = 80)</u>:
  - Significant reduction in prob-focused rumination ($b = -.10, p < .001$).
  - Significant reduction in emo-focused rumination ($b = -.13, p < .001$).

Hilt & Swords, 2021

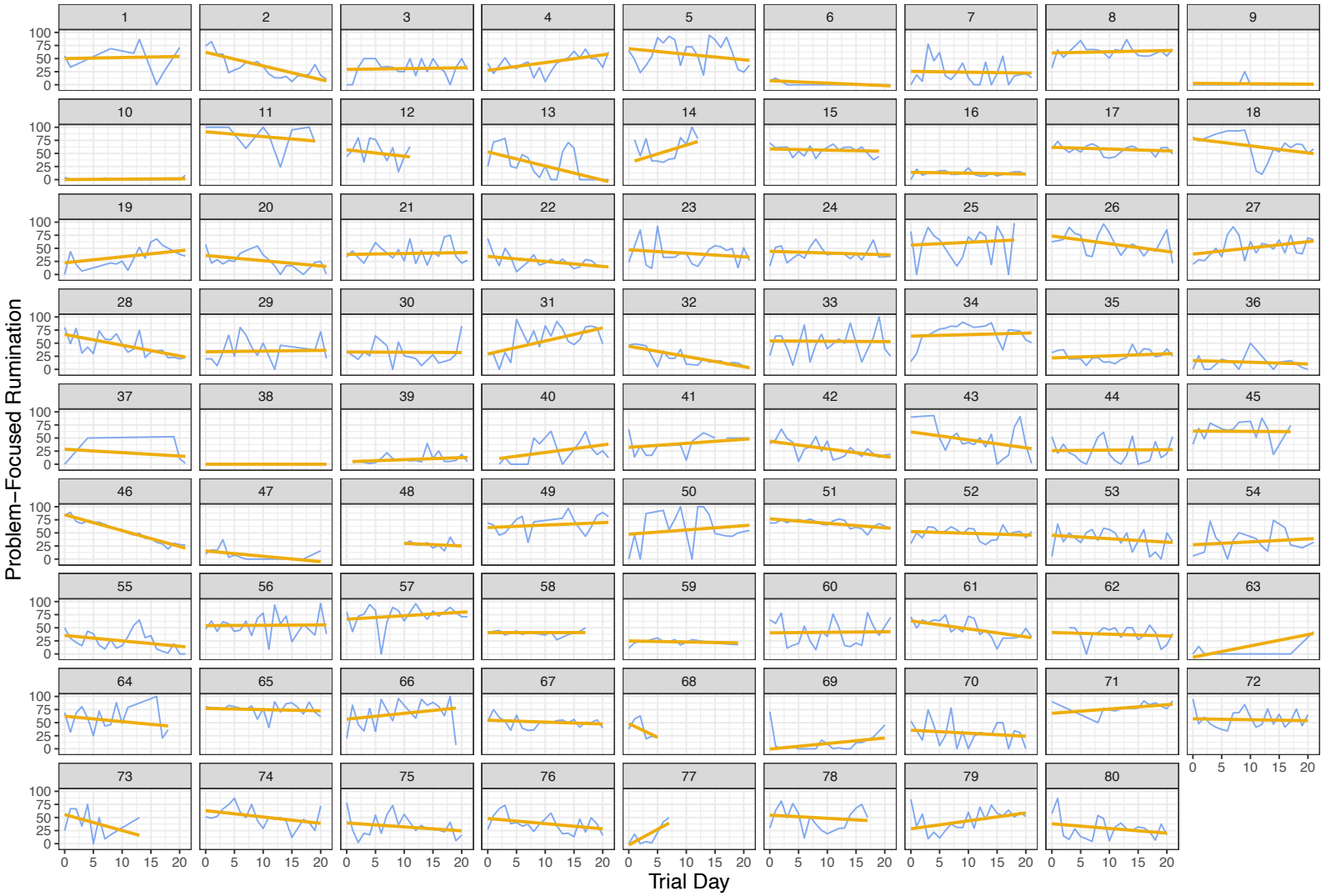
Webb et al. 2021

Overall Outcomes

- <u>Study 2 (n = 152)</u>:
  - Group x Day interaction for prob-focused rumination (t = -3.22, p = .001).
  - Group x Day interaction for emo-focused rumination (t = -2.14, p = .03).



Webb et al., *JCCP*, 2022


Problem−Focused Rumination
Trial Day
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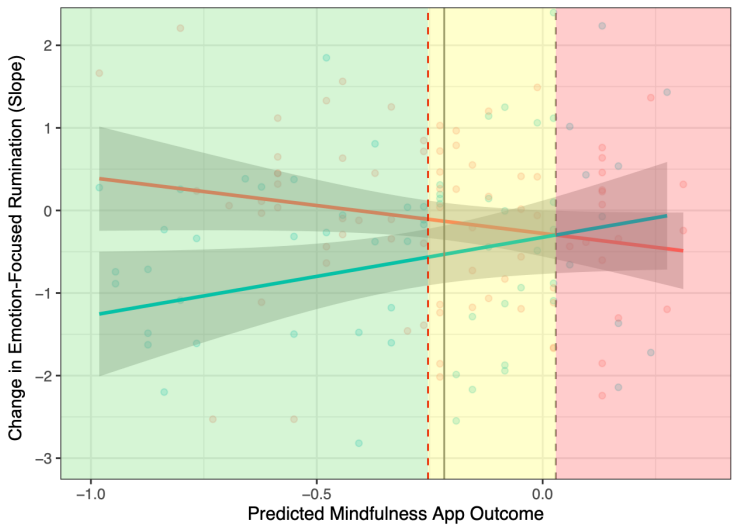
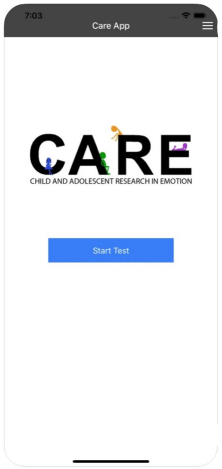
Study 1 Predictive Model

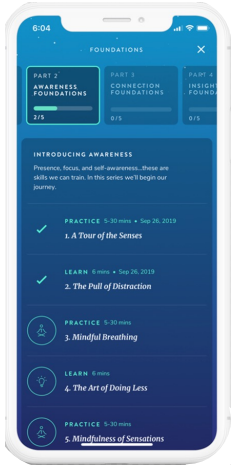
Results of Elastic Net Regularization Models

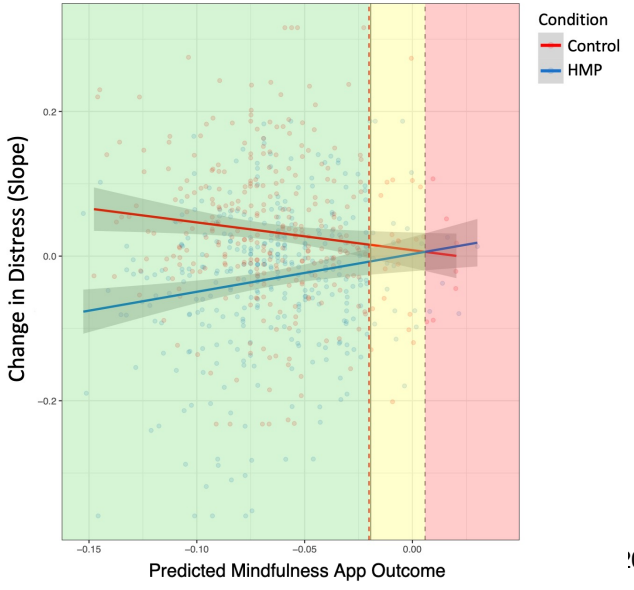
	Immediate Effects of Mindfulness Exercises		***Cumulative (3-week) Intervention Effects***	
Predictors	**Rum_{Prob}**	**Rum_{Emo}**	**Rum_{Prob}**	**Rum_{Emo}**
Age	0.31			
Gender	1.29	1.50		
ERQ Suppression		-3.77	-0.42	-0.09
ERQ Reappraisal		-0.92		0.19
CRSQ Rumination		2.49		0.15
CRSQ Distraction		2.56	-0.12	-0.38
CRSQ Problem Solving			0.12	0.17
FFMQ Observe	1.66			
FFMQ Describe				-0.20
FFMQ Awareness		0.68		
FFMQ Nonjudgement			-0.28	
FFMQ Nonreactivity		-0.80	0.22	
CDI Total				
MASC Total				0.05
History of NSSI				
History of Suicidal Ideation				
Prior mindfulness exposure				
R-Squared (RMSE)	.14 (10.9)	.22 (14.4)	.25 (1.3)	.17 (1.3)

Webb et al., *Mindfulness*, 2021









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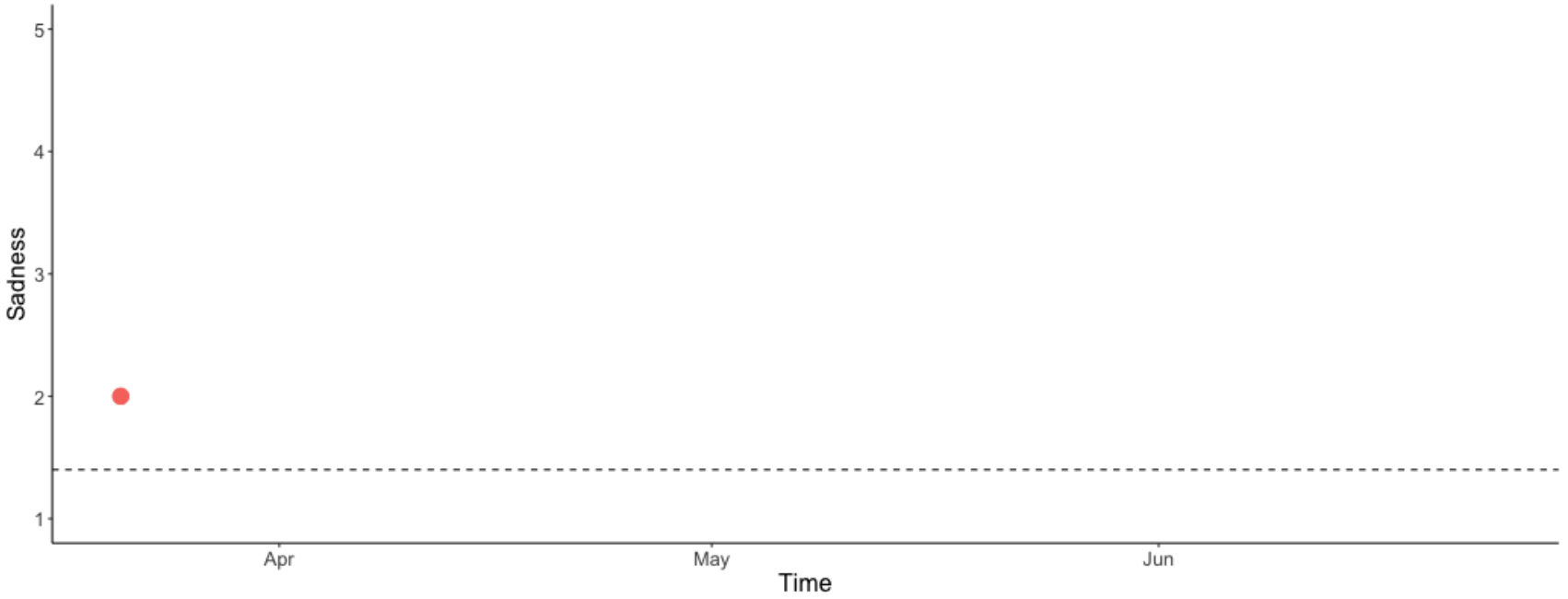
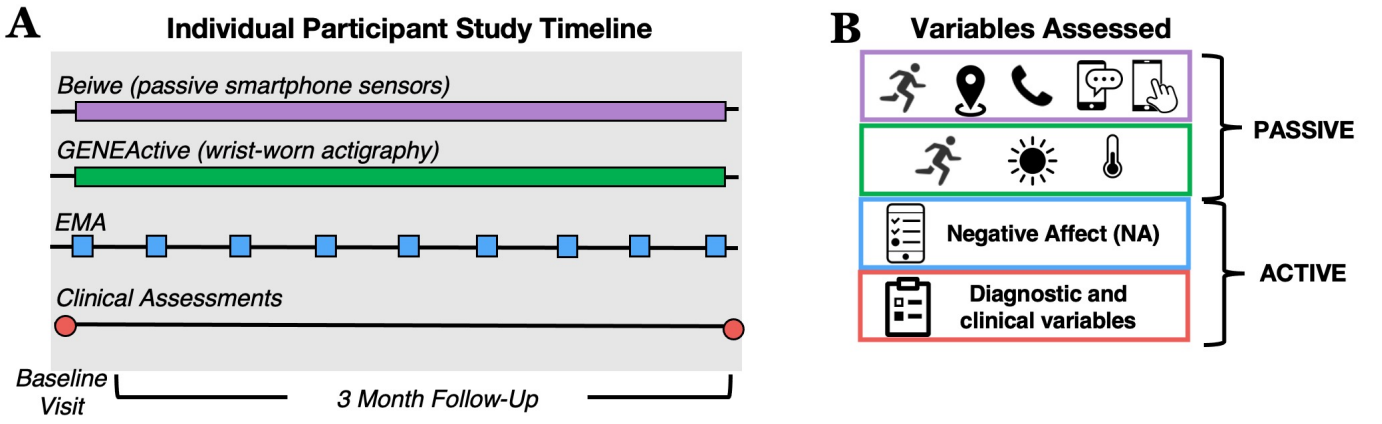
Webb et al., *JMIR*, 2022

Using Smartphones to Predict Negative Emotions



Ren et al., *Psych Med,* 2022

Study Design



Ren et al., *Psych Med,* 2022

Features Extracted

- Daily % Home
- Distance from Home
- Places Visited Hourly
- Places Visited Daily
- Daily Mobility Area
- GPS Available

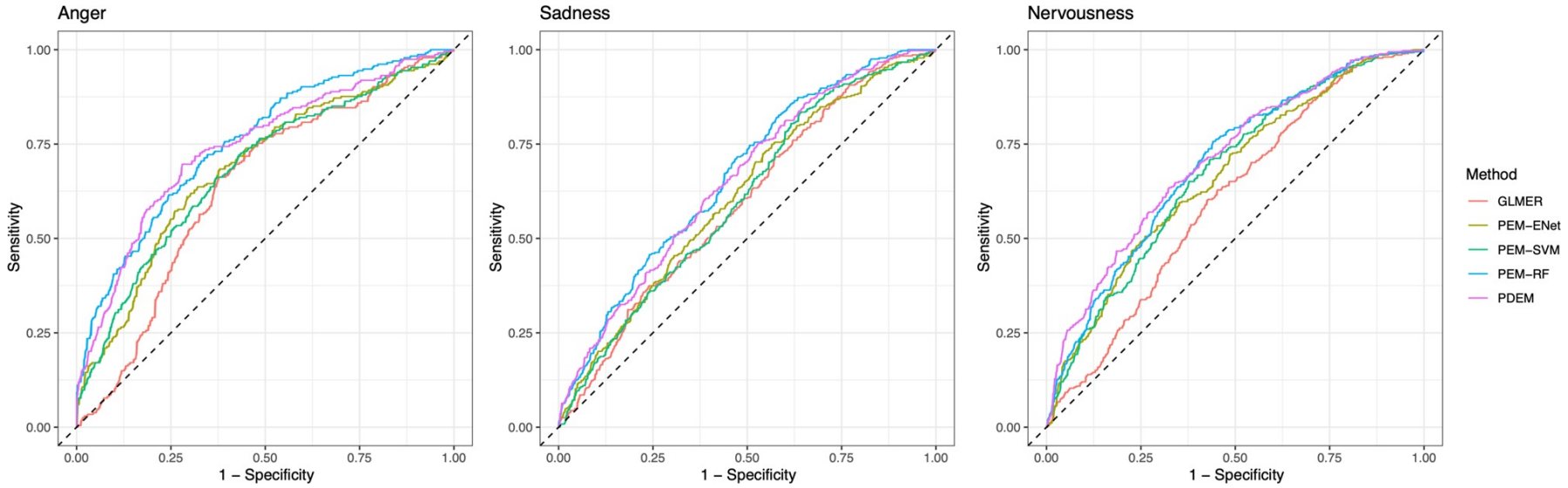
- Hourly activity score

- Time of Day

- Phone Use (hr)
- Phone Use (MinsDay)
- Phone Use (MinsHr)
- Sleep Onset Time
- Wake Time
- Sleep Duration

Ren et al., *Psych Med,* 2022

Results



	AUC			Accuracy		
Method	Anger	Sadness	Nervousness	Anger	Sadness	Nervousness
GLMER	0.64	0.59	0.60	0.63	0.56	0.58
PEM-ENet	0.69	0.61	0.67	0.67	0.59	0.63
PEM-SVM	0.70	0.60	0.67	0.64	0.57	0.63
PEM-RF	0.73	0.66	0.70	0.69	0.63	0.66
PDEM	0.74	0.66	0.71	0.71	0.65	0.67

Limitations & Future Directions

1. Limited set of smartphone-derived variables
    i. Other features may improve predictive performance (e.g., meta-data on calls/texts, teen social media use, recorded vocal tone/characteristics, peripheral measures of physiological arousal from wearable)

2. Sample size was small (although focused on within-person predictions)
    i. 80 subjects w/ 1 year of data collection (w/ Justin Baker, MD, PhD)

3. Denser EMA sampling strategy (i.e., more surveys per day) would provide more granularity in assessments of affect fluctuations and a larger within-person dataset for modeling
    i. But careful not to overburden teen participants (e.g., careless, random or stereotyped responding)

Thank You

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Early diagnosis = Better Outcomes

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