Tracking Behavioral Symptoms of Mental Illness and Delivering Personalized Interventions

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1 in 6
suffer from mental illness
Depression is the leading cause of disability worldwide

<50% Of US adults with mental health disorder receive treatment

Most common cause for hospitalization in the US
Mental Health costs

$193B  Cost of serious mental illness costs in US in terms of lost earning

$26B  Annual re-hospitalization cost for Medicare Patients with depression are 3 times more likely to be re-hospitalized within 90 days

45%  Untreated patients cite cost as a barrier
What are everyday indicators of decline in mental health?
“My wife can tell by my walk”
“I didn't want to wake up. I was having a much better time asleep”
“my legs bounce, speech goes fast ... I even eat too fast”
“I barely have any social contact"
My wife can tell by my walk (bipolar disorder)
I didn't want to wake up. I was having a much better time asleep (clinical depression)
My legs bounce, speech goes fast ...I even eat too fast (mania)
I barely have any social contact (schizophrenia)
FROM HEAD TO TOE WEARABLE TECHNOLOGY

SHIRT
Conductive thread means a computer is literally built into the fabric of the shirt, providing the processing power for all the other wearable gadgets.

WRISTBAND
A sensor that tracks movement to determine the number of steps taken through the day – 10,000 is ideal – and how much sleep the wearer gets at night.

WRISTWATCH
Vibrates when a message arrives and displays it on the watch face. Tells the time too.

HAND
Embedded under the skin is a chip containing medical records, passport data and credit records. Information is transferred by waving the hand over a suitable scanner.

TROUSERS
Also made with conductive thread, the trousers take the energy generated by movement and use it to power the other gadgets.

SHOES
GPS chip provides directions using LED lights in each shoe: the left shoe indicates direction, while the right shows distance.

GLASSES
Overlays navigation directions and information about points of interest directly on to the wearer’s field of vision.

GRAPHIC: JOHN BRADLEY
Audio
Recording audio … what about privacy

Harry Caul is an invader of privacy. The best in the business. He can record any conversation between two people anywhere. So far, three people are dead because of him.
Privacy-sensitive processing of speech

- Record and store information about *when* and *how*
- Throw away information about *what*
Fully Automated Conversation Processing

- Multi-party conversations automatically found: 91% – 95% accuracy
- Speaker turns automatically segmented: 73% – 81% accuracy

[Wyatt, et. al. – ICASSP 2007]
Continuous assessment of well-being using mobile devices

We are seeking Kendal residents as volunteers to wear a mobile computer sensor for 2 weeks to learn about how to measure physical activity and behavior. Volunteers will also complete survey tools and participate in a brief focus group about the device.

Couples and social groups are encouraged to join!

[Rabbi, et. al. – Ubicomp 2011]
How much we speak matters
How much we speak matters
Privacy-sensitive audio and mental health

**Correlation between amount of speech and mental health**

<table>
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<th>Measure</th>
<th>CES-D</th>
<th>SF-36 MCS</th>
<th>Friendship Scale</th>
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Simple behavioral information are correlated with high-level mental health states.
StressSense: identify stress from human voice

[Lu, Rabbi, et. al. – Ubicomp 2012]
State of the art today: medical sensors to detect stress

somewhat invasive and cumbersome
Listen and identify stress from human voice

- Spectral Features
- Speaking Rate
- Pitch Features
- MFCCs
- TEO-CB-AutoEnv

Voicing Inference
Robust voice/non-voice classification

Zero Crossing Rate (ZCR)

Low Energy Frame Rate

Spectral Entropy

Voiced Frame
Pick only voiced frames for stress detection.

Speech Features
Compute acoustic stress features

TEO-CB-AutoEnv

MFCCs

Stress Classification
Infer the Stress states of the speaker.

Pitch Features
Standard deviation, Range, Jitter, etc.

Speaking Rate
Low frequency changes in energy approximate syllabic rate.

Spectral Features
Spectral centroid, High frequency ratio
Challenges in continuous stress detection

• Expression of stress may have strong dependencies on personality type

• Physiological characteristics such as gender and age will influence the vocal parameters

• There is a wide spectrum of stress types, and they are expressed differently
Need to personalize without pain
Community similarity networks

Data & Labels

Physical Similarity Network

Lifestyle Similarity Network

Sensor Data Similarity Network

Stage 1

Similarity Sensitive Boosting

Stage 2

Similarity Network Co-Training

[Abdullah, Lane, Rahman, et. al. – AAAI 2012]
BodyBeat: sensing subtle body sounds

[Rahman, et. al. – MobiSys ‘14]
Designing a microphone for body centric sounds

- Ambient Noise/External Sounds
- Silicone Plastic
- Piezoelectric Sensor
- Body-Centric Sounds
From data to intervention
Case study: MOODRHYTHM

[Winner – Heritage open mHealth $100K challenge]
Behavior triggered messaging
Your sleep has been irregular the past few nights. Many people with bipolar disorder find it difficult to get out of bed in the morning.

Here are 3 strategies others have found helpful. Pick one to try.

- Move your alarm: “Moving my alarm forces me to get up to turn it off. Once I’m up it’s easier to stay up.”
  - I will do this!
- Social Plan: “I make a plan to meet a friend for coffee or a walk which gets me out of the house.”
- Tech Support: “I use the Puzzle Alarm App - to turn it off you have to complete Math puzzles which wake me.”

+ Add Your Own
Taking into account Illness traits

Patient Engagement
Increased reward sensitivity

Changing the treatment of mental health across healthcare

- Patient-Centered
- Rich Sensing
- Clinically Validated
- Tailored Intervention