Monitoring Health Behaviors with Sensor Mobile Technology

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Wearable and Implantable Technologies (WIT)
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Wearables
Wearables

Research

Consumer
What do wearables offer?

- Physical Activity, Sleep, Circadian Rhythmicity
- Electronic Diary (EMA):
  - Mood, energy, routines
- Heart Rate (ECG, bpm)
- Blood Glucose
- Ambient light, temperature (circadian markers)
- Voice
Scientific questions

- Physical activity and health
- Circadian rhythms
- Sleep quality
- Response to treatment
- Epidemiology of aging
- Compliance
- Individualized therapy
Accelerometers

- Detects acceleration in three orthogonal planes

- [https://www.youtube.com/watch?v=irjG9Y4NGnE](https://www.youtube.com/watch?v=irjG9Y4NGnE)
Macro- and Micro-scale

- Macro-scale – summarized data (1 minute intervals)

- Micro-scale – raw accelerometry data collected (10Hz+)
Stage 1: Episode Detection

- Non-wear time
- Posture: sitting, lying, standing, driving, stairs climbing, ...
- Activity: walking, running, driving, ...
- Sleep: rest/wake, in/out of bed, ...
Stage 2: Feature extraction

- **Walking**: cadence, stride-variability, asymmetry, ...
- **Sleeping**: time in bed, fragmentation, variability, ...
Stage 3: Feature Fusion

- Example: a subject with a CHF-related hospitalization
Challenges

- Need **new** methods that can be applied to:
  - thousands of subjects
  - very large data sets (10 Tb+)
  - free-living environment
  - no visual labeling (camera or person);
  - large between- and within- person variability
Sensor fusion

ENAR & JSM 2019: Monitoring health behaviors with multi-sensor mobile technology
Personal health data banks

- Personal small data (from wearables)
- Big data from health providers
- Link both in personal health account
Two snapshots

• Motor Activity Research Consortium for Health (mMARCH)
• Monitoring individuals with Congestive Heart Failure
Motor Activity Research Consortium for Health 
(mMARCH)
Biological processes associated with regulation of homeostatic domains assessed by mobile tracking
mMARCH

• Leverage mobile technology via
  – standardizing data collection protocols across sites
  – developing and applying novel analytical methods

• The range of scientific questions
  – interrelationship of physical activity, sleep and mood
  – interplay between sleep, stress, and alcohol use
Tracking Inter-relationships of Motor Activity, Sleep, Mood, and Energy via Mobile Technologies: Evidence for Cross-Domain Dysregulation in Bipolar I Disorder; JAMA: Psychiatry (in press)
Actigraphy and EMA
• **Heart failure** (HF) is a leading chronic disease in the elderly
• Lifetime risk is 20% for those over age 40 in the US
• HF burden exceeds $30 billion (> 50% on hospitalization costs)
• Identifying subjects with increased risk of hospitalization is important
CHF

- **Static risk models** include demographics, comorbidities (AFib, hypertension, diabetes mellitus), income, etc.
- **Dynamic risk models** may be more accurate by including real-time data from wearables
- Cardiac Care Center of Columbia University Medical Center
- 59 individuals with congestive heart failure (CHF)
- 3-9 months of follow up
CHF

- 24 individuals had adverse clinical events
  - 14 hospitalizations
  - 10 emergency room visits

- **Goal:** model within-subject pre/post event change in patients status

- **Method:** track multi-feature representation in three domains
  - sleep
  - physical activity
  - diurnal/circadian patterns
No-event group subject

- 8 months of monitoring
- Low week-to-week variability
- Had no hospitalizations
Event-group subject

- 8 months of monitoring
- High week-to-week variability
- Had a hospitalization
Multi-domain approach

• Track three domains
  – sleep (11:30pm-07:00am)
  – physical activity (07:00am-11:30pm)
  – diurnal/circadian patterns (12:00am-12:00am)
Multi-domain approach

• Physical Activity (PA)
  – Intensity (SePA, LiPA, MVPA), duration (bouted, fragmented), frequency (30-60 mins per day);
  – Steps, Energy Expenditure, Heart Rate Reserve

• Sleep (SL)
  – Stages (REM, NR1-3), transitions/duration, sleep efficiency, fragmentation, sleep onset

• Circadian Rhythmicity (CR)
  – parametric, non-parametric models, strength, stability, variability
ACES
Event group
Conclusion

• ACES may be useful for
  – in pre-event dynamic assignment of risk
  – post-event monitoring of patient status
  – potentially for pre-event intervention

• What is the meaning of pre-clinical (silent) events
• Pre-clinical episodes: not all high-risks periods ends with an event (in both groups)
• Future
  – External validation: on-going multi-site pilot
Joint work with

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