Social Sensing for Epidemiological Behavior Change

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Definition of Epidemiology

- **"Epidemiology is the study of patterns of health and illness and associated factors at the population level."**
  - **Outbreak investigation**
  - **Biology**
  - **Biostatistics**
  - **Social Science disciplines**

Introduction

- How is individual behavior affected by illness and stress?
- Measure characteristic behavior change in symptomatic individuals
  - Mobile phone application
    - Co-location
    - Communication
- Predict health status of an individual

Benefits

- **Understanding how people behave when they are infected**
  - **Lack of realistic social interaction data and spatio-temporal data**
- **Modeling can be made more accurate**
  - **Results can be used in the SIR model**
    - **Number and frequency of contacts on Susceptible -> Infected transition**
  - **Face-to-face interaction in contagion process**

The Experiment

- **Two months of data from an undergraduate residence hall**
  - **Individuals surveyed daily for symptoms**
  - **Behavioral changes when individuals are sick**
    - **Total communication, communication patterns, network diversity, entropy of movement**

Related Work

- **Mobile Phones as Social Sensors**
  - **Eagle and Pentland**
    - **Reality Mining – social network structure, and recognition of patterns in daily user activity**
  - **Gonzalez et. al**
    - **Call detail records used to characterize spatio-temporal regularity**
- **Google Flu Trends**

Related Work Cont.

- **Sociometric Badge**
  - **Identify human activity patterns and analyze conversational prosody features**
  - **Vocal features, body motion, relative location**

Data Source

- **Undergraduate Dormitory**
  - **80% participated in the study, most of the remaining 20% were spatially isolated**
  - **Pro-technology orientation**
  - **Even distribution among academic years**
  - **54% males and most were Engineering, Mathematics, and Science majors**
- **Incentives**
  - **Windows Mobile Phones and $1 a survey**

Data Sets

- **Social Interaction Data from Mobile Phones**
  - **Call data records**
  - **SMS logs**
  - **Bluetooth proximity and WLAN location sensing (every 6 minutes)**
- **Symptom Data via Daily Self-Report**
  - **Physical and Emotional Symptoms**
  - **20/69 participants FLU immunized**

Survey Questions

- Do you have a sore throat or cough?
- Do you have a runny nose, congestion or sneezing?
- Do you have a fever?
- Have you had any vomiting, nausea or diarrhea?
- Have you been feeling sad, lonely or depressed
- lately?
- Have you been feeling stressed out lately?

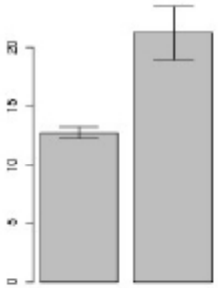
Survey Data

- Immunized Participants not considered
- Survey Data
  - 63% survey completion rate
  - Grouped into 48-hour periods
  - Symptoms labeled as FLU by medically trained epidemiologist
    - 12 cases identified, lasting 5-7 days

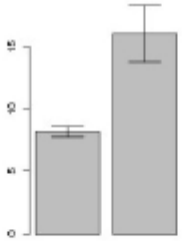
Sensor Data

- Total Communication – Phone Calls and SMS
- Communication (10PM – 9AM on weekdays)
- Communication Diversity
- Physical Bluetooth Proximity day and night (10PM – 9AM on weekdays)
- Physical Bluetooth Proximity excluding students
- University WLANs and non-University WLANs

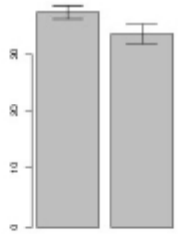
Behavioral Effects of Low Intensity Symptoms (Runny Nose, Sore Throat and Cough)



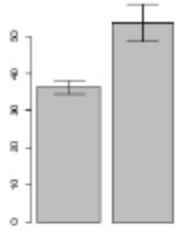
(a) Total communication increases ***



(b) Late-night early morning communication increases **

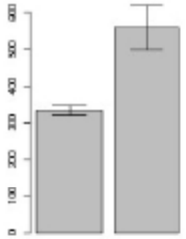


(c) Overall Bluetooth entropy decreases *

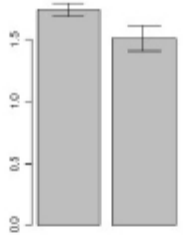


(d) Total WLAN APs detected increase **

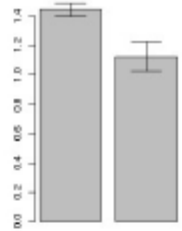
Behavior Effects of Higher-Intensity Symptoms (Fever and Influenza)



(a) Blue-tooth entropy with re-spect to other dorm residents increases ***

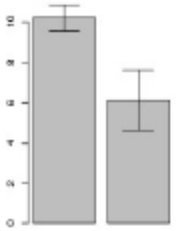


(b) WLAN entropy with respect to university WLAN APs reduces *

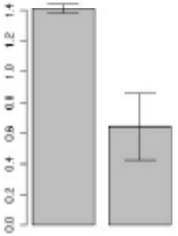


(c) WLAN entropy with respect to external WLAN APs reduces **

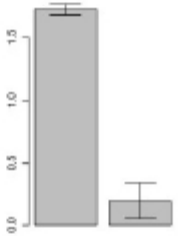
Behavior Effects of Fever



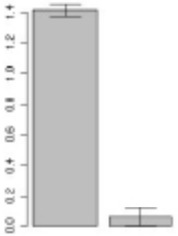
(a) Late night early morning calls and SMS decrease **



(b) Late night morning Bluetooth counts and entropy decrease*

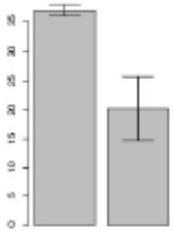


(c) WLAN based entropy with respect to university WLAN APs decreases ***

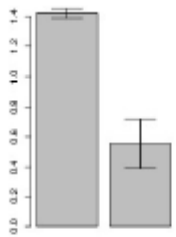


(d) WLAN Entropy with respect to external WLAN APs decreases ***

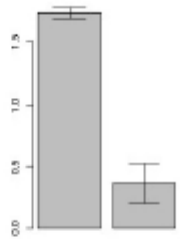
Behavior effects of CDC-defined influenza



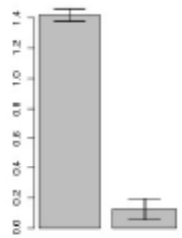
(a) Total Bluetooth interactions and entropy decrease **



(b) Late night early morning Bluetooth entropy with respect to other participants decreases **



(c) WLAN based entropy with respect to university WLAN APs decreases ***



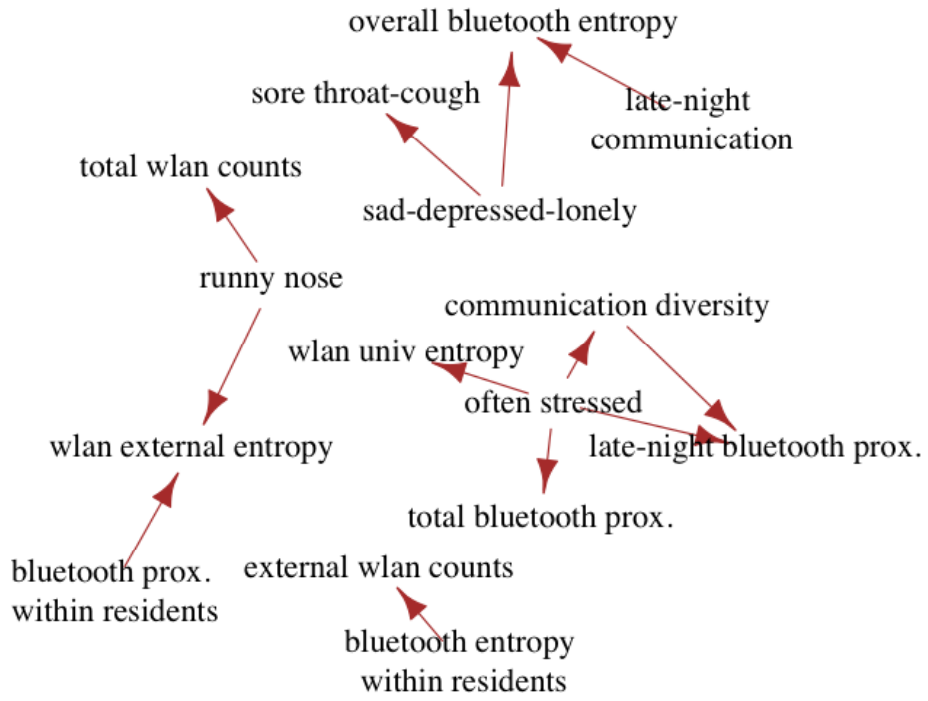
(d) WLAN Entropy with respect to external WLAN APs decreases ***

Symptom Classification Using Behavioral Features

- Cell phones can predict illness
- K-nearest-neighbor-clustering
  - stress + depression
  - runny nose + sore throat
  - fever + influenza
  - runny nose + sore throat + fever + influenza
- Bayesian-network classifier with MetaCost
  - Accuracy between 60% - 80%

Temporal Flux Between Behavior, Stress and Physical Symptoms

- **Granger causality test**
  - **Poor noise immunity**
- **Phase Slope Index (PSI) Method**



Conclusions

- **Limitations**
  - **Bluetooth signal strength**
  - **Statistical tests assume independent samples**
- **Doctors and nurses can use diagnostic information**
  - **Early detection of conditions**
  - **Better healthcare**
  - **Lower costs**

References

- **Social Sensing for Epidemiological Behavior Change, Anmol Madan, Manuel Cebrian, David Lazert and Alex Pentland, MIT Media Lab and Harvard University, Cambridge MA**
- http://hd.media.mit.edu/badges/
- http://www.google.org/flutrends/
- http://en.wikipedia.org/wiki/Epidemiology