Location Variability from Commodity Phone Sensors is Negatively Associated with Self-reported Depression Score: A Pilot Study

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**Hypotheses**

Location patterns from phone sensors are correlated with clinical depressive symptoms.

**Background**

- Major depressive disorder (MDD) is a serious and prevalent disease with an unpredictable course.
- Smartphone technology is ubiquitous and can assist doctors by monitoring patients’ symptoms and behavioral patterns. However, the extent to which the course of depression can be predicted with cell phone data remains unknown.

**Study Protocol**

- Participants: n=12 MDD & n=4 healthy controls
- Monitoring time: 8 weeks
- Phone measurements: 24/7 measurement of locations using WiFi, GPS & cellular network
- Clinical measurements: Biweekly assessment for depression symptoms using Hamilton Depression Rating Scale (HDRS)

**Methods**

- We calculated total standard deviation (SD) of location data, (SD_{latitude} +SD_{longitude})/2, in the week prior to the assessment.
- To remove the effect of the time spent at home around nighttime and while sleeping, we constrained the hours to between 9AM and 6PM to estimate the location changes only throughout the day.
- We used the full 24 hour for the weekend prior to the assessment.

**Results**

There was a statistically significant negative relationship between the total SD of location within day hours the week prior to the assessment (p=0.031) and HDRS total scores (M1 model).

Also, there was a statistically significant negative relationship between the total SD of location over the weekend prior to the assessment (p=0.036) and HDRS total scores (M1 model).

**Model Selection**

To assess the relationship between the HDRS total location variability in the week prior to clinical assessment while accounting for individual differences, we used linear mixed-effect (LME) models.

- We developed two models:
  - M1: LME with random intercept
  - M2: LME with random intercept & slope
- We selected the model with a better balance between complexity and good fit based on Bayesian Information Criterion (BIC). For weekday: \(\text{BIC}_{M1}=454.6, \text{BIC}_{M2}=463.1\), for weekend: \(\text{BIC}_{M1}=454.6, \text{BIC}_{M2}=462.5\).

**Conclusions**

- Location variability during day hours is negatively associated with HDRS score in the week prior to the assessment.
- The same trend is observed for location variations over the weekend prior to the assessment.