Typing Kinematics As Proxy Metrics for Mood And Cognition in-the-wild: An iOS BiAffect Study

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Background

Current advances in mobile health technologies and wearable devices can be leveraged for long-term, continuous and unobtrusive data collection that can reconcile shortcomings in current neuropsychological assessment of mood symptomatology and cognitive performance, by providing ecological validity and high temporal richness of measurements to address intra-individual variations.

To this end, we present the largest to date naturalistic crowd-sourced study on typing kinematics from a demographically diverse sample, enriched for mood disorders.

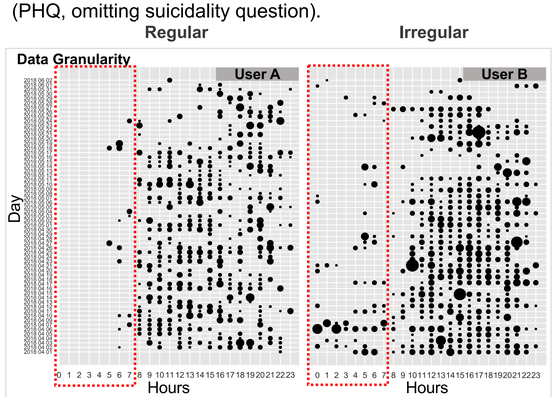
Objective

Our research is focused on BiAffect, a mobile health application leveraging Apple's ResearchKit, that collects typing kinematics metadata (i.e., number of characters, autocorrect, backspaces, typing speed), while preserving content anonymity.

Our aim was to assess how circadian rhythms and age affect cognition and mood as measured by passively collected typing metrics, while controlling for demographics and typing mode (one vs. two handed typing)

Methods

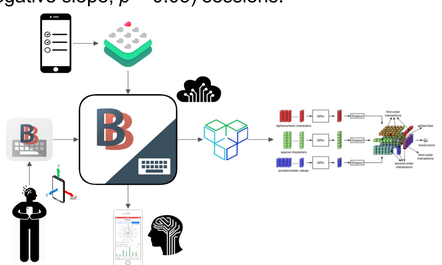
Data collection and demographics: Since March 2018 we collected >40 million keypresses from 998 users. After performing data quality control, cleaning and all preprocessing steps, we isolated a dataset comprising of 248 most active participants who reported their age (range: 18-82, 37.7± 11) and gender (71% females 27% males and 2% non-binary). To investigate effects of depressive symptoms on typing performance, a secondary analysis was conducted on 146 users who completed the Patient Health Questionnaires 8 (PHQ, omitting suicidality question).



Feature extraction:

Typing speed and variability: To separate events encoding word-level typing as opposed to thinking or pausing, we performed a separate analysis on the median (50th percentile) and long (90th percentile) inter-key delay (IKD). We also measured IKD variability via the median absolute deviation (MAD).

Typing mode: To distinguish between one- vs. two-handed typing, IKD was linearly regressed to the distance between the center of the two touch events-of-interest on a per session basis. The slope of this linear regression and its corresponding p-value are used to classify one-handed (positive slope, $p < 0.05$) and two-handed (negative slope, $p > 0.05$) sessions.



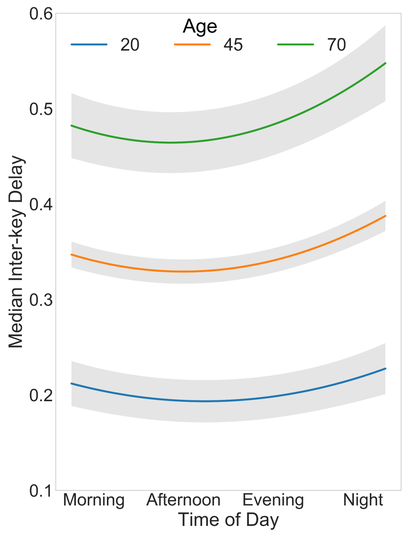
Statistical Analysis: To capture effects of age, circadian rhythms and mood we used hierarchical mixed-effects models with dependent variables of median IKD, probing pure typing speed, long IKD, indicating pausing (IKD at 90th percentile), and MAD IKD, measuring typing speed variability. Random effects of the models included the user as the cluster (ICC = .81) and allowed each user to have their own slopes of the time of day (both linear and quadratic) and different intercepts for their typing mode. Fixed effects were tested hierarchically adding the time of day, age of the user, typing mode, gender, autocorrects and characters per session. Lastly, a separate analysis was conducted using the PHQ score as a main effect on the models prescribed before. Model improvement was assessed via deviance testing.

Results

Typing kinematics exhibit aging effects and diurnal patterns

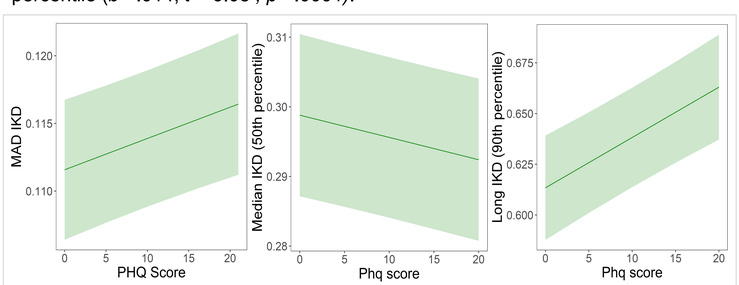
We report a positive linear effect for age on median IKD ($b = 0.069$, $t = 14.9$, $p < .0001$) and MAD IKD ($b = 0.028$, $t = 13.9$, $p < .0001$), such that older users typed slower and more variably. Results supported a 2nd order polynomial effect of diurnal patterns, with fastest (1st order, $b = 1.31$, $t = 5.77$, $p < .0001$; 2nd order, $b = 2.76$, $t = 14.15$, $p<.0001$) and least variable (1st order, $b = 0.68$, $t = 6.14$, $p < 0.0001$; 2nd order, $b = 1.33$, $t = 13.68$, $p < .0001$) typing speed occurring midday.

Lastly, we found an interaction between the time of day and age, such that older people exhibited a more pronounced slowing in typing speed (1st order, $b = 0.48$, $t = 2.06$, $p = 0.041$; 2nd order, $b = 0.48$, $t = 2.38$, $p = 0.019$) at the end of the day/early hours of the morning



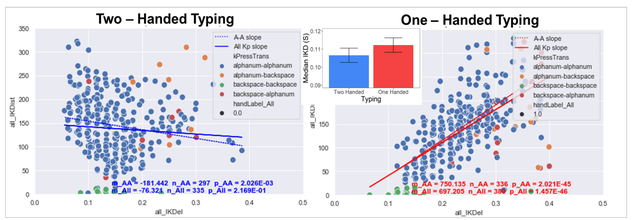
Typing kinematics capture variations in mood ratings

We found an overall increase in typing speed variability ($b = .0013$, $t = 3.74$, $p = .0002$) in users reporting elevated depressive symptoms (i.e., higher PHQ), potentially driven by the shorter median IKD ($b = -.0019$, $t = -3.83$, $p = .00013$) which measures pure typing, and longer pauses, probed by the IKD at the 90th percentile ($b = .014$, $t = 6.08$, $p < .0001$).



Effects of typing mode on IKD

As expected, typing mode (one vs. two handed typing), was found to be a significant predictor of typing speed, with one handed typing being much slower ($b = -0.014$, $t = 7.50$, $p < .0001$) and more variable ($b = .0056$, $t = 6.65$, $p < .0001$) than two-handed typing



Conclusion

Our main findings 1) established the utility of collecting keyboard dynamics in the wild to examine the association between typing performance and aging in the context of diurnal patterns, 2) demonstrated the sensitivity of our keyboard-derived metric to changes in severity of depressive symptoms and 3) support the feasibility of BiAffect in successfully recruiting participants using a crowd-sourced open-science research paradigm.

Our goal is to eventually provide real time feedback (via the BiAffect dashboard) on tying performance, that can be used by participants to gain insight into their neuropsychological state.

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