

M.Sc. Thesis proposal (SUPER EARLY DRAFT)

Classifying brain activity using low-cost biosensors and automated time tracking

Erik Bjäreholt

(dat13ebj@student.lu.se, erik@bjareho.lt)

Student Erik Bjäreholt
 Supervisor Markus Borg
 Examiner Elizabeth Bjarnarson
 Start date 10th June (realistic?)
 End date 30th September (realistic?)

online over the last few decades, and this trend is expected to continue. While several studies have been tracking how people spend time on their devices a wider study of how people's app usage has changed over time and how it varies with demographics, is not publicly available.

Furthermore, how different device activities affect the user behaviorally and neurologically is of interest for many areas of research, including:

CONTENTS

| | | | |
|------------|--|---|--|
| I | Background | 1 | |
| I-A | Automated time trackers | 1 | <ul style="list-style-type: none"> • psychological well-being, such as depression and social anxiety [1][2], stress [3], self-esteem, life satisfaction, loneliness, and depression [4]. • the impact of screen time on children and adolescents [5]. • attention span among media multitasking adults [3]. • enhancing personal productivity [6]. |
| I-A1 | Commercial use | 1 | |
| I-A2 | Research use | 2 | |
| I-A3 | ActivityWatch | 2 | |
| I-B | Low-cost functional brain imaging . . . | 2 | Understanding device use and the underlying cognitive processes are essential when designing for motivation, engagement and wellbeing in digital experiences [7]. |
| II | Problem description, research goals and questions | 2 | |
| II-A | Goals | 2 | A. <i>Automated time trackers</i> |
| II-B | Questions | 2 | Automated time-trackers have been developed for computing devices for various applications such as tracking productivity, managing excessive use of social networking sites (SNSs). |
| II-C | Challenges | 2 | 1) <i>Commercial use:</i> Companies like RescueTime [8], Hubstaff [9], and others offer automated time tracking as a service. These services let the user track their screen time by installing a program on their device which tracks the active application and sends the data to their servers for storage and analysis. The user can then view their data in a dashboard on the service's website. Some of these services, like RescueTime and Hubstaff, are marketed towards teams and professionals, who want to keep track of individual and team productivity. |
| III | Methodology | 2 | |
| IV | Scientific contributions | 2 | |
| V | Resources | 2 | |

NOTES & TODOS

I. BACKGROUND

People spend more time than ever using computing devices. Work, entertainment, and services, have been steadily moving

Other limitations of these services, such as low temporal resolution and lack of detail, cause additional issues for certain

tasks that are timing-sensitive (such as ERPs) or preprocessing steps that can take advantage of high level of detail (like classifying activity).

2) *Research use*: Previous research has been published which used automated time trackers, such as TimeAware [6] and ScreenLife [10]. However, the previous contributions are, like the commercial services, not open source or permissively licensed and therefore not suitable for use by external researchers.

3) *ActivityWatch*: As a solution to these privacy and data resolution issues we have build ActivityWatch, a free and open source automated time tracker [11]. ActivityWatch remedies issues with previous solutions around source availability/licensing, privacy, and cross-platform support.

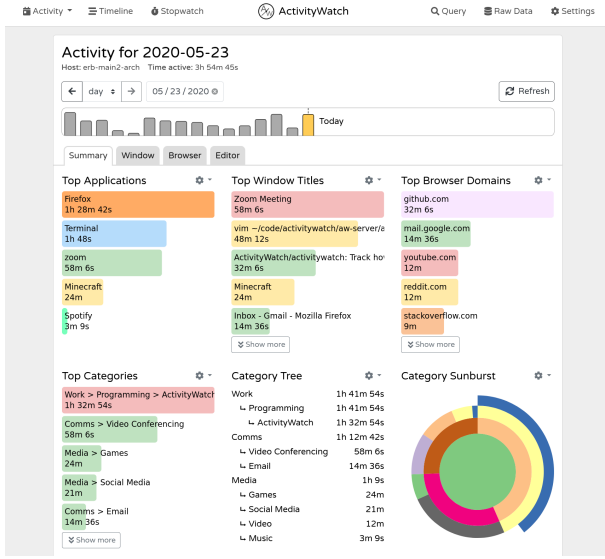


Fig. 1. ActivityWatch activity dashboard. Showing top applications, window titles, browser domains, and categories.

B. Low-cost functional brain imaging

Functional brain imaging methods such as fMRI, fNIRS, and EEG, have been used to study the relationship between cognitive or physical activity, and brain activity [12][13][14]. The more accurate methods such as fMRI are costly and inflexible/impractical for many uses. However, the recent availability of low-cost biosensors such as EEG, HEG, and fNIRS, enables studying brain activity during real-life tasks.

Functional brain imaging techniques hold the promise of relating cognition to physical activities and brain structures. As an example it has been shown that it is possible to classify what task a participant is undertaking using fMRI [12], which has been replicated using EEG and low-cost biosensors [14].

But they are not without their limitations, among them a low signal-to-noise ratio [15], yet visual evoked potentials (VEPs) have been shown to be sufficient for high-speed BCI applications [16].

Convolutional Neural Networks (CNNs) have been successful in classifying time series in general [17], and EEG data in particular [18]. Additionally, Hierarchical Neural Networks (HCNNs) have been used for EEG-based emotion recognition [19].

II. PROBLEM DESCRIPTION, RESEARCH GOALS AND QUESTIONS

We want to investigate whether EEG and other low-cost biosensors can be used to accurately classify device activity in a broader context than previous studies. This could be useful to future BCI applications where a command might be specific to a particular context.

A. Goals

- TODO

B. Questions

Can the OpenBCI system be used to...

- Classify which device activity the user is engaging in?

C. Challenges

- EEG data collection (limited time for data collection)
- Scope creep (hopefully resolved by the time this document is finalized)
- TODO

III. METHODOLOGY

We will collect EEG data from subjects while they are using their own computer with ActivityWatch installed. We will then categorize the activity that ActivityWatch recorded and use it to train an EEG classifier on device activity.

IV. SCIENTIFIC CONTRIBUTIONS

- The open source automated time-tracker ActivityWatch.
- A EEG classifier for device activity.
- Relationships found between device activity and brain activity, as measured by EEG.

V. RESOURCES

- ActivityWatch, an open source automated time tracker (already developed by the author, but never before used in a scientific publication)
- OpenBCI Cyton biosensing board (8 channel) and Ultra-cortex headset
- HEGduino

REFERENCES

- [1] Maarten H. W. Selfhout et al. "Different types of Internet use, depression, and social anxiety: The role of perceived friendship quality". In: *Journal of Adolescence* 32.4 (Aug. 1, 2009), pp. 819–833. ISSN: 0140-1971. DOI: 10.1016/j.adolescence.2008.10.011. URL: <http://www.sciencedirect.com/science/article/pii/S0140197108001218> (visited on 05/13/2020).
- [2] Dhavan Shah et al. "Nonrecursive Models of Internet Use and Community Engagement: Questioning Whether Time Spent Online Erodes Social Capital". In: *Journalism & Mass Communication Quarterly* 79.4 (Dec. 1, 2002). Publisher: SAGE Publications Inc, pp. 964–987. ISSN: 1077-6990. DOI: 10.1177/107769900207900412. URL: <https://doi.org/10.1177/107769900207900412> (visited on 05/13/2020).
- [3] Gloria Mark, Yiran Wang, and Melissa Niiya. "Stress and multitasking in everyday college life: an empirical study of online activity". In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. CHI '14. Toronto, Ontario, Canada: Association for Computing Machinery, Apr. 26, 2014, pp. 41–50. ISBN: 978-1-4503-2473-1. DOI: 10.1145/2556288.2557361. URL: <https://doi.org/10.1145/2556288.2557361> (visited on 05/22/2020).
- [4] Chungjung Huang. "Time Spent on Social Network Sites and Psychological Well-Being: A Meta-Analysis". In: *Cyberpsychology, Behavior, and Social Networking* 20.6 (June 1, 2017). Publisher: Mary Ann Liebert, Inc., publishers, pp. 346–354. ISSN: 2152-2715. DOI: 10.1089/cyber.2016.0758. URL: <https://www.liebertpub.com/doi/10.1089/cyber.2016.0758> (visited on 05/13/2020).
- [5] Kaveri Subrahmanyam et al. "The impact of computer use on children's and adolescents' development". In: *Journal of Applied Developmental Psychology*. Children in the Digital Age 22.1 (Jan. 1, 2001), pp. 7–30. ISSN: 0193-3973. DOI: 10.1016/S0193-3973(00)00063-0. URL: <http://www.sciencedirect.com/science/article/pii/S0193397300000630> (visited on 05/13/2020).
- [6] Young-Ho Kim et al. "TimeAware: Leveraging Framing Effects to Enhance Personal Productivity". In: *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. CHI '16. San Jose, California, USA: Association for Computing Machinery, May 7, 2016, pp. 272–283. ISBN: 978-1-4503-3362-7. DOI: 10.1145/2858036.2858428. URL: <https://doi.org/10.1145/2858036.2858428> (visited on 05/13/2020).
- [7] Dorian Peters, Rafael A. Calvo, and Richard M. Ryan. "Designing for Motivation, Engagement and Wellbeing in Digital Experience". In: *Frontiers in Psychology* 9 (2018). Publisher: Frontiers. ISSN: 1664-1078. DOI: 10.3389/fpsyg.2018.00797. URL: <https://www.frontiersin.org/articles/10.3389/fpsyg.2018.00797/full?report=reader> (visited on 05/23/2020).
- [8] *RescueTime: Automatic Time-Tracking Software*. Library Catalog: www.rescuetime.com. URL: <https://www.rescuetime.com/> (visited on 05/23/2020).
- [9] *Hubstaff: Time Tracking and Productivity Monitoring Tool*. Library Catalog: hubstaff.com. URL: <https://hubstaff.com/> (visited on 05/23/2020).
- [10] John Rooksby et al. "Personal Tracking of Screen Time on Digital Devices". In: *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. CHI '16. San Jose, California, USA: Association for Computing Machinery, May 7, 2016, pp. 284–296. ISBN: 978-1-4503-3362-7. DOI: 10.1145/2858036.2858055. URL: <https://doi.org/10.1145/2858036.2858055> (visited on 05/13/2020).
- [11] *ActivityWatch: Open-source automated time tracker*. In collab. with Erik Bjäreholt and Johan Bjäreholt. URL: <https://activitywatch.net/> (visited on 05/23/2020).
- [12] Benjamin Floyd, Tyler Santander, and Westley Weimer. "Decoding the Representation of Code in the Brain: An fMRI Study of Code Review and Expertise". In: *2017 IEEE/ACM 39th International Conference on Software Engineering (ICSE)*. 2017 IEEE/ACM 39th International Conference on Software Engineering (ICSE). ISSN: 1558-1225. May 2017, pp. 175–186. DOI: 10.1109/ICSE.2017.24.
- [13] Keum-Shik Hong, Noman Naseer, and Yun-Hee Kim. "Classification of prefrontal and motor cortex signals for three-class fNIRS-BCI". In: *Neuroscience Letters* 587 (Feb. 5, 2015), pp. 87–92. ISSN: 0304-3940. DOI: 10.1016/j.neulet.2014.12.029. URL: <http://www.sciencedirect.com/science/article/pii/S0304394014009744> (visited on 05/22/2020).
- [14] Davide Fucci et al. "A Replication Study on Code Comprehension and Expertise using Lightweight Biometric Sensors". In: *2019 IEEE/ACM 27th International Conference on Program Comprehension (ICPC)*. 2019 IEEE/ACM 27th International Conference on Program Comprehension (ICPC). ISSN: 2643-7171. May 2019, pp. 311–322. DOI: 10.1109/ICPC.2019.00050.
- [15] D. J. McFarland and J. R. Wolpaw. "EEG-based brain-computer interfaces". In: *Current Opinion in Biomedical Engineering*. Synthetic Biology and Biomedical Engineering / Neural Engineering 4 (Dec. 1, 2017), pp. 194–200. ISSN: 2468-4511. DOI: 10.1016/j.cobme.2017.11.004. URL: <http://www.sciencedirect.com/science/article/pii/S246845111730082X> (visited on 05/13/2020).
- [16] Martin Spüler. "A high-speed brain-computer interface (BCI) using dry EEG electrodes". In: *PLoS ONE* 12.2 (Feb. 22, 2017). ISSN: 1932-6203. DOI: 10.1371/journal.pone.0172400. URL: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5321409/> (visited on 05/13/2020).
- [17] Bendong Zhao et al. "Convolutional neural networks for time series classification". In: *Journal of Systems Engineering and Electronics* 28.1 (Feb. 2017). Conference Name: Journal of Systems Engineering and Electronics, pp. 162–169. ISSN: 1004-4132. DOI: 10.21629/JSEE.2017.01.18.

- [18] Robin Tibor Schirrmeyer et al. “Deep learning with convolutional neural networks for EEG decoding and visualization”. In: *Human Brain Mapping* 38.11 (2017). _eprint: <https://onlinelibrary.wiley.com/doi/pdf/10.1002/hbm.23730>, pp. 5391–5420. ISSN: 1097-0193. DOI: 10.1002/hbm.23730. URL: <https://onlinelibrary.wiley.com/doi/abs/10.1002/hbm.23730> (visited on 05/22/2020).
- [19] Jinpeng Li, Zhaoxiang Zhang, and Huiguang He. “Hierarchical Convolutional Neural Networks for EEG-Based Emotion Recognition”. In: *Cognitive Computation* 10.2 (Apr. 1, 2018), pp. 368–380. ISSN: 1866-9964. DOI: 10.1007/s12559-017-9533-x. URL: <https://doi.org/10.1007/s12559-017-9533-x> (visited on 05/22/2020).
- ActivityWatch: Open source automated time tracker*. In colab. with Erik Bjäreholt and Johan Bjäreholt. original-date: 2016-04-27T15:26:09Z. May 23, 2020. URL: <https://github.com/ActivityWatch/activitywatch> (visited on 05/23/2020).

FURTHER READING

- John Rooksby et al. “Personal tracking as lived informatics”. In: *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. CHI ’14. Toronto, Ontario, Canada: Association for Computing Machinery, Apr. 26, 2014, pp. 1163–1172. ISBN: 978-1-4503-2473-1. DOI: 10.1145/2556288.2557039. URL: <https://doi.org/10.1145/2556288.2557039> (visited on 05/13/2020).
- Tsung-Sheng Chang and Wei-Hung Hsiao. “Time Spent on Social Networking Sites: Understanding User Behavior and Social Capital”. In: *Systems Research and Behavioral Science* 31.1 (2014). _eprint: <https://onlinelibrary.wiley.com/doi/pdf/10.1002/sres.2169>, pp. 102–114. ISSN: 1099-1743. DOI: 10.1002/sres.2169. URL: <https://onlinelibrary.wiley.com/doi/abs/10.1002/sres.2169> (visited on 05/13/2020).
- Yu Zhang et al. “Multi-kernel extreme learning machine for EEG classification in brain-computer interfaces”. In: *Expert Systems with Applications* 96 (Apr. 15, 2018), pp. 302–310. ISSN: 0957-4174. DOI: 10.1016/j.eswa.2017.12.015. URL: <http://www.sciencedirect.com/science/article/pii/S0957417417308291> (visited on 05/13/2020).
- Ji Peng Koh. “Brain computer interface via EEG signals”. In: (2018). Accepted: 2018-04-23T02:21:24Z. URL: <https://dr.ntu.edu.sg/handle/10356/73955> (visited on 05/13/2020).
- Lamyaa Sadouk. “CNN Approaches for Time Series Classification”. In: *Time Series Analysis - Data, Methods, and Applications* (Nov. 5, 2018). Publisher: IntechOpen. DOI: 10.5772/intechopen.81170. URL: <https://www.intechopen.com/books/time-series-analysis-data-methods-and-applications/cnn-approaches-for-time-series-classification> (visited on 05/22/2020).
- Christian Mühl et al. “A survey of affective brain computer interfaces: principles, state-of-the-art, and challenges”. In: *Brain-Computer Interfaces* 1.2 (Apr. 3, 2014). Publisher: Taylor & Francis _eprint: <https://doi.org/10.1080/2326263X.2014.912881>, pp. 66–84. ISSN: 2326-263X. DOI: 10.1080/2326263X.2014.912881. URL: <https://doi.org/10.1080/2326263X.2014.912881> (visited on 05/22/2020).