Mobile Crowd Sensing in Clinical and Psychological Trials – A Case Study

Rüdiger Pryss, Manfred Reichert, Jochen Herrmann
Ulm University
Institute of Databases and Information Systems
ruediger.pryss@uni-ulm.de,manfred.reichert@uni-ulm.de,
jochen.herrmann@uni-ulm.de

Berthold Langguth, Winfried Schlee
University of Regensburg
Clinic and Policlinic for Psychiatry and Psychotherapy
berthold.langguth@medbo.de,
winfried.schlee@gmail.com

***Abstract*—Many highly prevalent diseases (e.g., tinnitus, migraine, chronic pain) are difficult to treat and universally effective treatments are missing. Available treatments are only effective in patient subgroups; i.e., medical doctors and patients have to figure out which therapy might be helpful in the patient's situation. Sufficiently large and qualitative longitudinal data sets, however, would be desirable to facilitate evidence-based treatment decisions for individual patients. On one hand, traditional sensing techniques (i.e., clinical trials) have many merits enabling evidence-based medicine. On the other, they have inherent limitations. First, clinical trials are very cost- and labour-intensive. Second, the traditional approach aims at reducing ecological heterogeneity to enable the investigation of homogeneous subsamples. Recently, a new paradigm emerged that offers promising perspectives for collecting large amounts of longitudinal patient data – Mobile Crowd Sensing. By utilizing smart mobile devices of a large number of patients, health information can be gathered from large patient collections as well as at many different time points and in various real life environmental situations. In the *TrackYourTinnitus* project, we implemented such a mobile crowd sensing platform to reveal new medical aspects about tinnitus with a particular focus on the variability of tinnitus over time depending on the environmental situation. In this paper, the current project status as well as first lessons learned from running the mobile application for twelve months are presented. In turn, the lessons learned are discussed in the context of the new perspectives offered by mobile crowd sensing in the medical field.**

***Keywords*-mobile crowd sensing, mobile healthcare application, tinnitus, tinnitus variablity, clinical trial, psychological trial**

I. Introduction

With a prevalence rate of 10-15 % of the population, Tinnitus is a frequent disorder that is difficult to treat [1]. Major challenges constitute the fact that tinnitus is a purely subjective sensation that can only be assessed by the report of the individual patient, the existence of different subtypes of tinnitus, which are distinct in their clinical characteristics, their pathophysiology and their response to specific therapeutic interventions [2], and the intraindividual variability of the conscious tinnitus perception over time [3]. In order to address these challenges, we, as a multidisciplinary research team of psychologists, physicians and computer scientists, developed a mobile crowd sensing [4] platform called *TrackYourTinnitus*[1](*TYT*). It comprises a website, a backend, and two mobile applications (iOS and Android apps). The latter track the individual tinnitus perception by providing two core features: First, patients have to fill out a specific questionnaire adapted for being used on smart mobile devices for assessing tinnitus perception characteristics and tinnitus-related parameters during the daily routine. Second, the smart mobile device records the environmental sound level, while a patient fills out the assessment questionnaire.

As the core feature of the *TYT* mobile crowd sensing platform, patients are asked to complete tinnitus assessment questionnaires at different times during the day on a random basis (up to 5 notifications per day out of 1,440 possible times). This procedure ensures that patients cannot foresee the time of being asked and are involved in various daily situations. Measuring tinnitus at different times of the day under real-life conditions significantly enhances the ecological validity of the clinical assessment.

In Section II, we report on the current status of the *TYT* mobile crowd sensing platform. Section III discusses first lessons learned. Section IV discusses related work and Section V concludes with a summary and outlook.

II. Project Status

Table I presents current project figures (April 2015). During the twelve months the project has been running we received $11,095$ randomly applied questionnaires. The number of users increases up to 20 per week. In the beginning, the apps and the website were only provided in German language. After three months, we added an English version. Currently, we realize Spanish, French, Polish and Portuguese versions. Psychometric validation of questionnaires in these languages has shown that results are comparable [5].

III. Lessons Learned

Manifold lessons have been learned during the project. The most important ones are briefly presented. *First*, in some user data, we could recognize specific patterns, e.g., an interaction of perceived tinnitus loudness with current

[1]Further information can be found at: https://www.trackyourtinnitus.org

Category	Value
Project start	4/2014
Registered users	822
User home countries	75
Reported problems and failures	10
Number of developed questionnaires	4
Programmers	1
Team size	5
Emerged requests for using platform	5
APP downloads iOS	1,045
APP downloads Android	673
Randomly processed questionnaires	11,095
Statistically processed questionnaires	1,583
Totally gathered answers	90,343

Table I: Project Figures

sound environment, current stress level, time of day, or level of concentration. In turn, these patterns represent a possible basis to guide patient behavior for in order to reduce tinnitus.
Second, in principle, users are motivated to participate due to their health impairment. However, more incentives must be provided to increase user motivation. Most randomly answered questionnaires were processed by only a small group of the registered users. We investigated all gathered data of this group and first results indicate that they severely suffer from their tinnitus. This experience of a severely suffering subgroup with high motivation to use the app clearly indicates the need for innovative forms of diagnostic assessment and therapeutic management of tinnitus. Hence, at this early stage, the developed mobile crowd sensing platform has primarily attracted severely affected tinnitus patients. For motivating patients who are less severely impaired, additional features will be required to increase the benefit of the app for this patient group.
Third, the requests from other research groups have encouraged us to implement features that can be used to customize the platform to specific needs. Note that these requests emerged from medical research groups indicating the openness of the medical community to innovative technologies for patient assessment. If legal and formal aspects (e.g., data security) can be resolved, the further development towards a large multi-centric as well as multinational data pool can be envisioned.

IV. Related Work

Note that mobile crowd sensing technology is still rarely used in a clinical context. This might be related to legal and data privacy issues [6], but also to the general resistance of health systems to adopt innovative data information technologies. For example, a large amount of patient data is still paper-based. However, it can be expected that digital data processing technologies as well as big data technologies may revolutionize clinical research and clinical practice.
Recently, various mobile applications have been developed for psychological studies [7]. In order to fully capitalize their potential, the pure adaption of existing questionnaires for mobile use will be outperformed by novel concepts for information collection [8].
In summary, in many different life domains the feasibility of mobile crowd sensing has been already proven. The medical field, albeit a theoretically highly promising application for crowd sensing approaches, seems to be still neglected.

V. Outlook and Summary

This paper introduced the *TYT* mobile crowd sensing platform. We presented the current project status and lessons learned. First results indicate that patients are actually motivated to use the platform, especially those severely suffering from tinnitus. Still more incentives and features are required to increase user motivation and hence to gather more valuable data on the different subtypes of tinnitus. Currently, we are working on two aspects. First, we statistically evaluate collected data to obtain new insights into the variablity of tinnitus. Second, we are working on the development of a sensor framework as well as feedback algorithms to automatically evaluate patient data. Altogether, using mobile crowd sensing and its application for psychological and medical trials offers promising perspectives.

References

[1] B. Langguth, "A review of tinnitus symptoms beyond'ringing in the ears': a call to action," *Current Medical Research & Opinion*, vol. 27, no. 8, pp. 1635–1643, 2011.

[2] M. Landgrebe, F. Zeman, M. Koller, Y. Eberl, M. Mohr, J. Reiter, S. Staudinger, G. Hajak, and B. Langguth, "The tinnitus research initiative (tri) database: a new approach for delineation of tinnitus subtypes and generation of predictors for treatment outcome," *BMC medical informatics and decision making*, vol. 10, no. 1, p. 42, 2010.

[3] W. Schlee, J. Herrmann, R. Pryss, M. Reichert, and B. Langguth, "How dynamic is the continuous tinnitus percept?" in *11th Int'l Tinnitus Seminar*, May 2014.

[4] N. Lane, E. Miluzzo, H. Lu, D. Peebles, T. Choudhury, and A. Campbell, "A survey of mobile phone sensing," *IEEE Communications Magazine*, vol. 48, no. 9, pp. 140–150, 2010.

[5] D. Zeman, "Data issues of the multilingual translation matrix," in *Proc of the 7th WS on Statistical Machine Translation*. Association for Computational Linguistics, 2012, pp. 395–400.

[6] D. Christin, A. Reinhardt, S. Kanhere, and M. Hollick, "A survey on privacy in mobile participatory sensing applications," *Journal of Systems and Software*, vol. 84, no. 11, pp. 1928–1946, 2011.

[7] J. Schobel, R. Pryss, and M. Reichert, "Using smart mobile devices for collecting structured data in clinical trials: Results from a large-scale case study," in *IEEE 28th Int'l Symposium on Computer-Based Medical Systems (CBMS)*, 2015.

[8] J. Schobel, M. Schickler, R. Pryss, F. Maier, and M. Reichert, "Towards Process-Driven Mobile Data Collection Applications: Requirements, Challenges, Lessons Learned," in *10th Int'l Conf on Web Information Systems and Technologies*, April 2014, pp. 371–382.