Activity Monitoring in Daily Life as an Outcome Measure for Surgical Pain Relief Intervention Using Smartphones

Julia Seiter, Sebastian Feese, Bert Arnrich, Gerhard Tröster
Wearable Computing Lab.
ETH Zurich, Switzerland
seiter@ife.ee.ethz.ch

Oliver Amft
ACTLab,
Signal Processing Systems
TU Eindhoven, Netherlands

Lucian Macrea, Konrad Maurer
Pain Research Unit,
Institute of Anesthesiology
University Hospital Zurich

ABSTRACT

We investigate the potential of a smartphone to measure a patient's change in physical activity before and after a surgical pain relief intervention. We show feasibility for our smartphone system providing physical activity from acceleration, barometer and location data to measure the intervention's outcome. In a single-case study, we monitored a pain patient carrying the smartphone before and after a surgical intervention over 26 days. Results indicate significant changes before and after intervention, particularly in physical activity in the home environment.

Author Keywords

Activity monitoring, smartphone, pain patient, intervention.

ACM Classification Keywords

H.5.2 Information interfaces and presentation: Misc..

INTRODUCTION

Around 20% of the world's adult population suffer from chronic pain [2]. While mild pain diseases are often treated with medication, seriously affected pain patients need surgery. For these patients the *University Hospital Zurich* applies a neurostimulator implantation. The therapy releases pain by stimulating nerves and proceeds as follows: In a minor intervention, electrodes are implanted on a predefined position at the backbone and connected to a neuro-stimulator device outside the body (Figure 1b). The correct position of the electrodes is crucial to obtain pain-relieving stimulations. In case of at least 40% pain relief in daily life during the test phase, the neuro-stimulator is fully implanted inside the body (Figure 1c) subsequently.

The neuro-stimulator intervention is invasive and patients who undergo the therapy are rare but heavily suffering from pain. To prevent therapy failure and unnecessary risk for the patient an outcome measure during the test phase is crucial. Furthermore, doctors are highly interested in the outcome after full implantation to provide optimal after-treatment.

It is assumed that a release in pain results in a change in

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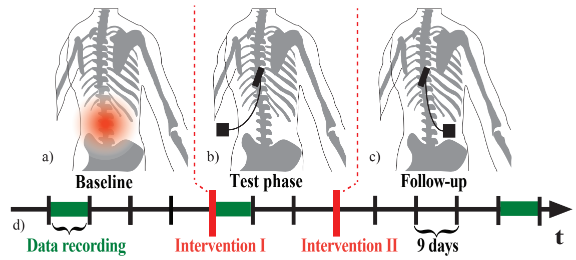

Figure 1. a) Patient with pain during baseline, b) in test phase, with test electrodes implanted (intervention I) but external neuro-stimulator, c) in follow-up with fully implanted system (intervention II), d) schedule for data recording during 9 days in each phase a), b) and c).

physical activity. Currently, outcome is assessed using subjective feedback from the patient such as activity diaries and quality of life questionnaires [3]. In pain patient monitoring actigraphs are frequently used to assess differences of the activity level between pain patients and healthy controls [4]. Assessing the patient's activity from smartphones would not require further sensors such as actigraphs and even allow modalities beyond accelerometry providing more comprehensive activity information. Therefore, in a single-case study we investigated the potential of the smartphone to measure changes in physical activity of a pain patient undergoing a pain relief intervention and analyzed the relevance of various features.

METHODOLOGY

System Implementation

For patient monitoring we used an Android application based on the Funf framework [1] featuring data logging, upload of data to a webserver and real-time visualization on a remote computer. Using the Sony Xperia Active smartphone a total battery life of around 17 hrs was achieved when logging acceleration and barometer signals (resampled to a frequency of 30 Hz) and GPS signals (updates every 3 minutes). Stop and start of data sampling was triggered by plugging-in and removing the charging cable. Plugging-in the cable in the evening enabled data upload and triggered a questionnaire, assessing the daily physical activity and pain level of the patient. The smartphone had only to be charged during night.

Features

We considered the features listed and defined in Table 1 to be indicators for the physical activity level of a patient. We assumed changes of activity levels before and after intervention might depend on the location of the patient, e.g. when being away from home, activities might be more constrained due to commitments at work, whereas at home they might be more unlimited. Therefore, all features were calculated for periods spent at home, away from home and overall (away+home). All features were calculated offline from the three axis acceleration signal $\text{acc}_{x,y,z}$, the filtered and derivated barometer signal δp and the GPS data. Thresholds were extracted from a feature validation dataset. On all the features we performed a two parameter 1-tailed Student's t-test to reveal substantial changes in features before and after intervention. The level of significance adopted was p=0.095 (weakly significant).

Evaluation Study

We monitored a 45 year old male patient undergoing a neurostimulator implantation, who had been suffering from intense leg and low back pain for more than 10 years. Before the study, we informed the patient about the smartphone system and its usage and recorded a validation dataset including *lying*, *sitting*, *walking* and *climbing stairs*. During data recording the patient carried the smartphone in a belt bag attached to the waist, whenever he was out of bed or water. Remote data access via a webserver allowed us to monitor data collection. As depicted in Figure 1d) we monitored the patient for 9 consecutive days in baseline, 9 days during the test phase, immediately after intervention I, and another 9 days during follow-up, starting from 4 weeks after intervention II, when wound pain was cured. Every evening the patient completed a questionnaire on the smartphone.

RESULTS

Pain Level versus Physical Activity Level

In total we recorded 341 hrs of data in 26 days including a daily questionnaire. Questionnaire assessed activity levels turned out to be highly subjective and no correlation between questionnaire and measured activity levels was found: e.g. average questionnaire activity levels in follow-up were 75% lower than in baseline while measurements increased by 10% in the same time. A decrease in pain level was expected to result in an increase in the measured physical activity level. The assumption was confirmed between baseline and follow-up. A 40% decrease in pain level resulted in 10% increase in the physical activity level (AL). However, the assumed pain-activity correlation was not confirmed for the test phase most probably due to post operative pain (40% decrease in pain level resulting in 24% decrease in activity (AL)).

Feature	Description
Trec	Total recording time.
Nc	Number of location clusters visited; kmeans clustering on GPS data, fusion of cluster centers closer than 10m.
Nct	Number of transitions in between different location clusters.
AL	$\text{IAA}_{\Delta t} = \int_0^{\Delta t} \text{rect}(\text{acc}_x)+\text{rect}(\text{acc}_y)+\text{rect}(\text{acc}_z)$; Δt=Trec, rect()=rectified signal.
I	Intensity. Number of intervals i within thresholds: min $<$ $\text{IAA}_{\Delta t_i} \leq$ max; $\forall i \mid \Delta t_i \in$ Trec, $\Delta t_i = 30$s.
Ilow	$0 < \text{IAA}_{\Delta t_i} \leq 30$
Imed	$30 < \text{IAA}_{\Delta t_i} \leq 110$.
Ihigh	$\text{IAA}_{\Delta t_i} > 110$.
C	Cadence. Number of steps S within thresholds: min $< S \leq$ max. Step detection:$(\text{acc}_x^2+\text{acc}_y^2+\text{acc}_z^2)^{\frac{1}{2}} > 0.3\frac{\text{g}}{\text{s}}$
nC	$\text{S} < 20\frac{\text{steps}}{\text{min}}$
Clow	$20 < \text{S} \leq 60\frac{\text{steps}}{\text{min}}$
Cmed	$60 < \text{S} \leq 90\frac{\text{steps}}{\text{min}}$
Chigh	$\text{S} > 90\frac{\text{steps}}{\text{min}}$
Ns	Number of steps.
Walk	Clow + Cmed + Chigh.
Nst	Number of instances climbing stairs; increased if $4.8 < \delta\text{p} \leq 8.4\frac{\text{m}}{\text{min}}$

Table 1. Features and their definition to desrcribe physical activity.

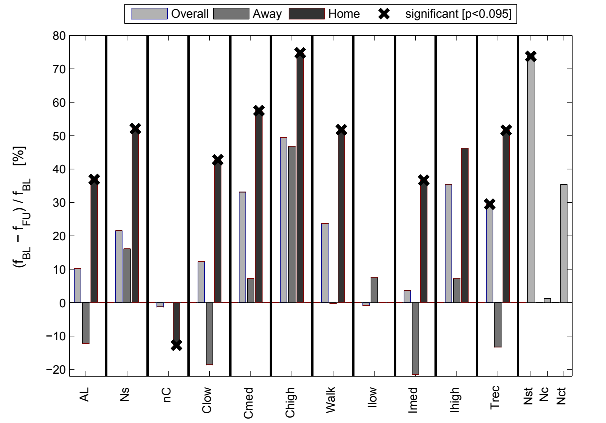

Figure 2. Mean percentage changes of features in follow-up $\mathbf{f}_{FU}$ towards the same feature in baseline $\mathbf{f}_{BL}$ and their statistical significance at home, away from home and overall (away + home).

Feature Analysis before and after Interventions

Figure 2 depicts percentage changes of features in follow-up related to baseline features. We measured significant increases in climbing up stairs (Nst), the total home physical activity level (AL), the recording time (Trec), number of steps walked at home (Ns), the medium intensity class at home (Imed) and movement cadence classes (Cmed, Clow, Chigh) at home. Thus, the feature analysis particularly pointed out increased physical activity in the home environment.

CONCLUSION

We investigated the usage of a smartphone for monitoring physical activity in daily life as outcome measure after a pain relief intervention. Questionnaire assessed activity levels showed no correlation to activity measurements. Therefore, activity questionnaires may not provide valid measurements to clinicians. While the patient's perceived pain level decreased by 40% in follow-up, we found a 10% increase in measured physical activity level. The smartphone's location information contributed strongly to provide meaningful activity measures. Especially features describing physical activity at home increased significantly. We conclude that smartphone based activity monitoring has the potential to provide objective intervention outcome to clinicians while not obstructing patients in their daily life activities.

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