Reliable Unsupervised Home Blood Pressure Self-Measurement Focus on Time-to-Rest using Sensor Fusion

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***Abstract* — To avoid white coat effect blood pressure self-measurement is used to improve validity. To get the most valid result for diagnostic use, blood pressure self-measurement requires that patients follow a number of recommendations. Studies indicate that patients do not follow the recommendations to a satisfying extent, why a setup has been made that helps the patients to follow the recommendations concerning the physical context of the patient. The recommendations are related to the physical context of the patient including sound, temperature and movement. We present a sensor fusion system for achieving this.**

Keywords; Blood pressure self-measurement, resting recommendations, Phidget sensors.

I. INTRODUCTION

For a large group of chronically ill patients with different diagnoses the blood pressure is particular important, to get an overview of the disease progression[1]. The blood pressure varies easily and small alterations in the blood pressure values can be critical for the patient, as well as cause wrong medication[2]. Therefore, it is important to measure the blood pressure under proper and comparable conditions which is difficult since it is necessary to measure the blood pressure regularly. In order to achieve the most correct blood pressure measurements for the patient and to avoid white coat effect, the patient can make self-measurements at home, where the atmosphere is relaxed and the patient feels at ease[3]. In this situation, the patient has to follow the recommendations for a blood pressure self-measurement which includes that the patient must be seated, relaxed, not talking and has to be in a quiet physical context before and during the measurement. To get the most valid blood pressure values it is important that the patient follows these recommendations, otherwise the values can be misleading by 20-60 mmHg[4]. A study has shown that 25-50% of patients with home blood pressure measuring devices do not know or do not follow the basic recommendations like being seated and being in a quiet physical context during the measuring procedure[4].

To secure a valid self-measurement of the blood pressure there is need for a device that controls that the patient follows the recommendations. The device can only control that the physical context factors of the patient meet the given recommendations, such as a quiet physical context and a relaxed position of the patient. The device cannot control the physiological parameters for the patient, meaning if the patient has smoked or taken medication just before the measurement.

A large group of the patients[5] with high blood pressure (limit value is 140/90 mmHg[3]) is senior citizens; hence the device is designed to help the patients to handle the recommendations in a better way compared to the situation without a device to support the measurement. The device will also have an economical stakeholder, as the society uses a lot of finances on medication error and working capacity in the health sector[6].

II. METHOD AND MATERIALS

The Adherence Strategy Engineering Framework (ASEF)[7] is used as development process model to investigate the problem domain, stakeholders, context and technology as well as designing a suggested solution. Our evaluation prototype is developed by the reduced adherence model (RAM) [7]and consists of sensor technology that will work as adherence verifiers and register the physical context of the patient [8].

A. Suggested solution

As a part of the self-measurement the patient has to be in a relaxed position and in quiet physical context. The patient and other people in the room, have to be silent and still during a five minute period before the self-measurement. The device verifies the behavior of the patient during these five minutes. The data of the blood pressure is saved in the device and the patient has the opportunity to see an overview of previous measurements in a defined time period. The device verifies the physical context of the patient and gives the patient a level of the physical context activity during the five minutes relaxing period. If the patient is not satisfied with the measurement and the physical context, the patient has the opportunity to make a new measurement.

The aim of the present paper is to investigate the suggested solution and evaluate whether the patient is sitting still and is in a quiet physical context in the five minutes before and during the Blood Pressure Self-Measurement (BPSM). To

support our solution we use three different types of sensors; respectively a sensor to detect movement, sound and temperature. Beside the sensors the evaluation prototype includes a HTC mobile phone and a blood pressure monitor. The data from the three types of sensors are associated with the blood pressure values so the patient has the possibility to access the physical context data to investigate the circumstances for a given blood pressure value. The reason for selecting a movement sensor and a sound sensor is to investigate if the patient is sitting still and is silent or in a quiet room. The reason for selecting the temperature sensor is that the temperature has an impact on the blood pressure values if the temperature is significant different from the room temperature[9].

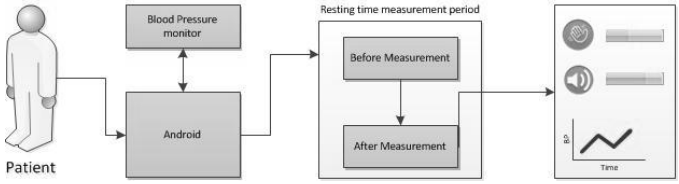


Figure 1 - Diagram of suggested solution

B. Test protocol

To set the sensitivity for the sensors in our device, we have created a number of experiments where we simulate being a patient using a BPSM device.

By experimentation, acceptable sensitivities for movement and sound are found. This is accomplished by recording sensor values for different levels of movement and sound, tweaking the sensitivities and repeating, until sensitivity levels are found that give comparatively low and high readings for low and high levels of movement/sound respectively, in the time frame of a BPSM.

To test the adherence verification ability of our evaluation prototype, we evaluated the system with non-hypertensive subjects, n=10. Ten patients in turn are told to do two BPSMs in a simulated BPSM situation, first adhering to the BPSM guidelines, and then not adhering. All tests are of a duration of one minute. This differs from the common recommendation of five minutes resting time, but since the aim is simply to collect sensor values for comparison, the duration is not important. The sensor results are collected in a log file for both tests. During the tests, four people are in the room at all times. During the adherence tests, everyone was quiet and stood or sat still. In the non-adherence tests, the three people talk with the patient. The movement sensors are pointed towards the patient, so the movement of the other three people is not recorded. The reason for having two movement sensors is simply to cover a greater angle, in case the evaluation prototype is not perfectly aligned to the patient. The room temperature is also recorded by the evaluation prototype.

C. Materials

The materials comprising our prototype were an A&D UA-767PBT-C BPSM device with bluetooth connectivity, a HTC Desire with Android 4.0.3, an Apple Airport Express WiFi access point and a Phidget SBC2 single board computer running Debian Linux, with two movement (PIR) sensors, a Sound Sensor and a Temperature Sensor connected.

The sensors are wired to the SBC2, and the HTC connects to both the SBC2 and the A&D UA-767PBT-C via WiFi. The patient uses the HTC to start the BPSM process. The HTC signals the SBC2 to start logging data from the sensors. The SBC2 sends running sensor values throughout the measurement period, which the HTC display on a unit-less percentage slider. After five minutes the SBC2 signals the HTC that five minutes have passed, and sends the final sensor values. The HTC starts the A&D device and the patient's blood-pressure is measured.

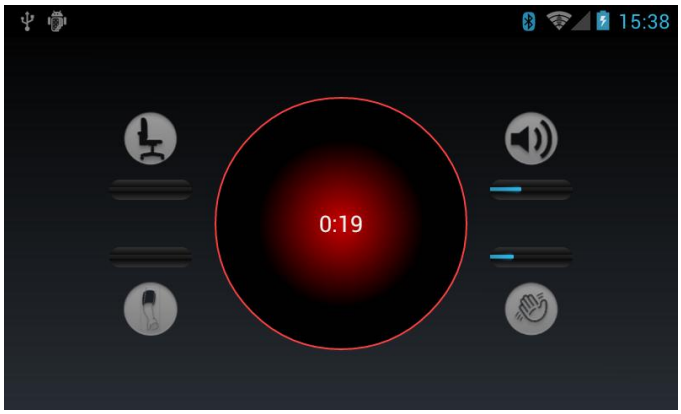


Figure 2 - Screenshot of the BPSM application during resting time count down.

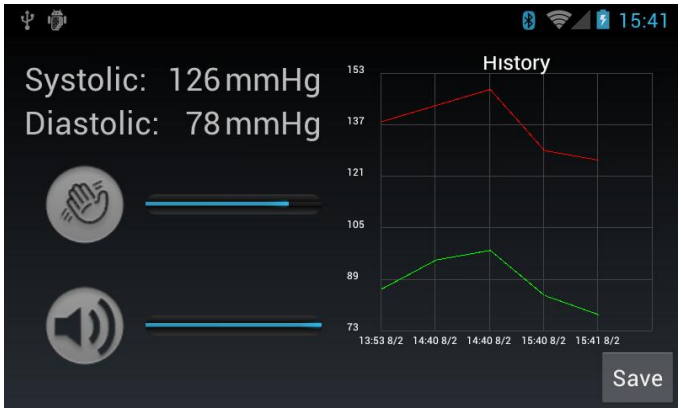
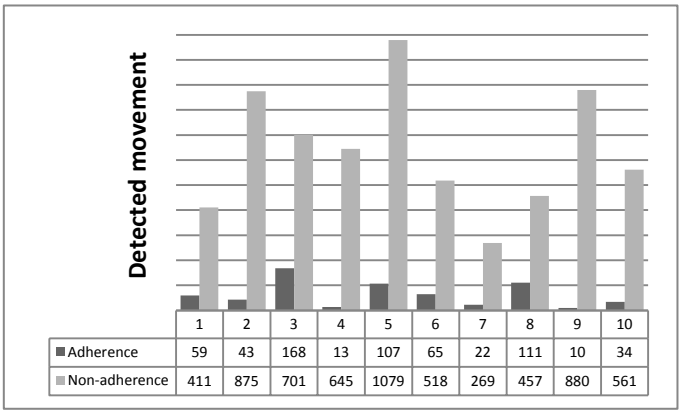


Figure 3 - Screenshot of the result and statistic site at BPSM application

III. RESULTS

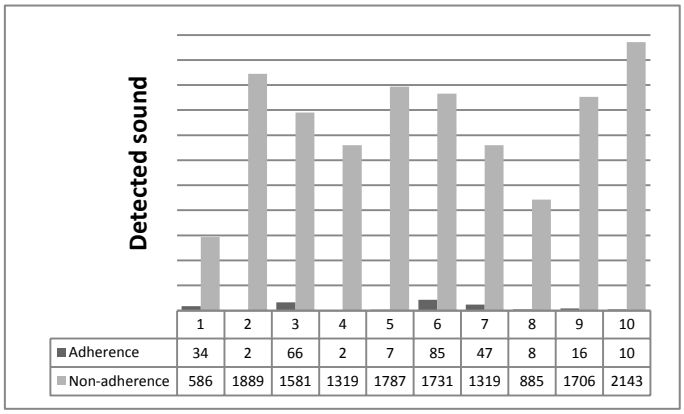
The evaluation prototype is tested with n=10. The 10 patients go through two test scenarios (adherence and non-adherence) as described in the test protocol. The results are listed in Table

1 and Table 2. Of the values for the two movement sensors, only the greater of the two is recorded.
Two-tailed, between subjects t-tests show $p(T \leq t)=0.000040$ for movement and $p(T \leq t) = 0.000005$ for sound, resulting in confidence levels of 0.999960 and 0.999995 respectively.



	1	2	3	4	5	6	7	8	9	10
Adherence	59	43	168	13	107	65	22	111	10	34
Non-adherence	411	875	701	645	1079	518	269	457	880	561

Table 1 - Detected movement for 10 test subject in to scenarios.



	1	2	3	4	5	6	7	8	9	10
Adherence	34	2	66	2	7	85	47	8	16	10
Non-adherence	586	1889	1581	1319	1787	1731	1319	885	1706	2143

Table 2 - Detected sound for 10 test subject in 2 scenarios.

IV. DISCUSSION

The following part discusses the challenges which were identified during the process of producing the prototype. The main issue of the discussion will be the relevance of the prototype due to the fact that it is not tested in real patient settings, only in simulated settings. Another, but equally important issue for the discussion part is the perspective of our prototype.

A. Noninvolvement of patients

The presumption, that the adherence verifiers will contribute with guidance and result in more validated blood pressure values, has not been demonstrated. Therefore, articles with comparable allegations are found and used as basis for validation of our solution. A study from Aalborg University, Denmark, shows that by giving diabetes patients more knowledge and influence in their disease via IT facilities can have a motivating effect on the patients to take proper care of their disease and be a contributing factor to changed life style and enhanced quality of life for the patient[10]. The equivalence between the studies is used as validation that our presumption can be achieved.

B. Results

The test results show a significant difference between sensor values collected from the adhering patients and the non-adhering patients. For the movement values, the smallest factor between non-adherence and adherence was 4.1, and the greatest factor was 88.0. The average factor was 22.0. For sound values, the smallest factor was 17.2 and the greatest factor was 944.5. The average factor was 238.0. For detecting certain types of non-adherence in BPSM, the evaluation prototype demonstrates a novel and reliable solution.

C. The relevance of the prototype

We argue that the prototype supplies an area of BPSM which has not been supported by previous work. To support the patient in the BPSM situation our prototype does help the patient to get better and more validated results, due to the fact that the patient does not know or does not follow the recommendations. We found that the main issue in this case is the ignorance of the recommendations. Only 70% knows that you must rest for five minutes before BPSM and even fewer know that you must be quiet during the BPSM (50%)[4].This prototype is not shielded from patients who do not follow the recommendation, but it will help them to remember the most important recommendations, like being seated and being quiet.

D. Future work

The sensor technology in the evaluation prototype works as adherence verifiers and register the actions and physical context of the patient. A future development could be an adherence aid technology that gives the patient feedback from the sensors. The feedback could help the patient to better adhere to the prescribed recommendations. The adherence aid will use the same sensors as the adherence verifiers, but will provide context-dependent feedback to the patient during the five minutes resting period. As a feature the device controls if the patient has rested enough and through interaction communication the device will inform the patient if he or she has to relax more during the five minutes or has to make a new measurement. As an extra feature the patient can add a comment to each measurement. If the patient is on vacation, is stressful at work or celebrating a birthday the blood pressure values can vary and the patient have the opportunity to point out, that there is a reason for the change in blood pressure. Also, this can contribute with a better understanding for the relation between context and behavior of a patient and the change in blood pressure values, which can result in an increased understanding in the medical field.

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