

# CONTEXT-AWARE PATIENT GUIDANCE DURING BLOOD PRESSURE SELF-MEASUREMENT

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## ABSTRACT

The importance of accurate measurement of blood pressure in the screening and management of hypertension during pregnancy is well established. Blood pressure levels can be measured manually by healthcare staff or by using a blood pressure self-measurement device, either at home or in the clinic. In order to be valid for diagnostic use the patient is required to follow a range of recommendations. However, these recommendations are not always followed. In an observational descriptive study we investigated the effect of introducing active patient guidance by providing context-aware feedback during the blood pressure self-measurement process. Preliminary results indicate that such active and context-aware guidance leads to more reliable measurements by inhibiting non-adherent patient behavior.

## KEYWORDS

Self-care, blood pressure self-measurement, adherence, reliability, context-aware, pervasive healthcare.

## 1. INTRODUCTION

Hypertensive disease in pregnancy represents a significant health problem. Accurate blood pressure (BP) measurement is important in the screening of women during pregnancy. The BP measurements are usually performed by trained healthcare staff in the clinic. However, this frequently causes white coat effect, a psychological anxiety induced phenomena, which is a well-known source of bias. This typically results in an artificially high BP as compared with the actual BP of the patient (Pickering et al. 2010). Furthermore, for achieving accurate BP measurements, a number of guidelines must be followed, including resting sufficiently before taking three successive measurements. As this process is time consuming, some clinics have allowed patients to self-measure their BP, following the blood pressure self-measurement (BPSM) method. Existing BP devices requires the patient to follow a range of recommendations in order to achieve accurate measurements (Pickering et al. 2008). These recommendations include that the patient must be: correctly seated, rested for five minutes, not moving or talking, in a quiet environment before and during measurements, legs not crossed, feet flat on the ground, arm supported at heart level, correct cuff size and mounting, as well as back supported (O'Brien et al. 2003). Previous studies have found that a majority of patients, including pregnant women self-measuring at outpatient clinics, do not comply with these recommendations; possibly leading to misdiagnosis and resulting treatment error (Wagner et al. 2013). In a range of studies the feasibility of using context-aware technology for improving the reliability of self-measured blood pressure data is investigated. Specifically, we suggest using ValidAid, a context-aware blood pressure self-measurement (BPSM) system, to model the user's context before and during measurements, and guide the user to increase measurement reliability. Thus, the aim of this study was to investigate the effectiveness and feasibility of using active and context-aware adherence aids to guide the self-measuring pregnant women.

## 2. METHODS AND MATERIALS

### System design

The ValidAid system is a research platform for investigating the effectiveness and feasibility of introducing novel context-aware interventions for facilitating improved adherence of patients self-measuring their BP. ValidAid consists of a clinically approved BP device (used: A&D Digital BP Monitor UA-767PBT, A&D Company Limited, Japan), a sensor chair equipped with embedded piezoresistive context-aware sensors for sensing user leg placement utilizing a rule based classification algorithm (used: FlexiForce, Tekscan Inc., US), for registering rest-time, back-supported, legs-crossed, and ambient noise-levels respectively. The ValidAid application runs on a touch screen (used: ASUS Eee EP121, Asus Inc., Taiwan) that integrates the BP device and sensor chair components, provides a user interface for the users, as well as performs audio classification of the data obtained. Data are made available to staff via a web-based system (figure 1).

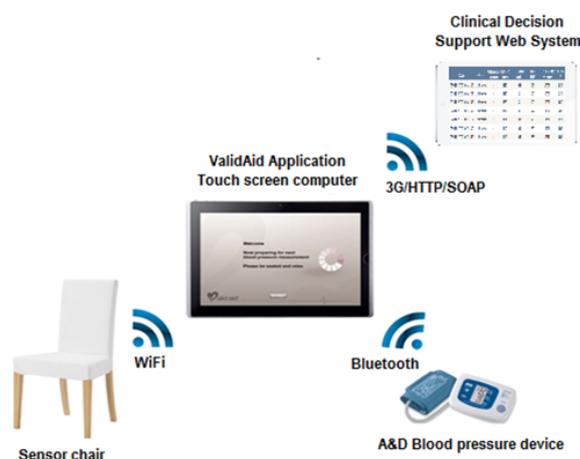


Figure 1. Overview of the ValidAid system

The audio classification algorithm for detecting talk during measurements has previously been validated in a laboratory study (Wagner et al. 2012). The algorithm will detect any talk in the vicinity of the system, including from relatives or staff. Likewise, the sensor chair has been validated with regard to its ability to accurately classify whether the patient is correctly seated and complies with the recommended rest time (Wagner et al. 2011).



Figure 2. Screenshot from the patient interface. In the top left corner we find the active adherence aid that provides a countdown timer indicating when the next measurement should be taken. If a patient performs a measurement prematurely she is instructed to redo the measurement. The list of recommendation that the patient needs to follow is placed in the center of the screen in a text-based format.

The user interface consists of a screen for providing instructions and context-aware feedback to the patient (figure 2). Besides the instructions, it will also automatically present the measured BP data along with contextual meta-data, including whether talk was detected, rest time was adhered to, legs crossed, and back supported. Only rest time is actively enforced, and the system will not allow the patient to continue until the needed rest time has been met. Also, the user interface allows the test facilitator to see previous measurements and entering patient data. If no data is input, the patient is automatically given a unique identification name.

#### *Setting*

The Department of Obstetrics and Gynecology delivers around 5.000 babies per year. The majority of the pregnancies are uneventful. However, a minority of women suffer from complications in their pregnancy leading to around 8.000 visits to the obstetric outpatient clinic per year for medical consultations. This includes pregnant women suffering from diabetes, hypertension, preeclampsia, and other. Some pregnant women are required to self-measure several parameters in the outpatient clinic. This includes performing BPSM unsupervised using an automatic blood pressure device that is available in the waiting room.

#### *Participants*

We included 34 women age 17 to 42. The participants were randomly selected among women scheduled for a nuchal translucency scan, at 12 weeks of gestation, at the department. Blood pressure self-measurement was performed after the scan, and only women who had a normal scan were asked to participate.

#### *Study design*

The test facilitator provided the participants with the necessary background information on the study purpose and structure. After having signed an informed consent, participants were instructed on how to obtain a reliable BPSM according to the internationally established recommendations on BPSM use (Pickering et al. 2010). Next, participants autonomously performed the self-measurements in a special enclosure at the outpatient clinic using the ValidAid system without being observed by the test facilitator. We wanted to investigate the potential of providing active and context-aware adherence aids to improve adherence. We chose to provide only a single active and context-aware adherence aid focusing on the participants' ability to rest at least five minutes before the first measurement, and rest at least one minute between the three measurements. We did not provide any active context-aware adherence aids with regard to the remaining context parameters: ambient noise-level, legs-crossed, and talking. However, these remaining context parameters were recorded and stored for data analysis. The recommendations are presented on screen during measurements as a text-based passive adherence aid.

### **3. RESULTS**

We obtained 108 individual measurements from 34 unique patients during a two week study. Of these, 29 patients took exactly the required three measurements, four patients measured four times, while one measured five times. In three out of four cases, the extra measurement was performed prior to the five minute rest limit. The detailed results of the BP measurements and context data can be seen in Table 1. In Table 2 the percentage of patients adhering to the individually measured recommendations is presented.

Table 1. Values measured by ValidAid. Presented as average  $\pm$  standard deviation, or specifically stated

Measured Parameter	Measured value
Systolic BP, average	108 $\pm$ 8 mmHg
Diastolic BP, average	73 $\pm$ 9 mmHg
Pulse/heart rate average	77 $\pm$ 10 bpm
Time seated, average	439 $\pm$ 117 s
Talk detected percentage of time, average	0.3 $\pm$ 1.6%
Legs crossed percentage of time, average	25 $\pm$ 39%

Table 2. The number of patients adhering to the recommendations during self-measurements using ValidAid

Recommendation adhered to	Patients adhering, Percentage.
Not talking	98%
Legs not crossed	85%
Rest time (5 min.)	96%
Back supported	44%
Quiet Settings	79%

#### 4. DISCUSSION

We found that most participants (85%) performed exactly the three required BP measurements. The remaining performed either four (12%) or five measurements (3%) respectively. There were three incidents of “premature measurements” typically taken within 15-60 seconds after the patient was first seated. However, the three patients eventually managed to wait a further 5 minutes before taking the next measurement, achieving three valid measurements in the end. The ability to recover from the erroneous process is likely due to the context-aware adherence aid which would subsequently inform the patient of the insufficient rest time and instruct her to redo the measurement when a premature measurement was detected.

One patient had actually rested sufficiently before starting the measurement process, but continued to take an additional two measurements after the system had indicated the successful receipt of the required three measurements. Thus, we need to further analyze whether the feedback concerning the successful completion is conveyed sufficiently clearly to the patient.

We observed adequate patient adherence to the recommendations with regard to rest time in general (96%) and refraining from talking during measurements (98%). However, the recommendation on keeping legs not crossed was only adhered to in 85% of measurements, while back supported was only adhered to by under half of the patients (44%). Inadequate patient adherence to any of the recommendations may cause critical bias (Pickering et al. 2010).

Results indicate that patients primarily comply to recommendations when they are actively guided. Using instructions and passive adherence aids did not seem to be sufficient for ensuring reliable measurements. Furthermore, the ValidAid system was only configured to provide active guidance with regard to rest time. Thus, it should be considered whether active and context-aware adherence aids should be introduced to verify and aid with regard to all of the recommendations. However, if we need to actively guide patients through all recommendations, equipment cost and complexity might make such a system infeasible to develop and deploy in the clinic.

Also, the effect of being overwhelmingly and continuously corrected by the system might also induce anxiety into some patients possibly leading to increased BP values, not unlike the white coat effect (Wagner et al. 2012). Such challenges need to be investigated in more detail. Using existing BP devices and telemonitoring systems does not support detecting non-adherent behavior. As a consequence, the quality of the data cannot be validated by staff, other than by relying on direct observation and intervention as needed. This is however not a cost-effective or feasible solution with current available staff resources. Therefore, we suggest deploying BPSM devices with a sufficient amount of context-aware adherence aids and verifiers for achieving the required accuracy for the patient group in question. Alternatively, patients could be provided with telemedicine BP devices for home use, also equipped with adherence aids; although this approach might likely incur higher equipment and maintenance costs, as well as increased administrative overhead. Several related studies have investigated the ability of the patients to accurately report the self-measured data, and found that up to 50% of all reported data contained errors as compared to the data stored in device memory (Johnson et al. 1999, Mengden et al. 1998, Myers 1998, Santamore et al. 2008). These results are in line with our findings, indicating a general tendency of non-compliance during unsupervised BPSM processes.

## 5. CONCLUSION

Existing devices and intervention methods for BPSM are not well-suited for self-measuring patients. This implies that healthcare staff needs to be present during the BPSM process. Thus, moving BPSM from the supervised clinical setting to the unsupervised setting is challenged by unknown patient adherence levels due to the limited technology support for self-measuring patients provided by existing devices and systems. We found it feasible to use a context-aware system, such as ValidAid, for improving self-measurement adherence and overcoming these challenges. However, more work is needed on this subject.

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