

Patient Acceptance of Blood Pressure Self-Measurement Equipment using Context-Aware Patient Guidance

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ABSTRACT

Background: Hypertensive disease and preeclampsia are serious medical disorders affecting pregnancy. Screening in early pregnancy may identify women at risk and enable prophylactic treatment. Accurate blood pressure (BP) measurement at the hospital outpatient clinic in the first trimester of pregnancy is an important part of this screening process. As the screening procedure is lengthy, lasting up to 30 minutes, an automated blood pressure self-measurement procedure could save sparse staff resources. However, patients tend to make errors when self-measuring, which could result in treatment-errors. Previous work has investigated equipping self-measurement stations with context-aware patient guidance, which is able to detect and mitigate such measurement errors, and even recover from them. The technical performance of these systems has previously been reported.

Objectives: The aim of this study was to evaluate patient acceptance levels when performing self-measurements using a context-aware patient guidance system as part of a blood pressure self-measurement (BPSM) station.

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Methods: In an observational study, 100 pregnant women were invited to self-measure their BP using a BPSM system consisting of a clinically validated BP device, and a context-aware sensor system for registering rest-time, talking, and other relevant context parameters, seeking to improve participant adherence through interactive guidance. Acceptance of the automated self-measurement, including the interactive guidance, was evaluated using a questionnaire in a follow-up interview session immediately after the self-measurement process. Participants were also invited to provide open comments on their experience.

Results: The majority of the participants, 93 %, felt comfortable using self-measurement equipment, while a minority of 8 % would have preferred staff assisted measurements. The majority of participants expressed mostly positive feelings associated with the user experience of self-measurement, with 83-88 % using positive utterances of the experience.

Conclusion: We found patient acceptance levels of performing self-measurements using interactive and context-aware guidance, without staff participation, to be an overall positive experience. Suggestions on how to mitigate the negative experiences were discussed, and these should be investigated further.

CCS CONCEPTS

• **Human-centered computing;** *Interaction design;* Empirical studies in interaction design

KEYWORDS

Measurement adherence, adherence, compliance, blood pressure, self-measurement, patient compliance, hypertension, pervasive healthcare, preeclampsia, telemedicine, telehealth, pervasive health, pervasive computing, context awareness, context, sensors.

1 INTRODUCTION

Hypertensive disease and preeclampsia (PE) are some of the most common medical disorders affecting pregnancy today [1, 2]. Approximately 2-5 % of all pregnancies are complicated by PE [3], a condition which is associated with an increased risk of fetal growth restriction, fetal death, and maternal morbidity including generalized seizures, intracerebral hemorrhage and severe and possibly lethal effects of multiple organ system damage [1]. Preeclampsia is defined as blood pressure (BP) levels of 140/90 mmHg or more measured on two occasions at least 4 hours apart after gestational week 20 [4]. Early diagnosis is essential to reduce the risk of complications [5]. Recent studies indicate that screening of asymptomatic pregnant women in their first trimester of pregnancy, and prophylactic medical treatment, can reduce the risk of developing severe PE [5-11]. Accurate BP measurement is an important part of this screening and in order to be valid for diagnostic use, a range of recommendations must be followed [12]. Recommendations include: a quiet setting before and during measurements, especially that the patient remains seated and rested for five minutes before the first measurement, not moving or talking, being correctly seated, legs not crossed, back supported, feet flat on the floor, arm supported at heart level and finally correct cuff size and mounting.

Introducing screening programs of pregnant women in their first trimester will require increased use of resources of trained personnel to perform BP measurements, which is difficult in the economically challenged European national and public healthcare systems. Existing BP devices do not track behavioral data in order to measure adherence/compliance to recommendations. With most existing point of care technologies available at the outpatient clinics, it is necessary for direct observation and intervention by staff in order to ensure the quality of the measurements, as there are no other means to validate measurements than through staff observation. Blood pressure self-measurement (BPSM) could save on staff resources and may perhaps help reduce the risk of white coat hypertension [13]. White coat hypertension is an anxiety related phenomenon, which results in artificially high BP measured by staff in a clinical context [13]. Recent studies have evaluated the ability of patients to self-measure BP and this has proved to be challenging [14]. The advances within pervasive computing technologies, including context-aware enabling technologies, provide an indication that interactive guidance of patients using context-aware sensors could allow for a transformation of many point of care technologies from being staff-guided and operated to becoming patient-operated and

self-guided [15]. In addition, context-aware technologies could potentially increase patient adherence levels, which could help reduce measurement-errors and the treatment-errors that could result from this. The effects of context-aware patient guidance on blood pressure self-measurement adherence levels have been reported previously [16]. Patient acceptance of these technologies and guidance needs to be investigated further, as good and positive user experiences are crucial for the success of these technologies, where both staff and patient confidence in the technology must be comparative to staff-operated interventions.

The aim of this study was to evaluate patient acceptance levels when performing self-measurements using a context-aware patient guidance system as part of a blood pressure self-measurement (BPSM) station.

2 METHODS

2.1 Study Design

We included 100 pregnant women attending routine ultrasound scanning, at gestational week 12, at the Department of Obstetrics and Gynaecology, Aarhus University Hospital. Participants were approached in the waiting room, before the scheduled scan. Verbal and written information, regarding the study purpose and structure, was given to all participants to ensure informed consent. Women, who had a normal first trimester scan and accepted to participate, were included in the study. Twin pregnancies were excluded. BP measurements were performed using a BP self-measurement station called ValidAid. The ValidAid system was also used to gather information on BP measurements and relevant context parameters, which have been reported elsewhere [16]. Patient age and actual gestational week were also recorded. Upon completion of the three measurements, each patient received a questionnaire to evaluate the acceptance of self-measurement.

2.2 Questions on user acceptance and experience

The questionnaire included seven questions, where participants were asked to score the experience of using the ValidAid system. Scores were divided into six categories using the Likert-scale: strongly agree, partly agree, neither-or, partly disagree, strongly disagree and do not know.

In order to further investigate the participants' experience and emotional response to the self-measurement station, we asked three follow-up questions: 1) Which words best describe your experience of having to self-measure your blood pressure? 2) Which words best describe the quality and credibility of the self-measurements performed by you

today (as opposed to measurements performed by the staff, a doctor or a nurse)? 3) Which words best describe your experience of the electronic guidance provided by the self-measurement station? We analyzed the data by sorting the words and utterances into a negative and a positive category, and we further analyzed the two categories to get closer to an understanding of the experience of use. This approach was inspired by Bardzell et al. [19], and provided a more open set of insights, than ratings in the Likert scale would allow for.

2.3 ValidAid platform

The ValidAid Platform was developed by The Department of Engineering, at Aarhus University, as a research system for exploring patient adherence during self-measurement of BP. The ValidAid platform is an automatic context-aware system for capturing self-measured BP data, combined with data regarding the patient's adherence to the instructions according to the international recommendations regarding BP measurement [20]. Some of the recommendations were actively enforced using on-screen interactive reminders, including rest-time and talking. The recommendations on keeping legs uncrossed and back supported were not actively enforced by the system.

The ValidAid system runs on a tablet computer (ASUS Eee EP121, Asus Inc., Taiwan) that integrates the BP device and context sensor components, provides a user interface for the users, as well as performs audio classification of the data obtained. The ValidAid system uses a clinically approved BP device (A&D Digital BP Monitor UA-767PBT, A&D Company Limited, Japan), a context sensor system including a chair with built-in piezo-resistive sensors for registering leg placement and correct seating, and back supported, and a graphical user interface [16]. The user interface consists of a screen guiding the patient through a series of three measurements based on input from the context sensor system and blood pressure device.

2.4 Blood Pressure Self-Measurement

Participants received an anonymous id number and, after careful verbal instruction on how to take reliable BPSM, they were left to autonomously perform three self-measurements in the ValidAid test setup with the aid of a BP device. They were instructed to be seated comfortably in a quiet area; their arm was supported at heart level, backs rested and legs not crossed. A small (<22 cm), normal (22–32 cm) or large (33–42 cm) adult

cuff was used, depending on mid-arm circumference [20]. Participants were required to rest five minutes before the first measurement and at least one minute between the following measurements. All participants were interactively guided with the aid of a countdown on the tablet computer; they were able to follow how long they had been seated and see when to take the three measurements. The participants were also warned not to talk, when talking was detected by the context sensors. There were no active context-aware adherence aids used for the remaining context parameters. These parameters were, however, recorded and stored for future analysis, the results of which have been reported elsewhere [16]. All measurements were automatically stored and data was made available to staff via a web-based system.

3 RESULTS AND DISCUSSION

3.1 Participant data

We recorded a total of 308 individual measurements from 100 unique patients including all relevant context data. Detailed results of participant data, including age, gestational age, systolic and diastolic BP, heart rate and MAP values can be seen in Table 1 and has been reported in [16].

Table 1: Participant data

Parameter	Value: Mean, [95% confidence interval]
Age (years)	29.9, [28.9 – 30.8]
Gestational age (weeks)	12+4, [12+3 – 12+5]
Systolic BP, mm Hg	109, [107.5 – 110.9]
Diastolic BP, mm Hg	72.3, [70.6 – 73.9]
Pulse, beats per minute	79.1, [77.0 – 81.3]
Mean Arterial Pressure	84.6, [83.0 – 86.1]

3.2 Questions on user acceptance

The questionnaire showed that 95% felt 'very comfortable' with self-measurement, 81% strongly agreed to this, whilst 14% partly agreed. Seventeen percent felt 'uncomfortable' having to self-measure, but only 7% expressed strongly agreeing to this. Ninety-three percent disagreed that they felt unnecessarily monitored by the BP equipment, 87% strongly disagreeing to this. Eight percent would have preferred that BP measurements were performed by healthcare personnel (see Figure 1 for details).

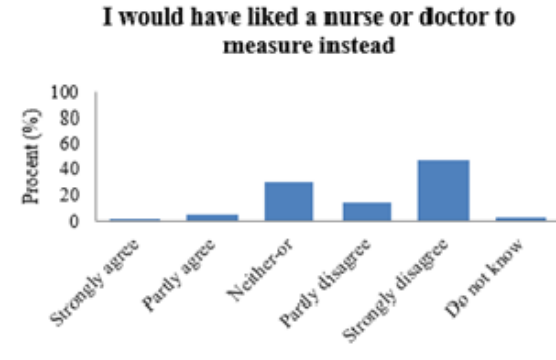
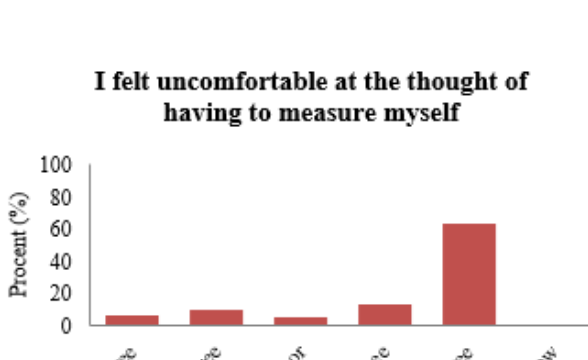
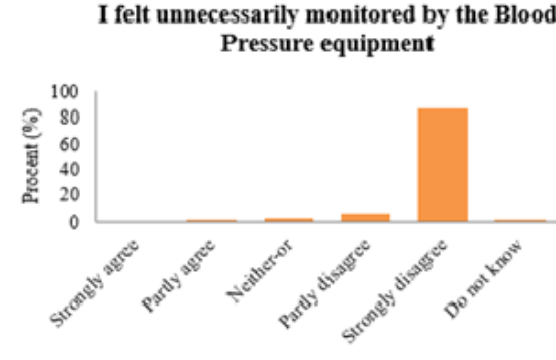
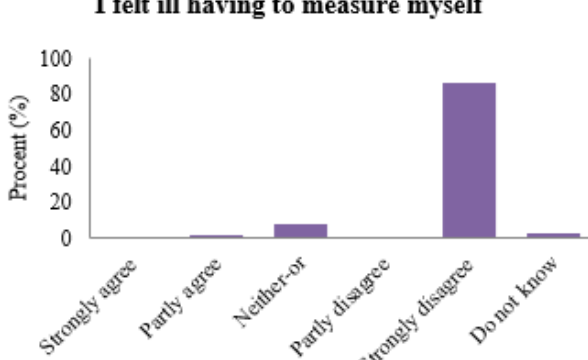
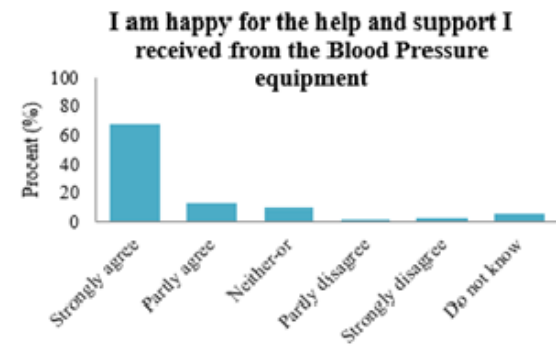
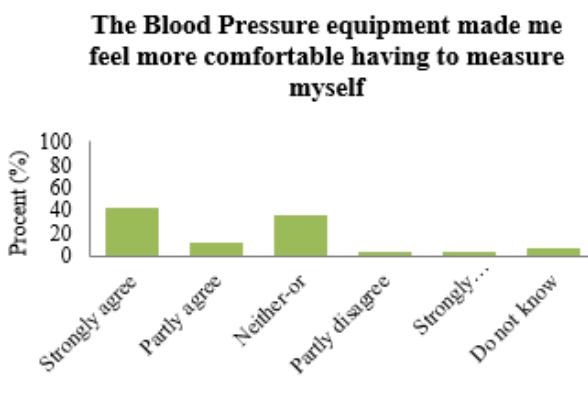
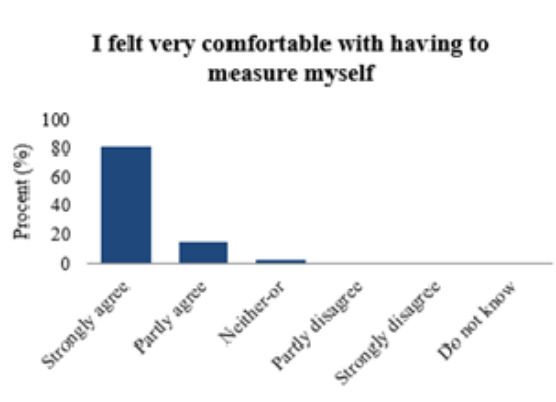


Figure 1: Questionnaire results detailing participation experience

3.3 Questions on user experience

In response to user experience, question no 1: Which words best describe your experience of having to self-measure your blood pressure? Ninety-nine of the participants answered the question while one participant (no. 92), refrained from doing so. A total of 32 positive and 4 negative utterances were found in the text analysis. Frequency of the positive utterances varied between one and 34 participants. Negative utterances varied between one and five participants (see table 2).

Table 2: Participant experience, Question 1

Participant experience	Number of participants using the word(s)	Words describing the experience
Positive	34	Nice
	17	Easy
	13	Relaxing
	12	Calm
	8	Okay
	6	Simple, comforting
	5	Exciting, good, not problems
	3	Pleasurable, familiar, great, interesting, neutral, good instructions, not stressful
2	Effortless, new experience	
1	Quiet, fun, liberating, educational, confidential, positive, comfortable, manageable, reasonable, straightforward, control, self-confidence, no interferences	
Negative	5	Unsure
	2	Slow
	1	Confusing, transgressive

The positive words point mostly in the direction of the pleasant and relaxed, while a fraction of the participants was more excited. This is repeated in the answers to question 3.

In response to the quality and credibility of participant self-measurement opposed to health personnel, question no 2: Which words best describe the quality and credibility of the self-measurements performed by you today (as opposed to measurements performed by the staff, a doctor or a nurse)? Ninety-eight of the participants answered the question and two

participants, participants no 26 and no 92, refrained from doing so. Ninety-two of the 100 participants experienced self-measurement as being reliable.

In response to the user experience of the electronic guidance, question no 3: Which words does best describe your experience of the electronic guidance provided by the self-measurement station? Ninety-eight of the participants answered the question and two participants, participants no 86 and no 92, refrained from doing so. A total of 36 positive and six negative utterances were found in the text analysis. Frequency of the positive utterances varied between one and 25 participants. Negative utterances were limited to a single participant (see Table 3).

Table 3: Participant experience, Question 3

Participant experience	Number of participants using the word(s)	Words describing the experience
Positive	25	Easy
	22	Understandable
	18	Fine
	15	Good
	14	Clear
	5	Okay
	4	Adequate, good guidance, no doubts, simple
	3	Informative, straightforward, sufficient
	2	Professional, easy-to-use, outstanding, short, effective, calm
	1	valid, trustworthy, enlightening, correct, functioning, fool-proof, modern, nice, accurate, very, concrete, usable, unproblematic, well-shaken, as expected, carefully described, super experience
	Negative	1

4 DISCUSSION

We found that the participants expressed words and utterances that mainly reflected positive feelings (between 83% and 88%). In fact, there were only four negative utterances in question 1 (corresponding to 12%

providing negative utterances), the first being “unsure”, where two of the four noted that it was their “own insecurity as to whether they have executed the measurements correctly”, a second being “confused”, and a third being “slow”, which is most likely associated with the entire process taking around 10-15 minutes of having to sit quietly and unengaged. The last negative utterance was “a bit transgressive”, which is likely to reflect the situation the pregnant women were in, creating a feeling of “being overwhelmed” by the self-measurement process.

The clear trend through the answers to question 2 is that participants had previous experience with BP measurements, and that they were confident that also self-measured BP measurements would be correct and valid. The participants felt they were “experts” in their own BP management, which was reflected in a number of utterances on reliability and validity.

The ValidAid self-measurement system was designed to provide interactive guidance in regards to “rest-time” and “avoid talking”. No guidance was provided for all other parameters. Therefore, it needs to be further investigated whether introducing additional context-aware adherence aids would be perceived as acceptable and relevant by the pregnant women. It could be speculated, that such a guidance system could have a negative effect on participants. Continuously being corrected by a self-measurement system could possibly result in increased anxiety which could lead to increased BP values, mirroring the white coat effect [17]. These challenges need to be investigated further.

Therefore, more work is needed in order to determine the optimal level of active adherence aids and verifiers used to achieve accurate measurements and the optimal self-measurement user experience.

5 CONCLUSIONS

The majority of the participants felt comfortable having to self-measure indicating overall high patience acceptance levels. A minority would have preferred the measurements to be taken by health care staff instead, which should be respected in order to avoid raised anxiety-levels in this group. Further development of the interactive features of the platform may potentially facilitate increased adherence to more of the recommendations and reduce patient feelings of insecurity related to self-measurement but could also lead to increased anxiety in case of too many corrective actions being suggested by the guidance system.

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