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David Claudio
Maria A. Velazquez
Wilfredo Bravo-Llerena
Gül E. Kremer
Andris Freivalds

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Usefulness of Wireless Technologies to Improve Emergency Department's Patient Care

David Claudio[1], Maria A. Velazquez[1], Wilfredo Bravo-Llerena[3], Gül E. Okudan[2,1], and Andris Freivalds[1]

[1]Department of Industrial and Manufacturing Engineering
[2]School of Engineering Design
The Pennsylvania State University
University Park, PA 16802, USA

[3]Internal Medicine Department
Dr. Ramon Ruiz Arnau University Hospital
Bayamon, PR 00956, USA

Abstract

The use of wireless technology and bio-sensors in healthcare applications has been proposed and successfully implemented in previous studies. While its use in healthcare seems promising the perceived utility and usefulness of such systems has not been assessed in detail. User feedback is crucial as it would determine the attitude towards using the technology and ultimately its success. This article presents the results of a study in which the perceived value and usefulness of wireless monitoring devices were assessed from the perspective of the patient and the nurses in the Emergency Department (ED). A field test in a real emergency department was conducted using wireless technology to monitor patient's vital signs. Both patients and nurses were asked to provide their feedback on utility and value of the wireless system in the form of a questionnaire. The results present the perceived usefulness and value of the technology for the two populations.

Keywords
Bio-sensors, healthcare, perceived utility

1. Introduction
The use of wireless technology and bio-sensors in healthcare applications has been proposed and successfully implemented [5-6, 8]. While this technology has been used mostly in emergency response applications, bio-sensors and wireless technology may be suitable to monitor patients' vital signs while they are waiting in the Emergency Department (ED) [8]. Some of the advantages of using this technology in the ED are: the availability of objective criteria to support the nurses' decision making, the improvement in quality of care due to the real-time knowledge of patients' health status, and the improvement of patients' prioritization by doing accurate assessment of the patients' conditions while waiting in the ED [8].

While the use of wireless technology with bio-sensing capability in healthcare has been implemented [5-6, 8], the degree to which the patients and the nurses are willing to use this technology and the perceived utility and value of it have not being assessed. To achieve success with the use of wireless technology and bio-sensors in the ED setting, both groups of users, patients and nurses, should be able to effectively use it. For the patient, using the technology implies wearing sensors in his/her ill body, which may be perceived as intrusive, uncomfortable and unnecessary. For the nurses, using the technology requires them to manage the information provided by the system and use it wisely to determine patients' condition despite the chaotic nature of a typical ED setting.

The frequency and willingness to use the technology would depend on its perceived value among other variables [9]. Therefore, the user feedback is fundamental to the effectiveness and success of the technology, as it would provide

insights on the attitude towards its use. Given that previous assessments of the use of this technology in the ED are limited to the technical capabilities, and that there is no information available on the perceived usefulness and value of this technology in the ED, we assert that it is necessary to evaluate usability aspects of the technology. Information about the users' perception will help us assess the effectiveness of the system, which may determine its eventual success.

This research investigates the perceived usefulness of using wireless technology and bio-sensors to monitor the patients' vital signs in the ED from the perspective of the patients and the nurses. The purpose of this paper is to provide insights on the perceived relevance of the technology to improve the quality of service, the perceived benefits in the quality of treatment and the perceived value of the continuous monitoring of vital signs. A field test in a clinical setting was conducted using wireless technology to monitor patients' heart rate, respiration rate, temperature, oxygen level and blood pressure while they waited in the ED waiting room. Collected data provided real-time information of the patients' conditions to the nurses. Both patients and nurses were asked to provide their feedback on the usefulness and value of the wireless system in the form of answers to a questionnaire. Preliminary assessments are included from both the patients' and the nurses' perspectives.

2. Literature Review

The use of wireless technology in healthcare has proven to be very useful and effective in many reported cases [1-4]. Some researchers have proposed the use of such technology for the purpose of patient tracking [1,2] and patient's status [3,4]. However, in recent years researchers have been focusing on the integration of wireless technology with bio-sensors to track and monitor patients [5, 6]. Curtis et al. [8] were among the pioneers of using wireless technology and bio-sensors in the ED. They developed a Scalable Medical Alert Response Technology (SMART) with the purpose of using wireless technology to constantly monitor patients' vital signs. After data is collected, software using a rule-based decision support system alerts the nurses on critical cases.

Gao et al. [7] conducted a study where they determined the vital signs that are good candidates to monitor based on protocols and discussions with paramedics. According to their study, the candidate vital signs are: 1) temperature, 2) pulse, 3) blood pressure, 4) respiration rate, 5) oxygen saturation, 6) peripheral vascular perfusion, 7) mental status, and 8) electrocardiography. They state that the sensors that measure the signs that are easy to use, portable, wearable, with less power consumption, and capable of providing continuous vital sign data are a blood pressure cuff to measure blood pressure, pulse oximeter to measure oxygen saturation, and a two-lead electrocardiogram to measure heart rate [7].

In this study, we proposed the use of wireless technology along with bio-sensors to monitor the patients' vital signs while waiting to be seen in the ED. The equipment includes a bio-harness that measures heart rate, temperature, and respiration rate, along with a wrist blood pressure monitor and wireless oxygen meter. The data collected by the bio-harness and the oxygen meter was sent to a computer program equipped with wireless connection. To implement the monitoring system the patients were required to wear the bio-sensors in multiple areas of their bodies and the nurses needed to be willing to use the patients' vital signs data. Our main concern was that instead of a tool to help provide better care, both the patients and the nurses would perceive the technology to be intrusive, non- value adding, and thus would refuse to use it. Accordingly, it was crucial to investigate the users' perception of the technology.

The importance of perceived usefulness and perceived ease of use in the user's acceptance of technological products has been highlighted by Davis [9] in his Technology Acceptance Model (TAM). The TAM provides an informative representation of the mechanisms by which design choices affect product acceptance and specifies the causal relationships between design features, perceived usefulness, perceived ease of use and attitude towards using the actual system [9]. Davis' technology acceptance model (TAM) proposed that the usage of the system or product will depend directly on the attitude towards using the product, which in turn is a function of the perceived usefulness and perceived ease of use, which depend on the system design features. Perceived ease of use refers to the degree to which an individual believes that using a particular product would be free of physical and mental efforts; and perceived usefulness refers to the degree to which an individual believes that using a particular system will enhance his/her job performance [9]. Based on TAM, both perceived ease of use and perceived usefulness are behaviors that affect the attitude towards using the product and consequently the product usage. Thus, understanding the factors that affect the perceived usefulness and ease of use would let us understand the level of willingness to use the technology.

In this research, we investigated the perceived usefulness of the system, the perceived value of continuous vital sign monitoring to the health care, the relevance of technology to improve the quality of service, and the perceived benefits in the quality of treatment. The *perceived usefulness*, in our context, refers to the degree to which nurses believe that using the wireless technology and bio-sensor system will enhance their job performance, and thus contribute to the quality of treatment for patients. The *perceived value* refers to the degree of importance and significance of vital signs' continuous monitoring for patient care. The *perceived benefit in the quality of treatment refers* to the extent to which the users perceive the technology as beneficial to the quality of treatment. From the patients' perspective, the *relevance of technology to improve the services* refers to the degree to which the patients think the technology employed is important to improve the quality of service. From the nurses' perspective, the *support tool for their work* refers to the degree to which the nurses feel the technology can support their work.

These metrics were created based on Davis' work on technology acceptance [9], and they were adapted from the TAM questionnaire for the specific context of this research. These metrics should provide insights about the system from the users' perspective, to understand the degree to which the patients and the nurses are willing to use and adopt the system.

3. Methodology

A field test in a real emergency department was conducted using wireless technology to monitor patients' heart rate, respiration rate, temperature, oxygen level and blood pressure while they waited in the ED waiting room, providing real-time information of the patients' conditions to the nurses. After using the technology, the participants were provided with a questionnaire in which they were asked to provide their feedback on utility and the value of the wireless system.

3.1 Participants

The participants were patients and nurses from a hospital in Puerto Rico. A total of 20 nurses from the ED and 40 patients were willing to participate in the usefulness survey. The triage nurses' population consists of about 40 nurses. A total of 45 patients were exposed to the technology. The average ages of the study subjects were 44.8 years and 41.5 years for patients and nurses respectively. 52% of the patient population was female whereas 95% of the nurses were female. All the participants were exposed to the technology, and its purpose was explained. They all participated voluntarily and they did not exhibit any major life-threatening issues.

3.2 Materials

To record the patient vital signs we used a bio-harness manufactured by Zephyr, which is a commercial chest strap that measures heart rate, temperature, and respiration rate. Zephyr's monitoring device provides real-time data on the physical status of individuals that enables tracking of their current status. We also used a wireless pulse oximeter (Model CMS-50E), which goes on the finger and measures the percentage of oxygen in the blood and pulse rate, and the Omron HEM-670IT Wrist Blood Pressure Monitor, a commercial blood pressure monitor cuff that goes on the wrist.

Two questionnaires (one for patients, and one for nurses), both composed of ten questions were used to measure usefulness and the other metrics mentioned. The differences between questionnaires were related to the relevance of technology to improve the quality of care for the patients, and the questions related to the perception of the technology as a support tool for the nurses. The questions were based on the TAM questionnaire developed by Davis [9], and they were adapted to the context of this research. Each question provided the participant with a Likert scale from 0 to 7, where 0 represented the worst and 7 represented the best responses.

3.3 Procedure

The participants from the patient population were selected randomly from the group of patients waiting in the ED. The participants' conditions were assessed to discard patients with critical conditions, and to ensure that the patient was aware of the experiment and conscious. The patients were instructed about the purpose and scope of the research, and they were asked for their consent to participate in the experiment. The bio-sensors were applied to the patients, and wireless technology was used to transmit the vital signs to the computer for recording. After 30 minutes, the patients were provided with the survey and asked to provide their feedback based on their experience with the equipment. The nurses were also selected randomly from the pool of nurses that work as triage nurses.

They were instructed about the purpose and scope of the research, and they were asked to apply the bio-sensors to the patients and observe how the wireless technology transmitted the vital signs and how they were recorded in the software. After their experience with four patients, the nurses were provided with the usefulness questionnaire and asked to provide their feedback based on their experience.

4. Results

One of the concerns we had was the level of comfort experienced by the patients while using the bio-sensors. A specific question asked the patients about their level of comfort while using the equipment and around 80% of the patients reported a high level of comfort while using the bio-sensors. This tells us that the equipment does not seem to be uncomfortable to wear or intrusive to the patients. Another concern was the degree to which the participants had concerns over confidentiality. Around 75% of the participants agreed that they had no concerns of their privacy being violated by the constant monitoring of their vital signs or by the fact that the equipment sends the data wirelessly to the computer.

The metrics describing the perceived usability, perceived value, perceived benefit in the quality of treatment, relevance of technology to improve the services, and support tool for their work were estimated by aggregating the answers of a group of questions related to the desired metric. For example, the perceived usefulness for the patient questionnaire was estimated by aggregating the Likert scale values for questions 2 through 10. For each patient, a summated value for the metric was estimated by adding the Likert scale values for each question, and an average value was estimated from all the questions comprising the metric. The summated and average values determined the metric value for each patient. From these aggregated values, average scores and percentage of respondents for the Likert categories were estimated.

The use of multiple Likert values to estimate a scale or metric is a suggested practice to improve the reliability of the results, and the validity of the scales in a questionnaire. Gliem and Gliem [10] proved single-item metrics are unreliable and therefore inappropriate to draw conclusions and inferences. The estimation and report of Cronbach's alpha coefficient is imperative to assess the internal consistency and reliability of any scale, and the analysis of the data must use the summated scales and not the individual questions [10]. The results for patients and nurses are shown in Tables 1 and 2, respectively. A brief description of the statistics is provided in Figure 1.

Mean of summated values – corresponds to the mean of the summation of the values chosen for all the questions related to the metric of interest. The summated values range will be defined by the number of questions in the metric. E.g., if there are 8 questions used to determine the metric, the min value = 0 and the max value = 56 (7 is the max value of each likert scale * 8 questions). The higher the summated value, the more positive perception.

Mean of average values – refers to the mean of the averages of the values chosen for all the questions related to the metric of interest. Likert scales go from 0 to 7. The higher the average value, the more positive perception.

Mean of inter-question correlations – refers to the mean value of the inter-question correlations, which are the correlations of each question with the sum of all the remaining questions. For example, if the metric is estimated using 8 questions, there will be 7 inter-question correlations computed: the correlation between the first question and the sum of the other 7 questions, the one between the second question and the sum of the other questions, and so on [10].

Alpha – Corresponds to the Cronbach's alpha coefficient of internal consistency. The Cronbach's alpha is the most frequently used metric to measure internal consistency and validity of the questions used to formulate a measure or scale [10]. It is estimated based on the number of questions used for the metric and the inter-question correlation. The closer the alpha value is to 1, the greater the internal consistency of the questions in the metric [10]. The following rules of thumb were provided by [11]: alpha >0.9 = Excellent, >0.8 = Good, > 0.7 – Acceptable, > 0.6 questionable, >0.5 Poor, <0.05 Unacceptable.

% of patients and nurses for a specific rating – refers to the percentage of patients who reported the specific level for the metric. The percentage is based on the averages for all the questions comprising the metric for each patient. For example, if 10 out of 20 patients have an average answer of 6 for a specific metric, the percentage of patients that reported the equipment to be very useful (likert scale value 6) will be equal to 50% (10/20*100%).

Figure 1: Definition of the statistics

Table 1: Results for patients for each metric

Perceived usefulness	**Mean**	**Var.**	**St. Dev**	**Min**	**Max**	**Alpha**
Summated values	53.43	14.30	3.78	40.00	56.00	
Average value (question means)	6.68	0.22	0.47	5.00	7.00	0.91
Inter-question correlations	0.57	0.01	0.09	0.44	0.67	
Based on average values for scale						
% of patients - extremely useful (7)	55.0%					
% of patients - very useful (6-6.99)	40.0%					
% of patients - useful (5-5.99)	0.1%					

Relevance of technology	**Mean**	**Var.**	**St. Dev**	**Min**	**Max**	**Alpha**
Summated values	20.20	2.06	1.44	15.00	21.00	
Average value (question means)	6.73	0.23	0.48	5.00	7.00	0.74
Inter-question correlations	0.49	0.01	0.08	0.43	0.58	
Based on average values for scale						
% of patients - extremely relevant (7)	67.5%					
% of patients - very relevant (6-6.99)	25.0%					
% of patients - relevant (5-5.99)	7.5%					

Perceived value added	**Mean**	**Var.**	**St. Dev**	**Min**	**Max**	**Alpha**
Summated values	26.73	5.08	2.25	18.00	28.00	
Average value (question means)	6.68	0.32	0.56	4.50	7.00	0.90
Inter-question correlations	0.69	0.00	0.07	0.62	0.78	
Based on average values for scale						
% of patients - extremely valuable (7)	65.0%					
% of patients - very valuable (6-6.99)	27.5%					
% of patients - valuable (5-5.99)	0.1%					

Benefits in the quality of healthcare	**Mean**	**Var.**	**St. Dev**	**Min**	**Max**	**Alpha**
Summated values	26.38	6.14	2.48	17.00	28.00	
Average value (question means)	6.59	0.38	0.62	4.25	7.00	0.82
Inter-question correlations	0.53	0.01	0.11	0.43	0.65	
Based on average values for scale						
% of patients - extremely beneficial (7)	57.5%					
% of patients - very beneficial (6-6.99)	27.5%					
% of patients - beneficial (5-5.99)	10.0%					

Table 2: Results for nurses for each metric

Perceived usefulness	**Mean**	**Var.**	**St. Dev**	**Min**	**Max**	**Alpha**
Summated values	48.70	37.91	6.16	38.00	56.00	
Average value (question means)	6.09	0.59	0.77	4.75	7.00	0.91
Inter-question correlations	0.56	0.02	0.13	0.43	0.80	
Based on average values for scale						
% of nurses - extremely useful (7)	20.0%					
% of nurses - very useful (6-6.99)	45.0%					
% of nurses - useful (5-5.99)	30.0%					

Perceived value added	**Mean**	**Var.**	**St. Dev**	**Min**	**Max**	**Alpha**
Summated values	25.10	7.67	2.77	19.00	28.00	
Average value (question means)	6.28	0.48	0.69	4.75	7.00	0.79
Inter-question correlations	0.49	0.01	0.08	0.44	0.60	
Based on average values for scale						
% of nurses - extremely valuable (7)	25.0%					
% of nurses - very valuable (6-6.99)	50.0%					
% of nurses - valuable (5-5.99)	20.0%					

Support tool for their work	**Mean**	**Var.**	**St. Dev**	**Min**	**Max**	**Alpha**
Summated values	24.60	8.88	2.98	19.00	28.00	
Average value (question means)	6.15	0.56	0.75	4.75	7.00	0.78
Inter-question correlations	0.46	0.02	0.13	0.29	0.59	
Based on average values for scale						
% of nurses - extremely supportive (7)	25.0%					
% of nurses - very supportive (6-6.99)	45.0%					
% of nurses - supportive (5-5.99)	25.0%					

Benefits in quality of treatment	**Mean**	**Var.**	**St. Dev**	**Min**	**Max**	**Alpha**
Summated values	25.10	7.46	2.73	18.00	28.00	
Average value (question means)	6.28	0.47	0.68	4.50	7.00	0.77
Inter-question correlations	0.45	0.01	0.11	0.33	0.57	
Based on average values for scale						
% of nurses - extremely beneficial (7)	20.0%					
% of nurses - very beneficial (6-6.99)	55.0%					
% of nurses - beneficial (5-5.99)	20.0%					

The perceived usefulness reported by the patients had an average value of 6.68 ($\alpha = 0.91$), which corresponds to a categorical value of *very useful*. In addition, the technology was categorized as extremely useful by 55% of the patients. Given the Cronbach's alpha of 0.91, the scale and the results are highly reliable. The perceived value added to the health system had an average response of 6.68 ($\alpha = 0.90$) corresponding to the category of *very valuable*. About 65% of the patients thought that the use of the technology was extremely valuable. The average value for the relevance of technology was 6.73 ($\alpha = 0.74$), with 67% of the patients categorizing the technology as *extremely relevant*. About 57% of the patients perceived the use of the technology as *extremely beneficial* for the quality of the care. The average value for this metric was 6.59 ($\alpha = 0.82$), which categorizes the equipment as *very beneficial*.

For the nurses, the perceived usefulness had an average of 6.08 ($\alpha = 0.91$), corresponding to the category of *very useful*, which was actually chosen by about 45% of the nurses to describe de usefulness of the technology. About 45% of the nurses perceived the equipment as very supportive, which correlates to the average value of 6.15 ($\alpha = 0.78$). The perceived value added to the health system had an average response of 6.28 ($\alpha = 0.79$) corresponding to the category of *very valuable.* About 55% of the nurses perceived the use of the technology as *very beneficial* for the

quality of the care. The average value for this metric was 6.28 ($\alpha = 0.77$), which categorizes the equipment as *very beneficial*.

For both the patients and the nurses, the average for the four metrics ranged from 6 to 6.99, which implies that for the metrics assessed, the user responses gravitated towards a very positive perception of usefulness and value. In addition, for all the metrics more than 50% of the participants thought that the technology was categorized from *extremely positive* to *very positive*. Overall, the metrics for the patient averages were slightly higher than the nurse averages, but the differences were negligible. These results are very encouraging, and they promote the use of the technology for continuous monitoring of the vital signs.

5. Conclusions

This research work investigated the perceived usefulness of using wireless technology and bio-sensors to monitor the patients' vital signs in the ED, with the purpose of providing insights on the perceived usefulness and value of the technology to improve the quality of service in the ED.

The prospective users of the system thought that the technology was very valuable and useful. Both the patients and the nurses have a positive reaction to the technology and the concept of continuous monitoring, which is very encouraging for the implementation of the technology in the ED. The results suggest that the technology and the concept of continuous monitoring will be adopted.

The results of this study provided us with a notion of the acceptance of the technology and the concept. Although we cannot directly predict or infer the degree of acceptability, the results of this study provide a sense of how the prospective users feel about the concept and the technology. In addition, this work intends to create awareness of the importance of assessing the user feedback before implementing a concept and technology. If the user perceives them as useful and valuable the opportunities of the technology to be used and implemented successfully are higher.

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