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AWARENESS OF WIRELESS SENSOR NETWORK POTENTIAL IN HEALTHCARE INDUSTRY: A SECOND UTAUT STUDY

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ABSTRACT
This study concentrates on investigating the degree of awareness, future adoption and uptake of wireless sensor networks (WSNs) (in particular Motes) in the Health Monitoring arena via the use of our second Web-based survey. The Unified Theory of Acceptance and Use of Technology (UTAUT) has been applied to determine how viable this technology will be for health monitoring in healthcare institutions and patients' homes. Results from our study show positive support for the acceptance of the technology yet reveal some real concerns about the issues of security, privacy, ethics and safety.

KEY WORDS
motes, wireless sensor networks, mobile healthcare technology

1. Introduction

Research has shown that mobile healthcare technology has the potential to support people in a variety of environments such as hospitals, health centers, aged care facilities and in homecare environments. It can also more easily manage transitions as patients move from or to acute, emergency, chronic, or primary care [2]. Governments and businesses have immediate access to specific, strategic information from remote web servers. Palm sized devices and flash cards store information that would have previously occupied large rooms as paper based records. Now the use of this digitized information gathered from various sensors and sensor networks, mobile digital devices and robots has the potential capacity to extend the Internet into a pervasive interconnected environment which can automatically monitor and collect societal, including health, information [16]. For example, the China Knowledge Grid Research Group is exploring the use of sensors to collect people's temperature and movement at airports, as well as collecting nature's variables such as humidity or water pollution to form simulations to study relationships among epidemics, society and nature [16]. This is of particular relevance in tracking the spread of the potentially lethal bird flu in 2005 - 2006.

Critical issues that have been identified for mobile eHealth applications include usability, adoption, interoperability, change management, risk mitigation, security and privacy, and return on investment [2]. This study concentrates on investigating the degree of awareness, future adoption and uptake of wireless sensor networks (WSNs) (in particular Motes) in the Health Monitoring arena via the use of a second Unified Theory of Acceptance and Use of Technology (UTAUT) survey. Part two of this paper provides a background to Motes, the methodology, the significance of Motes as a wireless network technology for health monitoring and outlines the three prototypes developed by the research team. It also describes the acceptance model, Unified Theory of Acceptance and Use of Technology (UTAUT) which has been applied to determine how viable this technology will be for health monitoring in healthcare institutions and patients' homes. In the third section the authors discuss the results of this second web based survey. Finally the paper concludes and points the way to future research.

2. Background

The layer of infrastructure that can digitize huge amounts of information coming from nature, either from the environment or from our own bodies (or biological networks) is in the shape of tiny wireless sensor network (WSNs) devices. These are capable of collecting environmental data sourced from remote geographical spaces to the most recondite places in our own bodies, for example, bio-nano sensors in our blood stream capable of monitoring personal health conditions. WSN applications must be capable of collecting, storing and handling huge amounts of data of a quite heterogeneous nature. They must be able to store and efficiently present to the user vast amounts of information in a timely manner. Furthermore these applications, once they start to be

utilized on a more common basis, must interact and share the obtained data with similar or even other types of applications from all across the world in a secure manner. However, at present, wireless sensor networks (WSN) are facing challenges in the technical, legal, security and privacy arena especially when applied to healthcare applications. It must also be remembered that they are still in an early stage of development.

2.1 Multi-faceted methodology

The multi-faceted research design comprises of a combination of research methodologies [3]. These include a literature review coupled with the development of three working prototypes to test the viability of Motes as healthcare monitors as well as the web based surveys. Initially the authors undertook a wide ranging literature review on the use of Motes in various applications, in particular in the health monitoring area [4], [5]. Figure 1 illustrates examples of health monitoring.

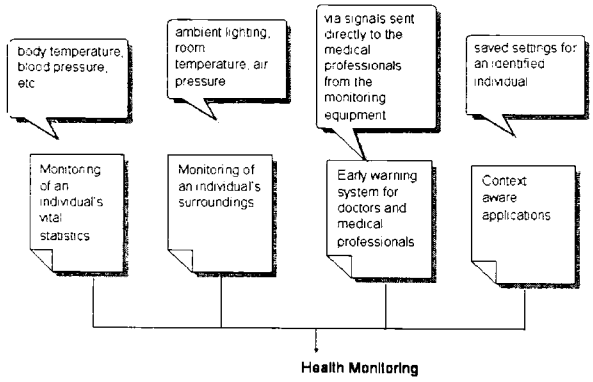

Figure 1 – Health Monitoring Examples

The use of Motes solves many of the problems and achieves many of the goals raised by the four points above. Current devices used for monitoring an individual's vital statistics, though highly accurate, are bulky and require wired connection between the individual and the monitoring device. Using Motes would reduce the amount of space required by these devices and only the Mote(s) would be connected to the patient [4], [5], [6], [7], [8]. Monitoring an individual's surroundings provides supplementary statistics, which may show a correlation with the patient's immediate state. It also serves as a tool for context-aware applications; for example, room settings in a hospital can be adjusted according to the requirements and condition of the patient. The biggest advantage that health monitoring may provide is to serve as an early warning system for doctors and other medical professionals [6]. Statistics gathered from the Motes may show a trend or correlation between each type of variable that may, upon reaching a set threshold, alert the health professionals. These statistics may be accessed via a web server to authorized individuals at any moment and location, thus, making it a very flexible system. [6]. Motes are illustrated in Figure 2.

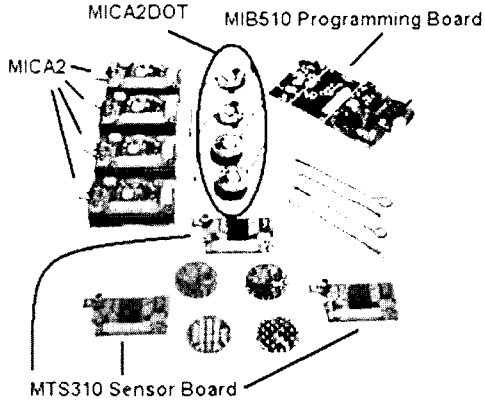

Figure 2 – Motes and Sensor Boards (www.xbow.com)

The multi–faceted research approach has resulted in the development of three prototypes to demonstrate the viability of commodity based wireless sensor networks (Motes) for health monitoring of chronically ill or aged persons. The authors have conducted two anonymous web surveys on the potential acceptance of these devices as health monitors by users. This second survey is also based on the acceptance model, *The Unified Theory of Acceptance and Use of Technology* (UTAUT) as a follow up to the previous pilot study [7] to help predict user acceptance or rebuttal of Wireless Sensor Networks and their reasons. The statistical analysis of the quantitative data of this second survey is the subject of the next iteration of this ongoing work and is discussed in this paper.

The initial pilot survey targeted a narrow group of IT professionals and students from Australia and Canada and produced positive results (n [participants] = 59) [7]. In order to gain a more representative sample of the population, the second follow-up survey sought a wider and more international cohort to ascertain the acceptance of motes in healthcare environments in a number of countries. Some of the questions were modified to ensure people were not confused by the language and text boxes were used to elicit more information from the anonymous participants (particpants [n] = 103) from Europe, Australia, Canada and the United States. Finally an open ended question at the end of the survey allowed the participants to comment on any issues or concerns they may have had with either the survey or the use of motes in a healthcare environment.

The authors invited anonymous participation from medical personnel, health departments and health academics and students as well as from a wide range of academics from different faculties such as Business, Information Technology and Law in a number of

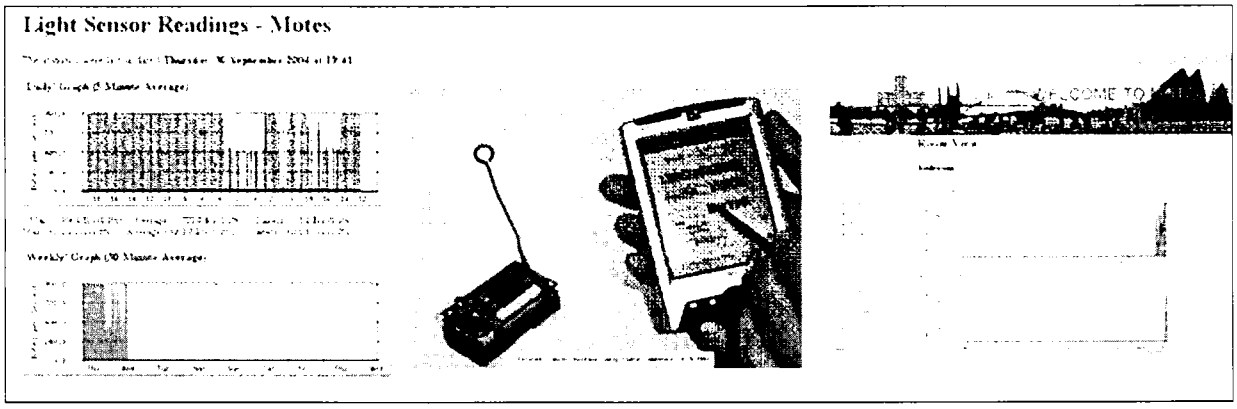

Figure 3a - Prototype 1: MRTG Graphs Figure 3b - Prototype 2: PDA Figure 3c - Prototype 3: Interface

countries including Norway, Greece, the United States, Canada and Australia. Participants were emailed the survey's website address and asked to complete the web survey and distribute the survey to colleagues in the same industry sector. After 2 months we had 103 completed surveys – as three people had completed the first survey only 100 surveys were used with the aim of investigating the degree of awareness of this type of technology and its potential acceptance.

2.2 Health monitoring system prototypes

The development of three prototypes helped the authors to understand the intricacies of working with these tiny devices over a period of 24 months. Many technical issues had to be resolved as these devices are still in a preliminary development stage and they are expensive. Our experience has been gained by working with a set of 10 motes (both Mica2 and Mica2Dot Motes) and sensors such as light, temperature, sound, and accelerometers rather than simulators which seem to be used by many other researchers in the wireless sensor network arena.

The first research test bed demonstrated that the use of the network management tool, Multi Router Traffic Grapher (MRTG) enables data from the motes to be displayed graphically on the web and thus allows medical staff the ability to access patient data from anywhere in the world by the use of a simple web browser [8] (see Figure 3).

The second research test bed demonstrated a similar system using PDAs. It was able to show that MRTG's compression is such that even with months of data, the amount of space required would only be a matter of hundreds of kilobytes. A remote feature of our system is also available, where authorized users are able to view the information graphically on a website. This data can be displayed on a laptop or PDA which has Internet connectivity. The system is more easily set up than the proprietary implementations [6]. Our third prototype improves on the performance and reliability of the system by separating the 'business logic' from the interface. The addition of Crossbow's Stargate allows for the ability to access the Mote sensor network by various mobile devices (PDA, cellular, etc).

2.3 The Surveys: Tools for applying UTAUT to Motes

The purpose of this paper is to identify the current perception of Motes, and in general, wireless sensor networks and determine its viability as a commercial product in a healthcare environment and/or as a lifesaving tool. The use of an opinion survey combined with a reference theory is the first stage in making early predictions of the rate of uptake. Conducting such a survey serves a number of purposes. It validates a known or new acceptance model, which can be used on developing new technologies.

2.4 Design and implementation of the second UTUAT survey

Traditionally acceptance models have been used to help explain and predict adoption of new technologies. They are based on specific factors, or constructs, that influence the individual's decision to adopt or reject a new technology. The paper [13] closely examined eight acceptance and adoption theories and combined the relevant constructs from different theories under one model, the Unified Theory of Acceptance and Use of Technology (UTAUT). UTAUT includes four determinants of user acceptance and technology usage. These acceptance models shared seven major concepts according to their constructs, of which four are considered direct determinants for user acceptance, namely [13]:

- Social influence
- Performance expectancy
- Effort expectancy
- Facilitating conditions

Along with these determinants are moderators (gender, age, experience and voluntariness of use) which affect the strength of the determinants. These determinants and

moderators influence an individual's behavioral intention (his/her planned intention towards the technology) – generally, to use it or not [13] (Figure 4). Motes are still in the research and development phase so only a part of this model was employed with the aim of informing researchers how the public perceives the new technology (whether they were previously aware of it or not). The results can lead to a new direction for the research – tailored for eventual public and commercial use.

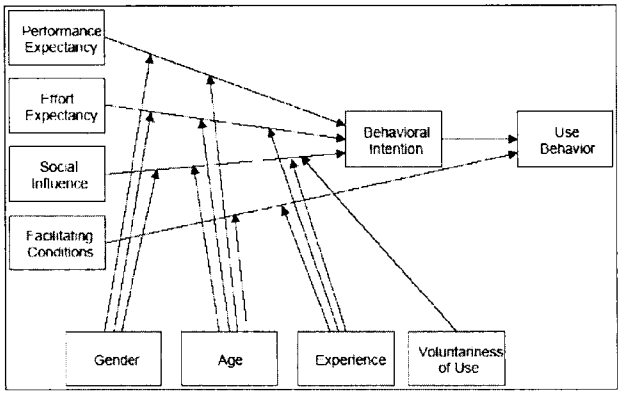

Figure 4 – UTAUT model [13]

To obtain as broad coverage of issues as possible, and because of a limited number of initiatives in Australia, web-based surveys were used in this research instead of face-to-face interviews. This ensures independence of time and place, and makes it possible to obtain responses from people from all around the world. Methods such as focus groups and personal interviews are more difficult to arrange for global responses. It also means that different time zones are not a problem, since the respondent can fill in surveys at any time and at their convenience. It offers a simple means of obtaining the results in a secure and anonymous fashion without having to undergo several procedures to ensure ethical standards, as this is meant to be the next stage in our research and to ensure more focused and open ended responses than were ascertained from the first pilot.

The questions were grouped in 4 Sections – Section 1 asked if the respondents were 1) familiar with motes and 2) whether they had previously completed the survey. If the respondents had not heard about motes, they were able to go to a set of screens which defined Motes and pictured them. Section 2 dealt with queries about Healthcare and Monitoring to establish if the respondents were satisfied with the current healthcare in their countries. Section 3 consisted of a series of questions that related to the use of Motes in Health monitoring, based on the four UTAUT determinants, namely Performance expectancy, Effort expectancy, Social influence and Facilitating conditions. Section 4 was concerned with demographic questions. The aim of the survey was to further test how the moderators affect the strength of the 4 determinants as defined by UTAUT. As mentioned previously, the qualitative analysis of the answers to the open ended question at the end of the survey when the respondents were asked to comment on any issues they had with the survey and/or the use of Motes in Health Monitoring has been explored in [8].

2.5 Survey population characteristics

The criteria used for user acceptance to a new technology follow the UTAUT model. To measure each criterion, a set of questions was formulated to relate to the Motes technology (Tables 1 to 4). Questions regarding the respondents' gender, age, education and career, in addition to their awareness of the technology, were solicited. For this survey the responses numbered 103. Most of the respondents were from Australia, and the other countries represented are shown on the graph that follows where AU is Australia, CA Canada, GR Greece, AT Austria, JO Jordan, US the United States of America and NO Norway.

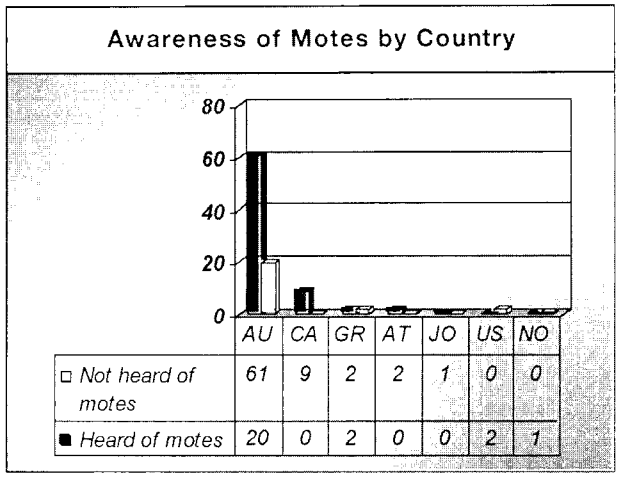

Figure 5 – Demographic Data

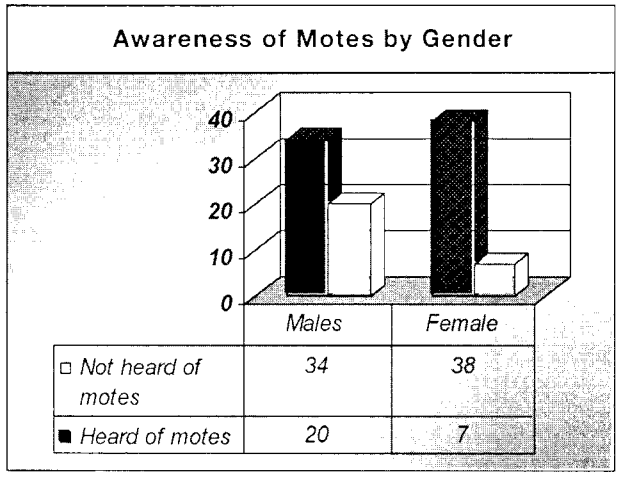

Figure 6 – Male and Female Representation

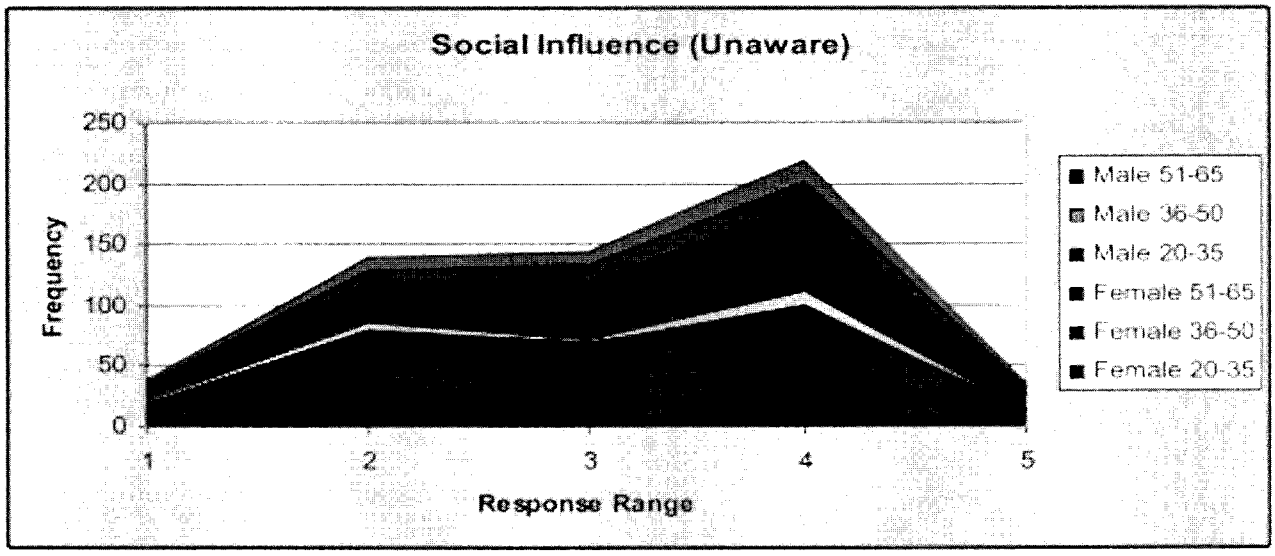

Figure 7 - Social Influence Responses (from people who had not heard of Motes previously)

The survey covered a time period of two months with the cut off date of 31 May 2005. Seventy five people who completed the second survey had not heard of Motes before, twenty five had heard about them whilst three had completed the first survey so did not have to fill it in all again. Two of these last mentioned people reported positive reactions to the potential use of motes in the health monitoring arena.

Of the people who had heard about motes before, twenty (20) were male and seven (7) were female, as shown in Figure 6 on the previous page. In this group eight (8) classified themselves as students, ten (10) as engineering professionals, five (5) as academics and one (1) as medical. In the group that had not heard about Motes before, thirty four (34) were male and thirty eight (38) female and one did not report gender.

This is in marked contrast with the preliminary survey when females were so significantly under-represented that we were not able to draw statistical conclusions for them. The breakdown of professional status for this group was as follows: twenty six (26) students, nine (9) engineers, twenty six (26) academics and eleven (11) medical. For the three people completing the survey for a second time, two (2) were males and one (1) was a female – the female identified herself as an engineer, while the males selected engineering and academic for their professional identification.

3. Quantitative Results and Discussion

The survey participants were asked to rate each question according to its relevance to them. A five-scale Likert measurement system was used – which ranged from 'Strongly Disagree'{1} to 'Strongly Agree' {5} – as opposed to previous validated measurement systems of seven levels [12] This takes into account that the time period that the survey was conducted was short, as the number of available respondents would not be sufficient for larger scales. For each factor, we present graphs (Figures 7-10) representing the proportion of the total responses that fall within each category in a 5-point Likert scale (1 being 'Strongly Disagree' to 5 being 'Strongly Agree'). Within each category, the contributions of the responses of the various gender and age groups have also been represented. For example, a total of 140 responses lie in the 4th category (Mostly Agree) in Figure 8, gathered from Performance Expectancy questions, of which a certain proportion was contributed by the Male 51-65 or Female 36-50 classification.

3.1 Social Influence

Four moderators have a direct influence on social influence: gender, age, voluntariness and experience. With gender differences, women are predicted to place more importance on this factor than with men due to psychological differences (i.e. – sensitivity, emotional, subjectivity) [9], [15]. In addition, as he/she grows with age, this determinant will be more salient as social factors become increasingly pertinent. However, as experience grows (and hence more awareness and objectivity), the importance placed on Social Influence decreases [14]. Due to social perception of the technology – from the number of people using it to its reputation – an individual can be significantly influenced in their decision to use it.

Figure 7 illustrates the frequency of answers, showing a breakdown according to gender and age in a Likert scale of 1-5 (Response Range) given a specific range of questions for a particular determinant, in this case Social Influence. This graph reports on the responses of people who had not heard of Motes before. The figure illustrates

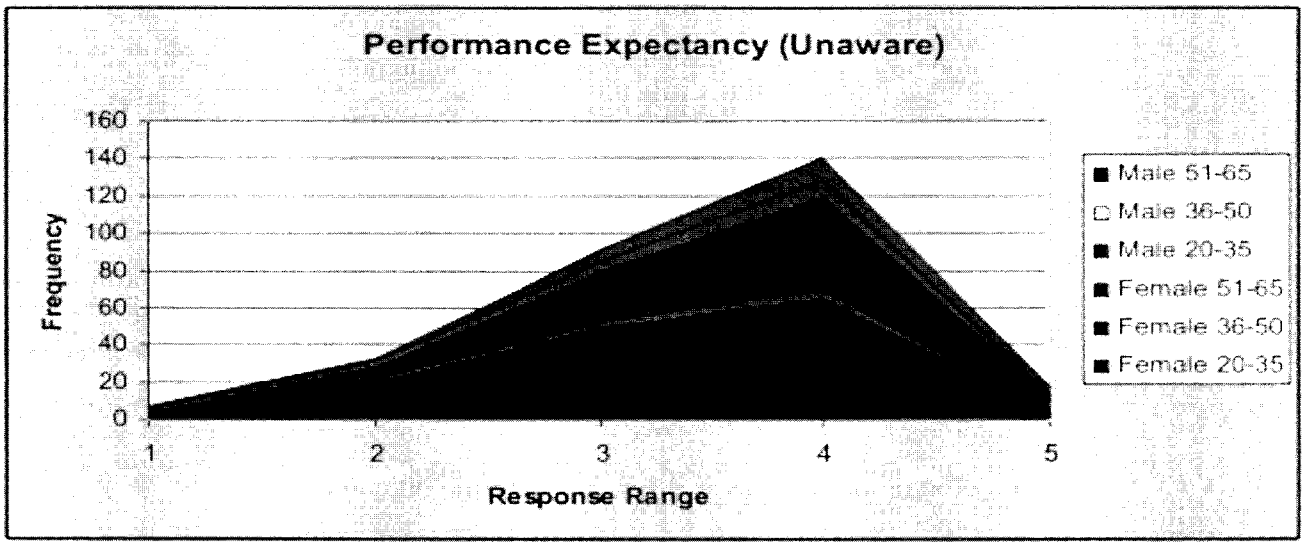

Figure 8 - Responses to Performance Expectancy Questions (people who have not heard of Motes before)

a trend that while the majority of people agree roughly half of the population will select the other alternatives thus making the average close to the middle response (3) of no opinion. Please note that the responses are to the range of questions regarding Social Influence.

I am satisfied with the current health care system in my country and/or the country I am currently residing in
I am satisfied with the methods and technology for monitoring health (home visits, heart monitor, etc)
I am satisfied with the amount of help from doctors, nurses, etc, either at the hospital or home care
I am satisfied with the response time of ambulances
My decision to use Motes would depend on the number of people using them
My decision to use Motes would depend on the number of people important to me using them
My decision to use Motes would depend on the quality/type of medical institutions promoting them.
My decision on using Motes would depend on the number of medical institutions promoting them

Table 1 – Sample Social Influence Questions

In the graph the females are more likely to agree with the questions on Social Influence. In our pilot survey females were under-represented but the results supported the Social Influence hypothesis – where the effect is stronger generally with younger women and those with minimal experience (students). As mentioned previously, in this second survey the numbers of female participants was much higher than in the pilot survey and age groups more widely varied. Of the persons reporting as females in the group that had not heard about motes before, 16 were in the 20 – 35 age group, 18 were in the 36 – 50 group and two were in the 51-65 group. One person did not report gender details in the 51-65 age group. Nine of the females in the 36-50 age group who had not heard of Motes before classified themselves as Medical which could have an influence on their answers. The younger males (20-35 age group) also reported a positive response to the Social Influence questions. From the text boxes, two contrasting opinions are presented below.

> *"This is an interesting and unexplored issue – using motes in Healthcare. It might be worthwhile to have some pilot tests using Motes in healthcare – or at least publicizing them."*
>
> *"I view them as the next generation of microprocessor and nothing to get excited about."*

The first comment indicates the need to demonstrate our prototypes as it would appear that some people did not fully understand them despite the fact that a short description and pictures were displayed for those who wanted an explanation. The second comment is interesting as it is from a person who was unaware of motes before this survey but did not feel they represented anything special.

3.2 Performance Expectancy

Originally defined as the "degree to which an individual believes that using the system will help him/her to attain gains in job performance," this determinant has been modified to fit according to gains in standard of living/quality of life due to the use of the technology [13]. Performance Expectancy is the strongest determinant of intention [13]; however, its effect is moderated by age and gender. It has been shown that technology use is different along gender and age lines. For example, men – especially young men – tend to be more receptive to new technology [10]. The two moderators are interrelated as differences in age represent psychological and societal differences [13].

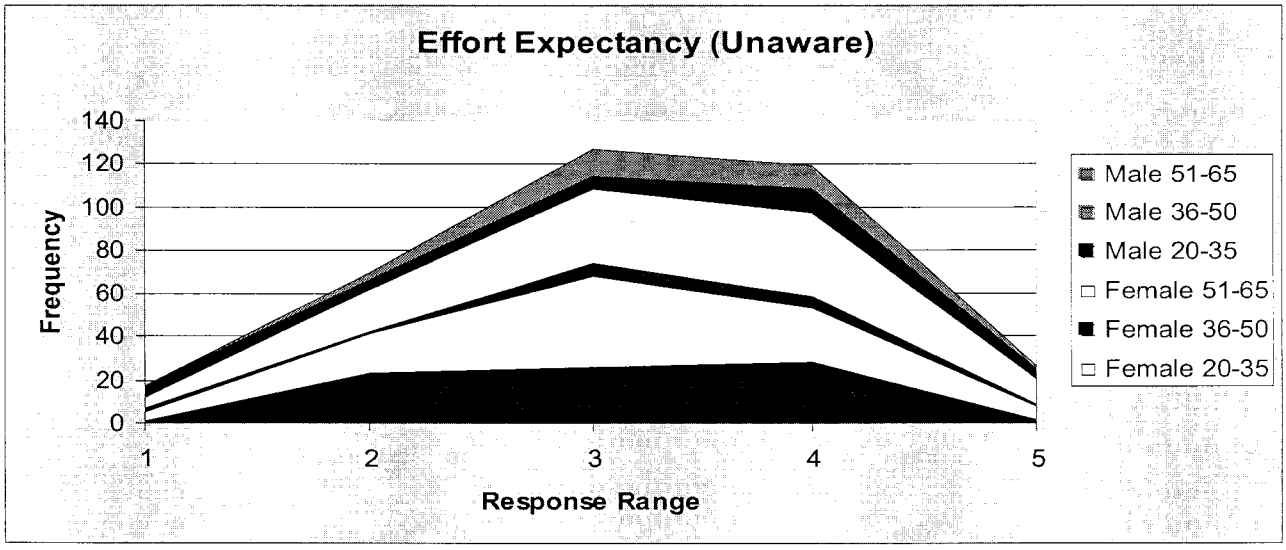

Figure 9 - Responses to Effort Expectancy

The hypothesis is :

The influence of Performance Expectancy on behavioral intention will be moderated by gender and age, such that the effect will be stronger for men and particularly for younger men [13], [1].

Below is a selection of sample questions pertaining to Performance Expectancy in this second survey.

Using Motes would enable me to do more things that I normally would not do (due to safety and health issues/concerns)
Using Motes to monitor my health would improve my quality of life
I feel that using Motes would increase my chances of survival in case of a medical emergency
I feel that Motes will be an improvement from previous and current monitoring systems

Table 2 – Performance Expectancy Sample Questions

Figure 8 (from the previous page) outlines the responses to the questions relating to performance expectancy from the people who had not heard of Motes before. It is notable that most people agreed with the propositions. It is clear that men and women in the 20 – 35 age group are seen to be more receptive to the technology. Results from this survey confirmed that younger men did have a more affirmative response towards the Motes' usefulness as predicted by the model and as seen from the results of the first and second survey. In the first survey however the number of female participants was too low to allow for any meaningful deductions. The text boxes solicited a range of comments regarding Motes in health environments which illustrated concerns about possible negative side effects for health as well as ethical and privacy worries.

"Can't see a need for them."

"Energy – How often do I need to change the batteries?"

"The developers should consider the radiation effect of these sensors on the human body."

"Human monitoring of any type needs serious consideration in ethical terms and also in terms of how implication of data collection and how this data will be used beside the purpose of first patient benefit from whom it is collected."

3.3 Effort Expectancy

This is traditionally the "degree of the ease of use of the system" [13]. Unlike in the original model, only the age and gender are likely to be significant in influencing an individual's Effort Expectancy. Experience implies interaction with the system, which would not be the case; thus, it will not be included. Gender and age are still included as moderators, having more effect for women. Previous research has shown that this determinant will have a stronger influence on behavioral intention with women than with men, and more so with those who are older [15].

The hypothesis for Effort Expectancy is:

The influence of Effort Expectancy on behavioral intention will be moderated by gender and age, such that the effect will be stronger for women, particularly older women [13], [1].

The results presented in Figure 9 show that a majority of the respondents either replied with a 3 (no opinion) or a 4 (agree) to the questions.

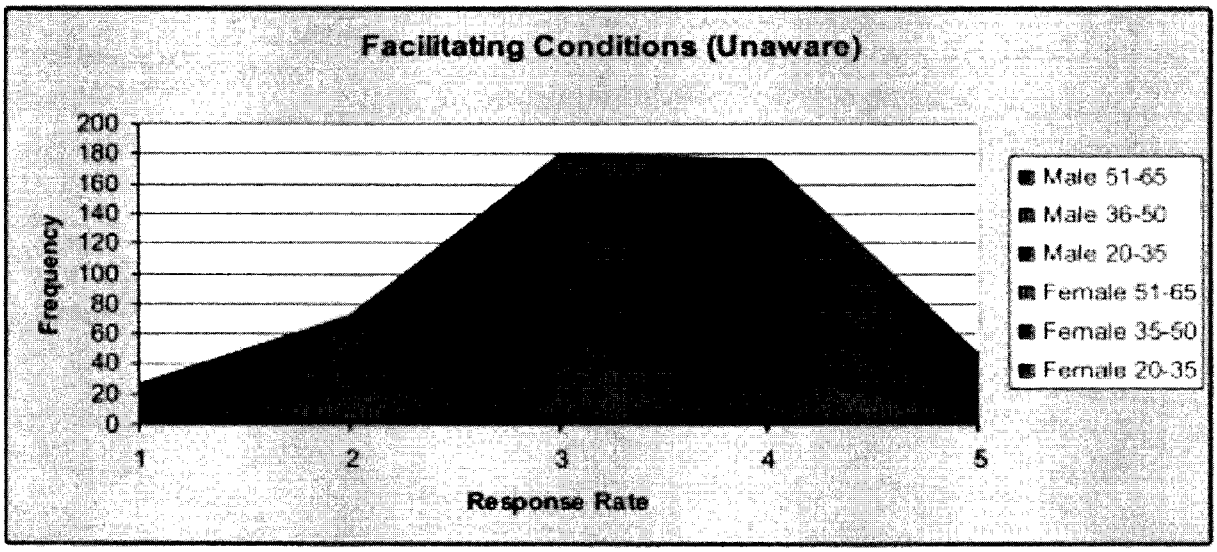

Figure 10 – Responses to Facilitating Conditions

Table 3 outlines sample questions that were asked to measure Effort Expectancy whilst Figure 9 shows the frequency of answers according to sex and age grouping.

I feel that the use of Motes in the home and hospital environment are a good fit
I feel that my interaction with the Motes will be clear
I think that they would be easy to deal with
I think that I would be able to tolerate some surprises in the Motes system
I would expect not to spend much time configuring/maintaining/dealing with them

Table 3 – Sample Questions for Effort Expectancy

The findings suggest that there needs to be more exposure of Motes to the general public; without it, they cannot have a solid opinion on it without making assumptions.

Comments regarding the use of motes reflected the above generalization:

"They have a long way to go to be a practical solution in the healthcare environment."

"I would be more comfortable with the idea of them if I saw them in action."

"I tend to be skeptical about the ease of using such devices and the availability of help when things go wrong."

"I would be concerned about ... maintainability of these Motes and whether they are safe."

3.4 Facilitating Conditions

This determinant deals with the "degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system [13]." It has been augmented to reflect a more individual basis where cost of using the system, compatibility with lifestyle/surroundings and aesthetics are considered. Research has shown that this determinant is not as significant in influencing an individual's behavioral intention when Effort and Performance Expectancy are present [13]. The reason is that Effort Expectancy suggests the presence of facilitating conditions and similarly with Performance [13].

The hypothesis for Facilitating Conditions is:

(a) Facilitating Conditions will not have a significant effect on behavioral intention [13], [1].

It has also been shown that Facilitating Conditions do have an effect on the usage of the technology. With growing experience, its effect is stronger due to people's increased ability to sustain use of the technology. Age is additionally a moderator in this case, as older individuals tend to require more support in dealing with the system [19].

(b) The influence of Facilitating Conditions on usage will be moderated by age and experience, such that the effect will be stronger for older individuals, particularly those with increasing experience [19], [2].

Note that usage here cannot be validated as the Motes have only recently become commercially available, and the main users are researchers. It only provides validation up to an individual's perceived intention on usage.

I feel that I would be able to deal with the Motes system in any situation
I have the resources (can be financial, equipment, etc) to afford Motes
I feel I have the technical knowledge (wireless, networking, circuits, etc) necessary to deal with the Motes if the need arises
I expect guidance and technical assistance would be available to me
I feel that using Motes would be compatible with most, if not all, aspects of my life
I feel that they would fit well with my lifestyle (independent/dependent, career, family)
I feel that using them will not interfere with other devices or systems I am using

Table 4 – Sample Questions for Facilitating Conditions

The sample questions are set out in Table 4 whilst the results of the survey for the questions on Facilitating Conditions are contained in Figure 10. Similarly to Effort Expectancy, responses were concentrated between 3 and 4 in this graph. Some of the written responses would appear to confirm some issues here:

> *" Motes sound very interesting – I would support their use if they were recommended after research to support their functionality."*
>
> *" Why don't you mention Privacy?"*
>
> *" I do feel that motes may violate privacy particularly if the wireless networking is not very secure. This is probably my major concern."*

4. Conclusion

Our research reports on a second UTAUT survey that has attempted to explore the factors that may affect the adoption of Motes as a tool in health monitoring. Preliminary results from this survey did show positive support for the acceptance of the technology yet revealed some real concerns about the issues of security, privacy, ethics and safety. A major drawback with the survey is the fact that most people were unaware of the technology before doing the survey and thus felt unable to make a considered judgment. Our next step is to demonstrate the most recent prototype to focus groups of elderly and infirm people to allay some of the fears people seem to have about the suitability of Motes as a tool for monitoring health issues.

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The Sixth IASTED International Multi-Conference on
Wireless and Optical Communications – WOC 2006

Welcome from the General Chair

On behalf of IASTED and the members of the international technical program committee, it is with great pleasure that I welcome you all to the Sixth IASTED International Conference on Wireless and Optical Communications (WOC 2006) in Banff, Alberta, Canada.

In spite of the progress made to date in the wireless and optical technology fields, there still exist many unresolved technical challenges. Solutions are proposed to some of these challenges by the 74 technical papers scheduled for presentation at this year's WOC conference.

We have received a total of 319 paper submissions out of which 138 papers were accepted and 97 papers were eventually published in the Conference Proceedings. These 97 papers have been arranged into 13 technical sessions. In addition, we have organized 2 tutorials: 1 tutorial on Computer Systems and Applications (CSA) and another on Wireless Networks and Emerging Technologies (WNET). We also have 2 keynote addresses and 3 plenary addresses to be given by renowned experts in the field, invited from industry, academia, and a government agency.

The technical program that you have in your hands is the result of the great effort of the members of the international program committee (IPC). This year we introduced a double-blind review process, and independent reviewers were selected from both the IPC members and many of the submitting authors. This extensive review process ensures the very high quality of the technical program. I thank all the members of the technical program committee and technical reviewers for volunteering their time and energy to conduct very high quality reviews, even at very short notice. Special thanks to all our invited speakers for coming to WOC 2006. Lastly, thank you to all the IASTED staff for their effort and hard work in organizing every detail of the WOC 2006 Conference.

Once again, I welcome you all to WOC 2006, and trust you enjoy not only the technical program but also hope you will find some time to enjoy the beautiful Banff sceneries.

Have a great Conference!

Abraham O. Fapojuwo
WOC 2006 General Chair

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