ISBN: 972-8924-06-2 © 2005 IADIS

ON THE ACCEPTANCE OF MOTES IN MAINSTREAM HEALTH MONITORING

Einstein Lubrin
University of Technology, Sydney

Elaine Lawrence
University of Technology, Sydney

Agnieszka Zmijewska
University of Technology, Sydney

ABSTRACT

The need for providing health services to a growing aging population is escalating as there are increasing constraints in hospital space and trained medical staff. As a result of the growing number of people who need some form of medical aid (such as monitoring, surgery, treatment) new solutions need to be applied to deal with this urgent situation. This paper discusses a recent addition to health monitoring – Wireless Sensor Networks (Motes) – and its possible acceptance as a reliable and efficient monitoring tool. An acceptance model, Unified Theory of Acceptance and Use of Technology (UTAUT) has been applied to determine how viable this technology will be in medical institutions and patients' homes. Thus, input derived from our preliminary survey provides a real-world opinion of Motes and how well the model reflects current attitudes and future outlook.

KEYWORDS

Motes, acceptance model, health monitoring

1. INTRODUCTION

Identified areas of research significance in wireless applications include consumer awareness and satisfaction with mobile services, upcoming trends that may influence future adoption and social and work practices that may favour the adoption and use of wireless application services [16]. This preliminary study attempts to answer these research needs by investigating the degree of awareness, future adoption and uptake of wireless sensor networks (WSNs) (in particular Motes) in the Health Monitoring arena. The authors have conducted a survey based on the acceptance model, *The Unified Theory of Acceptance and Use of Technology* (UTAUT) to help predict user acceptance or rebuttal of Wireless Sensor Networks and their reasons.

This paper explores the factors that could influence the uptake of wireless sensor networks (motes) as a first stage for a proposed empirical study on the potential effects of WSNs in health enterprises. Part two provides a technical overview of WSNs and its significance as wireless network technology, while part 3 describes the intended application for WSNs. Part 4 justifies the selection of UTAUT as a tool for the potential adoption or rebuttal of WSNs. Part 5 outlines the study design and methodology, namely a preliminary cross-sectional study used to explore the factors that could influence consumers' views on this technology. In part 6 the authors discuss their findings. In the conclusion the authors explain how this preliminary work will serve as a foundation for further research into the implementation of this technology.

2. TECHNOLOGY OVERVIEW OF MOTES

Motes, commonly known as "Smart Dust," are tiny microcomputers that employ wireless media to communicate with other Motes. Made with off-the-shelf parts, they are relatively low cost compared with other wireless devices with the same functionality and allow for what is known as Commodity-Based Wireless Networking. They range in size from a few centimeters to a matter of millimeters; as a result, they can be placed in the most space-constrained area. Each Mote has the capability of providing various sensor measurements, ranging from measuring the surrounding magnetic field and sound level, to measuring temperature and acceleration. With a variety of sensor types, applications for these Motes can be realized such as in military applications (enemy detection) or in health applications (monitoring of vital statistics). However, these and many other applications require another feature inherent in every Mote.

Every Mote has the ability to self-form an ad-hoc wireless network with other Motes [3], [4]. As an individual component, these Motes have limited benefits. As a network, however, more advantages can be recognized. An obvious benefit is the ability to cover a larger area. The sensor network utilizes a multihop protocol that allows Motes to forward packets from other Motes to one that is close by, but cannot be reached by the original sending Mote [3], [4]. This also leads to another benefit: the network is adaptable. Depending on the arrangement of the devices (either due to new Motes within range or failed Motes in the network), they can form a network that provides the best path for communication [3].

Because these Motes are wireless and can self-form into a network they may be placed in remote regions which people find difficult to access. All these benefits however come with a price. The Motes' small size limits the amount of power available to each device yet the effect of this constraint is reduced since most of the component parts of a Mote consume little power. As an example, Berkeley's Mica family of Motes uses widely available AA 4.5V batteries as their power source [3]. In addition to this, the individual components can be programmed to sleep when not in use. By employing a particular sleep algorithm, power savings can be optimal [3].

3. HEALTH MONITORING

Health Monitoring encompasses several aspects:

- Monitoring of an individual's vital statistics (body temperature, blood pressure, etc)
- Monitoring of an individual's surroundings (ambient lighting, room temperature, air pressure, etc)
- Early warning system for doctors and medical professionals (via signals sent directly to the medical professionals from the monitoring equipment)
- Context aware applications (saved settings for an identified individual, etc)

The use of Motes solves and achieves many of the problems and 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.

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 provides is the fact that it serves as an early warning system for doctors and other medical professionals (Emergency Medical Services). 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. Our first research testbed has 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 [13]. Our second research testbed implemented a similar system using PDAs. We were 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. Our system is more easily set up than the proprietary implementations.

3.1 Examples of Health Monitoring Projects

The healthcare market is among the fastest growing markets for WiFi and other Wireless Technologies[12]. There are already numerous research projects in this area, a number of which have gone commercial. Many wireless mobile devices have been developed to monitor people's health and wellbeing especially those suffering from diabetes, high blood pressure or heart disease. For example, the US company Globus uses the Paradigm Diabetes Management System, a blood glucose monitor and insulin pump that work together to manage diabetes wirelessly [9]. The European Community's MobiHealth (2002-2004) demonstrated the Body Area Network (BAN) consisting of software programs, hardware devices (including sensors) and Bluetooth communication between devices such as the MobiHealth GPRS Pregnancy Body Area Network (BAN) [7]. Schwiebert et al (2001) [14] have described their challenges in wireless networking of human embedded smart sensor arrays in developing a retina prosthesis.

4. UNIFIED THEORY OF ACCEPTANCE AND USE OF TECHNOLOGY (UTAUT)

The authors have applied the Unified Theory of Acceptance and Use of Technology (UTAUT) to predict the potential adoption of WSN technology. The Unified Theory of Acceptance and Use of Technology (UTAUT) (Fig. 1) by [19] is an amalgamation of several published acceptance models (see Table 1), combining common constructs among the models. These acceptance models shared seven major concepts according to their constructs, of which four are considered direct determinants for user acceptance namely [19]:

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

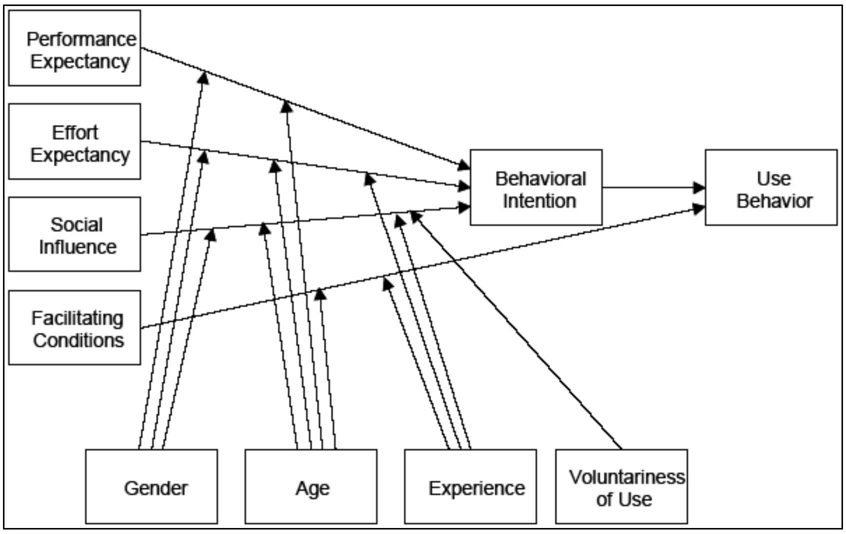

Figure 1. Original Unified Theory of Acceptance and Use of Technology Model [19]

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 behavioural intention (his/her planned intention towards the technology) – generally, to use it or not [19].

The rest of the section will discuss a slightly modified UTAUT to fit with the indirect use of technology – specifically with wireless sensors that are intended for use in a healthcare situation but without dealing with the actual technology.

4.1 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 [19]. Performance Expectancy is the strongest determinant of intention [19]; 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. [11] The two moderators are interrelated as differences in age represent psychological and societal differences [19].

> H1: The influence of Performance Expectancy on behavioural intention will be moderated by *gender* and *age*, such that the effect will be stronger for men and particularly for younger men [19], [2].

Results from our survey confirmed that younger men did have a more affirmative response towards the Motes' usefulness. Further discussion is presented in Part 6.

4.2 Effort Expectancy

This is traditionally the "degree of the ease of use of the system [19]." Unlike the original model, only the age and gender are 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 behavioural intention with women than with men, and more so with those who are older [18].

> H2: The influence of Effort Expectancy on behavioural intention will be moderated by *gender* and *age*, such that the effect will be stronger for women, particularly older women [19], [2].

Our sample did not include a sufficient number of female participants to validate H2; however, this will be discussed in a later section.

4.3 Social Influence

This determinant refers to the "degree to which an individual perceives that people he/she considers important believe that the individual should also use the new system [19]." As more people – especially those who are considered important – use the technology, the more likely it is to be given credentials as a safe and widely used technology. 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) [18], [10]. 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 [17]. Due to social perception of the technology – from the number of people using it to its reputation – an individual can be significantly influenced in his/her decision to use it.

> H3: The influence of Social Influence on behavioural intention will be moderated by *gender, age, voluntariness* and *experience,* such that the effect will be stronger for women, particularly for older women and for those in the early stages of their experience [19], [2].

From our results, we can validate that younger persons who have limited experience do have stronger response to Social Influence. This result will be expanded in the Findings and Discussion section.

4.4 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 [19]." 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 behavioural intention when Effort and Performance Expectancy are present [19]. The reason is that Effort Expectancy suggests the presence of facilitating conditions and similarly with Performance [19]. A power analysis was used to detect the likelihood of a type-II error.

> H4a: Facilitating Conditions will *not* have a significant effect on behavioural intention [19], [2].

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].

> H4b: 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 at present are researchers. It only provides validation up to an individual's perceived intention on usage.

5. METHODOLOGY

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 and/or 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. As previously mentioned – with Motes still in the research and development phase – only a part of the UTAUT model is employed. Instead, it presents researchers an idea of 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.

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 means that we could 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 first stage.

5.1 Measuring Criteria: Survey

As previously discussed, criteria used for user acceptance to a new technology follows the UTAUT model. To measure each criterion, a set of questions was formulated to relate to the Motes technology (Tables 2 to 4). Questions regarding his/her gender, age, education and career, in addition to his/her awareness of the technology, were solicited. The survey participant would rate each question according to its relevance to him/her. A five-scale Likkert measurement system was used – which ranged from 'Strongly Disagree' to 'Strongly Agree' – as opposed to previous validated measurement systems of seven levels [15]. 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.

The survey was undertaken anonymously, using a free survey creation tool – Quask (www.quask.com). The survey (Fig. 2) was run entirely as an Internet-based survey for approximately two months with the results collected and tabulated. Invitation to participate in the survey was given via electronic mail to mainly staff and students from post secondary institutions in Australia and Canada. Individuals from this sample were more likely to provide more informed responses due to their technical background.

Participants ranged from younger students to older professionals to meet the requirements for analysis. Individuals were solicited from two countries with similar societal values and economies: Australia and Canada. The distinction was not made in the survey, which has the implication that societal differences can play a role in user acceptance. The researchers had no way of knowing if people from other countries chanced upon the survey and completed it. However, the fact that these two countries are very similar may reduce that effect, if any. A possible side-effect may just represent a higher variance in the responses. After two months, a total of 59 individuals participated. Undergraduates and postgraduates, as well as academics and other (industry, medical) professionals were among the participants.

A key group has been sufficiently represented among those surveyed: IT/engineering, which comprises of students, academics and professionals. This group would be the first to recognize the technology and would provide the strongest indicator to the future of Motes. Of the 59 that were surveyed, 56 were in this group (28 IT/engineering students – post and undergraduate, 24 IT/engineering professionals, 7 IT/engineering academics). Only 3 were outside the group and were under Medical. The researchers saw this population as an appropriate sample for this preliminary study which would give reliability and validity to the statistics as a precursor to the industry study to follow.

It is important to note that within this group the majority of those surveyed were male (50 were male, only 9 were female) and part of the 20-35 age group (9 were over this age group). With a majority male sample population, this is currently representative of the demographics within this field.

The UTAUT theory was investigated by asking about the respondents' knowledge of the existence of Motes - if they stated they had not heard about the devices a small pop up section outlined briefly what motes were and how they worked (See Figure 2). Most of those surveyed have not previously been exposed to Motes (10 out of 59 have heard of the technology); however, many of them have been exposed to the concept of wireless sensor networks.

The following tables outline how the questions of the survey fit into the categorization of the UTAUT theory. Averaged results for the questions are also shown.

Table 1. Question set for survey, performance/quality

Performance/Quality Expectancy	**Average Score (SD, V)**
Using the system would enable me to do more things I would not normally do (either because of safety issues or concerns)	4 (1, 1)
Using Motes to monitor my health would improve my quality of life	4 (1, 1)
I feel that using Motes increases my chances of survival in case of a medical emergency	4 (1, 1)
I feel that this will be an improvement towards previous and current monitoring systems	4(1, 1)

Table 2. Question set for survey, effort expectancy

Effort Expectancy	Average Score (SD, V)
Learning to use the system would be easy	3 (1, 1)
My interaction with the Motes will be clear and understandable	3.3 (0.8, 0.6)
I think that they would be easy to deal with	3.2 (0.9, 0.8)
I would expect not to spend much time configuring/maintaining it	3.2 (0.8, 0.6)
I think that they would be flexible to deal with	3.6 (1, 1)

Table 3. Question set for survey, facilitating conditions

Facilitating Conditions	Average Score (SD, V)
I feel that I would be able to control the system in any situation	3 (0.8, 0.6)
I have the resources necessary to use Motes	2.9 (0.73, 0.53)
I feel I have the technical knowledge necessary to use Motes	3.2 (1, 1.1)
I expect guidance and technical assistance would be available to me	3.8 (0.9, 0.8)
Using the system is compatible with most, if not all, aspects of my life	3.5 (0.8, 0.6)
I feel that it would fit well with my lifestyle	3.4 (0.7, 0.6)
I feel that the system is compatible with other systems that I use	3.2 (0.8, 0.7)

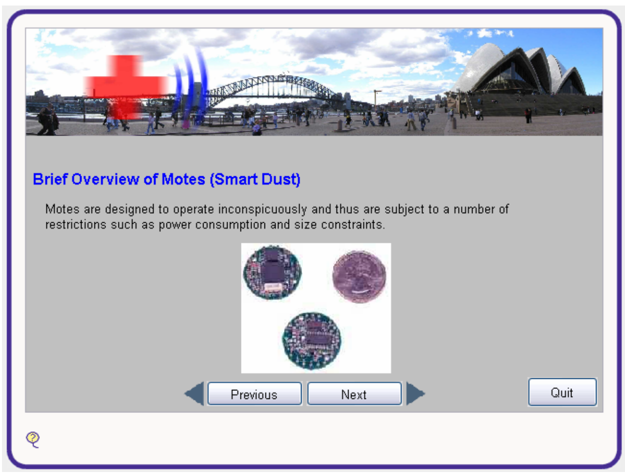

Figure 2. Motes survey [5]

6. FINDINGS AND DISCUSSION

The following tables provide the average score for each indicator. It can be seen that the results do indicate a correlation with the four determinants with a few exceptions. Table 4 shows that the Performance Expectancy effect was stronger for younger men. A slight difference with women aged 36-50 may seem to contradict the hypothesis; however, that result is most likely not representative of the female population as the number of female participants was distinctly low. Similarly, in Effort Expectancy, the effect seemed to be much stronger with younger men instead of with older women. Table 6 shows the results support Social Influence hypothesis – where the effect is stronger generally with younger women and those with minimal experience (students). A power analysis performed on the non-significant Facilitating Conditions showed a high likelihood (over 90%) of detecting medium effects. Power analysis aims to indicate whether an experiment was suitably designed. A high power leads to a higher ability of detecting reasonable departures from the null hypotheses. Due to a limited sample size, a power analysis would also indicate whether the size was adequate enough to provide a high power.

Table 1. Mean score for performance expectancy determinant

Performance Expectancy - Mean (SD, V)					
Male			Female		
20-35	36-50	51-65	20-35	36-50	51-65
3.78 (0.71, 0.5)	3.5 (1.32, 1.74)	-	3.32 (0.55, 0.3)	4.25 (0.5, 0.25)	3.5 (0.58, 0.33)

Table 2. Mean score for effort expectancy determinant

Effort Expectancy - Mean (SD, V)					
Male			Female		
20-35	36-50	51-65	20-35	36-50	51-65
3.34 (0.81, 0.65)	3.14 (1.26, 1.6)	-	3.17 (0.92, 0.85)	3.2 (0.84, 0.7)	3.6 (1.52, 2.3)

Table 3. Mean score for social influence determinant

Social Influence - Mean (SD, V)						
	Male			Female		
	20-35	36-50	51-65	20-35	36-50	51-65
Student	3.62 (0.87, 0.76)	3.13 (1.13, 1.27)	-	3.81 (0.98, 0.96)	-	-
IT/A	3.47 (0.82, 0.67)	2.15 (0.88, 0.77)	-	3.75 (0.5, 0.25)	3.25 (0.96, 0.92)	3.5 (0.58, 0.33)

Table 4. Mean score for facilitating conditions determinant

Facilitating Conditions - Mean (SD, V)						
	Male			Female		
	20-35	36-50	51-65	20-35	36-50	51-65
Student	3.28 (0.73, 0.53)	2.79 (0.7, 0.49)	-	3.18 (0.72, 0.52)	-	-
IT/A	3.34 (0.89, 0.78)	3.26 (1.4, 1.96)	-	3.14 (0.38, 0.14)	3.86 (0.9, 0.81)	3.57 (0.53, 0.29)

We can see that it is possible that the acceptance of Motes can be predicted using UTAUT. The early stages of exposure to the technology (17% have heard of Motes, which only became a known research area within the past couple years) resulted in a less pronounced response on the questions from the participants. However, as the results do follow the UTAUT model, it can be seen that the perception of Motes is a positive one and would lead to an affirmative intention to use it.

Overall, our results favoured the outlook that Motes provide an improvement within their lives, one of the goals of health monitoring. This coincided with a positive view of its ease of use, albeit, less pronounced due to their inexperience and minimal exposure. With the sample being mostly students in the 20-35 range, the tendency is to conform according to social pressures [19], [1], [15]. This is due to the fact that they are at a relatively early stage of their experiences and must rely on opinions and decisions from more experienced individuals, whether accurate or not [14], [1], [15]. The results show that the effect is higher than with older groups.

7. CONCLUSION

Our research has attempted to explore the factors that may affect the adoption of Motes as a tool in health monitoring. This paper employed the UTAUT model to determine these factors and provide an initial outlook of Motes. Preliminary results from the survey did show positive support for the acceptance of the technology. Although the impact of Motes as a health tool cannot be currently realized, the increasing amount of research into developing health monitoring systems shows that the interest is there and that it is here to stay. Projects such as the MobiHealth and CodeBlue [15] from Harvard and Boston University show that it is already possible to create an effective and feasible monitoring system. With further research into the perception of Motes in health monitoring, the results can be further validated and extended to a wider group. The results have already been shown to follow the UTAUT model; thus, the necessary ingredients for technology acceptance are present. As a result of this preliminary survey we are now conducting a second, follow up survey aimed at a wider and more international cohort to ascertain the acceptance of Motes in healthcare environments in other countries.

REFERENCES

[1] Agarwal, R. and Prasad, J, 1997. The Role of Innovation Characteristics and Perceived Voluntariness in the Acceptance of Information Technologies. *Decision Sciences*, Vol. 28, No. 3, pp. 557-582

[2] Anderson, J. E. and Schwager, P. H. SME Adoption of Wireless LAN Technology: Applying the UTAUT Model. *Proceedings of the 7th Annual Conference of the Southern Association for Information Systems.*

[3] Crossbow Technology Inc (2004) [Online]. Available: http://www.xbow.com

[4] Culler, D.E. et al, 2004. Overview of Sensor Networks. *IEEE Computer Society*.

[5] Davidson Measurement (2004). [Online] Available: http://www.davidson.com.au

[6] Davis, F. D. et al, August 1989 User Acceptance of Computer Technology: A Comparison of Two Theoretical Models. *Management Science*, Vol. 35 No. 8, p 982, 22p

[7] Konstantas, D., 2004. The Mobihealth Project. *IST Project IST-2001-36006, European Commission: Deliverable 2.6* [Online] Available:http://www.mobihealth.org

[8] Malan, D. et al, April 2004. CodeBlue: An Ad Hoc Sensor Network Infrastructure for Emergency Medical Care. *International Workshop on Wearable and Implantable Body Sensor Networks, Imperial College*. London, England.

[9] Managing Diabetes With Wireless Insulin Pump: Patients Input Diet Plan, Device Matches Insulin Levels. POSTED: 4:54 pm EST February 16, 2004 [Online] Available:http://www.thewbalchannel.com/womansdoctor/2850769/detail.html

[10] Miller, J.B. , 1976. *Toward a New Psychology of Women*, Beacon Press, Boston.

[11] Minton, H.L. and Schneider, F.W, 1990. *Differential Psychology*, Waveland Press, Prospect Heights, IL.

[12] PBI Media, 2003 Strong Prognosis For Wireless In Healthcare, *Communications Today*. [Online] Available:http://www.findarticles.com/cf_0/m0BMD/35_9/98013124/p1/article.jhtml

[13] Riudavets, J. et al, 2004. Multi Router Traffic Grapher (MRTG) for Body Area Network (BAN) Surveillance. *4th WSEAS Int. Conf. On APPLIED INFORMATICS AND COMMUNICATIONS (AIC'04)*, Tenerife.

[14] Schwiebert, L. et al, 2001. Research challenges in Wireless networks of Biomedical Sensors. *ACM SIGMOBILE 7/01 Rome Italy; ACM ISBN 1-58113-422-3/01/07.*

[15] Taylor, S., Todd, P., 1995a. Assessing IT Usage: The Role of Prior Experience. *MIS Quarterly*, Vol. 19, No. 2, pp. 561-570.

[16] Valeri, L. and Robinson, N. Defining a Strategy Roadmap for mBusiness Applications and Services: Background Draft paper, IST-2001-39164. [Online] Available: http://www.mobiform.org

[17] Venkatesh, V. and Morris, M.G., 2000. Why Don't Men Ever Stop to Ask for Directions? Gender, Social Influence, and Their Role in Technology Acceptance and Usage Behavior. *MIS Quarterly*, Vol. 24, No. 1, pp. 115-139, 2000.

[18] Venkatash, V. et al, 2000. A Longitudinal Field Investigation of Gender Differences in Individual Technology Adoption Decision-Making Processes. *Original Behaviour and Human Decision Processes*, Vol. 83, No. 1, pp 33-60.

[19] Venkatesh, V. et al, 2003. User Acceptance of Information Technology: Toward a Unified View. *MIS Quarterly*, Vol. 27 No. 3, pp 425-478.