INTERNATIONAL JOURNAL OF MEDICAL INFORMATICS XXX (2008) XXX–XXX

journal homepage: www.intl.elsevierhealth.com/journals/ijmi

Public views of mobile medical devices and services: A US national survey of consumer sentiments towards RFID healthcare technology

James E. Katz[a,*], *Ronald E. Rice*[b]

[a] *Department of Communication, Rutgers, The State University, New Brunswick, NJ 08901, USA*
[b] *Department of Communication, 4840 Ellison Hall, University of California, Santa Barbara, CA 93106-4020, USA*

ARTICLE INFO

Article history:
Received 28 July 2007
Received in revised form
20 May 2008
Accepted 2 June 2008

Keywords:
RFID
Cell phones
New technology
Public opinion survey
Mobile health applications
Mobile telephones
Privacy concerns

ABSTRACT

A 2007 national public opinion survey of 1404 Americans revealed variations in sentiments concerning the desirability of several mobile healthcare technologies based on RFID. The survey appears to be the first reasonably national public opinion survey of US adults concerning their attitudes towards mobile healthcare technology. The survey revealed high levels of interest in emergency intervention services, but much less so in health information and monitoring services. Interest in RFID personal medical technology was positively associated with high levels of trust in others and social support. At the same time, a small minority were negatively disposed towards such applications. In those cases, the negative sentiment appears heightened when the mobile healthcare application is offered in a modality attached to the body as opposed to a somewhat more physically remote option, i.e., attached to one's cell phone.

© 2008 Elsevier Ireland Ltd. All rights reserved.

As part of the Syntopia Project [1], the authors have conducted a series of studies of new communication technology and healthcare. This article describes one study which examines public perceptions of personal healthcare technology under conditions of mobility. This is a topic of growing importance as healthcare is increasingly being provided used through mobile devices and the promise of ubiquitous computing grows closer. In particular, medical and health applications that are currently Internet-based will be increasingly available via portable platforms [2]. Medical devices, personal digital medical records, and diagnostic procedures are themselves becoming increasingly portable [3]. An International Telecommunications Union report foresees a so-called world of intelligent things [4]. Among the many benefits of increasingly networked technologies is the promise of mobile health informatics applications including those relying on cell phones, RFID (radio frequency identification devices), and telemedicine technologies (e.g., [5]).

Yet these technologies are also perceived by many as threats and liabilities at several levels. Threats range from concerns the personal level to the society-wide level, covering issues of civil liberties and individual autonomy to name but a few [6,7]. Liabilities include not only the legal dimension, but also possible personal harm, say for instance from over-exposure to emitted frequencies, addiction, or the harm-

* *Corresponding author*. Tel.: +1 732 932 7500.
E-mail addresses: j.k@rutgers.edu (J.E. Katz), rrice@comm.ucsb.edu (R.E. Rice).
1386-5056/$ – see front matter © 2008 Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.ijmedinf.2008.06.001

Please cite this article in press as: J.E. Katz, R.E. Rice, Public views of mobile medical devices and services: A US national survey of consumer sentiments towards RFID healthcare technology, Int. J. Med. Inform. (2008), doi:10.1016/j.ijmedinf.2008.06.001

ful interaction of otherwise benign devices. There are also questions of resistance and nonacceptance [8].

One trajectory of mobile healthcare applications has particular relevance here, namely portable forms that are in the possession of or are even placed on or in the patient. Some of these are RFID technologies, and there have already been numerous experiments using them [4,9]. While many such applications are promising in their potential, there is uncertainty whether people will have any interest in such technologies, and there is already vociferous opposition to them [10].

Public concern over these devices can interfere with, as well as inform, good policy development on several levels. First, broad public policy can proscribe efficacious devices on ethical or value grounds. A parallel example may be seen in US prohibitions on stem cell research. Second, public concern can interfere with acceptance of a technology that could be useful. This for example could be a "market failure," or at least a substantial percentage of potential users opting out, making the device economically infeasible. Finally, there could be individual resistance due to ignorance or malicious urban myths, thus leading people to mistakenly forego something that would be helpful to them. This is analogous to individuals thinking that certain childhood vaccination program are dangerous, thus creating a risk not only for their own children but for their communities; or thinking that individual digital medical records will exceed current paper-based medical records rights, about which most people are poorly informed [7]. These technologies are also being opposed on religious grounds. Many web sites point to a passage in the biblical chapter of Mark as justification for their opposition. Verse 16-17 states that the Antichrist will "causeth all" to "receive a mark in their right hand, or in their foreheads and that no man might buy or sell, save he that had the mark") as a prophetic warning to resist RFID as the mark of the devil. See, for example, "America: Freedom to Fascism" [www.rfid-666.com] and "Prophecy News Watch" [http://www.prophecynewswatch.com/]. Again these could have spillover effects comparable to objections to blood transfusions and organ transplants, and could have similar implications for efficacious healthcare administration as well as expand the domain of value conflicts and regulatory supervision of medical professionals.

These and other concerns about policy determinations of medical technology are not only theoretical, as can be seen by legislative steps that have already been taken or are being considered in the law enforcement domain. Two states, Wisconsin and North Dakota, have passed legislation proscribing mandatory microchip implantation in humans, even while other states (e.g., Oklahoma) are considering requiring that they be implanted in certain violent criminals upon their release from prison [11].

Therefore, independent of the particular capabilities of mobile healthcare systems that are being evaluated for deployment, it is important to understand the general sentiments of the public in order to both address legitimate concerns and prepare to counter wrong and misguided understandings. As important as this understanding is to the success of proposed systems, it is beyond the scope of this article to address the question comprehensively. Rather, our purpose is to shed light on one aspect of public opinion – the use of mobile services and RFID technology for personal health applications – through analysis of a national survey of public opinions about potential mobile healthcare technology.

1. Relevant literature

1.1. *Literature on use of the technology*

There has been for several years a discussion of ubiquitous technology, and smart, interactive devices are proliferating, and there has been significant speculation about what this means in many domains, including medicine [5]. Many devices are being developed and tested to provide patients greater access to and control over health information, and to reduce error through better information flow (such as web-based prescription follow-up messaging, [12]. There is an important literature on personal and ubiquitous healthcare technology. Much of this literature can be considered "technology-driven" because it involves the proposal and evaluation of systems that can address health care needs. A prominent albeit secondary topic in the literature is the potential or actual responses of users to such systems; usually these analyses are drawn from small group of professionals or users, either potential or real.

Varshney [13] offers a vision of mobile and ubiquitous "Pervasive Healthcare" which would offer "healthcare to anyone, anytime, and anywhere by removing locational, time and other restraints while increasing both the coverage and the quality." He suggests that healthcare applications could be divided into at least seven categories. For present purposes, these categories can be consolidated into the following: prevention, maintenance and monitoring, incidence detection and intervention. As will be seen later, we draw on these categories in structuring the analysis of public views towards mobile medical devices and services. A variety of pervasive healthcare demonstrations and proposals have been presented in the literature which have relevance for our inquiry. While these are fairly numerous, a few of them from countries around the world can be touched upon here to convey the range of issues in which understanding public perceptions could be helpful.

First, in terms of mobile phones, Finnish researchers Koskinen and Salminen [14] developed a mobile communication tool which is customizable depending on user requirements and physician guidance. Researchers in the UK have experimented in obesity treatments using a mobile phone that shared activity information among groups of friends. They found that awareness encouraged reflection on, and increased motivation for, daily activity. However, they also uncovered problems with network reliability related to such applications [15]. A US-based study looked at having users self-monitor caloric balance in real time using a mobile phone. This was done as part of an attempt to modify user behavior to reduce obesity. In this study, Tsai et al. [16] conducted a 1-month feasibility study to measure compliance and satisfaction among a sample of 15 participants randomized to one of three groups. They concluded that the mobile phone was as good as or even superior to paper-based systems. The preliminary results sug-

Please cite this article in press as: J.E. Katz, R.E. Rice, Public views of mobile medical devices and services: A US national survey of consumer sentiments towards RFID healthcare technology, Int. J. Med. Inform. (2008), doi:10.1016/j.ijmedinf.2008.06.001

gest that the mobile phone could be helpful, but by no means is a panacea.

As to RFID technology, a 2006 press release said that the technology is being used in areas such as laboratory analysis, mammograms, blood transfusions, medication delivery, prostate treatment, and LASIK eye surgery [17]. In addition to commercial applications, RFID technology is also the subject of several research projects. An experiment using RFID technology was also performed in a US hospital emergency department. Miller et al. [18] used RFID technology to validate or substitute for duration estimates of activity which ordinary comes from standard sources including manual records and staff estimates. One of the conclusions of the study was that staff apparently experienced anxiety about personnel evaluations that might be forthcoming from the system's deployment.

An RFID project was trialed at a Taiwanese hospital in conjunction with a national effort to combat SARS. The project demonstrated the feasibility of RFID in hospitals but also highlighted not only technical difficulties but also both the difficulty of persuading medical professionals to accept and use the system [19].

One theme that comes through from several of these studies is that attitudes towards computer systems, level of threat perceived by new technology, and one's position in a network of social relationships, all affect user evaluations and perceptions. This brief review of the few select applications of mobile healthcare technology also makes readily apparent that these technologies exist in an experiential, social and cultural environment that influences their acceptability and use [20]. This point has been made by researchers on mobile communication technology, including by Campbell and Russo who have shown how adaptation decisions about and attitudes towards mobile communication technology, including non-normative uses, are influenced by social contexts and contacts [21]. It is also clear that attitudes towards the Internet and social support systems affect the use of advanced communication technologies [1].

Similarly, many researchers, such as Leventhal et al. [20], have found that demographic, gender, and ethnic-racial dimensions can be highly significant in affecting acceptance of treatment regimes, and even the presentation of symptoms. Hence, in addition to the continuing efforts to develop portable technologies to provide consumers with information from their health care providers (people and institutions), there also is the need to consider the consumers' experiences with information and communication technology, and the possible impacts [13]. Åkesson et al.'s review of the few such studies identified three primary themes: support and help, education and information, and telecommunication instead of on-site visiting. They concluded that consumers gained confidence and knowledge, improved their health status, and did not feel that reduced face-to-face meetings or privacy were significant problems [22]. Similarly, Rigby [23] reviewed research on ubiquitous technologies in health settings, noting that they are still primarily in developmental and pilot use stages. He notes several crucial areas requiring attention and research, such as on the diversity of applications, large increases in data, and increasing dependency, generating pragmatic, ethical and liability issues.

1.2. *Literature on public perceptions of RFID technology*

Moving to the next level of analysis, it may be noted that data have been collected in several countries on public and professional responses to both specific technologies and more generalized concerns. These studies have shown that fears about RFID devices for healthcare are not limited to the privacy concerns of patients and consumers but spill over into a wide range of issues. For instance, health care providers, such as nurses, are concerned about workplace monitoring and increased workloads (such as operation and maintenance) associated with RFID systems in hospitals and health care institutions, and these should be included in any implementation and evaluation of such systems [24].

A study of adult primary-care patients in New Zealand analyzed influences on concerns about sharing patient information among health care stakeholders, and knowledge of how that information was being used [25]. People were more willing to have their identity shared among health professionals, but less so to third parties. They were more willing to have their information shared if it were anonymous. And the more personal the information, the less willing to have it shared. Perhaps more fundamentally, 90% had incomplete or no knowledge of how their health information was in fact already being shared. This last result is similar to Yao, Rice and Wallis's [26] finding that people asked about their attitudes towards digital medical records were around 50% incorrect on stakeholder access to individuals' paper-based records. They also concluded that the more that people believe in the right to privacy and the more they desire privacy in the physical world, the more they are likely to have online privacy concerns (about both companies and other entities). Further, these beliefs are influenced by psychological dispositions (need for privacy, and a self-efficacy) and expertise with information/communication technology.

In terms of broader public opinion, the open literature concerning mobile healthcare applications is sparse. A review of the literature uncovered no national random surveys of public opinion towards mobile medical technology or RFID health applications, neither in the US or in other nations. The authors also made inquiries of marketing firms specializing in public attitudes towards RFID technology as well as of a survey specialist at an RFID standards advocacy body. These organizations indicated that they were unaware of any such surveys.

At the same time, there have been some public opinion surveys concerning matters such as RFID, most of which are proprietary and have not been made available to the research community. Even the few general surveys that are reported there appeared not to be national random surveys. We here summarize several examples of recent general surveys concerning RFID (but not specifically focused on health applications).

A 2006 EU online survey (thus not a random sample) concerning RFIDs found that two-thirds of the 2,190 respondents believed that EU data protection and privacy legislation was currently inadequate and that stronger privacy protection laws were needed [27,28]. A multi-nation series of focus groups conducted (set in Asia, Europe, and US) in 2003 found that there was little knowledge of RFID technology and that even

Please cite this article in press as: J.E. Katz, R.E. Rice, Public views of mobile medical devices and services: A US national survey of consumer sentiments towards RFID healthcare technology, Int. J. Med. Inform. (2008), doi:10.1016/j.ijmedinf.2008.06.001

once the benefits were discussed there was a resigned, negative sentiment towards them. In particular, for the United States, the analysis concluded that the "overall response was neutral to negative" [29, p. 8]. Further, the research determined that focus group members identified that although privacy was a paramount concern, health risks were also seen as "a key worry" [29, p. 7]. A study conducted in 2003 [30] of an internet panel (thus not a random sample) of more than 1000 adult Americans found that only 23% of respondents said that they had ever heard of RFID technology. However, among those who said they had heard of it, their perceptions were mixed, with 42% viewing RFID favorably, 10% viewing it unfavorably, and 48% indicating that they did not know or had no opinion. Interestingly, although privacy concerns were rated highest – in the upper 60 percentile levels – health effect concerns were also quite substantial among the sample: 56% of the respondents said they were "extremely concerned" about this issue relative to RFID. Women rated this health concern more highly than did men. Even more narrowly drawn surveys do not show much appreciation for mobile healthcare technology. A random survey to asthma healthcare professional and patients found little enthusiasm for cell phone technology for disease monitoring and management. The survey of 130 respondents showed significant questions regarding clinical benefit, impact on self-management, and workload and cost [31].

These studies show that public knowledge or even awareness of RFID technologies is low. Yet despite (or perhaps because of) this, fears about the technology's privacy threats are high.

Other demographic and social factors, common to studies of the internet and other new media and information technologies, may also be relevant. People who keep in touch with family and friends who are far away might be more concerned about monitoring their own health because of a lack of close-by interpersonal relations; on the other hand, those with more family/friends close by may feel greater social support and thus openness to providing healthcare information. Those who have greater generalized trust in others may be more open to using such technologies for personal health information. Those with greater interpersonal social support might be more prone to communication with those others, and share with those who provide healthcare support, about personal healthcare issues. The literature generally argues that those with greater concerns about threats to privacy, and a stronger belief in privacy rights, would be more opposed to providing personal health information. Finally, it may be the case that the same demographics that are associated with digital divides in technology adoption and use (see [1]) would also be associated with interest in RFID healthcare services: younger age, males, greater education, married status, Caucasian/Asian, and greater income.

None of the research we could find in the open literature was conducted on the basis of a random survey. All of it is now several years old, when usage of the cell phone was less omnipresent than it is today, and thus attitudes reflected in the surveys may be predicated on a different set of experiences and values. Hence, we believe it would be helpful to understand the current public attitudes towards mobile healthcare technology.

1.3. *Research questions*

The basic research questions motivating this study, then, are:

RQ1. What is the preliminary interest in cell phone and RFID-based healthcare services?
RQ2. Does it matter how the technology might be provided? Reviewing the possible technologies and the implementation, there are two likely ways that the technology could be implemented for personal healthcare monitoring and communication. The first way would be external, such as in the form of a handheld or strap-on technology that is near but separate from the body. This is roughly analogous to a cell phone which is often carried in hand, or in a holster or pocket; or it may even be attached to or provided as a service in a cell phone. It can also be attached to or integrated with clothing. The second way would be attached to or implanted in the body. We wanted to see if there was much difference in attitudes towards RFID health applications depending on these two modalities.
RQ3. What social and demographic factors might be associated with these levels of interest? This question is important because these dimensions have been shown in other domains to be important correlates of peoples' acceptance of new technologies, compliance with physician instructions, and perceptions of health problems [20].

2. Methods

2.1. *Data*

The overall research strategy was to conduct a public opinion survey to examine how interest in mobile medical informatics might vary according to an individual's background, experiences and attitudes, and by the particular uses to which the system might be put. Based on earlier work, cited above, it was plausible that attitudes towards Internet technology, privacy, trust, social support and demographics would be associated with attitudes towards potential mobile medical informatics systems. Consequently, an instrument was constructed to measure these concepts and assess their relationships.

To gather the data that would inform these questions, a total of 1404 Americans over the age of 17 were surveyed using random-digit dialing in February and March 2007. Up to 5 callbacks were used to get in contact with the household member selected using the "most recent birthday" methodology to ensure a quality sample. The resulting sample was approximately the same as the general population as measured by the US Census Bureau, except for slightly greater age (see Appendix A). Over-sampling (resulting in what might be considered a stratified sample) was done of African-Americans and young males in order to get an adequate number of respondents within those groups in light of budget constraints and target sample size.

The instrument itself consisted of four primary sets of questions. In the first set, respondents were asked about their opinions of general new video and text services for mobile phones. The second set asked respondents asked about interest in potential healthcare services which could theoretically

Please cite this article in press as: J.E. Katz, R.E. Rice, Public views of mobile medical devices and services: A US national survey of consumer sentiments towards RFID healthcare technology, Int. J. Med. Inform. (2008), doi:10.1016/j.ijmedinf.2008.06.001

be available through RFID technology. The third set asked about trust, social support, and several Internet and privacy topics. The fourth set asked about standard demographics.

Each of the RFID healthcare services could be provided in either of two forms—via a mobile device like a cell phone, or via long-lasting tape on one's arm. The two forms were randomly varied across respondents, using this wording: "Scientists are doing research on a tiny electronic tag. One use might be for health monitoring. This tag would be..."

- "placed on person's arm with long-lasting tape" (option randomly given to half of sample) OR
- "placed on a person's cell phone" (option randomly given to other half of sample)

"... How interested would someone like you be in using the tag for the following..."

With this random variation in phrasing, we were able to compare the sample's attitudes towards the mobile technology depending on its closeness to the body. While we were tempted to also ask about attitudes towards inserting devices subcutaneously, preliminary explorations led us to conclude that many members of the public would terminate the interview, since they would become concerned about the legitimacy and intrusiveness of the questions.

2.2. Measures

Cell phone video and text services included seven recent and new services (two of which were health-related), rated from 1 = a very good idea to 5 = a very bad idea. *RFID healthcare services* were indicated by five functions, rated from 1 = lot of interest to 5 = a bad idea). These constituted one principal component, so were used to create an overall mean scale of *RFID Health Care Services*.

Physical distance to family and friends has long been considered important determinants of telecommunications usage [32]. As well, this aspect of social relationships plays a critical role in both health care delivery and outcomes [33]. Respondents were asked by whether most of one's friends and family that the respondent keeps in touch with lived closer than 25 miles, about evenly split, or most lived farther than 25 miles away.

Trust is an important predicate in social relationships and has been shown to affect behavior on both the micro and macro scale [34]. It affects the relationship between the individual and other sectors of society, including government, insurers and the government [35]. It also is an important element in patient physician relationships, including voluntary disenrollment from a physician's practice [36]. Trust was measured by one question.

Social support was derived primarily from Zimet, Dahlem, Zimet and Farley's [37] 12-item scale, with four items each representing sources of social support from family, friends and one's significant other. We used one of their items from each of the three sources and one overall relating to personal relationships. These represented one dimension, and were used to create a mean scale—"social support".

Privacy was measured by three questions from Katz and Tassone [38] and two from Yao, Rice and Wallis [26]. The first three relate to *threats to personal privacy* (general threats, from organizations and agencies, and the use of computers) identified in a broad review of national surveys on attitudes towards privacy and surveillance. The second two relate to a *basic right to privacy*, based on frequently cited definitions of privacy, including Warren and Brandeis [39], "people should have the right to be left alone," and Westin [40], "people should have the right to control their personal information." The two resulting dimensions were used to create two mean scales—"threat to privacy" and "right to privacy".

Demographic variables included *gender, education, marital status, race/ethnicity, income,* and *age*. Table 1 below provides the response categories for *gender*, *education* and *income; age* was measured in years. *Marital status* included seven responses of never married/single, married, living with partner, divorced, widowed, married but separated, other. First these were recorded into three categories (the first, the second two, and the last four). While multivariate analysis of covariance showed some significant differences in the dependent variables between the second and third categories, they were small and prevented use of this form of a marital measure in regressions. So the final measure included not/no longer married as the first category and married/living with partner as the second category. *Race/ethnicity* initially offered seven categories, but the largest by far (81%) was white/Caucasian, so the variable was recorded into non-white/non-Caucasian and white/Caucasian. We know that Asians have quite different Internet adoption and usage patterns compared to African-Americans and Hispanics [1], but the sample sizes were too small to analyze separately.

Table 1 provides the descriptive statistics for the items and scales, along with scale dimensionality (eigenvalues and variance explained by principal components, varimax rotated) and Cronbach alpha reliabilities.

3. Results

3.1. Cell phone health applications

Positive interest in mobile phone services (a lot of interest, some interest; or very good idea or good idea) ranged from 11.6% for watching TV on a cell phone screen, 12.3% for getting ads about products or services), 14.2% for getting notices about bargains offered by local merchants, 24.9% for receiving brief health information notices, 31.2% for playing games, 71.2% for having a hotline to a doctor, to 84.4% for finding directions when lost. It is interesting to note that helpful interventions in difficult situations (doctor access hotline and directional assistance when lost) are ranked approximately the same, and brief healthcare information is comparable in interest level to game playing. Thus, these comparisons provide a rough index to perceived potential value.

3.2. RFID healthcare services

Table 2 presents the survey responses according to mean interest level in potential healthcare services available via an RFID

Please cite this article in press as: J.E. Katz, R.E. Rice, Public views of mobile medical devices and services: A US national survey of consumer sentiments towards RFID healthcare technology, Int. J. Med. Inform. (2008), doi:10.1016/j.ijmedinf.2008.06.001

Table 1 – Descriptive statistics for questions and scales

Scales and items, value ranges, eigenvalues and alpha reliabilities	N	Mean	S.D.
Cell phone services			
1 = very good idea to 5 = very bad idea			
Watch TV	1106	3.72	.88
Get ads about products or services might be interested in	1106	3.83	.91
Find directions when you're lost	1106	1.99	.86
Hotline to a doctor at anytime	1106	2.23	.89
Sent brief notices about important health information	1106	2.33	.95
Sent notices about bargains from merchants where you're traveling	1106	3.60	.91
Have a screen on the phone that shows a map of where friends or family members are at anytime	1106	3.08	1.09
That your friends or family have a screen on their phones that lets them see where you are at anytime	1106	3.28	1.11
RFID healthcare services (eigenvalue = 3.58; var = 72%; α = .90)	1404	2.76	1.07
1 = a lot of interest to 5 = a bad idea			
Monitoring health such as pulse or blood pressure	1404	3.07	1.19
Alerting potential health problems, e.g., diabetes	1404	2.18	1.26
Storing medical info for accident or emergency	1404	2.52	1.30
Lower cost medical insurance	1404	2.60	1.34
Personalized health info "just for you"	1404	2.82	1.25
Trust: generally speaking, most people can be trusted	1404	2.79	1.01
1 = strongly agree to 5 = strongly disagree			
Interpersonal social support (eigenvalue = 2.44; var = 61%; α = .78)	1404	1.80	.62
1 = strongly agree to 5 = strongly disagree			
You get the emotional support you need from your family	1404	1.82	.83
You get a great deal of satisfaction from your personal relationships	1404	1.80	.73
You can count on your friends when things go wrong	1404	1.86	.81
You have a special person who is a real source of comfort to you	1404	1.73	.81
You can't be too careful in life [reverse scored]	1404	3.74	.96
Privacy threat (eigenvalue = 1.55; var = 30.9%; α = .53)	1404	2.14	.72
1 = strongly agree to 5 = strongly disagree			
Organizations and agencies ask you for too much personal information	1404	2.02	.98
Present use of computers is an actual threat to personal privacy in the country	1404	2.46	1.05
How concerned about threats to your personal privacy in America today?	1395	1.93	.97
Privacy right (eigenvalue = 1.58; var = 31.6%; α = .72)	1404	1.47	.56
1 = strongly agree to 5 = strongly disagree			
No one should be able to gather or disclose your personal information without your consent	1404	1.46	.64
People should have the right to control their personal information	1404	1.49	.63
Age	1359	51.99	17.80

	N, Percent
Family/friends distant	N = 1379
Most friends/family keep in touch <25 miles	34.2%
They are split about equally between the two distances	35.2
Most friends/family keep in touch >25 miles	30.6
Gender	N = 1404
Female (0)	54.3%
Male (1)	45.7
Education	N = 1394
Less than high school	2.4%
High school	26.7
Some college	27.4
College graduate	29.6
Graduate work	13.9
Marital status binary	N = 1390
Not/no longer	36.9%
Married	63.1
Race/ethnicity binary	N = 1403
Non-white/non-Caucasian	23.0%
White/Caucasian	77.0

Please cite this article in press as: J.E. Katz, R.E. Rice, Public views of mobile medical devices and services: A US national survey of consumer sentiments towards RFID healthcare technology, Int. J. Med. Inform. (2008), doi:10.1016/j.ijmedinf.2008.06.001

Table 1 (*Continued*)

	N, Percent
Income	N = 995
Less than $25,000	18.1%
$25,000 to less than $50,000	31.0
$50,000 to less than $75,000	19.7
$75,000 to less than $100,000	12.8
$100,000 and over	18.5

device. They all lie between neutral and some interest. As there was relatively little difference in how the questions were answered across the two placement types (via cell phone or a device taped to the skin), except for those who thought the service was a bad idea (discussed below), the two subsamples were combined.

Table 2 also shows that positive interest in these potential services (from 1 a lot of interest to 5 = a bad idea) ranged from 36.2% for monitoring health, 46.3% for alerting about potential health problems, 47.6% for storing medical information, 54.3% for getting lower cost medical insurance, and 58.2% for receiving personalized health information. It is possible to discern a rough hierarchy in this list, with "alerts," "monitoring," and personalized health information at the somewhat lower end of the hierarchy, and with tangible (economic) or immediate (emergency) benefits rated more highly.

But consider just those who said they felt any particular function was "a bad idea"—between 6.6% and 8.3% of the respondents. This is a narrow range and suggests little variation among those who describe the applications as a bad idea. That being said, it is also the case that there is variation in the "bad idea" rating depending on the placement type. For each potential function, greater percentages of respondents in the "taped" placement type felt the function was "a bad idea" than did those in the "cell phone" placement type.

As Table 3 shows, for two of the five potential functions there are statistically significant differences in the evaluation depending on the placement type. That is, respondents presented with the more invasive "tape to arm" are more likely to think using the RFID healthcare services of "monitoring health" and "lower cost medical insurance" are "bad ideas." While this difference was not significant for the other three functions, the means were slightly more negative if the device were directly connected to the body. In a sense, a field experiment was conducted among two random samples. The only difference in the "stimulus" was the description of the proposed healthcare device's placement. This very specific test, in the context of the prior mean and percentage results, suggests that while there is not likely to be widespread antipathy for topically applied devices, the public is somewhat less accepting of subcutaneously inserted devices.

3.3. *Influences on interest in RFID healthcare services*

Several possible influences on the 5-service scale of interest in mobile healthcare technology were tested: distance of close family/friends, trust in others, interpersonal social support, a basic belief in privacy rights, concerns about threats to privacy, demographics (age, gender, education, marital status, race/ethnicity, and income), and as a control (though we have

Table 2 – Mean and percent interest in potential functions of RFID mobile healthcare technology overall and for each RFID placement type

Potential function	Mean		
	Overall	Attached to cell phone	Taped to arm
Monitoring health such as pulse or blood pressure	3.07	3.05	3.09
Alerting potential health problems, e.g., diabetes	2.81	2.83	2.80
Personalized health info "just for you"	2.82	2.84	2.79
Lower cost medical insurance	2.60	2.55	2.64
Storing medical info for accident or emergency	2.52	2.51	2.53

Potential function	A lot/some interest (1, 2)			A bad idea (5)		
	Overall	Cell phone	Taped to arm	Overall	Cell phone	Taped to arm
Monitoring health such as pulse or blood pressure	36%	36.2%	36.2%	8.3%	6.8%	9.7%
Alerting potential health problems, e.g., diabetes	46	45.4	47.1	6.7	6.3	7.1
Personalized health info "just for you"	47	58.4	58.0	6.6	5.8	7.4
Lower cost medical insurance	54	55.3	53.3	7.3	6.0	8.5
Storing medical info for accident or emergency	58	46.5	48.8	6.6	5.7	7.5

N = 1404 overall, 702 in each condition.
From 1 = a lot of interest, 2 = some interest, 3 = a little interest, 4 = no interest, 5 = it's a bad idea.
Note: No significant *t*-test differences for any of the functions across the two conditions.
N = 1404.

Please cite this article in press as: J.E. Katz, R.E. Rice, Public views of mobile medical devices and services: A US national survey of consumer sentiments towards RFID healthcare technology, Int. J. Med. Inform. (2008), doi:10.1016/j.ijmedinf.2008.06.001

Table 3 – t-Test results for difference in mean percent of RFID placement type: mobile phone (0) or taped to arm (1) for respondents indicating each potential function is "a bad idea"

Potential function	N	Mean	Std. error	Mean difference	Significance
Monitoring health such as pulse or blood pressure	116	.59	.05	.09	.03*
Alerting potential health problems, e.g., diabetes	94	.53	.05	.03	.25
Personalized health info "just for you"	93	.56	.05	.06	.13
Lower cost medical insurance	102	.59	.05	.09	.04*
Storing medical info for accident or emergency	93	.57	.05	.07	.09

Note: Means above .50 indicate greater frequency of respondents indicating the function is "a bad idea" if they are in the "taped to arm" placement type. Significance tests are one-tailed, as we would expect more negative attitudes for those presented with the "tape to arm" modality.

* $p < .05$; one-tailed significance tests.

Table 4 – Correlations of possible influences on RFID health care services scale

Possible influences	RFID healthcare services (1 = lot of interest; 5 = a bad idea)
Trust	.03
Interpersonal social support (1sa)	.02
Family/friends in touch—close/middle/distant	.08 **
Privacy right (1sa)	.04 *
Privacy threat (1sa)	−.01
Gender (F0 M1)	−.02
Age	.06*
Education	.04
Marital (0 never no longer, 1 married)	.02
Race/ethnicity (0 other, 1 W)	.09**
Income	.03
Placement type (0 attached to cell phone, 1 taped to arm)	.01

* $p < .05$; ** $p < .01$; one-tailed significance tests.
N = 1404 for all except distance, age, education, and marital (from 1359 to 1394), and income (995).

seen there is no influence), the physical modality of the services (attached to cell phone, or by tape to one's arm). Table 4 shows the correlation of each of these variables with the RFID healthcare services scale (where 1 indicates "a lot of interest"). Only four had any significant correlation: closer proximity to family and friends, less concern about one's privacy right, being younger, and being non-white/non-Caucasian.

Taking into account shared variance among the four significant influences, the RFID healthcare services scale was regressed on those variables (entered stepwise). Only two percent of the variance in the RFID healthcare scale was explained ($F = 8.0$, $p < .001$), by closer proximity family and friends (beta coefficient = .07, $p < .01$), less concern about one's privacy right (beta = .05, $p < .05$), and being non-white/non-Caucasian (beta = 1.0, $p < .001$).

4. Discussion

While there was not much variance explained by the final regression, it is worthwhile to bear in mind that the interest in a new technology is probably due to a great number of factors, only a few of which are measured here, and even so not terribly precisely. We asked questions speculating about potential adoption of RFID health care devices, services with which they have had few analogous experiences, so we cannot measure current uses and attitudes. It seems a safe assumption that respondents have not had much of an opportunity to think deeply about the potential services or the questions posed during the survey. Their attitudes then represent a first, and in most cases a speculative, reaction to services with which they are unfamiliar. Hence the responses are open to change with the addition of more information or experience. Further, the questions themselves did not permit any opportunity to explore in depth respondent views towards the technology; nor could they provide a nuanced understanding of the particular situations in which respondents find themselves, and how these would affect interest in and outlook towards the technology.

On the other hand, the survey does provide a snapshot of the underlying outlook of Americans towards a several mobile healthcare services in the context of other potential services. Moreover, unlike the other surveys of RFID technology, the survey is both a random nationally representative set of data and one uniquely focused on health care technology provided through both cell phones and RFID technology.

In terms of physical closeness of family and friends, it may be that proximity leads to greater social interaction, attentiveness and concern. People who are more engaged with local friends may be also more engaged with health issues since this might be a corollary of interpersonal discussion in familiar conversation. In terms of belief in privacy, Duce [21] and Wu, Wang and Lin [41] among others have highlighted the importance of privacy issues in evaluation of mobile healthcare

Please cite this article in press as: J.E. Katz, R.E. Rice, Public views of mobile medical devices and services: A US national survey of consumer sentiments towards RFID healthcare technology, Int. J. Med. Inform. (2008), doi:10.1016/j.ijmedinf.2008.06.001

technology. While the positive directionality of the relationship is not what the literature predicts, it is plausible that those who are attentive to privacy concerns are also the most interested in personally utilizing new technology in ways that can minimize privacy risk while improving health status. As has been previously argued in another context [42], what most concerns people is disclosure of personal information to friends and neighbors, rather than distant entities such as government. This is in distinction to the emphasis the civil libertarians place on privacy invasion from business or government. If this argument is correct, it would make sense that a highly mobile personal healthcare technology could be seen as a supporting rather than detracting from one's privacy.

In terms of race/ethnicity, it is clear that many ethnic groups are among the early adopters of cell phone technology, and also of a variety of enhanced telecommunication services [43]. To the extent that race/ethnicity is also related to income and general access to health services, non-white/non-Caucasians may be more interested in personal, mobile health information devices.

This analysis of a 2007 national public opinion survey of 1404 Americans revealed variations in interest in and desirability of several mobile healthcare technologies. Despite the cries of alarms of critics concerning the possible dangers of these technologies generally, and of RFID in particular, there does not seem to be high levels of public concern about them. However, neither does there seem to be overwhelmingly strong positive interest. At the same time, the physical placement (not including actual insertion into the body) of potential RFID health care devices does not seem to arouse public concern except for a small minority (among those who are strongly negatively disposed towards such applications). In those cases, the negative sentiment often appears heightened when the mobile healthcare application is offered through placement on the body (here, taped to the arm).

The results suggest high levels of public interest in emergency intervention services, but much less so in health information and monitoring services. Statistically, those who are physically closer to family and friends with whom one keeps in touch, have a stronger belief in basic privacy rights, and are non-white/non-Caucasian seem more positive towards RFID-base healthcare technology. These correlates of interest have been identified in the prior literature with interest in, or adoption of, other telecommunication services and technology. In sum, public and consumer resistance to new mobile healthcare technology may not be as great as implied by previous nonrandom surveys and focus groups.

Appendix A

A commercial survey sampling company used random-digit dialing computer-assisted telephone interviewing from late February to early March 2007 to obtain a nationally representative sample of 1404 U.S. respondents over 18 who have a telephone, over-sampling young males, Hispanics and African-Americans. The final sample is similar the to US Bureau of the Census statistics [44] for people 18 and over except for age:

- Gender: 46% male, 54% female (vs. US 49, 51%).
- Ethnicity: 81% white, 10% black (vs. US 74, 12%); 1% South Asian, 1% Pacific Rim (vs. US Asian 4%); 13% Latino (vs. US 14.5%); and 6.6% "other".
- Age: the median age was 52 (vs. US approximately 47; this had to be derived because the US data are for all ages whereas our sample was for 18 and up).

The following statement is in conformance with the principles of disclosure of the US National Council on Public Polls: This sample, as is true for all sample surveys, whether or not they use probability sampling, is subject to multiple sources of error which are most often not possible to quantify or estimate, including sampling error, coverage error, error associated with nonresponse, error associated with question wording and response options, and post-survey data cleaning and adjustments. Therefore, we would prefer to avoid the words "margin of error" as they are misleading. All that can be calculated are different possible sampling errors with different probabilities for pure, unweighted, random samples with 100% response rates. These are only theoretical because no published polls come close to this ideal.

Summary points

What was already known on the topic:

- Virtually no systematic information was available about public attitudes towards personal mobile RFID medical technology applications.
- Critics have long decried the possible abuse of this technology.
- Public concerns have prompted numerous legislative bodies to consider regulating the technology.
- Many believed that the attachment of RFID technology would be viewed by broad sectors of the public as undesirable or unacceptable.

What this study added to our knowledge:

- This research for the first time provides a nationally representative sample of consumer attitudes on the topic of RFID medical informatics.
- Public opposition to RFID technology does not appear to be widespread, and in fact there is enthusiasm for some applications.
- Evidence suggests that attachment of RFID devices to the body is not viewed as objectionable by much of the public. Specifically, placement of RFID-based medical informatics devices on the arm by tape vs. as part of one's mobile phone does not seem to affect acceptability judgments except in a small percentage of the sample.

Please cite this article in press as: J.E. Katz, R.E. Rice, Public views of mobile medical devices and services: A US national survey of consumer sentiments towards RFID healthcare technology, Int. J. Med. Inform. (2008), doi:10.1016/j.ijmedinf.2008.06.001

REFERENCES

[1] J.E. Katz, R.E. Rice, Social Consequences of Internet Use: Access, Involvement and Interaction, The MIT Press, Cambridge, MA, 2002.
[2] Y.L. Hsu, C.C. Yang, T.C. Tsai, C.M. Cheng, C.H. Wu, Development of a decentralized telehomecare monitoring system, Telemedicine Journal & E-Health 13 (1) (2007) 69–77.
[3] Health Devices, Radio-frequency identification: its potential in healthcare, Health Devices 34 (5) (2005) 149–160.
[4] ITU, An Internet of things, International Telecommunications Union, Geneva, 2005, http://www.itu.int/osg/spu/publications/internetofthings/InternetofThings_summary.pdf.
[5] P. Boland, The emerging role of cell phone technology in ambulatory care, Journal of Ambulatory Care Management 30 (2) (2007) 126–133.
[6] A. Cavoukian, Tag, you're it. Privacy Implications of Radio Frequency Identification (RFID) Technology, Information and Privacy Commissioner, Ontario (Canada), 2004, http://www.ipc.on.ca/images/Resources/up-rfid.pdf.
[7] K. Wallis, R.E. Rice, Technology and health information privacy: consumers and the adoption of digital medical records technology, in: M. Murero, R.E. Rice (Eds.), The Internet and Health Care: Theory, Research and Practice, Lawrence Erlbaum Associates, Mahwah, NJ, 2006, pp. 279–311.
[8] J.E. Katz, R.E. Rice, S. Acord, Uses of internet and mobile technology in health systems: organizational and sociocultural issues in a comparative context, in: M. Castells, G. Cardoso (Eds.), The Network Society: From Knowledge to Policy, Brookings Institution Press, Washington, 2005, pp. 183–214.
[9] N. Oliver, F. Flores-Mangas, HealthGear: automatic sleep apnea detection and monitoring with a mobile phone, Journal of Communications 2 (2) (2007) 1–9, http://www.academypublisher.com/jcm/vol02/no02/jcm02020109.pdf.
[10] K. Albrecht, L. McIntyre, Spychips: How Major Corporations and Government Plan to Track Your Every Move with RFID, Thomas Nelson, New York, 2005.
[11] T. Lewan, Microchip implants raise privacy concern (July 21) (2007), http://apnews.myway.com/article/20070721/D8QH34P80.html.
[12] S.N. Weingart, H.E. Hamrick, S. Tutkus, A. Carbo, D.Z. Sands, A. Tess, R.B. Davis, D.W. Bates, R.S. Phillips, Medication safety messages for patients via the web portal: the MedCheck intervention, International Journal of Medical Informatics 77 (3) (2008) 161–168.
[13] U. Varshney, Pervasive healthcare and wireless health monitoring, Mobile Networks and Applications 12 (2–3) (2007) 113–127.
[14] E. Koskinen, J. Salminen, A customizable mobile tool for supporting health behavior interventions, in: Annual International Conference of the IEEE Engineering in Medicine & Biology Society (Conference Proceedings), 2007, pp. 5908–5911.
[15] I. Anderson, J. Maitland, S. Sherwood, L. Barkhuus, M. Chalme, M. Hall, B. Brown, H. Muller, Shakra: tracking and sharing daily activity levels with unaugmented mobile phones, Mobile Networks and Applications 12 (2–3) (2007) 185–199.
[16] C.C. Tsai, G. Lee, F. Raab, G.J. Norman, T. Sohn, W.G. Griswold, K. Patrick, Usability and feasibility of PmEB: a mobile phone application for monitoring real time caloric balance, Mobile Networks and Applications 12 (2–3) (2007) 173–184.
[17] SkyeTek Press Release, Patient safety increasingly reliant on RFID; Patient safety one of many applications RFID-enabled by SkyeTek's Advanced Universal Reader Architecture (AURA), (17 May) (2006), retrieved April 12, 2008 from Factiva Database.
[18] M.J. Miller, D.M. Ferrin, T. Flynn, M. Ashby, K.P. White, M.G. Mauer, Using RFID technologies to capture simulation data in a hospital emergency department, in: L.F. Perrone, B.G. Lawson, J. Liu, F.P. Wieland (Eds.), Proceedings of the 38th Conference on Winter Simulation, Monterey, California (December 3–6, 2006), 2006, pp. 1365–1370.
[19] S.-W. Wang, W.-H. Chen, C.-S. Ong, L. Liu, Y. Wen, RFID application in hospitals: a case study on a demonstration RFID project in a Taiwan Hospital, in: Proceedings of the 39th Hawaii International Conference on System Sciences, 2006, http://ieeexplore.ieee.org/xpl/RecentCon.jsp?punumber=10548.
[20] H. Leventhal, T. Musumeci, R. Contrada, Current issues in new directions in psychology and health: theory, translation, and evidence-based practice, Psychological Health 22 (4) (2007) 381–386.
[21] S. Campbell, T.C. Russo, The social construction of mobile telephony: an application of the social influence model to perceptions and uses of mobile phones within personal communication networks, Communication Monographs 70 (4) (2003) 317–334.
[22] K.M. Åkesson, B.-I. Saveman, G. Nilsson, Health care consumers' experiences of information communication technology—a summary of literature, International Journal of Medical Informatics 76 (9) (2007) 633–645.
[23] M. Rigby, Applying emergent ubiquitous technologies in health: the need to respond to new challenges of opportunity, expectation, and responsibility, International Journal of Medical Informatics 76 (2007) S349–S352.
[24] J.A. Fisher, T. Monahan, Tracking the social dimensions of RFID systems in hospitals, International Journal of Medical Informatics 77 (3) (2008) 176–183.
[25] R. Whiddett, I. Hunter, J. Engelbrecht, J. Handy, Patients' attitudes towards sharing their health information, International Journal of Medical Informatics 75 (7) (2006) 530–541.
[26] M.Z. Yao, R.E. Rice, K. Wallis, Predicting user concerns about online privacy, Journal of the American Society for Information Science & Technology 58 (5) (2007) 710–722.
[27] A. ElAmin, EU public wary of RFID, privacy survey finds, Food Production Daily (October 23) (2006), http://www.foodproductiondaily.com/news/ng.asp?n=71489-rfid-privacy-supply-chain.
[28] R. Wessel, EU RFID survey shows privacy protection a prime concern, RFID Journal (October 16) (2006), http://www.rfidjournal.com/article/articleview/2736/1/1/.
[29] H. Duce, Public Policy: Understanding Public Opinion, Cambridge University, Cambridge, Auto-id Centre Institute for Manufacturing, 2003, http://www.rfidconsultation.eu/docs/ficheiros/Understanding_Public_Opinion_autoIDcentre.pdf.
[30] Cap Gemini, RFID and consumers: understanding their mindset. A U.S. Study examining consumer. Awareness and perceptions of radio frequency identification technology, CapGemini Ernst & Young, 2004, http://www.rfidconsultation.eu/docs/ficheiros/CPRD_RFID_mindset_ES.pdf.
[31] H. Pinnock, R. Slack, C. Pagliari, D. Price, A. Sheikh, Professional and patient attitudes to using mobile phone technology to monitor asthma: questionnaire survey, Primary Care Respiratory Journal 15 (4) (2006) 237–245.
[32] B.B. Brandon (Ed.), The Effect of the Demographics of Individual Households on Their Telephone Usage, Ballinger, Cambridge, MA, 1981.
[33] J.S. House, K.R. Landis, D. Umberson, Social relationships and health, Science 241 (4865) (1988) 540–545.

Please cite this article in press as: J.E. Katz, R.E. Rice, Public views of mobile medical devices and services: A US national survey of consumer sentiments towards RFID healthcare technology, Int. J. Med. Inform. (2008), doi:10.1016/j.ijmedinf.2008.06.001

[34] B. Wellman (Ed.), Networks in the Global Village: Life in Contemporary Communities, Westview Press, Boulder, CO, 1999.
[35] A. Vukic, B. Keddy, Northern nursing practice in a primary health care setting, Journal of Advanced Nursing 40 (5) (2002) 542–548.
[36] D. Safran, J. Montgomery, H. Chang, J. Murphy, W. Rogers, Switching doctors: predictors of voluntary disenrollment from a primary physician's practice, Journal of Family Practice 50 (2) (2001) 130–136.
[37] G.D. Zimet, N.W. Dahlem, S.G. Zimet, G.K. Farley, The multidimensional scale of perceived social support, Journal of Personality Assessment 52 (1988) 30–41.
[38] J.E. Katz, A.R. Tassone, Public opinion trends: privacy and information technology, Public Opinion Quarterly 54 (1) (1990) 125–143.
[39] S. Warren, L. Brandeis, The right to privacy, Harvard Law Review 4 (1890) 193–220.
[40] A. Westin, Privacy and Freedom, Atheneum, New York, NY, 1967.
[41] J.H. Wu, S.C. Wang, L.M. Lin, Mobile computing acceptance factors in the healthcare industry: a structural equation model, International Journal of Medical Informatics 76 (1) (2007) 66–77.
[42] J.E. Katz, Public concern over privacy: the phone is the focus, Telecommunications Policy April (1991) 166–169.
[43] C.E. Batt, J.E. Katz, Consumer spending behavior and telecommunication services: a multi-method Inquiry, Telecommunications Policy 22 (1) (1998) 23–46.
[44] U.S. Bureau of the Census, Fact Sheet, US Bureau of the Census, Washington, DC, 2007, http://factfinder.census.gov/servlet/ACSSAFFFacts?_event=Search&geo_id=&_geoContext=&_street=&_county=race&_cityTown=race&_state=&_zip=&_lang=en&_sse=on&p ctxt=fph&pgsl=0 10.

Please cite this article in press as: J.E. Katz, R.E. Rice, Public views of mobile medical devices and services: A US national survey of consumer sentiments towards RFID healthcare technology, Int. J. Med. Inform. (2008), doi:10.1016/j.ijmedinf.2008.06.001