

Monitoring chronic pain: comparing wearable and mobile interfaces

Iyubanit Rodrguez, Carolina Fuentes, Valeria Herskovic

Pontificia Universidad Católica de Chile, Santiago, Chile

Abstract. Technologies to monitor patients are becoming widespread and they are more convenient for patients and can potentially reduce health care costs. Chronic pain is a pain that lasts more than 3 months and negatively affects the welfare of patients. Pain is subjective, so the only way to successfully evaluate it is to ask the patient, but it is usually made during a visit to the doctor and not in a real scenario. There are applications that allow people to self report pain episodes at any time, but adherence rates for these applications are often low, some tools are a burden and sometimes are not portable. The purpose of this article is the understanding of the characteristics of technology that help the adherence and adoption for the development of systems to self-report pain. Therefore, we have implemented two technological solutions for the self-report of pain: a mobile application and a wearable device, in order to compare the solutions to measure the rate of user acceptance, and also to get feedback about fundamental features of interfaces to report pain levels. To evaluate the two solutions we conducted an ethnographic study (interviews) with 12 people. The results showed that the wearable device has a greater acceptance (76%) and a device for reporting pain must be specific to this purpose, aesthetically pleasing to the user and allow users to report their pain easily and at the right time. In other words, applications to monitor pain should provide benefits to the user and be available at any adequate time and place to improve the adoption of these technologies.

1 Introduction

Patient monitoring is technology to manage, control and treat patients while collecting information remotely [24]. These technologies are becoming widespread: they are more convenient for patients and can potentially reduce health care costs [17]. The information that is collected by these systems is sent to health-care professionals, who receive a medical report in real-time and can improve the patient's diagnosis and treatment [1].

Chronic pain is pain that lasts more than 3-6 months and adversely affects patients' wellbeing [21]. Pain may also interfere with daily activities and affect health, employment and life [19]. Pain is subjective, so the only way to evaluate it successfully is to ask the patient [15], which is usually done during a doctor's appointment. There are several pain measurement scales [20] suited to different

types of patients. This work proposes remote monitoring for patients with pain, in order to understand the patients' pain levels during longer time periods. We propose two types of interfaces for pain monitoring: a mobile application and a wearable device. Our research questions are the following ones:

1. Which is more appropriate (has a higher rate of user acceptance) for monitoring pain: a wearable interface or a mobile application?
2. Which characteristics, or features, of the interface, are critical for users to be able to report their pain levels?

This paper is organized as follows. First, we discuss related work, considering self-report of pain and technologies to report pain. Then, we describe the design and characteristics of our prototypes. Section 4 describes our methodology, then section 5 describes the results and their discussion. Finally, section 6 presents our conclusions and discusses possible avenues of future work.

2 Related work

This section presents the related work: first, we discuss how pain is reported. Then, we review literature about self-reporting technologies and then we discuss interfaces for the self-report of pain.

2.1 Pain measurement

Several scales, aimed at different target users, exist to report pain (Figure 1). The visual analog scale (VAS) requires little training from patients [9]. However, elderly people with cognitive impairment or mobility problems may have trouble using it and it can not be administered over the phone [9]. The scale of faces (WBS) is suitable for use by children and elderly people [13]. The numerical scale (NRS) can deliver results graphically and verbally [28]. The NRS scales and descriptive scale (VRS) are best suited for patients with dementia [10]. For people who can not use one of these scales, for example pre-verbal children, observation and opinion of their relatives or caregivers can be used [10].

Physicians usually use one of the previous scales to ask patients about their pain during their appointment. This may be problematic, as pain is then evaluated mainly during the clinic visit [5], and not in a real scenario. Additionally, pain is usually registered on paper, which can cause information loss and difficulties in analyzing and searching for data [26].

2.2 Technology for pain monitoring

A system for patients to report pain from anywhere, at any time, can be used to monitor the evolution of pain levels [2]. Self-reporting can help patients become more aware of the characteristics of their pain, e.g. its intensity, patterns, triggers and location [22], and be more engaged in the self-management activity [16].

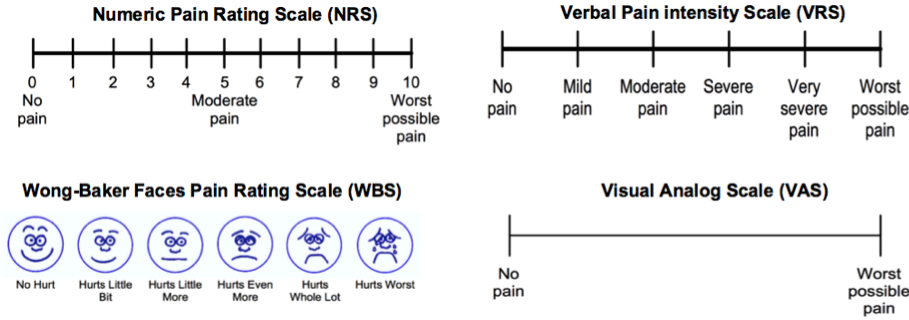


Fig. 1. Types of scales for measuring pain. Adapted from [8, 20].

Several applications allow people to report episodes of pain at any time [11]. One mobile application displays a human figure and asks the user to indicate the position, intensity and type of pain he/she feels [14, 25]. Another application also incorporates virtual reality [26]. Researchers have also proposed tangible technology that allows users to easily record their pain [2].

These types of applications allow new avenues of patient-doctor interaction [26] and patients feel confidence that their diagrams will be interpreted correctly, while doctors consider the diagrams and text descriptions complete and relevant [14].

Adherence rates for these applications are often low [23], and some tools are burdensome [16] and sometimes not portable. For these reasons, we believe that understanding the characteristics of technology that help adherence and adoption is crucial to develop systems that are useful for patients with pain.

3 Design of self-reporting interfaces

We implemented a wearable device and a mobile application to self-report pain. Both of these technological solutions use a simple VRS scale with three levels of intensity (Low, Medium and High). When the user feels pain during his/her daily life, he/she may report pain intensity by using the application. This information can be shared, e.g. sent to health professionals (see Figure 2).

3.1 *PainApp*: a mobile application to report pain

We implemented PainApp, a simple Android application that asks users about their pain level and stores the information in a database. The information can then be sent through email, bluetooth, social networks, etc (Figure 3). The application was designed considering older adults as the target users, as they more often suffer from pain. For this reason, we used considerations such as high color contrast, simplicity, large font, tactile interaction and explicit messages [7, 12].

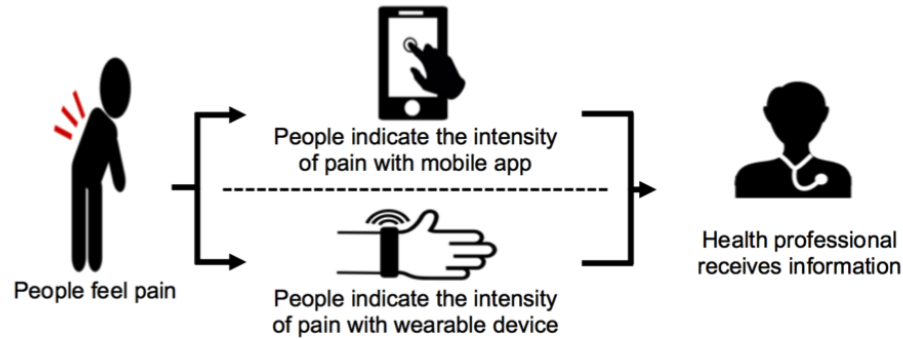


Fig. 2. Scheme for self-reported pain

3.2 *B-pain*: a wearable device to report pain

We implemented B-pain, a wearable device (worn on the body, e.g. embedded in clothing or accessories [18]). B-pain was designed to be worn as a bracelet, and it implements the same scale as the previous application: a VRS scale with three levels of intensity (Low, Medium and High). *B-pain* was implemented using Lily-Pad Arduino USB (electronic card based on the microcontroller Atmega32U4), blue, yellow and red LEDs, conductive fabric to create buttons, thread and a 110mAh battery. Figure 4 shows some components of the bracelet and the completed prototype.

When a person feels pain during the day, he/she can report the intensity of pain with the bracelet by pressing one of three buttons (green = low, yellow = medium and red = high) and receive feedback through the LED light (see Figure 5).

4 Methodology

We used a qualitative methodology for data collection: we applied semi-structured interviews. Each interview lasted about 15 minutes. To evaluate the solutions the participants interacted with the mobile application and wearable device and then we collected four types of information:

- Questionnaire results regarding digital skills (based on DIGCOMP [6]).
- Results from a usability evaluation using SUS (System Usability Scale) [4].
- Questionnaire results regarding usability of the wearable device.
- Audio recordings from the interviews.

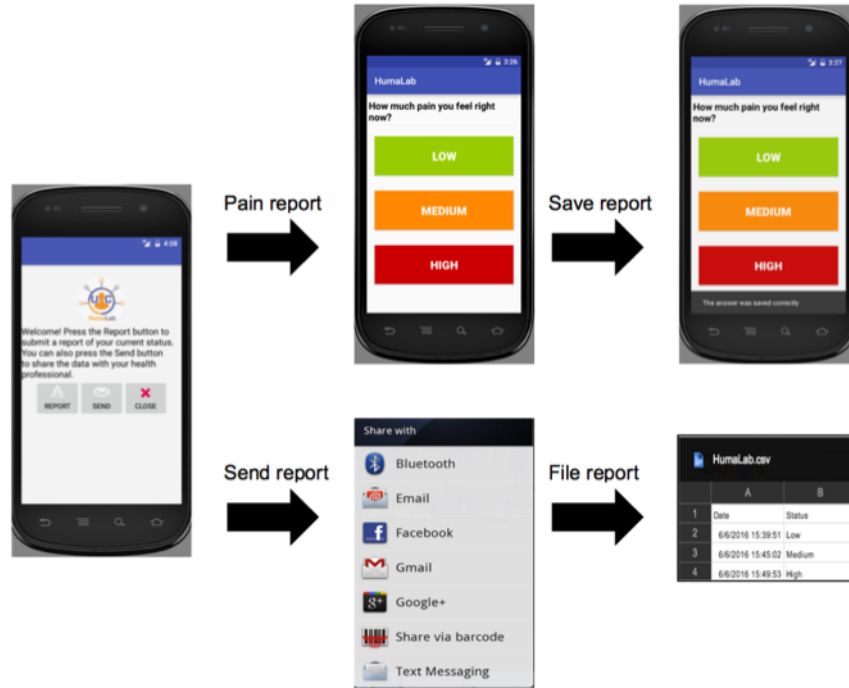


Fig. 3. Mobile app to self-report pain (*painApp*)

4.1 Participants

Our participants were 12 undergraduate students from different specialities (6 women and 6 men). The average age of participants was 26 with a standard deviation of 5.4. All participants have *above basic* digital skills.

4.2 Assessment tools

- DIGCOMP is a standardized instrument to measure digital competences, where users are categorized into one of four possible groups, according to their digital skill levels: *none*, *low*, *basic* or *above basic* [6].
- System usability scale (SUS) is a quick way to measure the overall usability of the system [4]. In this scale, scores below 60 indicate poor usability, while scores over 80 indicate very good usability [27].

4.3 Experiment

We performed semi-structured interviews with 12 participants in total during May 2016. To avoid bias, half of the participants interacted with the mobile

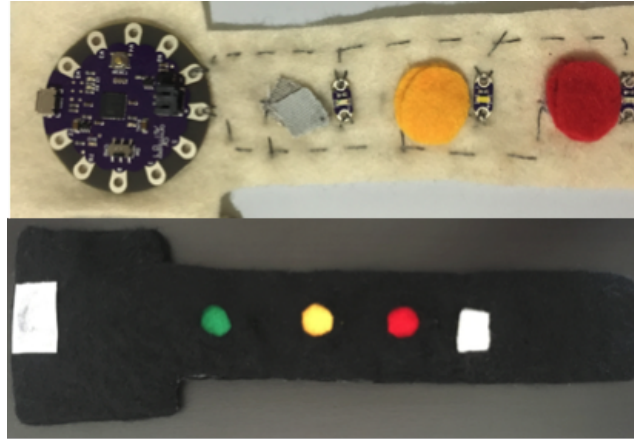


Fig. 4. *B-pain*. Above: inside view, below: outside view.

application first and the wearable device second, and the other half performed the opposite process. Each interview had the following structure:

1. One researcher gave a brief introduction about the study and its purpose.
2. The participant read a scenario describing a person with pain (a college student who after a car accident is suffering from chronic back pain).
3. The first interface was explained.
4. The participant was given time to interact with the first interface.
5. The researcher asked questions about the interface, using a predefined question set to guide the discussion.
6. Steps 3-5 were repeated with the second interface
7. The researcher asked questions comparing the two interfaces.
8. Finally, participants completed the DIGCOMP test, SUS questionnaire and user experience survey (see Figure 6).

4.4 Analysis

Interviews were recorded and transcribed. Subsequently, each interview was assigned a code (P1 to P12). We used thematic analysis to code and analyze the data [3]. Some quotes from participants are provided in the results (translated from Spanish).



Fig. 5. B-pain: (a) person uses the wearable on the wrist. (b) person indicates the intensity of pain by pressing the button (red light for feedback).

5 Results

5.1 Which is more appropriate (has a higher rate of user acceptance) for monitoring pain: a wearable interface or a mobile application?

67% of participants found the wearable device (B-pain) was more simple, while only 16.5% found the mobile application simpler (and 16.5% found that both technologies are equally simple). P4: *"the bracelet, because it's easy and fast. If I feel pain just I need to push a button, while with the cellphone I have to turn it on, open the application, and then report pain"*. 75% of participants believed that the wearable device allows users to report pain at the right time, whereas the mobile application does not, because the user is delayed by opening his/her smartphone and finding the app.

When participants imagined suffering from some kind of chronic pain, 67% indicated that they would prefer to use the wearable device. P1: *"The wearable device is easy to use, does not bother me and would not be difficult to use."*

Regarding the digital skills necessary to use each interface, 41.6% of participants believed the mobile application requires some knowledge about how to use a smartphone, while 33% believed the wearable device only requires a brief initial explanation about how to use it.

However, users not only found differences between both prototypes; they also believed the two prototypes could complement each other in different situations. P8: *"Maybe the bracelet and the app should be linked, and instead of mailing the data it could be sent to the app..."*. For example, the bracelet could be easier to use in some situations (e.g. driving) while the mobile application would be more appropriate in others (e.g. gala dinner). P6: *"I have the phone nearby but*

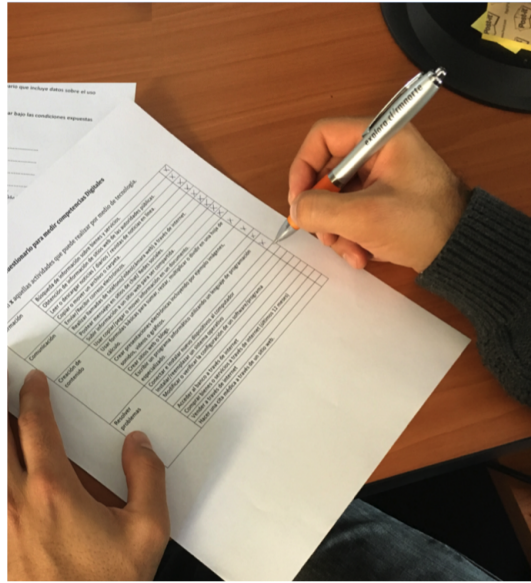


Fig. 6. Evaluation of prototypes.

wouldn't use it in the kitchen or car, while in the car it is easier to press the button and in other cases I would use my cellphone”.

5.2 Which characteristics, or features, of the wearable interface, are critical for users to be able to report their pain levels?

The B-pain device had a SUS score of 87, which represents good usability. Table 1 displays the average score (in a 5-point Likert scale) for each of the questions in the user experience questionnaire given at the end of the experiment. Most questions have very good scores, and the issues of “comfortable to use” and “response time is slow,” have a greater dispersion. We also analyzed the semi-structured interviews, usability and results using thematic analysis, and present our insights below.

Low cognitive load B-pain requires a low cognitive load from the users. The device is simple to understand as it resembles a traffic light and it only has one functionality. P12: “I liked the colors, they are traffic light colors, and everyone is familiar with them.”. One user did mention that this device might not work for colorblind users, so it is important to complement the interface with, e.g. words or textures, that can help users with disabilities or other conditions use them.

Table 1. Results of user experience questions for B-pain device

Statement ^a	Average	Standard deviation
1. The bracelet is comfortable to use	4,00	1,00
2. The bracelet is heavy to carry	1,08	0,28
3. Bracelet elements are messy	1,17	0,37
4. Response time is slow	2,00	1,22
5. The bracelet is intuitive to use	4,58	0,86

^a Scale: 1 (strongly disagree) to 5 (strongly agree) for each question.

Anytime/anywhere availability The bracelet is easily available at all times facilitating access to self-report. We call this anytime-anywhere availability “*when you need it, you have it*” (WYNIYHI).. P1: “*you are always carrying it, while you may have left your cellphone far away and not have it on hand to report pain at that exact moment*”.

Materials It is important to consider the type of material with which the wearable device is designed. Materials can cause problems for users, e.g. allergies. We found the current material of the prototype (felt) is not appropriate, and that future versions must consider the aesthetics and functionality of the bracelet materials. P3: “*I’d be scared to drop it in the water... I don’t know what it’s made of or whether it would give me allergies or something like that... and if you want to go to a party this could be aesthetically unpleasant.*”

The feedback given to the user should be clear and at the right time, so that the user is aware that the actions have been properly completed. P6: “*It is difficult to use outside because the light is too small to know whether it is working or not*”.

Self-reflection Reporting pain through a device is useful not only to share information with medical personnel, but also for users to be able to reflect on their own pain. P2: “*I like that it makes me aware of pain ... and I can have an answer, it is received by a doctor or a group of persons with pain and I can feel understood or that someone knows about this pain.*”

5.3 Oversimplification of pain

The three buttons to self-report of pain in the wearable device are simple to understand by users, however, they do not take into account intermediate levels of pain. To improve the adoption, it is necessary to give users a greater choice of pain intensity levels, but without making the design more complex. P2: “*It may be missing more options, pain is not only physical it can also be emotional, spiritual and there are many types of pain, this only involves a general concept of pain.*”

6 Conclusions

This paper presented a comparative study of two prototypes that allow users to self-report pain during their daily lives, allowing medical workers to monitor their pain: (1) a simple mobile application and (2) a bracelet. Both prototypes use a simple 3-level pain scale (low, medium, or high). We evaluated our prototypes with 12 participants, who were more favorable towards the wearable device.

We believe it is important that a device for reporting pain must be dedicated, aesthetically pleasing to the user, and allow users to report their pain easily and at the right time.

Our proposal and preliminary evaluation present some limitations that we would like to acknowledge. Firstly, the participants were all people without pain and all of them undergraduate students with above basic digital skills. It is possible that they are more open to trying new technology and positive towards novel interfaces such as wearables. Secondly, these prototypes were tested during a short period of time. Longer evaluation is need to truly assess adoption and usability. Nevertheless, the evaluation was a first step to identify concerns about the design of a wearable device to report pain before evaluating with patients that suffer chronic pain.

The next steps in this research are to create a second version of the bracelet prototype that can be tested for a longer period of time by patients suffering from pain. We will also improve *B-pain* by performing interviews and co-design sessions with patients who suffer chronic pain, therapists and clinical teams who work with patients with chronic pain.

Acknowledgment

This project was supported partially by CONICYT-PCHA/Doctorado Nacional/13-21130661,2014-63140077, CONICIT and MICIT Costa Rica PhD scholarship grant, Universidad de Costa Rica and Fondecyt Project (Chile), grant: 1150365.

References

1. ALAHMADI, A., AND SOH, B. A smart approach towards a mobile e-health monitoring system architecture. In *2011 International Conference on Research and Innovation in Information Systems* (Nov 2011), pp. 1–5.
2. ALAKARPPA, I., RIEKKI, J., AND KOUKKULA, R. Pervasive pain monitoring system: User experiences and adoption requirements in the hospital and home environments. In *Pervasive Computing Technologies for Healthcare, 2009. PervasiveHealth 2009. 3rd International Conference on* (April 2009), pp. 1–8.
3. BRAUN, V., AND CLARKE, V. Using thematic analysis in psychology. *Qualitative Research in Psychology* 3, 2 (2006), 77101.
4. BROOKE, J. Sus-a quick and dirty usability scale. *Usability evaluation in industry* 189, 194 (1996), 4–7.

5. CHHIKARA, A., RICE, A., MCGREGOR, A., AND BELLO, F. In-house monitoring of low back pain related disability (impaired). In *Engineering in Medicine and Biology Society, 2008. EMBS 2008. 30th Annual International Conference of the IEEE* (Aug 2008), pp. 4507–4510.
6. FERRARI, A. Digital competence in practice: An analysis of frameworks. Tech. rep., Research Centre of the European Commission, 9 2012.
7. FERRON, M., MANA, N., AND MICH, O. Mobile for older adults: Towards designing multimodal interaction. In *Proceedings of the 14th International Conference on Mobile and Ubiquitous Multimedia* (New York, NY, USA, 2015), MUM '15, ACM, pp. 373–378.
8. GARRA, G., SINGER, A. J., TAIRA, B. R., CHOCHAN, J., CARDOZ, H., CHISENA, E., AND THODE, H. C. Validation of the wong-baker faces pain rating scale in pediatric emergency department patients. *Academic Emergency Medicine* 17, 1 (2010), 50–54.
9. HAWKER, G. A., MIAN, S., KENDZERSKA, T., AND FRENCH, M. Measures of adult pain: Visual analog scale for pain (vas pain), numeric rating scale for pain (nrs pain), mcgill pain questionnaire (mpq), short-form mcgill pain questionnaire (sf-mpq), chronic pain grade scale (cpgs), short form-36 bodily pain scale (sf-36 bps), and measure of intermittent and constant osteoarthritis pain (icoap). *Arthritis Care & Research* 63, S11 (2011), S240–S252.
10. HORGAS, A. Assessing pain in older adults with dementia @ONLINE, 2012.
11. HUANG, Y., ZHENG, H., NUGENT, C., MCCULLAGH, P., BLACK, N., VOWLES, K. E., AND MCCracken, L. Feature selection and classification in supporting report-based self-management for people with chronic pain. *IEEE Transactions on Information Technology in Biomedicine* 15, 1 (Jan 2011), 54–61.
12. IGLESIAS, R., GOMEZ DE SEGURA, N., AND ITURBURU, M. The elderly interacting with a digital agenda through an rfid pen and a touch screen. In *Proceedings of the 1st ACM SIGMM International Workshop on Media Studies and Implementations That Help Improving Access to Disabled Users* (New York, NY, USA, 2009), MSIADU '09, ACM, pp. 63–70.
13. JACKSON, D., HORN, S., KERSTEN, P., AND TURNER-STOKES, L. Development of a pictorial scale of pain intensity for patients with communication impairments: initial validation in a general population. *Clinical medicine* 6 (2006), 580–585.
14. JANG, A., MACLEAN, D. L., AND HEER, J. Bodydiagrams: Improving communication of pain symptoms through drawing. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (New York, NY, USA, 2014), CHI '14, ACM, pp. 1153–1162.
15. M., M., AND A., B. Giving narcotics for pain. *Nursing* 19, 10 (9 1989), 161–165.
16. MACLEOD, H., TANG, A., AND CARPENDALE, S. Personal informatics in chronic illness management. In *Proceedings of Graphics Interface 2013* (Toronto, Ont., Canada, Canada, 2013), GI '13, Canadian Information Processing Society, pp. 149–156.
17. MJ, F., AND J, G. Telemedicine and remote patient monitoring. *JAMA* 288, 4 (2002), 423–425.
18. MOTTI, V., KOHN, S., AND CAINE, K. Wearable Computing: A Human-centered View of Key Concepts, Application Domains, and Quality Factors. In *Proceedings of the 16th international conference on Human-computer interaction with mobile devices & services* (Toronto, 2014), pp. 563–564.
19. O, G., M, V. K., GE, S., AND R, G. Persistent pain and well-being: A world health organization study in primary care. *JAMA* 280, 2 (1998), 147–151.

20. ON PAIN CONTROL, T. N. I. Pain assessment scales @ONLINE, 2001.
21. PAIN ASSOSATION, A. C. Glossary @ONLINE, 2016.
22. RINI, C., WILLIAMS, D. A., BRODERICK, J. E., AND KEEFE, F. J. Meeting them where they are: Using the internet to deliver behavioral medicine interventions for pain. *Translational Behavioral Medicine* 2, 1 (2012), 82–92.
23. ROSSER, B. A., V. K. E. K. E. E. C., AND MOUNTAIN, G. A. Technologically-assisted behaviour change: a systematic review of studies of novel technologies for the management of chronic illness. *Journal of Telemedicine and Telecare* 15, 7 (2009), 327–38.
24. S., R. *mHealth: New Horizons for Health through Mobile Technologies: Based on the Findings of the Second Global Survey on eHealth*. Healthc Inform Res, 2012.
25. SERIF, T., GHINEA, G., AND FRANK, A. O. Visualizing pain data for wheelchair users: A ubiquitous approach. *J. Mob. Multimed.* 1, 2 (June 2005), 161–177.
26. SPYRIDONIS, F., HANSEN, J., GR
ONLI, T.-M., AND GHINEA, G. Paindroid: An android-based virtual reality application for pain assessment. *Multimedia Tools Appl.* 72, 1 (Sept. 2014), 191–206.
27. TULLIS, T., AND ALBERT, W. *Measuring the User Experience: Collecting, Analyzing, and Presenting Usability Metrics*. Morgan Kaufmann Publishers Inc., San Francisco, CA, USA, 2008.
28. WILLIAMSON, A., AND HOGGART, B. Pain: a review of three commonly used pain rating scales. *ISSUES IN CLINICAL NURSING* 14 (2005), 798–804.