Investigations to Develop a Fully Adjustable Intelligent Toilet for Supporting Old People and Persons with Disabilities – The Friendly Rest Room (FRR) Project

Paul Panek[1], Georg Edelmayer[1], Charlotte Magnusson[2], Peter Mayer[1], Johan F.M. Molenbroek[3], Håkan Neveryd[2], Robert Schlathau[4], and Wolfgang L. Zagler[1]

[1] fortec – Research Group on Rehabilitation Technology
Favoritenstrasse 11/029, A-1040 Vienna, Austria
{panek,edelmayer,mayer,zagler}@fortec.tuwien.ac.at
http://www.fortec.tuwien.ac.at/frr

[2] Certec, Division of Rehabilitation Engineering, Lund University
Box 118, SE-221 00 Lund, Sweden
{charlotte.magnusson,hakan.neveryd}@certec.lth.se

[3] Industrial Design Engineering, Delft University of Technology, Landbergstraat 15
2628CE Delft, The Netherlands
j.f.m.molenbroek@io.tudelft.nl

[4] Multiple Sclerosis Society Austria, Währinger Gürtel 18-20, A-1090 Vienna, Austria
R.Schlathau@viennaairport.com

Abstract. The FRR (Friendly Rest Room) project creates and evaluates prototypes of a more user friendly intelligent toilet for old persons and for persons with disabilities. Additionally, applicable knowledge regarding needs and wishes of old and/or disabled persons and their care persons are documented. In this paper the user driven research approach, ethical aspects and the iterative user centred design process are outlined. First results from user tests of lighting, human computer interface and preferred seating heights are described.

1 Introduction and Aim

Many of today's toilets in private and public places are not satisfying the specific needs of European citizens who are facing physical and cognitive limitations. The FRR project is carrying out the necessary research and design steps in order to build and test prototypes for a Friendly Rest Room (FRR) for older persons and/or persons with disabilities. All the elements of the FRR will adjust semi-automatically to the individual needs of older persons with functional limitations or persons with disabilities, allowing them to gain greater autonomy, independence, self-esteem, dignity, safety, improved self-care and, therefore, enable them to enjoy a better quality of life. The methods and technologies involved range from contactless smart card technologies with read-write capabilities, voice activated interfaces, motion control and sensor systems and mechanical engineering, as well as ergonomic research, design for all

K. Miesenberger et al. (Eds.): ICCHP 2004, LNCS 3118, pp. 392–399, 2004.

philosophy, gerontechnology and medical and social sciences. The aim of the FRR project is to empower old and/or disabled persons to use public restrooms in Europe even despite an increasing level of disability and to support secondary users by providing an innovative, user-friendly and highly adaptable, smart toilet system.

2 Methods

According to a multidisciplinary approach the consortium brings together end-user organisations representing a wide range of European countries, universities, research and rehabilitation centres as well as industrial partners in the area of industrial and public design and the sanitary industry.

2.1 Involvement of Users and Collection of User Needs

The project involves broad user driven research to define the user parameters for designing and developing the FRR systems. User involvement takes place in all the stages of the research and problem solving process of the FRR development and testing. Starting from given restrooms [17] ("standard restrooms") it is necessary to find out (a) what older and/or disabled toilet users (primary as well as secondary users) experience as difficult and (b) what they regard as helpful. This is done by applying social research methods (interviews, observations, questionnaires, and secondary statistics) and by referring to given technical/design solutions represented in the different FRR prototypes generations or FRR design specifications. For this reason 3 user test sites have been established in Sweden (Univ. of Lund), in Greece (Univ. of Athens) and in Austria (Vienna Univ. of Technology).

2.2 User Test Sites and Ethical Aspects

The three User Test Sites are organised and maintained by the local FRR project partners. At each site independent User Boards consisting of 7-10 expert users, care persons and professionals from therapy, nursing and medicine and user representing organisations have been established. Additionally, each site is equipped with a "physical toilet prototype" in order to run user tests.

The setting-up and carrying out of the user tests is being accompanied by ethical reviewers in order to ensure the protection of the dignity and privacy of test persons and users involved [18]. In addition, to ensure the ethical quality of the on-going work, the reviewers also help to develop new horizons in the design process about the intimate and sensitive aspects of toileting, personal hygiene and public health as a psychological and cultural phenomenon.

2.3 Qualitative and Quantitative Research

One of the main tasks of qualitative research in the FRR project are the user tests which are carried out in several cycles with a relatively small group of specifically

selected users. The users are asked to use the prototype system and if they have agreed to be observed, the sociologist takes field notes. Technical data are measured by the sensors of the prototype. After the test post-test interviews are conducted. The methodology is based on the "Theoretical Sampling" method and on the "Grounded Theory" by Strauss and Corbin [1]. Additional to the user test cycles, where the users interact with new FRR prototype generations and reflect about interaction during the post test interview (open interviews recorded & transcribed), other methods for collection of qualitative data have been used: Expert knowledge has been gained during expert workshops by conducting exploratory interviews with secondary users and is also continuously provided by user boards.

In 2002 and 2003 FRR questionnaires about the personal situation regarding using one's own toilet were distributed in nearly all regions of the German speaking Europe among members of seniors' organisations by FRR partner Eurag and by the MS-Society of Austria in their members´ journal. Additionally, Greek, English and Dutch versions of the questionnaires have been distributed nationally.

2.4 Iterative and User Centred Design

In the FRR project 4-5 cycles of testing and redesigning [12], [16] are foreseen in order to come up with the final FRR system beginning of 2005. Computer Based Interview tools [13], [14] have been developed as a tool to get feedback and response from users, professionals and experts to different design proposals.

The development process of each part in the FRR is based on both literature and own FRR-research and takes place mostly in The Netherlands by the FRR-partners Landmark and TUDelft. Earlier research on anthropometry of 600 elderly in The Netherlands [27] is used as a reference in this FRR design process. The design prototypes have been pre-tested by students of Industrial Design Engineering, partly using an aging simulation kit developed by Loughborough University in the Third Age Suit-project [28]. After the pre-tests the prototypes are sent to the tests sites in order to be evaluated with old people and users with disabilities.

As an example for a basis of the toilet design Fig. 1 illustrates the large variety in two body dimensions within the population of 600 elderly and 150 young people. The popliteal height is the lower leg length and is relevant for the sitting height. The elbow-seat height is relevant for the armrest. The figure shows that there is almost no correlation between these two measurements. This means that the designers are recommended to make the two product dimensions independently adjustable.

3 Ongoing Activities and Preliminary Results

Currently the 3rd test cycle has been successfully completed and is being analysed. The specification, design and manufacturing process will come up with the 4th prototype generation to be evaluated by older persons and disabled users in May 2004.

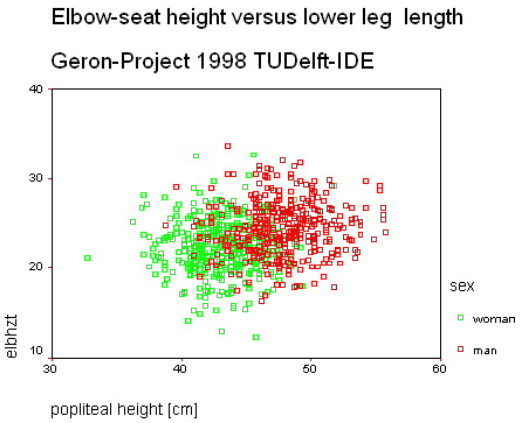

Fig. 1. Distribution of popliteal height and elbow-seat height [27].

3.1 Design of the Computer Interface

To obtain user input on the design of the computer interface different methods have been used [12], [16]. The process started with an expert user evaluation of a set of scenarios and sketches. This evaluation was performed by expert users both in Lund (Sweden) and in Vienna (Austria). Following this first test, demonstrators of both a voice interface and a hand held control were implemented. The voice interface was based on ASR 3200 (embedded system) from ScanSoft [26]. The hand held control demo interface was implemented on a Pocket PC device (Compaq iPAQ™ 5500) as this type of hardware has a colour screen, is of approximately the right size and allows for the use of images, text and sound. It is important to point out that this device is not intended for the final FRR system, but has been used for obtaining user feedback on different ways to design the computer interface. Preliminary versions of both voice interface and hand held control interface has been tested by groups of expert users both in Lund (Sweden) and in Vienna (Austria). The tests performed so far have confirmed the design approach used.

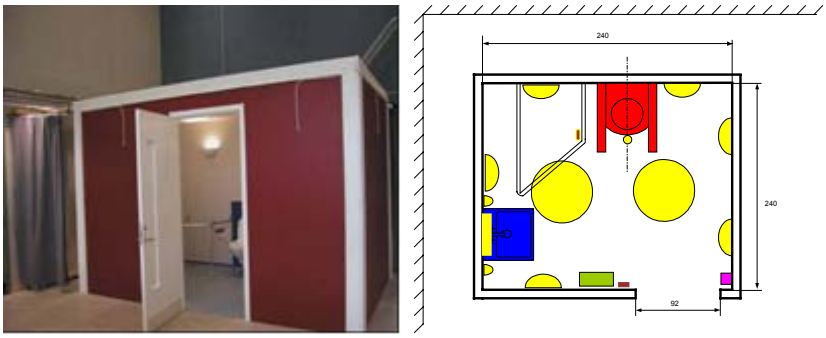

Fig. 2, 3. The FRR test room in Lund. Left side (Fig. 2) shows the entrance door, in the background the toilet bowl. Right side (Fig.3) shows site plan with bowl, sink and light sources.

3.2 Lighting Tests and Conclusions

Figure 2 and 3 show the test room (usability laboratory) that has been built at the test site in Lund. It was not possible to use a standard usability laboratory because of the privacy aspects involved in toileting. The size of the room was determined by the Swedish standard of 2.40 m x 2.40 m. Illuminance and contrast issues along with the overall impression have been the focus of the tests in Lund. The toilet and sink are connected to the water supply and sewer.

The test room is designed with optimal differences in colour contrast between wall and floor, and between toilet/sink and wall. A blue-painted strip of wood was installed where the floor meets the wall to emphasize the difference in contrast. The NCS (Natural Color System) Lightness Meter [19] was used to measure the difference in contrast. Twelve lamps were installed in the test room:

- Six lighting fixtures on the walls directed upwards.
- Two lighting fixtures with frosted glass mounted in the ceiling.
- Three lights with frosted glass installed around the mirror.
- One spotlight installed directly over the toilet seat.

Frosted glass and lighting fixtures directed upwards were chosen, because many persons with visual impairments prefer indirect lighting. The test set up supplies between 300 and 550 lux when using the maximal effect of the light fixtures. Swedish standards for bathrooms ask for 200 lux, and 300 lux for old persons. From the user tests the following can be concluded:

- Adaptable lighting is necessary
- More work on lighting conditions at the sink (380 lux for sitting users and 416 lux for standing users are not enough for some users with visual impairments).
- One spotlight over the toilet is not enough for the users. If more spots are used, it minimizes the risk that the working area is thrown into the shadow cast by the hands.
- To achieve the optimal lighting solution an extended test time and the possibility for the tester to adapt the lighting on her/his own is required.

3.3 Preferences Regarding Sitting Heights – Preliminary Results

The test site in Vienna is using an Hungarian product from Clean Solution Kft [2] which has been significantly modified with additional adjustable grab bars, position sensors and a PC-unit for controlling the toilet and for measuring and logging the users' preferred positions. This prototype is installed in a laboratory environment without being connected to the water supply and sewer. The focus of the user tests has been put on users with limitations in lower parts of the body, meaning users moving with wheelchair, cane or other walking aids.

For the test, the users were asked to transfer to the toilet seat (with clothes on) and to adjust the height and tilt of the toilet seat to the optimal position. Three types of optimal positions were measured: (1) optimal position for sitting down = transferring to the toilet, (2) optimal position for sitting = using the toilet and (3) position for

standing up = transferring back to the wheelchair (standing up). Many of the test persons used the test equipment for a time of about 30-60 minutes, therefore several positions were tried and some of them were classified by the test persons as being optimal. The measured values for the sitting height have been transformed using a correction formula in order to become independent from the influences caused by different designs of toilet seats and different tilt angles and different parameters of the used prototypes.

Several test runs were carried out. In the following, the test run in June 2003 is outlined in more details. A height adjustable toilet additionally connected to a PC for steering, measurement and logging purposes was used. The sample consisted of 17 persons (7 male, 10 female) between 15 and 82 years of age (average 53,5), partly older persons (5 persons over 60 years) partly MS (multiple scleroses) patients. The test-persons are partly using wheelchairs, walking aids or sticks.

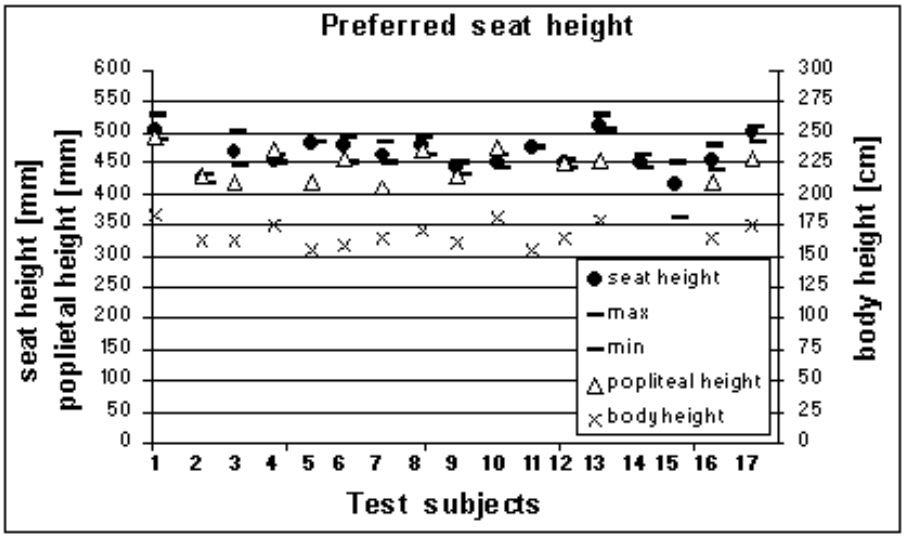

Fig. 4. Preferred set heights and basic anthropometric data of 17 test participants in Vienna.

Figure 4 shows measured preferred seat heights for 'position sitting'. Each user has an individual bandwidth of preferred seat heights. The total used range of heights was 364 mm to 529 mm. The popliteal lengths of the test-persons varied between 41 and 49 cm, body height between 183 and 156 cm (average 168.2). There is little correlation between the anthropometric data (popliteal height, body height) and the preferred (average) sitting position. It is obvious, that the different needs of the test-persons need to be covered by the toilet. Preferred seat heights (and also preferred height of supporting bars) cannot necessarily be derived from body parameters but are individual preferences, surely influenced by (remaining) physical abilities. More work on this is currently being done in order to identify important parameters for the future FRR system.

4 Discussion and Outlook

The multidisciplinary approach of the FRR project is ensuring a wide horizon to come up with innovative and reasonable approaches which are meeting the users' needs and the economic necessities. An important feature of the FRR project certainly is the strong user involvement which also can be observed in the way the project is structured, especially with the different user test sites and the independent user boards. The 4th prototype is planned to be evaluated in May 2004, the final FRR system will be validated 2004/2005. More information is to be found on the web site of the FRR consortium: `http://www.frr-consortium.org`

Acknowledgement

FRR is partially funded 2002-2005 by the European Commission as project QLRT-2001-00458 in the Quality of Life program. Project partners are: Industrial Design Engineering – Delft University of Technology (NL), fortec – Vienna Univ. of Technology (AT), Certec – Dep. of Rehabilitation Engineering, Lund University (SE), EURAG - European Federation of the Elderly (AT), Laboratory of Health Informatics – University of Athens (GR), Applied Computing – Dundee University (UK), Landmark Design Holding (NL), Clean Solution Kft (HU), SIVA (IT), HAGG – Hellenic Association of Geriatrics and Gerontology (GR).

References

1. Strauss, J.Corbin: Basics of Qualitative Research - Grounded Theory Procedures and Techniques, Newbury Park, 1990
2. Clean Solution Kft, Hungary, http://www.cstechnologie.com/
3. F. Aminzadeh, N. Edwards, D. Lockett, R. C. Nair: Utilization of bathroom safety devices, patterns of bathing and toileting, and bathroom falls in a sample of community living older adults, in Technology and Disability 13 (2000), ISSN 1055-4181, IOS Press, pp. 95-103.
4. FRR – Friendly Rest Room Project Web Site: http://www.frr-consortium.org
5. H. Hyppönen: Handbook on Inclusive Design of Telematics Applications, 1999, electronically available on http://www.stakes.fi/include/handbook.htm
6. H. Neveryd, J. Molenbroek, P. Panek: FRR - Friendly Rest Rooms for Elderly and Disabled Persons - A User Centered R&D Project, to be printed in proceedings of Gerontechnology Conf., Miami, U.S., 2002
7. H. Pain, S. Gore, D. L. McLallan: Choosing bathing and showering equipment for people with disabilities, in C. Bühler, H. Knops (Eds.): Proc. of the 5th AAATE Conf., IOS Press, pp. 397-401, 1999.
8. Halkiotis S, Botsis T, Liaskos J, Mantas J. Knowledge Management Approach in the FRR project (poster). In: MIE 2003. CD ROM Proceedings of the Medical Informatics Europe Conference; 2003 May 4-7, Saint Malo, France; 2003.

9. Halkiotis S, Botsis T, Liaskos J, Mantas J. Managing Information and Knowledge gained in the FRR project. In: ICICTH 2003. Proceedings of the 1st International Conference on Information Communication Technologies in Health; 2003 Jul 11-13; Samos Island, Greece; 2003. p. 294-298.
10. INCLUDE Project: INCLUsion of Disabled and Elderly people in telematics, TELEMATICS project 1109, Web Site: http://www.stakes.fi/include/
11. J. A. Sanford: Best Practices in the Design of Toileting and Bathing Facilities for Assisted Transfers – Final Report fro US Access Board, August 2001, http://www.access-board.gov
12. J. Nielsen: Usability Engineering, Academic Press, 1993.
13. Joel S, Alm N, De Campo ME, Gregor P, Hands K, Hine N, Panek P. Eliciting sensitive information about toilet needs using a computer based interview (poster). In: AAATE 2003. CD ROM Proceedings of the 7th European Conference for the Advancement of Assistive Technology; 2003 August 31-September 3, Dublin, Ireland; 2003.
14. K. Hands, P. Gregor, D.R. Peiris, A. F. Newell: A computer-based interviewing tool for usability engineering (UsE-IT), in: CHINS 2001 Consumer Health Informatics Network Scotland, Glasgow, 2001
15. K. Pesola: Bathroom – an important Detail in Designing for Older People, in C. Bühler, H. Knops (Eds.): Proc. of the 5th AAATE Conf., IOS Press, pp. 392-396, 1999.
16. K. T. Ulrich, S. D. Eppinger: Product Design and Development, Second Edition, McGraw-Hill, 2000.
17. Kira, Alexander. The Bathroom, Viking Press, New York, 1976.
18. M. Rauhala, P. Topo: Independent living, technology and ethics. Technology and Disability 15(2003)205-214.
19. NCS - Natural Color System, http://www.ncscolor.com
20. Older adultdata. The handbook of measurements and capabilities of the older adult: data for design safety, Anthropometric and strength data on older people aged 60 and over, publications@dti, Department of Trade and Industry, UK, June 2000
21. P. G. Morasso, L. Baratto, R. Capra, G. Spada: Preventing the risk of falling in elderly patients, in: I. Placenia Porrero and E. Ballabio (Eds.): proc of the 3rd TIDE congress, IOS Press, pp. 101-104, 1998.
22. P. Gregor, A.F. Newell, M. Zajicek: Designing for Dynamic Diversity – Interfaces for Older People, in ASSETS 2002, ACM ISBN 1-58113-464-9-02/07, pp 151-155
23. P. Panek, H. Neveryd, W.L. Zagler: "The FRR Project: Developing a More User Friendly Rest Room"; Presentation: AAATE '03, Dublin; 08-30-2003 - 09-03-2003; in: "Assistive Technology - Shaping the Future"; G. Craddock, L. McCormack, R. Reilly, H. Knops (ed.); IOS Press, Volume 11 (2003), 1 58603 373 5; 678 - 682.
24. R. de Bruin, J. FM Molenbroek, T. Groothuizen, M. van Weeren: On the development of a friendly rest room, proceedings of the INCLUDE conference 2003, Inclusive Design for Society and Business, 2003
25. Sourtzi P, Panek P, Liaskos J, Mantas J. Friendly Rest Room (FRR): Developing the concept and the product. In: Proceedings of the Alzheimer Europe Conference; 2003 June 13-15, Thessaloniki, Greece; 2003.
26. Speech Recognition ASR 3200 from Scan Soft, http://www.scansoft.com
27. Steenbekkers, LPA, J.M. Dirken, C.E.M. van Beijsterveldt, J.F.M. Molenbroek, A.I.M. Voorbij: Design-relevant characteristic of ageing users; background and guidelines for product innovation (Series Ageing and Ergonomics, Volume 1). Delft University Press, Delft (NL), 1998, ISBN: 90-407-1709-5
28. The Third Age Simulation Suit, Taurus, Loughborough University, retrieved from the WWW on March 31st, 2004: http://www.lboro.ac.uk/taurus/simulation.htm