A Friendly Rest Room: Developing Toilets of the Future for Disabled and Elderly People
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Overview of the FRR Project; Designing the Toilet of the Future

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Abstract. Although the topic still is surrounded by taboos in our modern society, the toilet area recently is becoming more and more subject of study and even redesign. The objective of the EU funded project 'Friendly Rest Room' (2002-2005) was to provide recommendations for improving the toilet area, in particular focussing on the special needs of elderly and disabled, by performing several user studies and exploring the potential of assistive technologies. The 10 project partners from 8 different European countries assured as well a multidisciplinary as multicultural vision on the subject matter. This chapter describes the approach that was chosen and in more detail the different ergonomic user studies that were performed. Problems and experiences with regards to ethics and cultural differences will be discussed. The results are presented in a basic list of user problems and illustrated by the first product development steps of the 'toilet of the future'.

Keywords: Applied Ergonomics, Inclusive Design, Toilet, Rest Room, Elderly, Disabled, Assistive Technologies, Ethics, Cultural Differences

1. Introduction

In our daily live we are increasingly being supported by the application of new technologies, from self-thinking washing machines to 'personal assisting' mobile phones. These modern machines often do not resemble their earliest versions at all and usually for the better (everybody who has washed by hand and board once will immediately agree). There is however one essential appliance we use multiple times every day which somehow escaped this modernisation: our toilet.

The toilet that is most commonly used in the western society is the 'sitting-type' toilet referring to the sitting posture one has when using it. This type of toilet looks not so much different to the first patented design for a water closet by Alexander Cummings in 1775[1]. Except for some improvements regarding water flush and sewage, the toilet basically has not changed since [2]. This is illustrated by the toilet bowl from 1910 in figure 1.

Apparently the design of the toilet is satisfactory to the majority of mankind, or maybe not? For a fact there are in the market a whole collection of products available that cunningly respond to shortcomings of the standard toilet; toilet brushes, toilet

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fresheners, toilet seat cleaners, toilet seat paper, toilet seat raisers for elderly, child toilet seats, toilet chairs, special soft toilet seats, toilet arm support bars, toilet back support bars, turning aids, stand-up toilet mechanisms, toilet paper tongs etc. From this collection 'add-ons' alone one can conclude that the current toilet design clearly does not cover for all the user's needs. Especially when it comes to hygiene, comfort and safety for children, elderly and disabled our 'modern' toilet is pitifully failing.

The rise in the ageing population will almost certainly blow up the difficulties even further. Not only the safety of older persons is at stake, since the risks of falling in the toilet area are high [3], also health care workers that assist elderly and disabled in their daily routines are suffering from a bad toilet design. They often have to work in difficult postures when transferring patients to and from the toilet and as a result back pains are a common noted complaint [4,5].

Clearly more research can and should be done to improve the toilet area. It is necessary to map the actual needs of the user, based on behaviour, habits and culture, the needs of caretakers etc. Study results should be translated into a toilet design that integrates all functions and offers a total approach instead of designing tools to overcome the flaws of existing sanitary. The use of new technologies in this toilet design makes sense: the modernisation of our toilet can begin.

Figure 1. A toilet bowl from ca. 1910

2. The Friendly Rest Room Project

2.1. General Objectives

The Friendly Rest Room (FRR) project (2002-2005) was initiated in an attempt to enlarge the autonomy, independence, dignity and safety of elderly and disabled people, and thus raise their overall quality of life. The FRR project was partially funded by the European Commission as project QLRT-2001-00458 in the 'Quality of Life and Management of Living Resources, Key Action 6: the Ageing Population and Disabilities' programme.

The user group elderly and disabled was chosen because of the obvious problems this group encounters in the current toilet design. The general idea was though that a toilet that suits the elderly and disabled, will also suit the young and healthy. This approach – Inclusive Design or Design for All (ensuring that the needs of the widest possible audience, irrespective of age or ability are addressed [6]) - was followed in the FRR project and now forms the first step in adapting our toilet design to the modern ages.

The FRR project aims at developing a user-Friendly Rest Room for the elderly and persons with limited abilities, which is facilitated by recent sociological, ergonomic and anthropometrical studies and technology developments. A more user-friendly lay-out of the room will be combined with a more user-friendly design of sanitary modules. A 'smart' toilet that will compensate the special needs of the user in a friendly way and increase their pleasure in life is the desired result [7].

The objectives of the FRR-consortium are in short:

- To develop Quality of Life products for the ageing population and people with limited abilities
- To generate knowledge and understanding regarding toileting, personal care and hygiene, and accident prevention
- To establish an independent consortium to implement additional research and development projects in the domain of 'caring homes for independent living'

2.2. Project Partners

Ten organisations and companies located in seven different European countries together form the FRR project-consortium, guaranteeing a wide geographic and cultural coverage. Each consortium partner represents a different area of expertise and as a whole the FRR consortium offers expertise in the fields of advanced robotics, rehabilitation technology and engineering, health care informatics, applied computing, product systems and ergonomics, product design and development, geriatrics and gerontology, sociology and ethics. An overview of the consortium partners is given in table 1.

2.3. Process

Research activities and design and development activities have taken place simultaneously in this project. The research objectives can be divided into two parts;

Table 1. The project-partners of the Friendly Rest Room project

FRR Consortium partners			
Abbrev.	Organisation / Company	Residence	Area of expertise
DUT	Section Applied Ergonomics and Design, Department Industrial Design, Faculty of Industrial Design Engineering, Delft University of Technology	Delft, The Netherlands	General Ergonomics, Anthropometrics and Bio-mechanics, Informational ergonomics, Safety studies and the Application of Product Ergonomics to Design Projects
FORTEC	Research Group on Rehabilitation Technology, Institute Integrated Study, Vienna University of Technology	Vienna, Austria	Electrical Engineering, Informatics, Biomedical Engineering and Precision Mechanics
CERTEC	Division of Rehabilitation Engineering Research, Department of Design Sciences, Institute of Technology, Lund University	Lund, Sweden	Rehabilitation Engineering and Design, Human Machine Interaction
EURAG	European Federation of Older Persons	Graz, Austria	Social Science, User Needs of Elderly
UOA	Health Informatics Laboratory, Faculty of Nursing, University of Athens	Athens, Greece	Health Care Informatics, Health Informatics Education and Standardisation
UNIDUN	Faculty of Engineering and Physical Sciences, Department of Applied Computing, University of Dundee	Dundee, United Kingdom	Computer-based System Design , Computer-based Interviewing Techniques
LM	Landmark Design Holding BV	Rotterdam, The Netherlands	Industrial Design, Inclusive Design
SIVA	Fondazione Don Carlo Gnocchi Onlus, Servizio Informazioni e Valutazione Ausili, Assistive Technology Research and Information Service	Milan, Italy	Medical, Social and Vocational Rehabilitation, Assistive Technology, Education and Information
HAGG	Hellenic Association of Gerontology and Geriatrics	Athens, Greece	Health and Social Welfare, Gerontology and Geriatrics, Health Promotion
CSO	Clean Solution Kft.	Debrecen, Hungary	Development and Implementation of Assistive Products for Elderly and Disabled

the first objective was to gather general knowledge about the problems elderly and disabled encounter in the toilet area. This knowledge then was translated into a set of design specifications gradually building up during the course of the project. The research activities that have been performed in this regard are:

- General literature study,
- Interviews with elderly, disabled and their caretakers about the toilet environment (CERTEC, FORTEC, EURAG, LM, TUD, UOA, HAGG)
- Multiple case-studies of elderly and disabled in their home toilet environment (SIVA),
- Questionnaire on toilet issues amongst elderly and disabled (EURAG),
- Development of a computer based interview tool (UNIDUN),
- Questionnaire on body posture during toileting and cleansing (LM),
- Study into user needs and preferences regarding illumination within the toilet area (CERTEC)
- Behavioural study of independently living elderly in their home toilet environment (TUD)
- Study into comfort of the toilet seat (TUD),
- Study into fall prevention in the toilet area (TUD).
- Behavioural study into the preferences of support bars near the toilet bowl (TUD) and
- Behavioural study on body posture during dressing/undressing, toileting and cleansing (TUD).

The second objective was to study whether the design solutions based on the growing design specifications were fulfilling the user needs and preferences and whether they indeed formed a solution that enabled elderly and disabled to use the toilet more safely and independently. This was done by testing several successive FRR prototype generations at 5 European test sites, the so called User Research Bases (URB). An overview of the URBs and the different test stages is given in table 2.

Table 2. Overview of URBs and the different successive prototype stages tested

	Organisation / Company	**Residence**	**Prototypes stages**			
			EPT(1)	APT(2)	BPT(3)	PPPT(4)
URB Athens	UOA, HAGG	Athens, Greece	X	X	X	X
URB LUND	CERTEC	Lund, Sweden	X	X	X	X
URB Vienna	FORTEC, EURAG	Vienna, Austria	X	X	X	X
URB Delft	DUT, LM	Delft, The Netherlands				X
URB Italy	SIVA	Milan, Italy				X

(1) Engineering ProtoType, (2) Alpha ProtoType, (3) Beta ProtoType, and (4) PreProduction ProtoType

In these URBs the FRR prototypes or parts of the prototypes were tested by in total more than 230 test persons from the user group of elderly and disabled.

Next, the general design and development objective was to translate the needs and preferences of the users into concrete product proposals. Developing a fully market ready Friendly Rest Room within the lifespan of the project was not feasible within the scope of this project, the results rather should serve as a basis for further developments of user-friendly restroom products.

The designers of the FRR (LM) aimed at creating a coherent environment in which the user feels at ease and in control, masking the technology which is used to make the environment adaptable to special needs. The design had to be culturally independent since the FRR should be used in the whole of Europe, and of course -while aiming principally at the user group elderly and disable- it should be accessible to as many users as possible.

The design process started with the thorough inventory of user needs and problems regarding the toilet area. Literature study was used, but additional and very important information was gained from the performed observations and interviews. After analysing the findings the first idea sketches were made, which were shown to users and experts. Their feedback was incorporated into the designs and subsequently the first prototypes were built and tested with actual users in a laboratory situation. These user test results were again incorporated into the designs, the redesigns were again evaluated by users and experts, and another series of (adapted) prototypes were built and tested. The cycle of 'design-evaluation-prototype-user test' has been run through several times before the final FRR design was a fact. With every step the knowledge about user needs, preferences and problems in the toilet area grew, and the necessary design specifications of the user-friendly toilet area became more precise. The prototypes were constructed and produced by the production company (CSO) in the final materials as much as possible, though sometimes less expensive and/or easier to process, materials, like MDF or steel, also were used.

The end result is a well thought-out layout of the toilet room, combined with a more user-friendly design of sanitary modules, which are perfectly in tune with each other, and addition of ´smart´ parts that automatically can adapt to compensate for the special needs of the user (see figure 2).

2.4. Ethics and Cultural Differences

An ethical committee was appointed for the project and advised the project on sensitive aspects of testing the FRR prototypes with elderly and/or disabled. Test subjects were always informed beforehand by means of a paper information kit and short before the user test subjects were instructed verbally by one of the researchers and asked to sign an informed consent. It was made clear to the test persons that they could end the test session on any point of time and that they were not obliged to answer questions they felt embarrassed with.

The set up of URBs located in different European countries was to gain test results that would mirror the different toilet habits, preferences and needs all over Europe.

Figure 2. Final design of a Friendly Rest Room

3. Ergonomic User Studies

Being the project's expert in the field of user-product interaction and translating ergonomic user needs into product specifications, Delft University of Technology (DUT) carried out several ergonomic user studies. Three of them will be described in more detail.

3.1. Study into Comfort of the Toilet Seat

In this study the objective was to define variables in the experience of comfort while sitting on a toilet seat. The test was conducted at a local DIY store. Subject were randomly selected by asking people shopping at the store to participate in the research. In total 20 persons participated (11 males and 9 females).

The test set up consisted of six toilet seats fixed on toilet bowls that differed with regards to shape and dimensions, except for 2 seats that only differed in colour.

After a short introduction subjects were asked to try the seats, with clothing. The seats were presented in different order to the subjects to avoid any carry-over-effects. The subjects were asked to describe the comfort of each seat and to compare and rank them. Following a short questionnaire was filled out.

Test results showed that the subjects could feel the difference in comfort between the seats and could distinguish several critical seat dimensions; slope and shape of the seat borders, shape and size of the hole, rounding of edges and total seat length and width. Surprisingly the seats that only differed in colour were rated very differently on the above dimensions, suggesting that to a certain extent visual aspects influence the experience of comfort.

3.2. Behavioural Study into the Preferences of Support Bars near the Toilet Bowl

The objective of this study was to collect both qualitative and quantitative information on the preferences of elderly users regarding the use and position of three different types of supports. In the preparation phase the test set up was evaluated by performing a pilot test with 5 student subjects that wore limiting braces and other gear to simulated old age.

A typological sample (stature, body mass, pulling force) was selected from a group of elderly earlier involved in gerontology studies at DUT. A total of 15 subjects participated in the study, 6 males and 9 females, age 58-79 yr. The test was partly recorded on video.

A test frame was developed around a height adjustable toilet with three types of adjustable supports; a horizontal front support, vertical front supports and horizontal side supports. Subjects were asked to sit down and stand up using the supports at various positions after having set the toilet at a comfortable height. For each type of support the subjects had to indicate the most comfortable position. They were also asked to point out which of the supports they would prefer in each step of the toilet act (sitting down, cleaning, and standing up).

The results incorporate quantified data on the absolute positions that were preferred during the different operations of toileting. Most subjects stated that sitting down and standing up is easier with than without the supports. This applies to all three types of support. The horizontal front supports showed some disadvantages though, for several subjects experienced feelings of confinement. For standing up and sitting down 50% of the subjects preferred the vertical supports (n=7). The horizontal bars were also chosen for standing up and sitting down, but subjects showed equal preference for the front support and the side supports. With regards to cleaning activities the vertical supports and the side supports were equally preferred. Some subjects indicated that they did not have a preference for any particular support when cleaning their body parts [8].

3.3. Behavioural Study on Body Posture During Dressing/ Undressing, Toileting and Cleansing

In this study the objective was to gain insight in the use patterns and preferences regarding different methods of perineal hygiene after using the toilet.

In the second part of the previous described study subjects were asked to pretend to go to the toilet in the laboratory toilet environment. They were asked to act as they would do normally, undress (to the level of underpants), sit down, simulate cleaning their intimate body parts with different types of cleaning utilities, stand up and dress again.

Standard ethical guidelines were followed: Subjects were carefully prepared, orally, in written and by means of informed consent. Additional ethical measures were taken to decrease the feeling of discomfort when subjects had to undress; during the actual user test female test subjects were accompanied by female researchers only and similarly male subjects were accompanied by male researchers.

The final part of the test consisted of a multiple-choice picture questionnaire, which addressed common toilet behaviour and postures during toileting including cleaning activities. A special multiple-choice picture questionnaire was used to explain the postures precisely, and to make filling the questionnaire easier and less embarrassing.

The results of the test revealed valuable insights into the behaviour patterns of different toilet activities including methods for perineal cleansing [9].

4. Results

In the FRR project new scientific, technical and professional knowledge has been gained about user problems and needs extracted from user involved testing and research, behavioural aspects concerning toileting and personal hygiene, the perception of safety, requirements with regard to assistive technologies, ergonomic and anthropometric data on elderly, the use of “inclusive design" principles and the use of computer based interviewing.

This knowledge was translated in a pre-production prototype of a restroom / toilet environment, which includes a range of innovative solutions for improving the user friendliness. The prototype includes amongst others a highly accessible space saving door, a "design for all" door handle, an individual adjustable toilet module, different types of grab bars to offer body support and guidance while moving or while using the toilet, a system for supporting sitting down or standing up, a manual control interface and a wash basin for personal hygiene while using the toilet.

Services offered provide control and monitoring functionalities, user interfaces, illumination functions for rest rooms, multilingual voice control and output functions, emergency and alarm functions, smart card technology for storing individual data, sensor systems for monitoring user activities and system software for control and interfacing [10].

An illustration of how the knowledge about user needs and problems was translated into a user-friendly restroom design is given by a description of found user problems and the corresponding FRR design solution ordered by the four general user areas (see figure 2) that can be distinguished in the toilet environment. See table 3a-3d.

Table 3a. User problems in the user area 'environment' and the corresponding FRR design solutions

ENVIRONMENT	Difficult to store personal belongings	Walking stick, sanitary towels, stoma requisites	The support surfaces of the toilet seat can also be used to put down personal belongings or handle sanitary provisions
	Difficult to distinguish the sanitary from the environment and floor from wall	Diminished sight	The colours of floor, wall, sanitary components and essential controls have been chosen to contrast with each other or otherwise a contrasting band of colour is put on wall and skirting-board. This makes it easier to judge the dimensions of the toilet area and locate its components and controls.

Table 3b. User problems in the user area 'access' and the corresponding FRR design solutions

User area	User problem	Underlying cause	FRR design solutions
ACCESS	Difficult to locate the toilet in (semi)public environment	Diminished sight	A special FRR accessibility sign in sharp contrasting colours that is placed at eye level on the outside of the door
	Difficult to see from a distance whether a toilet is in use	Walking limitations	An illuminated lock-unlock indicator which is integrated in the top of the doorframe as well as the door handle
	Difficult to open the door	Diminished arm force, use of walking aid or wheelchair	A special triangular shaped and large door grip[1] makes it easier to open the door from a wheelchair, with one hand or with an elbow
	Difficult to manoeuvre through the door opening	Diminished arm force, use of walking aid or wheelchair	A door[2] with hinges around two points slides in a top rail, resulting in a sideways and inwards moving door. Less space is needed when turning, hence a larger door width is possible. Movement of the door is very light.
	Difficult to lock the door	Psychological: fear of accidents or death	A floor fall monitoring system that senses unusual user movements or stillness combined with an alarm system

Table 3c. User problems in the user area 'commute' and the corresponding FRR design solutions

COMMUTE	Difficult to move to the toilet: too little manoeuvring space	Wheelchair, walking aid	Different spatial dimensions are chosen for wheelchair (1.90x2.50m) and walking aid (1.20x1.80m) and as less objects as possible on or near the floor e.g. hanging toilet bowl
	Difficult to move to the toilet: large space without any support	Walking limitations	The toilet area is circumcised by a wall mounted support bar, which makes the path from door to toilet provided with continuous support. The bar has an extruded shape with no external mounting points and a rounded inside, which makes it very easy to clean.

Table 3d. User problems in the user area 'toilet' and the corresponding FRR design solutions

TOILET	Difficult to undress, turn round and sit down	Loss of balance, diminished muscle flexibility	Vertical toilet support bars offer support while standing, turning and sitting down. The bars can rotate in a horizontal plane to accommodate to different user dimensions or can be moved entirely sideways to have them out of the way. The toilet[2] that can be adapted in height and angle automatically by means of remote control or voice activation.
	Difficult to undress and transfer to toilet	Wheelchair	Combined with the automatic toilet; A toilet seat with extra support surfaces adjacent to the seat, the total forming a rectangular shape, is facilitating the independent transfer from wheelchair to toilet and vice versa.
	Difficult to sit stable on toilet	Paralyses	Combined with the automatic toilet; Horizontal toilet support bars offer support when sitting on the toilet and can be automatically adapted in height and width by remote control or voice activation.
	Difficult to clean intimate body parts	Loss of balance, diminished muscle flexibility	Combined with horizontal body support bars; A moveable washbasin can be used to clean hands or body parts while seated on the toilet. The washbasin is equipped with faucet and shower function. Underneath the basin an additional light source improves visibility while cleaning intimate body parts.
	Difficult to stand up and dress	Diminished force, loss of balance, diminished muscle flexibility	Combined with vertical and horizontal support bars, transfer toilet seat and automatic toilet; The curved ending of the horizontal support bars is facilitating a natural hand grip when standing up.

(1) Earlier developed product by LM, (2) Earlier developed product by CSO

The final FRR pre-production prototype was tested and evaluated by elderly and disabled test persons at 5 different URBs and demonstrated at the Rehacare Fair in Dusseldorf, Germany, November 2004 (see figure 3). The most essential parts of the final prototype were also installed in day-care centre for MS patients 'Caritas Socialis' in Vienna, Austria, January 2005 and effectively tested for 39 days by patients (n=29) and nurses (n=12).

The test results showed a high degree of satisfaction amongst users, as well as a positive effect on the perception of autonomy, safety and dignity amongst users [11]. In conclusion we can say that the objectives of the project have been reached.

5. The First Friendly Rest Room: Toilet of the Future?

The FRR project has been a unique and successful project with regards to several aspects. First of all knowledge and understanding has been gained about toileting, accident prevention, personal care and the application of new technologies in the toilet environment. Secondly several prototypes of user friendly rest rooms have been developed, built and tested with elderly and disabled test users. However, what has not been attended to might be even more interesting. For instance topics as; general user behaviour in the toilet, including habits, rituals, cultural differences; the experience of hygiene; the experience and acceptance of new technology; standards and building regulations; influence of architects and real estate developers; socio-economical issues on financing; application of innovative materials; all have been studied little or not at all. Partly this can be explained by the lack of time and resources within the project's parameters. For the other part it was caused by a hidden problem: the taboo subject matter. The problem was not that the test persons were unwilling to participate. They were on the contrary remarkably straightforward about their habits and problems, perhaps being less embarrassed by the subject of toileting when faced every day with problems or even the need for personal assistance in this private area. The sensitivities lay with the researchers themselves. Despite that test persons were carefully prepared the – usually young and healthy – researchers found it inappropriate to ask them about their toileting habits. The fact that test persons were older and disabled persons, for whom a lot of respect was felt, made it even more inappropriate. The extent to which

Figure 3. Final prototype of a Friendly Rest Room

the taboo subject influenced the researchers differed culturally, as in some European countries it was more an issue than in other, though it was to a certain amount present in every country. The multiple-choice picture questionnaire on toilet postures as a result was vividly rejected by some of the project partners because of the drawn pictures of body postures which were regarded unacceptable [12].

Nevertheless it is essential in user centered design to know everything about the reality of user behaviour, and as a derivative about the needs and problems of the user group. This is even more important when a topic is concerned that is generally not spoken about, like toileting. The user problems with toileting that were found in this project, were found more or less in passing, for instance through remarks of subjects during the prototype testing.

Another pitfall for user centered design, encountered in the project and caused by the taboo subject, is that researchers to avoid talking in detail about the topic of toileting are letting the test users simply decide that a product is good or not, but never ask why. It is undisputed that of all things the why question in particular has to be answered in order to come to a truly user centered design. The risk is –especially in innovative products for instance when new technologies are applied- that test users tend to agree with solutions they are familiar with, not necessarily being the best solution from an ergonomic point of view.

So is a user-friendly rest room still staying in the future? Although the project's objectives have been reached, the final prototype still is far from market ready and many areas of study are yet to be explored. For this reason it may come to no surprise that the final tests also revealed a lot of unanswered questions regarding technology, costs, safety, hygiene, and brought many supplementary suggestions for improvement. Concluding, there still is a long road of research and development to go before we can truly say our toilet environment is adapted to the requirements of modern time; designed for all, irrespective of age or ability. Though now the first step is made.

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