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Virtual environment (CAVE) as a tool for end-user participation in hospital design: a case study

Abstract

Several studies indicate that virtual reality (VR) systems in general and the computer-assisted virtual environment (CAVE) in particular are useful for end-user participation in an environmental design process. This study describes the use of group discussions in a computer-assisted virtual environment (CAVE) in evaluating end-user participation in a planning and design process. The study discusses an extension (Y building) to the South Ostrobothnia Central Hospital, the environmental features that were possible to evaluate in the CAVE, and the utilization of a virtual environment in a hospital planning process.

The CAVE used in the planning process of the new extension of the hospital is a room comprising 3 walls, a ceiling, and a floor, on a scale of 1:1. Images generated using computer graphics cards are projected onto these surfaces, which, when viewed through stereoscopic glasses, are transformed into a three-dimensional full-scale environment.

The main aim of the project was to study the use of CAVE as a common platform and language for architects, other planners, and multiprofessional end-user groups participating in the planning and design process of a hospital building.

We collected qualitative end-user opinion data in the CAVE on the modelled study rooms. An examination room and a patient room were selected because hospitals regularly have multiple identical examination rooms and patient rooms. The third unit, the emergency centre, is a new unit in the South Ostrobothnia Central Hospital, and its design involved several functional issues.

The end users visited the CAVE environment in small focus groups. The total number of visitors in the CAVE was over 280. Approximately 90% of the visitors strongly agreed or somewhat agreed on the ease of commenting on the environment in the CAVE. The most important property of a CAVE-type virtual environment is its scale, i.e. the ability of visitors to perceive the environment as almost real. Most issues identified by the end-users in the modelled facilities were utilized by the architect in the detailed design of the facilities for South Ostrobothnia Central Hospital.

The potential use of virtual environments at different stages of the design process offers exciting possibilities. Technological development can also enable more extensive use of virtual environments in the future.

Key words: virtual reality; CAVE; computer-assisted virtual environment; end-user participation; design process

List of illustrations:

Introduction

The South Ostrobothnia Central Hospital is a secondary health care unit which serves a population of 200 000 inhabitants. The hospital was built in several stages, the first of which was completed in 1977. This presentation discusses an extension measuring 33 870 m². This extension has been in the pipeline since 2003 and was completed in August 2012. It comprises 1300 rooms, 134 beds and facilities for approximately 20 different units. The new building will employ approximately 450 people. Some of the new facilities will be occupied by the primary health care services of the City of Seinäjoki.

Evidence-based design (EBD) is a growing field of science that confirms that some aspects of conventional hospital design contributes negatively to the level of risk and stress of patients and staff. Thus, by improving physical settings, hospitals can be better places to work, safer and more conducive to healing (Ulrich et al. 2004). As hospital buildings are likely to remain in place for decades and as the EBD-literature indicates a relation between physical settings and health, it is useful to invest in building and designing better hospital facilities and so avoid longer-term costs.

Communicating with the end-users group can be crucial in building design. A key issue in this communication is the way in which the designs are presented to the end-users. Traditional means of visualization include, for example, 2D drawings, 3D images on a screen or on a display, and scale models. In hospital design, full-scale completed mock-ups have also been used to test designs with end-users. However, the use of traditional visualization tools for user participation can inhibit feedback and cause a loss of information because they lack practicality and easy access to different views (Al-Kodmany 1999), while full-scale mock-ups can be time consuming and expensive to build. Especially due to the different training and professional backgrounds of end-users, the need for a common language is vital for mutual understanding in the planning and design process. Virtual reality (VR) systems show promise as a tool for conveying ideas to end-users. However, for a hospital design team to decide on whether to invest in VR systems, they would have to understand the strengths and limitations of these systems.

In a previous project also conducted in the South Ostrobothnia Central Hospital (Wahlström et al. 2009), 11 nurses and 11 patients were interviewed both in a virtual ward in the CAVE and in an actual ward from a real hospital. After analysing how the real environment was evaluated, the study analysed whether the same functions and elements that were found to be relevant for end-users could also be evaluated in the CAVE. Nurses and patients participated in the study by evaluating a bathroom and/or four patient rooms modelled by the CAVE and the actual hospital wards. Most of the issues identified in the actual hospital wards could be evaluated also in the CAVE, i.e. aesthetics; correct location of equipment, supplies and materials; distraction by or the good companion of other patients, as well as window positions and sizes, and the living/workspace. In the opinion of the end-users, the CAVE was useful and pleasant.

Some studies have looked at VR systems in end-user participation in environmental design. Majumdar et al. (2006) investigated the use of VR in a courtroom design. In Heldal's (2007) study the use of desktop-based VR was beneficial during a road planning process. Westerdahl et al. (2006) compared end-user experiences in VR to users' experiences in an office building that was completed similarly to the VR model. Drettakis et al. (2007) studied the use of a VR environment in domains of architectural design and urban planning. Mobach (2008) studied the effects of a VR supported participatory design approach in the construction of two community pharmacies. Seron et al. (2004) investigated the CAVE-type virtual environment as a tool for a full-size train design.

Few studies have investigated the use of a CAVE-type VR in a collaborative design process. Fröst and Warren (2000) carried out a study where laboratory layouts were designed collaboratively by using the CAVE, with end-users making several visits to their future labs in the CAVE. According to the authors the CAVE helped in the collaborative design process by providing a method with which study participants' ideas could be better formulated, analysed, tested, and realised.

Dunston et al. (2007) described the use of the CAVE in producing a virtual hospital patient room. A pilot test was made in which nurses were introduced to the CAVE environment. The authors reported that nurses liked the immersed and interactive sense of the CAVE, which could not be achieved with a 3D desktop environment.

The city in which our study was carried out is also home to the Seinajoki University of Applied Sciences and its virtual laboratory. For the purposes of this project, the South Ostrobothnia Hospital District joined forces with a number of partners to use the virtual laboratory as a design tool to allow end-users to participate in project planning as efficiently as possible. In addition to the virtual laboratory, the project also involved two other design tools that promote user participation: a system for managing user requirements and an online feedback system, both of which fall beyond the scope of the current paper.

The computer-assisted virtual environment (CAVE) used in the project is a room comprising 3 walls, a ceiling, and a floor. The final wall is open to allow access into the space. The walls measured 3.0 x 2.5 metres. Images generated using computer graphics cards are projected onto these surfaces, which, when viewed through stereoscopic glasses, are transformed into a three-dimensional full-scale environment. Surrounding the CAVE there is a larger, darkened room where the projectors are placed (Figure 1). Modelling was based on Autodesk 3DS Max software.

Figure1. CAVE and its surroundings (Photo by Esa Nykänen)

Research question

The project arose from the need to find new approaches to more user-oriented health facility planning and design. The aim was to create tools which facility owners, service deliverers, administrators and end-users can use to monitor the implementation of requirements for the building during the planning process and through the lifecycle of a building. The particular focus of this paper is the use of the CAVE as a common platform and language for the architects and end-users in the design process. Evidence-Based Design further highlights the user-oriented approach.

This paper serves three purposes. First, it presents a case in which end-users evaluate the designs of a patient room, an examination room and an emergency unit in a CAVE environment. Second, it presents the qualitative data on end-user opinions gathered in group discussions in a CAVE and how the data can be utilized in the design of a hospital environment. Finally, the paper investigates how the study participants evaluated and experienced the CAVE system itself and whether they consider the presentations in the CAVE to be realistic.

Methods and selection process

In the previous project (Wahlström et. al.) we tested the virtual environment by interviewing single persons, patients and nurses in the CAVE. In this project we used group discussions as a method to bring out the views of different professionals and to find a common language. The groups were multiprofessional: staff from the Seinäjoki central hospital and Seinäjoki health centre, doctors, nurses, planners and administrators, architects and engineers from the consulting companies, and employees from the construction companies, and representatives of a committee on accessibility of the city of Seinäjoki. The aim was to encourage the visitors to exchange opinions and ideas during the group discussions in the CAVE.

CAVE is a VR theatre in the shape of a cube with display screens that surround a viewer as presented and defined by Cruiz-Neira et al. (1992, 1993). The most important property of a CAVE-type virtual environment is its scaling, i.e. the ability of visitors to perceive the environment as almost real in scale. Visitors are able to move to some extent within the space itself and to travel longer distances with the help of a 3D mouse. Another important characteristic is the quality of the virtual environment; in this case, the environment also featured realistic lighting and shadows, surface structures, colours, and views out of windows, in addition to furniture and accessories. The project included models for three different environments: an examination room (18 m^2), a patient room (26.5 m^2), and an emergency centre (1100 m^2). These environments were selected because hospitals regularly have multiple identical examination rooms and patient rooms. The emergency centre is a new kind of unit, and its design involved several functional issues which needed to be tested in as real an environment as possible. The aim was to research the care processes and patient–nurse interactions in the selected facilities.

When a user walks around in the CAVE, his movements are being tracked with electromagnetic sensors as the 3D environment adjusts to the user's perspective. The visitor wearing stereoscopic glasses and a tracker can for instance peep under the bed and interact with the environment. The program creates simultaneously new virtual images on the walls of the CAVE and changes the view in real-time. The closer to this visitor the other members of the group stay the better their illusion of the environment is.

The end users visited the environment in small focus groups of 6–10 visitors on average (Bryman & Bell 2003). Each visit lasted for an hour. All conversations that took place in the virtual environment were recorded and video-taped. The visits were also photographed. After the visit, each visitor was asked to fill in a questionnaire in which they could analyse the properties of the projected spaces more systematically. The objective behind using several simultaneous methods was to ensure the scientific scope of the analyses. The visitors were also asked to give feedback on the usefulness of the method.

Collection of data	**Findings**	**Analysis of data (method)**
questionnaires	187 returned questionnaires	SSPS software
visits to CAVE	280 visitors in 44 groups 34 recordings (44*) 34 videos photographs	thematic contents analysis

Table 1. Data collection and analysis methods. *including the groups evaluating guiding and signs and the groups of builders.

Results and analysis

The total number of visitors in the virtual environment was just over 280. The visitors included different kinds of hospital professionals, hospital administrators, construction professionals, representatives of a committee on accessibility, as well as architects. During the visits, the visitors were positioned at the front of the CAVE and an architect told them about the space which they were entering and about what the space would be used for.

Figure 2. A group of visitors in the CAVE (Photo by Esa Nykänen)

The architect was asked not to comment on the solutions but to explain them as neutrally as possible. The end users/visitors were asked to comment freely on all of the properties of the environment. Each visit was generally followed by lively conversation and by the visitors filling in the questionnaires provided. A total of 187 visitors filled in the questionnaire. The questionnaires were analysed using SPSS software. The recordings were decoded and the text analysed by means of thematic content analysis.

A total of 34 recordings were made of group interviews. Ten of the recordings dealt with the patient room and the adjoining bathroom, thirteen recordings discussed the examination room, and seventeen recordings related to the emergency centre. Some of the visitor groups tested all three virtual environments.

The content analysis revealed a total of 14 primary themes. After a further content analysis, a total of 26 secondary themes were identified. The primary themes and secondary themes are listed in Table 1 and Table 2 below. The visitors made a total of almost 4600 observations.

Primary themes	
Layout	Safety
Accessibility	Lighting
Furnishings	Colours
Accessories	Blinds/curtains
Materials	Aesthetics
Durability	Virtual environment
Ergonomics	Hygiene

Table 2. Primary themes of the analysis

Secondary themes	
Accessibility	Safety
Ergonomics	Type
Aesthetics (art)	Accessories
Hygiene	Lighting, daylight
Practicality	Blinds/curtains
Easy to open windows	Attractiveness
Furniture	Colours
Touchability	Privacy
Positioning	Acoustics
Need	View
Dimensions	Durability, ease of maintenance
Layout	Materials
Functionality	Note

Table 3. Secondary themes of the analysis

Some of the secondary themes were such that they could not be experienced in the virtual environment but were nevertheless discussed, such as the ease of opening windows and the acoustics.

In terms of examination rooms (Figure 3), the most important primary themes were furnishings, accessories, and layout. Secondary themes were used to analyse in more detail what aspects of the primary themes were identified in group discussions, i.e. to analyse in more detail what aspects of the layout the visitors found to be most important. The most popular topics in the primary theme furnishing were positioning, the functionality of a particular piece of furniture, and the type. With regard to furniture, the order of priority was 1) type, 2) functionality, and 3) positioning. With regard to accessories, positioning and functionality were considered equally important, while the type of the accessory was deemed the third most important attribute. Visitors commenting on the use of the virtual environment primarily talked about its usefulness and secondarily about the equipment and different requirements.

Figure 3. Virtual model of an examination room (Image by UKI Arkkitehdit Ltd)

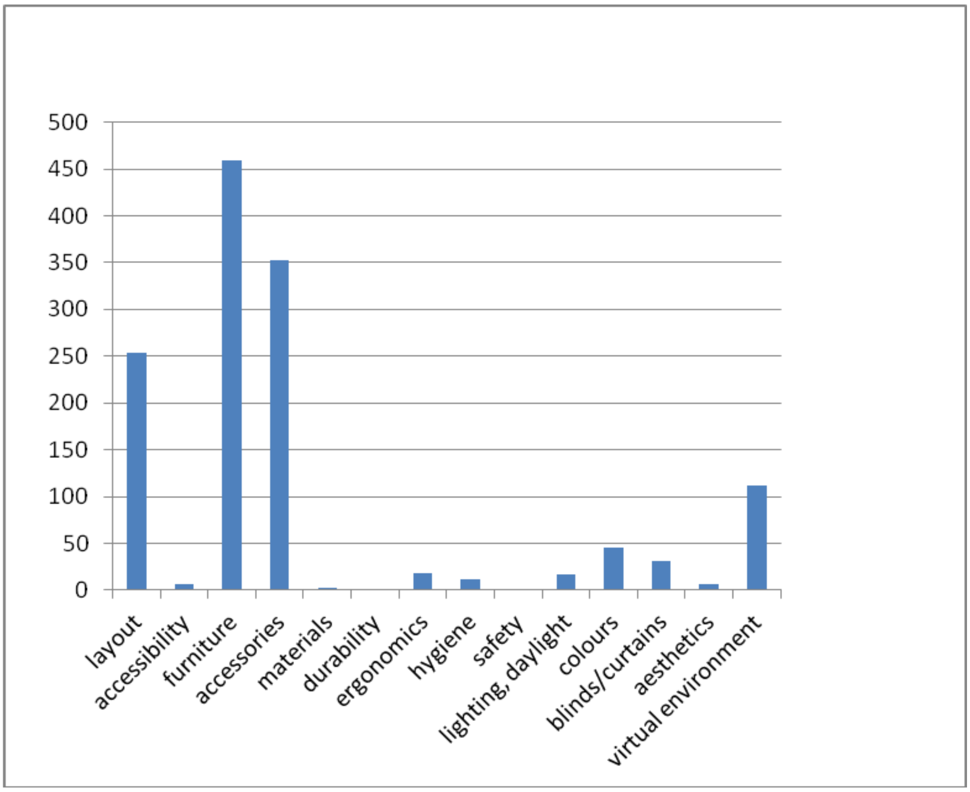

Figure 4. Primary themes of the examination room (thematic analysis)

Figure 5: Virtual model of a patient room (image by UKI Arkkitehdit Ltd)

With regard to patient rooms (Figure 5), the primary themes were accessories, furnishings, and the virtual environment, and then colours and layout. The most important characteristics identified with regard to furniture were type and functionality. With regard to accessories, the visitors mostly commented on type and positioning and almost as much on functionality. The visitors gave many general comments about the virtual environment.

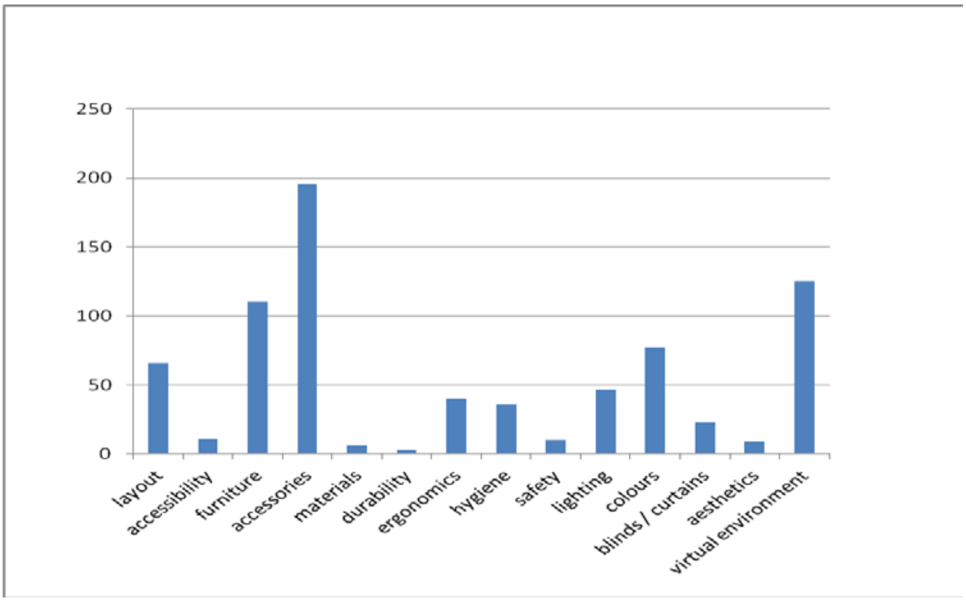

Figure 6. Primary themes of the patient room (thematic analysis)

The accessories of the bathroom adjoining the patient room were discussed a lot. The comments related to type, positioning, and functionality. The most frequently commented aspects of the bathroom layout were positioning, dimensions, functionality and type. For such a small space, the bathroom attracted a lot of attention: 534 comments compared to the 758 comments received for the patient room itself. This demonstrates how critical a part that bathroom attributes play in the overall design.

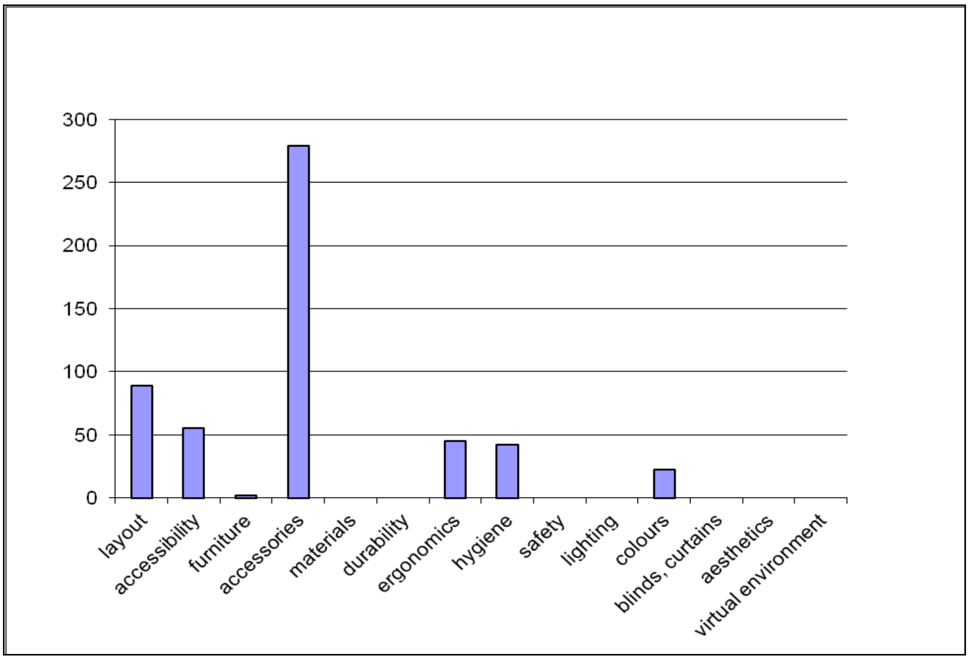

Figure 7. Primary themes of the bathroom (thematic analysis)

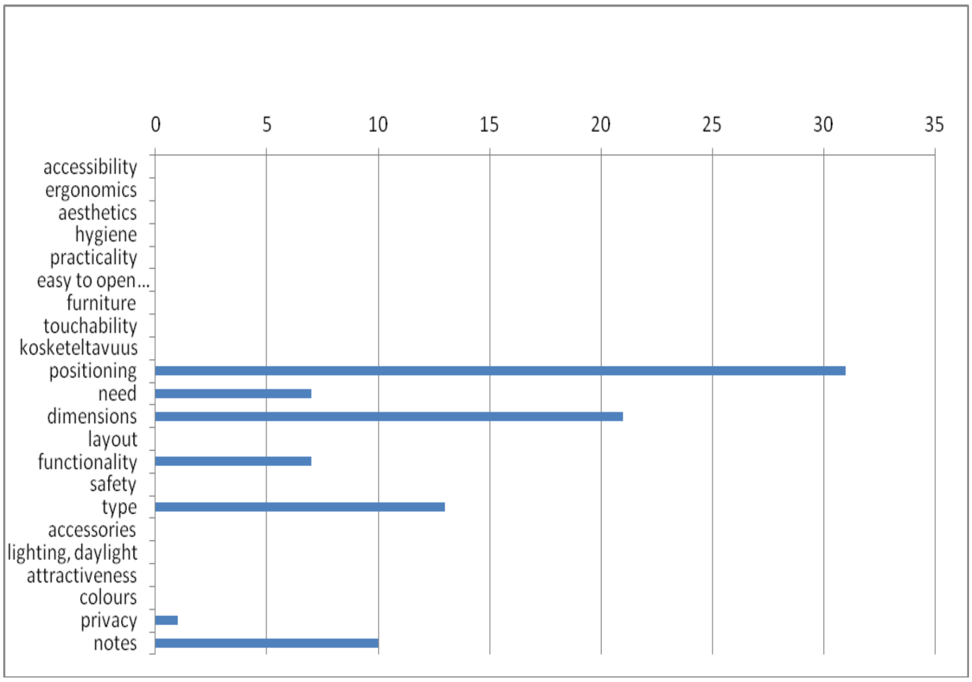

Figure 8. Secondary themes in the primary theme layout of the bathroom (thematic analysis)

Layout was by far the most important theme identified with regard to the emergency centre (Figure 10). The number one secondary theme in layout was functionality, followed by the positioning and functionality of different elements. Considerably fewer comments were received on accessories, although plenty of comments were received on their type, functionality, and positioning. The third most important primary theme was furnishings, with type, functionality, and positioning as the secondary themes. As regards the use of the virtual environment, the emergency centre attracted the most comments on functionality as well as the usefulness and layout of the virtual environment.

Figure 9. Virtual model of an emergency centre (image by UKI Arkkitehdit Ltd)

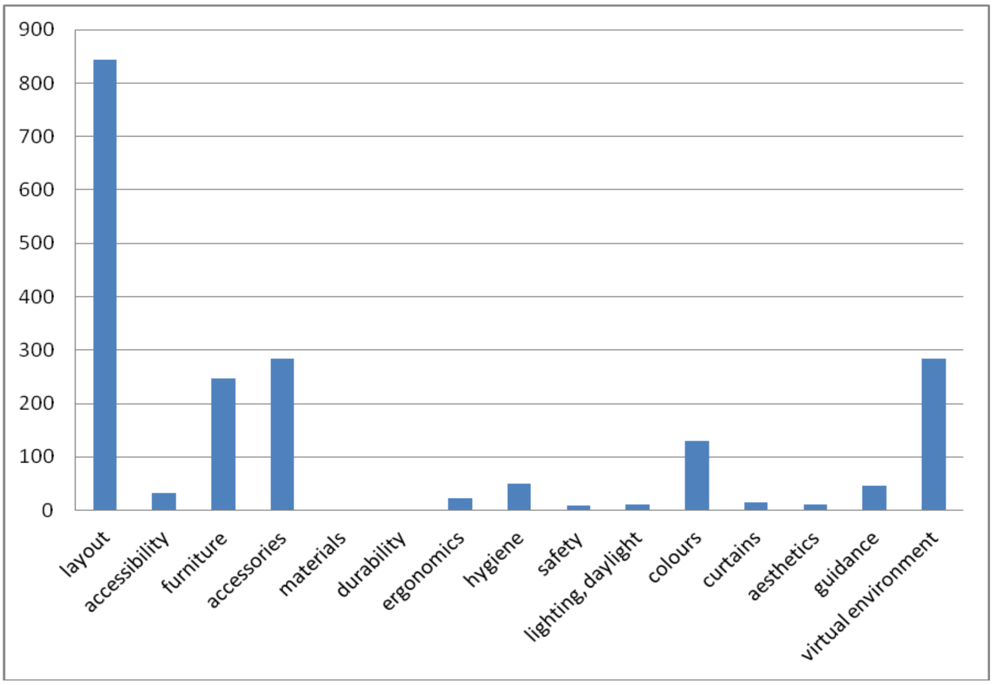

Figure 10. Primary themes of the emergency centre (thematic analysis)

Being the largest of the spaces modelled, the layout of the emergency centre was discussed more than were the other spaces. This is interesting, as visitors were required to visualise and move around a relatively complex space. The comments also involved a lot of role-play, identifying with either staff or customers. The visitors were able to assess the process without difficulty, and the architects had to answer some tough questions. This demonstrates that virtual environments are well suited to assessing complex units and processes as well as the three-dimensional properties of individual functions and spaces such as the positioning of furniture and the attributes of accessories.

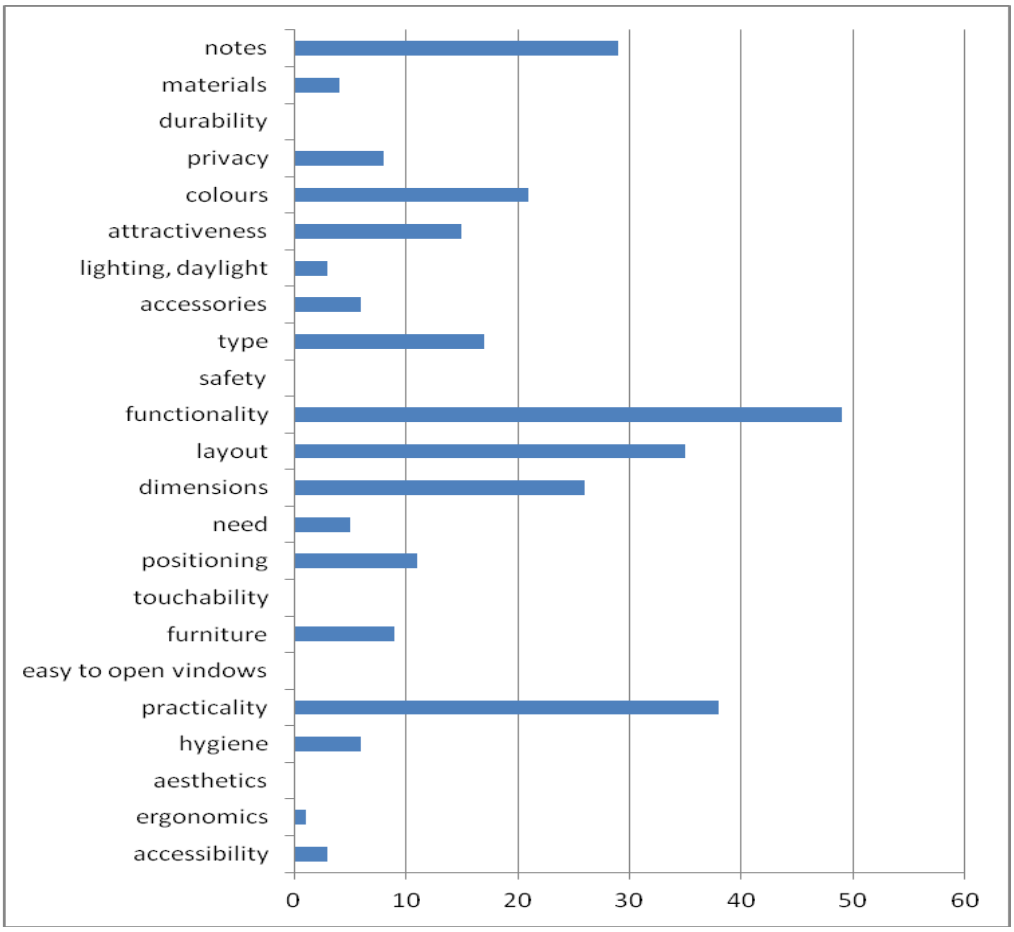

Figure 11. Secondary themes in the primary theme "virtual environment" of the emergency centre (thematic analysis)

The questionnaire

The themes of the questionnaire and the decoded discussions in the CAVE cover the same environmental features. The questionnaire can be seen as a checklist for the visitors following the visit to ensure that any relevant issue has not been left out during their visits in the CAVE. In many cases the discussion during the completion of the questionnaires was lively and brought up useful additional information that was analysed together with the discussion in the CAVE. The questionnaire was necessary to bring out visitors' opinions on the CAVE as a planning tool, and background information on the visitors such as age group, sex and profession.

The questionnaire was returned by 187 visitors, with 158 fully completed and carried forward to be analyzed using SPSS software. The number of female visitors was 118 (74.7%) and male visitors 32 (20.3%) (8 missing). Of the visitors 91 (57.6%) were nurses, 15 (9.5%) doctors and 40 (25.3%) other professionals in health care (12 missing). Slightly more than 50% were in the age group 36–50, around 21% of the visitors were in the group 20–35 and around 27% of the visitors were in the age group 51–65.

The questionnaire was structured and questions/the environmental features were grouped according to the most common physical and functional properties of the spaces. The questionnaire was composed of 8 sections with 2–6 statements. The visitors then assessed the statements using a 5-point Likert Scale; (strongly disagree, somewhat disagree, don't know, somewhat agree, strongly agree). The statements covered the positive aspects of the following environmental and functional properties:

- FIRST IMPRESSION /attractiveness, functionality
- SPACE / adequateness, layout, barrier-free to move and work
- FURNITURE, EQUIPMENT/ positioning, functionality, number
- ACCESSORIES/ functionality, positioning, outlets, gases
- COLOURS, LIGHTING/ attractiveness, sufficiency
- FUNCTIONALITY / suitability, ergonomics, safety
- COMFORT / space, furniture, privacy, working peace, view, daylight
- CAVE / usefulness, reality, easy to comment, teamwork

The results of the assessments of the examination room, patient room (incl. bathroom) and emergency centre were analysed separately. The following table (Table X) describes the results.

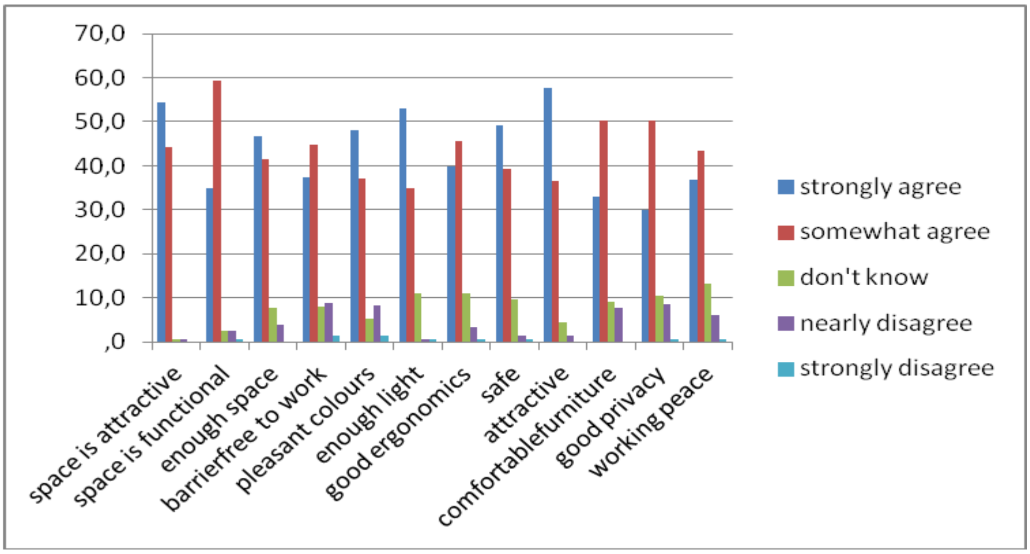

Figure 12. Evaluation of all spaces in the CAVE (questionnaires)

The assessments overall were positive. Some 80–90% of the visitors strongly agreed or somewhat agreed with most of the positive statements. Slight differences can be found in the statements concerning functionality, a barrier-free work environment, good ergonomics and peaceful working environment, which were evaluated less positively than the other statements.

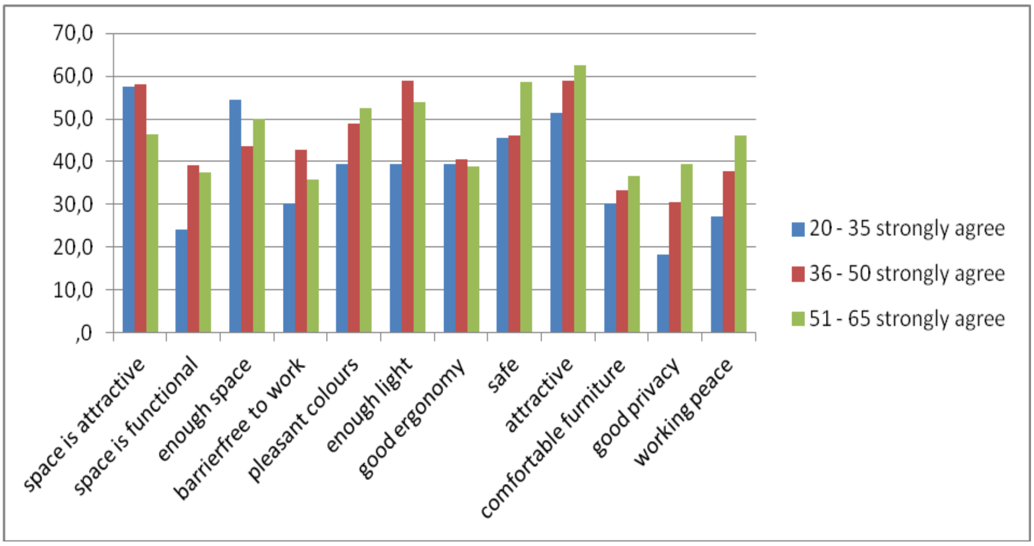

Figure 13. Age group differences in the CAVE. Strongly agree on all spaces (questionnaires)

Comparing the assessments "strongly agree" of the different age groups revealed differences. The youngest age group, visitors aged 20–35 years, were more critical than others in evaluating functionality, barrier-free working environment, lighting, privacy, and peaceful working environment. The oldest group, visitors aged 51–65 years, were satisfied with all features of the environment except the attractiveness of the premises. The evaluations of the middle group, visitors aged 36–50, fell between the other two groups.

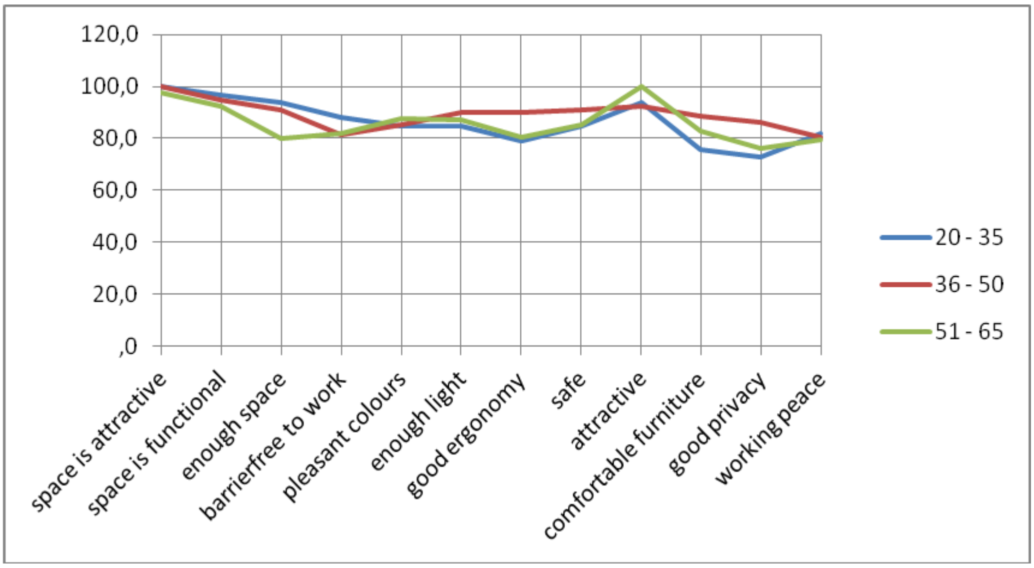

Figure 14. Age group differences strongly agree and somewhat agree comments on all spaces (questionnaires)

Differences between age groups decrease when we count together "strongly agree" and "nearly agree" opinions (Figure 14). The oldest group, visitors aged 51–65 years, were most critical in regard to the amount of space but most often chose "strongly agree" in regard to the attractiveness of the space. The youngest age group, visitors aged 20–35, were most critical of the privacy and furniture. Overall the assessments were positive, with 75–100% of visitors "strongly agreeing" or “somewhat agreeing” with the different features of the environment. A more detailed evaluation reveals some differences between the examination room, patient room and emergency centre.

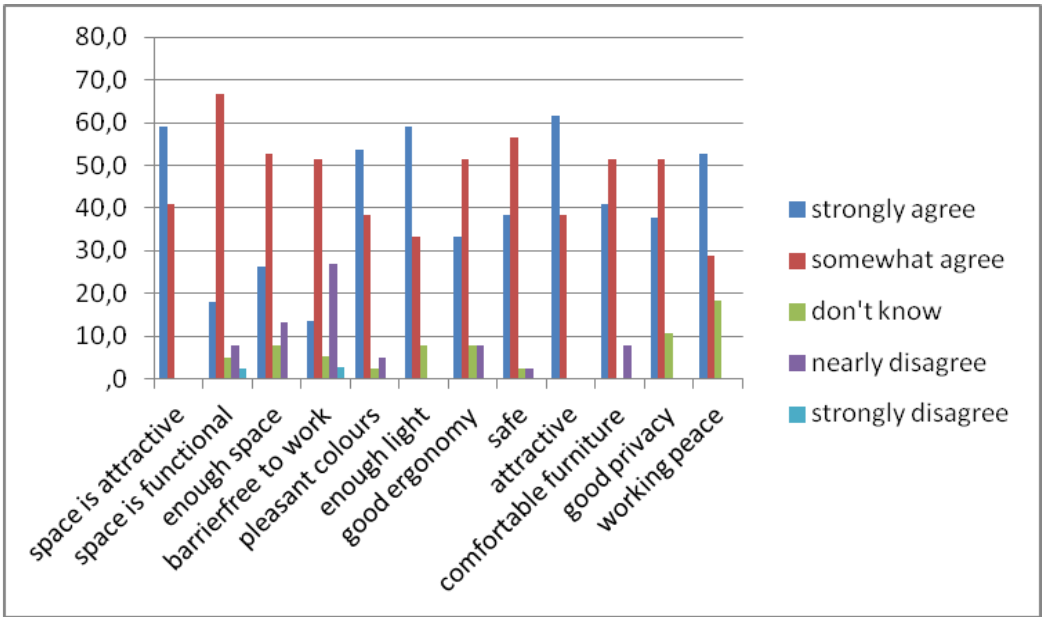

Figure 15. Comments on the examination room in the CAVE. All age groups (questionnaires)

All visitors strongly agreed or somewhat agreed with the attractiveness of the examination room (Figure 15). In terms of being a barrier-free working environment, only 65% of the visitors strongly agreed or somewhat agreed. The main reasons were a need for more space around the couch, and the placement and space for the furniture. With regard to safety, colours, lighting, the pleasantness of furniture and privacy, from 90–95% of the visitors strongly agreed or somewhat agreed. In regard to the amount of space, ergonomics, functionality and peaceful working environment, 80–85% of the visitors strongly agreed or somewhat agreed with the statements. The assessment of the examination room was significant because there will be 110 of these rooms in the new building. While most of the furniture will be movable, it is still important to assess that there is adequate space, which will also support the flexible use of the facilities in the future.

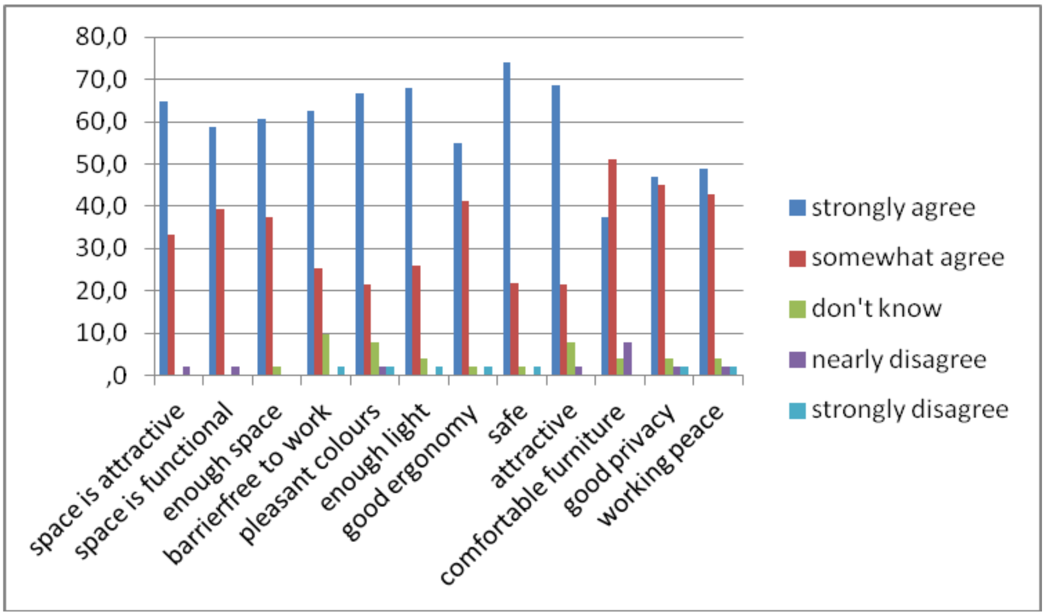

Figure16. Comments on the patient room in the CAVE. All age groups (questionnaires)

The patient room was evaluated even more positively than the examination room (Figure 16.). There were more visitors who strongly agreed than those who somewhat agreed. Some 95% of the visitors strongly agreed or somewhat agreed with the statements on safety, functionality, ergonomic and adequate space. Nearly all visitors strongly agree or somewhat agreed with positive statements about the colours, lighting, attractiveness, pleasantness of furniture, privacy and peaceful working environment. The only feature that did not receive totally positive assessments was ergonomics, in which nevertheless 90% strongly agreed or somewhat agreed with a positive statement.

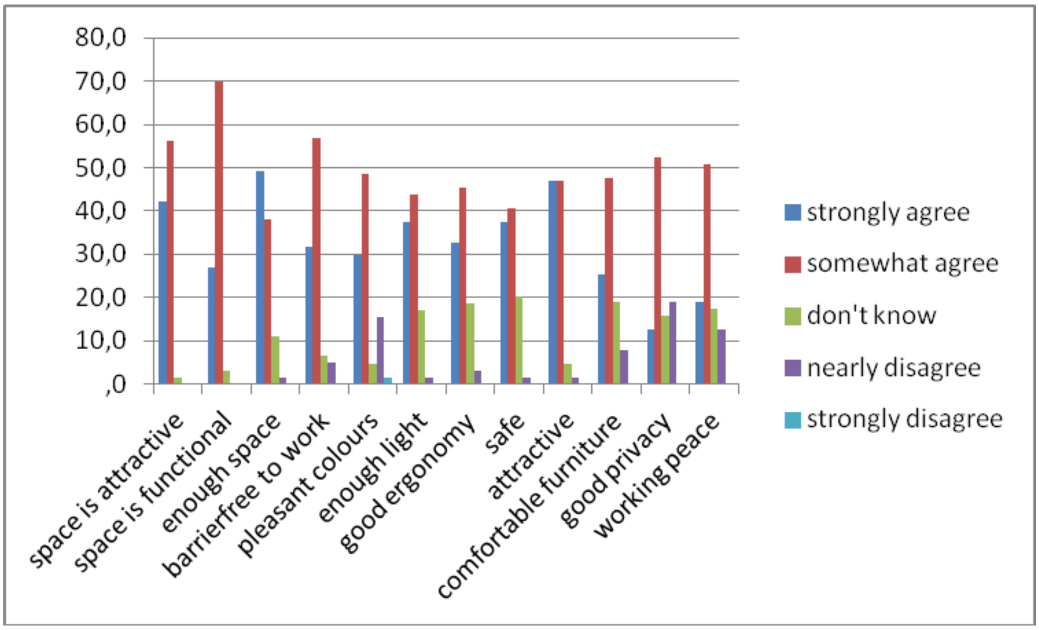

Figure 17. Comments on the emergency unit in the CAVE. All age groups (questionnaires)

More differences were found in the assessment of the emergency unit (Figure 17). More often the visitors somewhat agreed than strongly agreed with positive statements on functionality, a barrier-free working environment, the pleasantness of furniture, privacy, and peaceful working environment, as well as colours, which raised lively conversations.

However, nearly 95% of the visitors strongly agreed or somewhat agreed with the attractiveness and functionality of the emergency unit. Almost 70% of the visitors strongly agreed or somewhat agreed with the privacy, peaceful working environment and the pleasantness of furniture, while 80% of the visitors strongly agreed or somewhat agreed with positive statements on the colours, safety, and lights.

Reasons for differences between the evaluations of the examination room, patient room and emergency unit

The emergency centre differs from the other rooms tested because of the size. The modelled area was approximately 1100 m^2. There were several spaces and issues to be assessed, such as care processes, persons working together, and patient–staff contacts. The plan was to merge the emergency unit of the hospital and the emergency unit of the health centre, although later, the merger process was cancelled, which led to changes in the functions and the designs of the area. The time of the study was actually the right moment for the evaluation of the layout of the emergency centre, so that the end-users evaluations could be utilized in the design.

Alternative patient rooms had been tested in the previous project already. Some of the visitors were very well acquainted with the room. This may have influenced the ease in evaluating the patient room and the positive assessments. A small space is easier to evaluate than a larger more complex space, although in a small space the evaluation can easily become very detailed. This is obvious when comparing the analysis of the recordings in the CAVE and the answers in the questionnaires.

This is a citation from one of the recorded discussions in the CAVE in the modelled patient room. The Architect has explained: “You can see on the painted wall close to the wardrobes the hooks. Someone suggested that there could be separate hooks for each of the patients (2 bed room).”

Visitor 1: *Not bad at all*

Architect: “What do they use the hooks for?”

Visitor 2: *Dressing gown for instance, or visitor’s coats. But then you think, there should be separate wardrobes also. When you undress you put on the dressing gown and the hooks and the wardrobe should be next to each other*

Visitor 3: *But still I think that’s the place for the wardrobes. If they are close to the window they shadow the light and the distance to the beds is too tight.*

Visitor 4: *Some wards have them now in the middle and that’s a very bad place!*

The open-ended comments of the questionnaires were mostly focused on the examination room and its furnishing, storage, functionality and colour. Comments on the patient room concerned a few comments on accessories, furniture and colours. Comments on the bathroom concerned accessories. In the emergency centre the comments focused on a barrier-free environment, accessories, furniture, ease of maintenance, functionality, privacy and colours.

At the end of the questionnaire the last statements concerned the use of the CAVE:

- The visit was useful
- The space was realistic
- Commenting was easy
- Teamwork was a good choice

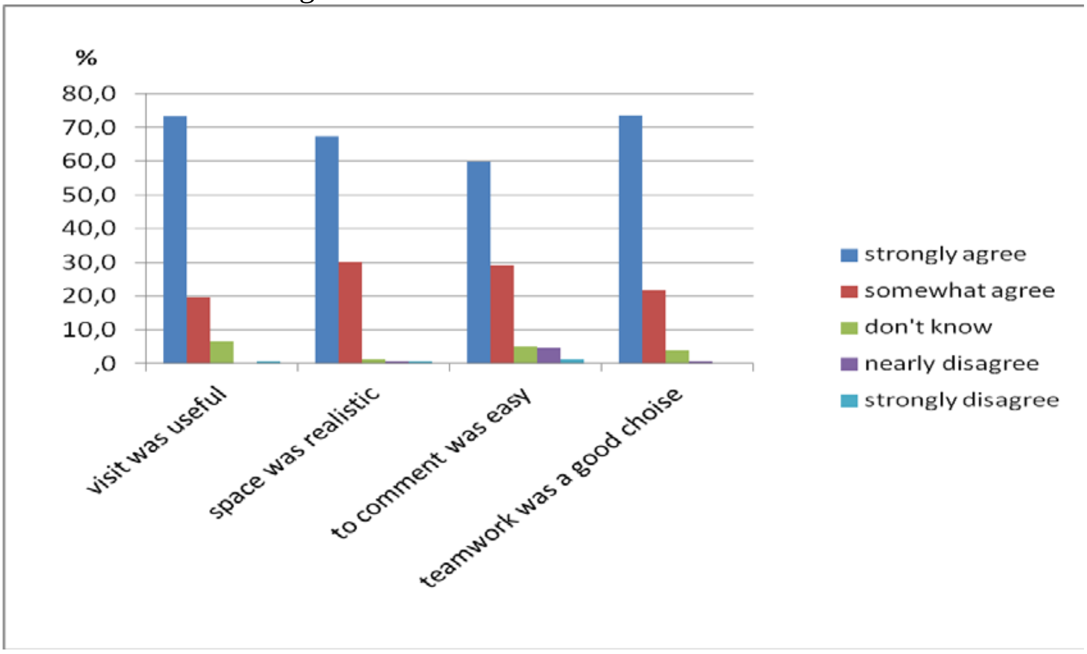

Figure 18. Comments on the use of the CAVE in the evaluation of spaces (questionnaires)

According to the questionnaire, more than 90% of the visitors strongly agreed or somewhat agreed with the statement “the visit was useful”. Approximately 65% of the visitors strongly agreed and 30% somewhat agreed that the environment was realistic. Approximately 90% of the visitors strongly agreed or somewhat agreed that “commenting on the environment was easy”. A total of 95% strongly agreed or somewhat agreed that “teamwork was a good choice” (Figure 18).

Discussion

The information gathered through the group interviews and questionnaires was substantial, covering qualitative features of the environment by way information on design details. The method confirmed the experiences of previous researchers that VR tools are well suited to collaborative design by professionals with different training. Though the CAVE has limitations, for instance, touching items is not possible, the scale and lighting were realistic. The immersion and interactivity of the CAVE enabled the visitors to comment on the features of the spaces immediately, which is vital when the aim is to gather all possible opinions of the end-users.

Valuable information was gained on assessing potential interactions between staff and patients, such as the interaction around the examination table in examination rooms, assisting patients around the bed and in the bathroom, monitoring patients in the emergency centre, access of patients’ visitors to controlled areas, as well as interaction upon the arrival and registration of patients at the emergency centre.

Useful comments were also received on other elements, such as the room attributes relating to cleaning and maintenance, the accessibility requirements of different types of patient, complex processes such as the care of emergency patients and special considerations such as signs. On the one hand, the fact that a lot of the comments focused on specific details illustrates that the visitors based their comments on previous experience. On the other hand, the visitors were also able to imagine and assess the future operation of the facilities realistically, which can be difficult on the basis of two-dimensional drawings.

The usability of a virtual environment will increase when objects can be moved and the size and form of the space can be modified in real time. Also, sounds could be added to give a feeling of immersion, leading further towards AR, augmented reality. Both technologies already exist. The use of BIM, building information modelling, will increase possibilities to utilize virtual modelling and virtual environments as a common tool and language between end-users, architects, engineers and other planners.

Changes made after the visits in the CAVE

The designs of the new building were nearly finalised when the project to use the CAVE as a planning tool was decided. The contractor had started work on the building site. Any major changes to the layout were not possible. However, it was still a good time for testing the new tool and to influence the detailed planning of the most common rooms, such as the examination room, patient room and the emergency centre. Accessibility, furnishings, equipment and the proposed colours in the environment could be tested in the CAVE as well as the guiding and care processes in the emergency centre. Minor details can interfere with a good design if they decrease the functionality. The new experience of multiprofessional cooperation in the planning has created a clear ownership to the premises by those who participated in the design process.

Altogether the number of changes made in the designs after the visits and the analysis of research material was approximately 20. Even though for the architect the number is quite low, the influence multiplies with the number of examination rooms (96) and patient rooms (113). Likewise, some design decisions were affirmed after being tested in the CAVE. The need for changes during the construction phase and after has clearly decreased, and this will have a positive influence on the construction costs. Some of the influences will not be realized immediately, such as costs related to maintenance and cleaning. Information on several issues will not be visible without follow-up studies and a post-occupancy evaluation at some time after the commissioning of the facilities.

Patient room

Patient rooms had been modelled and evaluated already in our previous project, which led to some changes such as increasing the width of the room. After these current evaluations only minor changes were needed, such as the position of the TV screen and the noticeboard. Several comments on textiles, colours, and furnishings were mentioned and were utilised in further planning.

En suite bathroom

This space was discussed a lot. Several comments focused on handrails and supports, their number and positioning. Those were checked and adjusted. Some accessories were changed to another type or added to or their positioning adjusted. A few more cupboards were needed.

The examination room

During the design meetings the furnishing of the examination room were discussed several times, although when visited in the CAVE, it was realized that some changes were necessary. The space around the examination table was too tight. The possibility for a refrigerator and X-ray viewing cabinets in each room was discussed. Escape doors to the next room were checked and changed where necessary.

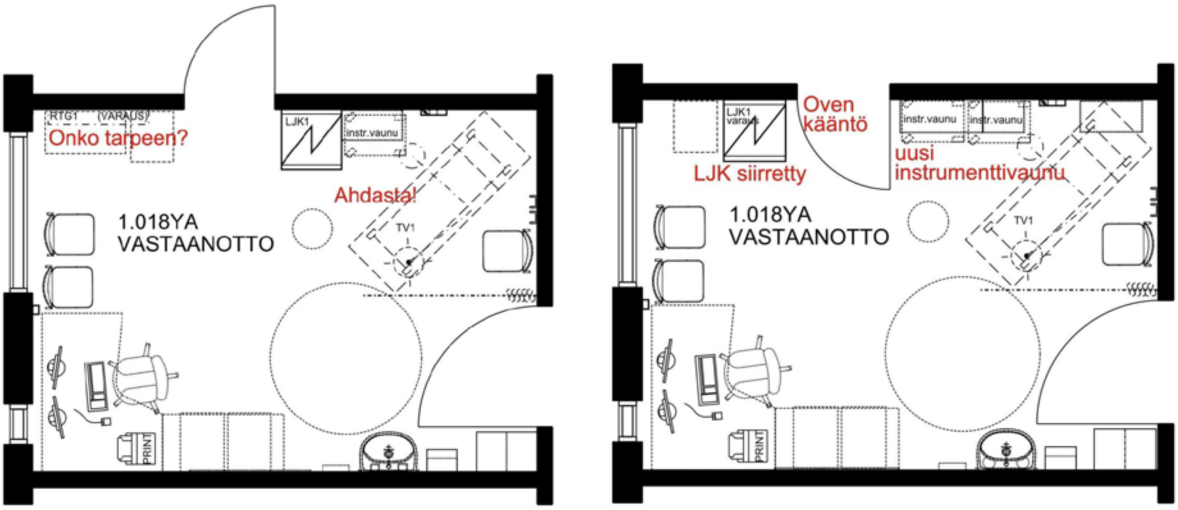

Figure 19. Changes in the examination room after the visits in CAVE (Image by Uki Arkkitehdit Ltd).

The emergency centre

The emergency centre is a large unit with several functions and spaces. The variety of comments by the visitors was extensive. Privacy was discussed both through the patient’s eyes and the staff’s eyes. To ensure privacy especially in the triage and in the observation rooms required a few changes in the design. The CAVE was an ideal environment for testing those spatial arrangements. The height of the windows between observation rooms and the sliding doors were changed. The triage was actually redesigned entirely but that was partly due to organizational changes in the very late phase. The furnishings of the observation rooms were redesigned after the visits in the CAVE. The peacefulness of the working environment in the observation unit and visibility to the patients were discussed but in the end the decision was to keep the nurses’ working area open in the middle. Several comments on furnishing and colours were also received for these spaces.

The emergency centre / guidance and signs

In a quite late phase of the project we were able to test the design of the guidance and signage in the emergency centre. The sizes, designs and positions were adjusted; also the names of the units and rooms required a more systematized structure. It was especially necessary to check the routes back to the front door. Walking around in the CAVE made commenting on these issues easy and realistic.

Conclusion

In the previous HospiTool project the virtual environment was tested by patients and nurses. The aim was to find the environmental features that can be adequately assessed in a virtual environment. In this project, the main aim was to establish whether a virtual environment could serve as a tool for cooperation between end-users and designers. The end-users were representing several professional groups who were either participating in the planning of the new hospital facilities or would eventually be using them.

The analysis of the decoded discussions shows how the end-users assess the environment in part through their previous experiences in other working environments. The doctors comment mainly on their personal working space. Nurses evaluate the environment both from the patient’s point of view and from their own view. No clear differences between age groups were perceived. The nurses were also good in assessing the overall functions and working processes. Maintenance and cleaning staff focused on materials, hygiene and details influencing maintenance processes. Representatives of the committee on accessibility concentrated on accessibility of the environment required by different user groups. This all enhances the participation of all user groups in the planning and design, and confirms the need for common tools and common language.

A virtual environment can be used in different planning and design phases. On the one hand, to achieve realism and immersion, several features and details have first to be decided, such as surface structures, lighting and furniture, while on the other hand they can be solved in principle as several alternatives. Variations of the most important spaces can be produced already in the beginning of the project, when the majority of the costs for the lifecycle of the investment in fact will be decided. In this project we learned that a virtual environment can be used to test large units and functional processes, with the size of the modelled emergency centre being about 1100 m^2.

During the later development phases a virtual environment is a useful tool for assessing features and details that are difficult to present and evaluate in two dimensional documents.

Summary

The experiences of this case study emphasize the importance of a common language that allows end-users, planners and designers to exchange ideas and cooperate equally during the planning process. The use of the CAVE offers an environment where all participants can communicate using the language and expressions they are most familiar with. The CAVE is a valuable tool in a participatory planning process. In the field of healthcare the development of technology and new health care processes offer ongoing challenges that require special knowledge not only in regard to design and planning, but several fields of expertise. The CAVE is one new tool with which to respond to these specific challenges.

The potential use of virtual environments at different stages of the design process offers exciting possibilities. Layout alternatives for recurrent spaces within the facility can be examined in the early stages of project planning and more complex spaces can also be visualised. Different shapes and sizes of spaces and the functionality of the different options can be examined for the purposes of producing preliminary drawings. As the design process progresses, more and more details can be added. Different alternatives can be examined more realistically and more quickly than with traditional methods. Technological development can also enable a more extensive use of virtual environments in the future. The equipment associated with virtual environments is already becoming increasingly advanced and compact, and future virtual environments may evolve into mobile solutions that can be adapted to different applications.

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