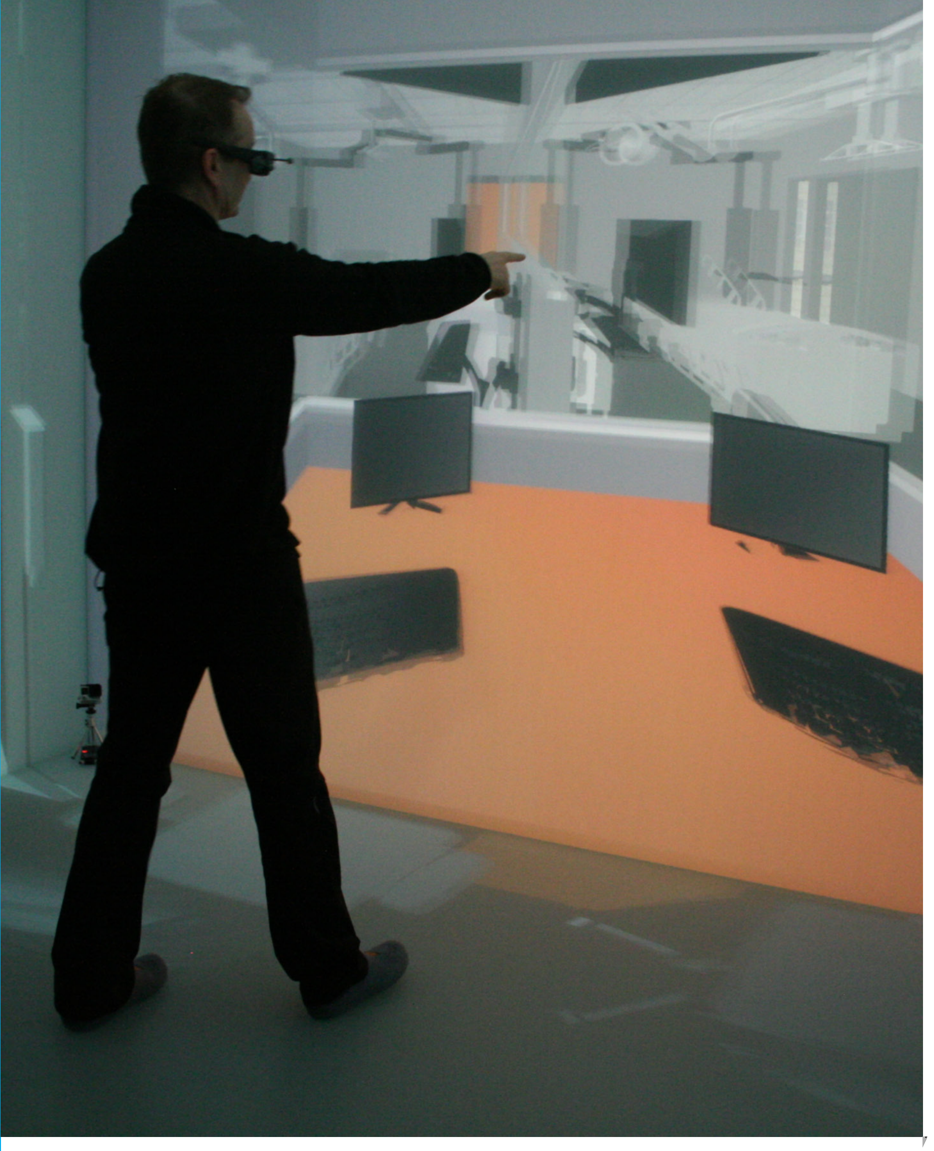

VISIONS • SCIENCE • TECHNOLOGY • RESEARCH HIGHLIGHTS

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A user-oriented, evidence-based design project of the first Finnish single room ICU

Results of EVICURES project

VTT TECHNOLOGY 252

A user-oriented, evidence-based design project of the first Finnish single room ICU

Results of EVICURES project

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Preface

There has been a rapid development in the health care processes during the last few decades. Because of that the old hospital buildings are no more optimal for the modern care. That’s why also in the Seinäjoki Central hospital we are both building new and fixing old in order to give better service to the patients.

We have had to admit that our knowledge falls short about how the conditions in the wards and in the out-patient units affect to the results of the care as well as the well-being of the staff. There is an evident need for the better evidence-based data what kind of aspect one should notice when designing hospital space.

In the EVICURES-project we have tried to add the scientific understanding of the designing the intensive care unit. The intensive care is one of the core activities of the acute hospital with the heavy emergency responsibilities. When putting quite a lot of money for making the new ICU we have no choice to fail.

EVICURES is a new link in the chain of the common projects of VTT and Seinäjoki Central hospital. We have found the model in which VTT takes care of the research and we give the real life environment for the research works pretty well as also this study proves. I hope we are able to continue our benefical co-operation still in many future projects.

Seinäjoki 13.3.2016

Jaakko Pihlajamäki
Director
The Hospital District of South Ostrobothnia

Contents

List of abbreviations

ANOVA	Analysis of Variance
BAC	Building Automation and Control
CAVE	Cave Aided Virtual Environment
CBE	Center for the Built Environment
EBD	Evidence-Based Design
GWA	Gallup Workplace Audit
ICU	Intensive Care Unit
JDS	Job Diagnostic Survey
SMBM	Shirom-Melamed Burnout Scale
SPES	Spatial Presence Experience Scale
UWES	Utrecht Work Engagement Scale

1. Background

1.1 Objectives

The EVICURES project (2014–2016) is developing a new user-friendly design model for intensive and intermediate care facilities. In this model, staff, management, patients and their families, and corporate, hospital district and other cooperation partners jointly participate in the design work from day one. EVICURES is the first project to study *evidence-based design* (EBD) activities in Finland. It draws on research information on EBD, users' views, and an extensive multidisciplinary network and its innovation expertise. In addition, the design of operations seeks to improve the quality and effectiveness of intensive care and increase patient and staff satisfaction.

The model will be utilized to design and build Finland's first EBD-based intensive and intermediate care unit at the Seinäjoki Central Hospital.

The secondary objectives of the EVICURES project are to assess how EBD impacts on care results, the incidence of complications, cost-effectiveness and the improvement of staff well-being. In the project we study changes in operations and the effects of environmental factors on care results, productivity, quality of working life and staff welfare on current and future facilities together with partners. We utilize the research results in the design of new intensive and intermediate care facilities.

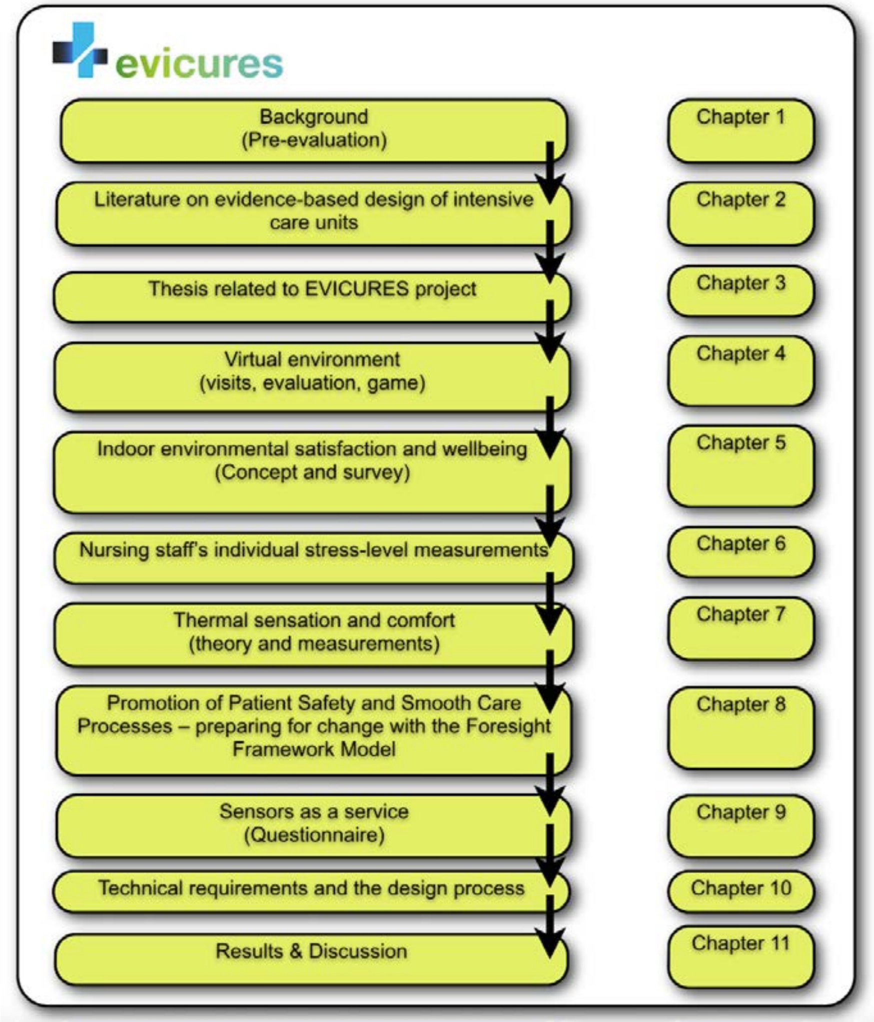


Figure 1. EVICURES Project structure.

1.2 Projects evolution

The EVICURES project's user-centred parts build on the former Hospital District of South Ostrobothnia's HospiTool (2006–2008) and HospiCaseY (2009–2011) projects. HospiTool was a joint project of VTT and STAKES and it was linked to an initiative launched by Finpro (Nykänen et al. 2009). HospiTool served as a platform for user-friendly development and management of facilities, products and services. The HospiCaseY project focused on the planning of the new Y-hospital building at the Seinäjoki Central Hospital (Yli-Karhu et al. 2011).

The technology part of EVICURES built on the former EU projects HosPilot and RE-CO (Re-Commissioning). HosPilot included an extensive demonstration in one of the hospital buildings. A full year of measurements compared the conventional HVAC and electricity systems to intelligent systems controlled by a building automation system. One floor was built with half traditional and half intelligent systems. The project showed the potential of intelligent building management to ensure the indoor environmental comfort to patients and personnel through control parameters. The re-commissioning project started as an energy saving project with little or no investment. By the end, the project was successfully improving indoor air quality without any investments. The lesson learned was the importance of co-ordinating indoor air pressure levels in multiple units within one building envelope. The multidisciplinary approach was common to all of the projects.

1.3 Present ICU

The existing facilities for intensive and intermediate care in Seinäjoki Central Hospital were built in 1977. The facilities have gone through only minor renovations and are at the moment inadequate in regard to space, building services, and modern care culture. New premises will include all intensive care facilities and most of the intermediate care rooms. The total number of beds will be 24. All the beds will be designed as single-patient rooms with private bathrooms. Many studies suggest that transitioning to single-bed rooms requires support for the staff to manage the changes in communication, visibility and social isolation (Apple 2012, Friesen et al. 2008). To ensure the best possible outcome in designing the new premises, the EVICURES project was launched to support end-users[1] participation and to utilize EBD.

1.4 Methods

The methods utilized in the EVICURES project were:

- **pre-occupancy evaluations** by ICU staff, patients and their relatives concerning the environmental effects (Chapter 1.4)
- **integrative literature review** of EBD research in intensive and intermediate care environments (Chapter 2)
- **computer-supported co-operation work** (CSCW) i.e. the collaborative design work in a cave-like virtual environment (CAVE) (Chapter 4.2)
- **presence experience** in virtual environments (Chapter 4.3)
- indoor environmental satisfaction and wellbeing questionnaire for staff (Chapter 5)
- physical **studies of stress** (Chapter 6)
- **workshops** for staff to encourage rethinking operations and supporting the change by means of the **Foresight Framework and Pathfinders methods** (Chapter 7)

- physical studies of **individual thermal sensation** (Human thermal Model) (Chapter 8)
- **Sensors-as-a-service** questionnaire (Chapter 9)

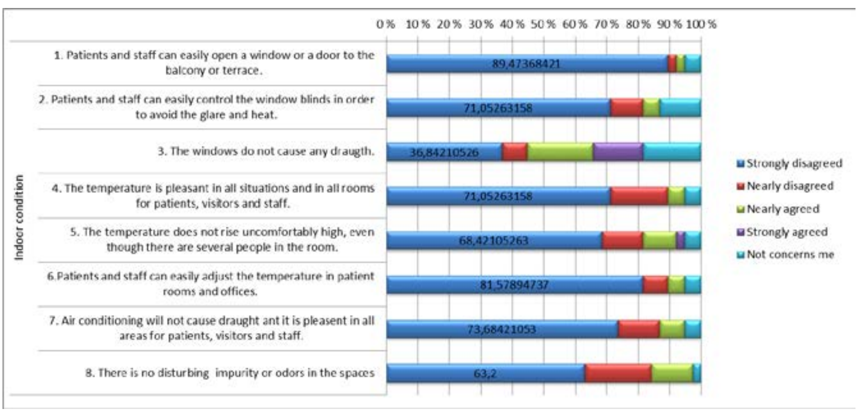
In the last stage of the project, the research results affected the functional requirements in the real design process. The ultimate goal is to achieve the new requirements in the new ICU as built.

1.5 Pre-occupancy evaluation

The EVICURES project conducted a pre-occupancy evaluation in spring 2014 by end-users (N=38), using the same questionnaire as in the former HospiCaseY project (Yli-Karhu et al. 2011). The web-form sent to staff elicited demographic information and offered 106 statements on nine different topics, including entrances and courtyards, architecture, indoor conditions (i.e. lighting, acoustics and atmosphere), durability, functionality, safety, comfort (i.e. privacy, community and aesthetics), accessibility and usability. All the topics had an open field for comments. The response scale was 'strongly agree', 'slightly agree', 'slightly disagree', and 'strongly disagreed', as well as a response for 'does not concern me'. The scale was planned so that participants should choose agree or disagree. The response rate among the staff members was approximately 76%.

According to this evaluation the staff end-users (N=38) criticized in general the state of acoustics, lighting, functionality, indoor air and the lack of privacy in the existing intensive and intermediate care unit. The best appraisals were given to the safety and security systems. The changes in medical care have led to crowding in the current rooms, while the extension of the hospital pharmacy led to a loss of windows a few years previously. Several staff members commented *'no windows, no problems with glare or draught'.* Table 1 presents the assessments on 'Indoor conditions' as an example. Over 90% of staff appreciated the collection of feedback from the staff.

Table 1. Statements of indoor condition.



A shorter questionnaire sent to patients and their relatives (N=36) was completed in November 2014. For their part the patients and their relatives rated the existing care environment as old-fashioned, uncomfortable and impractical and they also criticized the lack of privacy. They were satisfied with the availability and presence of staff and security. Differences were noticed between patients and relatives, which should be analysed in future studies (Luomala & Ovaska 2015).

The evaluations will be repeated between 12 to 18 months after the occupancy in the new premises so as to compare the results with the pre-occupancy evaluation and to evaluate the success of the design.

2. Literature on evidence-based design of intensive care units

Already in the late 1800s Florence Nightingale (1859) realized the importance of fresh air, fresh water, light and cleanliness in the environment. More and more research evidence has accumulated on the impacts of environment on patients, family members and nurses over the last thirty years. Evidence-based design (EBD), as a concept, was introduced in the 1990s (Ulrich et al. 2008). EBD is the process where decisions about the built environment are based on credible research to achieve the best possible outcomes (Hamilton 2003). A well-designed physical environment supports the health and wellbeing of patients, family members, and nurses. Single patient rooms, lower noise level, increased use of natural lighting, views to the outside and better possibilities for infection control also improve the safety and quality of treatment (Rashid 2006, Ulrich et al. 2008, Wenham & Pittard 2009).

Intensive care units typically care for patients with a life-threatening condition or with reduced vital organ functions. An intensive care environment is often noisy, restless and stressful, which can undermine the physical and psychological wellbeing of patients, family members and nurses in the intensive care unit. Constant exposure to high levels of noise, bright lights, various measures and the brief rest moments have a negative influence on intensive care patients and their family members (Meriläinen 2012, Xie et al. 2009).

The rapid development of intensive care has inevitably led to intensive care environments that in many ways do not fully correspond with present demands (Almerud et al. 2007). The application of evidence-based design helps involve patients, family members and staff in the planning process of the new intensive care environment, resulting in a better correlation of the final product with the needs of end-users.

The aim of this integrative review was to describe the evidence-based design of an intensive care unit. The objectives of this review were to apply the results to hospital design projects and improve the intensive care environment. The integrative review method was chosen because it is the only approach that allows for a combination of diverse methodologies. The review can combine data from the empirical and the theoretical literature. This integrative review brings together information about the evidence-based design of intensive care units (Whittemore

& Knafl 2005). This integrative review has been conducted using Whittemore and Knafl's (2005) five stages: 1. problem identification, 2. literature search, 3. data evaluation, 4. data analysis and 5. presentation. Conclusions are drawn on the basis of existing research data (Torraco 2005, Whittemore & Knafl 2005).

Table 2. The systematic literature search process.

Search terms: evidence-based design, healing environment, environment*, environmental interventions, hospital design*, outcomes, patient safety, staff safety, infection, hand washing, medical errors, falls, pain, sleep, stress, depression, confidentiality, social support, satisfaction, single rooms, noise, nature, light, intensive care units, intensive care, critical care

Inclusion criteria:

- described evidence-based design
- described intensive care environment
- original scientific research
- was published 2005–2016
- full text was available from databases
- was written in English or Finnish

Exclusion criteria:

- described hospital environment at a general level
- was a literature review
- was a dissertation or a professional opinion

	Medic	Medline (Ovid)	CINAHL	Web of science	SCOPUS
Included based on the titles	13	448	167	117	92
Included based on the abstracts	3	125	117	81	48
Included based on full text	1	30	25	5	20
Included in this review	0	18	20	4	8

The literature search was conducted systematically (Whittemore & Knafl 2005) using Medic, Medline(Ovid), CINAHL, Web of science and SCOPUS databases. The search was limited to works from 2005–2016. The time limit was set in order focus on recent research. The studies were selected by one author of the integrative review according to the inclusion and exclusion criteria (Table 2).

The research data (N=50) consisted of quantitative (n=35) and qualitative (n=7), with some studies using both methods (n=8). The systematic literature search process is presented in Table 2. The studies included in this review were evaluated by using JBI Qari and JBI MAStARI evaluation tools (Joanna Briggs institute reviewers' manual) and the quality of the selected studies was good.

The data were analysed with thematic analysis, which identifies, analyses and reports themes within the data. The theme describes the phenomenon from the point of view of the research questions (Braun & Clarke 2006). The studies were read rigorously and results related to the research question were selected from the data. These results were used as a basis for forming the themes and the sub-themes. The results of this integrative review will be utilized in the EVICURES project and published following the completion of the project (Koskela 2016).

3. Theses related to EVICURES project

The EVICURES project offered several thesis topics for nursing students at the School of Health care and Social work at the Seinäjoki University of Applied Sciences. The topics included typical evidence-based design themes like patient privacy, acoustics, natural lightning, and benefits of single-patient rooms. During autumn 2015, three theses were completed (see literature review) in connection with this project, dealing with patient privacy and noise in intensive care units.

Chesop and Nabunya (2015) studied the privacy of patients admitted to the ICU. The aim of their systematic literature review was to evaluate how nurses can uphold patients' privacy in ICU. The objectives of the study were to help nurses understand the need and effectiveness of patient privacy in the ICU and to understand the concept of privacy and its benefits to patients. The method was a systematic literature review of 19 scientific articles obtained from CINAHL EBSCOhost (n=16), PubMed (n=1) and text books (n=2). The data were analysed using inductive content analysis. The two major themes found were privacy (patients, family and end-of-life care) and nursing perspectives (practices, ethics and strategies) in the ICU. There were similarities in the themes that were identified irrespective of the evidence in the study or the country of origin. Privacy issues emerged on a broad spectrum and the difficulties of preserving and respecting patients' intimacy due to the ICU environment were highlighted. Solutions and strategies to combat privacy issues emerged quite clearly. Decision-making in the ICU is a complex phenomenon, since the patient's clinical situation presents time demands and ethical challenges to nurses.

In Manninen and Mäntyniemi's (2015) thesis the aim was to provide information to the EVICURES project about patients' experiences of noise in the ICU. The purpose was to describe the patients' experiences of the ICU environment and the patients' experiences regarding noise in the ICU. The data were collected both manually and by using CINAHL, Medic and Melinda databases with the keywords *patient*, *experience*, *ICU*, *nursing environment* and *noise*. The data consisted of one Finnish and eight foreign publications (a doctoral thesis and research articles). The data were analysed using content analysis. The results were processed from the perspective of the physical, psychological and social aspects of the patient experience. Nurses have a significant role in patient experiences in the ICU environment; there are many kinds of noise in the ICU and patients experience noise either as a disturbance or a calming influence.

Mäki and Pollari (2015) examined the experiences of family members regarding the noise in the ICU and the physical nursing environment. This literature review used both the CINAHL, Medic, Medline/PubMed and Nelliportal databases as well as manually searching. The data were analysed using content analysis. The noise in the ICU is a thing to note and family members felt it was an imposition and appreciate the quiet care environment. They experienced the physical nursing environment as an appreciated space and have negative emotions as well, they are able to be present and to receive information about the patient.

4. Virtual environment

4.1 CAVE

4.1.1 Technology

The CAVE – Cave Automatic Virtual Environment – was presented at the SIGGRAPH expo in Chicago in 1992. It was invented by a research group at Illinois University in Chicago. The research team's key researchers were Carolina Cruz-Neira, Daniel J. Sandin and Thomas A. de Fanti. CAVE is room size and shape environment, usually 3 m^3, built out of several rectangular display walls, which are typically rear projected. Projectors display a computer generated stereoscopic image, which is tracked according to the viewer's position and orientation. Stereoscopy provides the third dimension to the image perceived by the viewer – depth.

Since the display screen (cubical) is not spherical like human vision, the image must be rendered to each display screen from an exact position. This position is the one of the viewer's eyes. In order to be able to draw a three dimensional computer model for a person in a cubical (or almost cubical) set of screens, the image must be skewed so that the perspective is correct for the viewer's left and right eye. This skew is applied to the image rendering by the visualization software. The result of displaying the stereoscopic image in real time according to the viewer's perspective is that the viewer is 'immersed' in a three dimensional environment created with the computer system. Figure 2 shows the CAVE without any content.

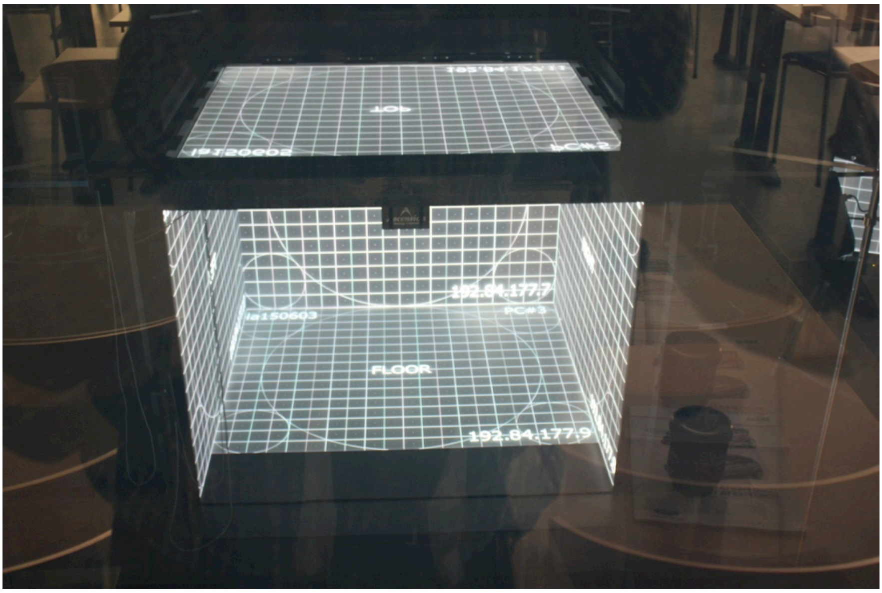


Figure 2. CAVE.

There are several methods used in stereoscopic vision. One of the methods uses liquid crystal shutter glasses. This technology – applied in the CAVE used in the EVICURES project – is based on time, with the viewing image for left-eye shown, and the right-eye vision blocked by the glasses, followed by the viewer's right-eye image being shown and the left-eye vision being blocked. These images are viewed sequentially and rapidly so that the viewer's eye perceives a fusion of the two images, creating a depth in the image.

The most common method for viewer's eye tracking in the CAVE is optical tracking, and this is the method used in the EVICURES project. It comprises a set of retroreflective markers attached to the tracked objects or body parts, and a set of cameras equipped with infrared LEDs. There are a number of infrared cameras attached around the edges of the CAVE. Each of the cameras sees a different vision of the tracked volume. According to the positions of those markers in each camera image, the tracking software is able to calculate the position of each tracked object or body part. In the case of CAVE, those tracked objects are two rigid bodies, the viewer's stereo glasses – which provide the exact position and orientation of the viewer's eyes – and the control device that the viewer is using to navigate in the three dimensional computer model and interact with the model using the buttons and analog controls of the device.

The visualization software takes care of rendering the stereoscopic image on each display wall of the CAVE, synchronously and properly skewed according to the perspective of the viewer's position and orientation in the CAVE.

4.1.2 EVICURES project as CAVE user

In the EVICURES project, some interactivity – behaviour – was added to the model with the visualization software. The viewer was prevented from flying in the model by restricting the viewer – the avatar – to the floor level, so as to make the navigation easier and more natural. The avatar was also restricted to being within the walls of the model, and so was unable to exit the outer limits of the 3D model. Sliding doors were set to open automatically in front of the avatar and to close behind the viewer. Medical ceiling-supply joints could be controlled with a joypad – a wireless game controller. Mirroring of objects provided the avatar with a visual cue that the viewer is in front of a mirror. Pre-set camera positions were used to adjust the corner of the bathroom in the computer model to be set exactly to the corner of the real CAVE – in order to extinguish the CAVE corner from the viewer and to improve the immersion.

Figure 3. Group evaluating the bathroom in CAVE.

The software used in the EVICURES project was TreeC Technology's VR4MAX. It is a real time graphics front-end software addon for Autodesk's 3dsMax design software, which was used in the end development phase of the 3D model in EVICURES. Currently, the state of the art software selection for the CAVE visualization would be Unity, with some CAVE enabling software. There are currently two software packages that make it possible to execute Unity applications in a CAVE environment, Mechdyne's getReal3D and MiddleVR. Even though Unity might offer much more degrees of freedom in the application development – i.e. creating a behaviour for a three dimensional computer graphics scene – it was not possible to purchase the software for the project. It is highly recommended that this problem is addressed in future projects. Unity, as a game engine software, would also provide an easy method for exporting the application in almost any hardware environment.

The 3D computer models viewed for the EVICURES project attendees were made to appear realistic. Correct parameters were set for illuminating lights in the scene according to the physical properties of the light fixtures and this lighting model was applied to the walls, floors and ceilings of the scene using the render-to-texture method. This operation, also known as 'texture baking', renders the effects of lights and shadows to the surfaces of the model, so that real time lighting is not required. In real-time computer graphics this has a remarkable impact on performance. The SeAMK cave is presented at http://www.seamk.fi/vrlab.

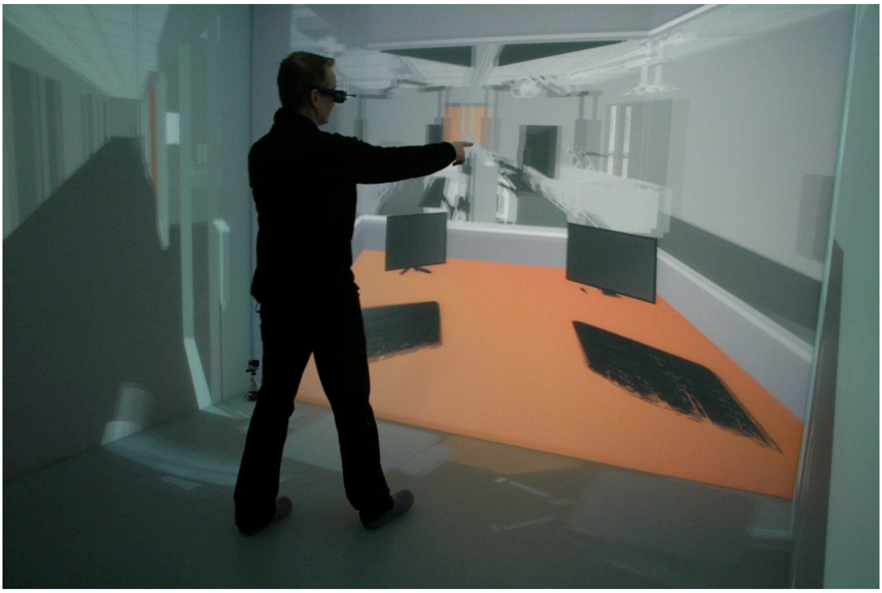


Figure 4. A staff member checking visibility from nursing station to bedside.

4.1.3 CAVE and the future of VR technologies

CAVE as a visualization display device differs a lot from head mounted displays (HMDs). HMD technologies utilise a display screen in front of the viewer's eyes, viewed through lenses. The display screen can be a mobile phone, a wireless solution, or it may be fed by a computer, which provides more graphics power. Currently, the resolution of the display unit is around 1080 x 1200 pixels, which is almost 1.3 million pixels. While in the EVICURES project, the CAVE provides 6.5 million pixels, these numbers cannot be compared, since in the CAVE, the whole scene is drawn in each display screen all the time but in HMD, only the viewer's field of view is drawn inside the HMD display. The field of view depends on where the viewer is looking, and this is continuously tracked in a similar way as in a CAVE. However, generally it can be said that the CAVE offers better pixel resolution compared to HMDs, but this may change in the near future, as HMDs gain in popularity and the display technology in turn advances quickly.

The CAVE has at least one advantage over HMDs. While the CAVE viewer sees his or her environment, i.e. body, hands and feet and also other persons in the CAVE, the HMD viewer's vision is currently blocked by the HMD. This situation will also change when front cameras on the front of devices are utilized and users are provided with a view of his or her real field of vision. However, interaction with other viewers will probably always be less profound with HMD viewers than for CAVE viewers. It may very soon be possible for several HMD viewers to view the same model with their headsets. While in CAVE all viewers will be focused more or less in the same direction, HMD viewers may each be looking in different directions, and therefore discussion in a group about the same subject may be much more challenging than a discussion in a CAVE.

The CAVE as a display solution will thus prove to be suitable for group work also in the future. The use of the CAVE or HMDs for visualization in a project such as EVICURES is not mutually exclusive. On the contrary, there are several issues that make it more appropriate to use HMDs for visualization. HMDs are cheaper, they are mobile and easier to use. Acoustic studies are easier to accomplish with HMDs and headphones. People will be more adapted to use HMDs as they gain in popularity. Several years ago some people had issues with wearing stereo glasses, but along with the rise in the popularity of virtual reality, even wearing a head mounted display is no longer a problem for most of us.

4.2 The design process in virtual environment

4.2.1 CAVE

In the EVICURES project a virtual environment provided the surroundings for collaborative design work, permitting face-to-face interaction. Small groups of 5–6 participants were given guided presentations of several designed spaces. An intensive care room, an intermediate care room, a single-patient bathroom and a nurses' front office were modelled in the virtual environment.

The computer-assisted virtual environment (CAVE) used in the project is a room comprising three walls, a ceiling, and a floor. The fourth wall was open so as to allow access into the space. Images generated using computer graphics are projected onto these surfaces, which, when viewed through stereoscopic glasses, are transformed into a three-dimensional full-scale environment. 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. Visitors are able to move to some extent within the space itself and to travel longer distances with the help of a 3D mouse.

4.2.2 Design

The design of the care rooms was completed in three separate phases in spring 2015. After each phase the modifications to the rooms were executed in accordance with feedback. In addition, each visitor was asked to complete a questionnaire in which they could analyse the properties of the spaces more systematically and evaluate the virtual environment experience. The total number of visitors in CAVE was 238. There were altogether 47 multi-occupational groups, and all the visits were recorded and videotaped. Table 3 presents the collaborative design process.

Table 3. The collaborative design process.

Dates	Number of groups	Number of participants	Number of design model	Task of participants	Task of architect and other designers
3–5.3.2015	14	61	1. model	Comment on the models of the intensive care room, intermediate care room, bathroom and nurse station	Study feedback and develop the models for second round
30.3–1.4.2015 7–8.4.2015	18	89	2. model	Comment on the models of the intensive care room, intermediate care room, bathroom and nurse station	Study feedback and develop the models for third round
5–7.5.2015	15	88	3. model	Comment on the models of the intensive care room, intermediate care room, bathroom and nurse station	Study feedback and transport the models to the floor plan and set the rooms in the best possible order

4.2.3 Visits

The visits to CAVE ran according to plan. The participants received information in advance about the EVICURES project, the location of the virtual laboratory, the length of the visit and the objectives for the visits. They were told that the design of rooms would entail three separate rounds and modifications would be done after feedback. To motivate participants to express unusual proposals, participants were informed that the rooms were incomplete and all comments and adjustments were more than welcome. Also, information about videotaping, photographing and recording their visits was provided.

A project worker organized participants into groups of four to six people. Groups were multi-occupational and participants were project stakeholders (nurses, doctors, cleaners, technical staff, designers and others).

Before the design session, the researcher introduced the project group, demonstrated how the work in practice happens in CAVE and explained the outlines for the CAVE presentation. Participants were told that they could comment at any time during the presentation.

The EVICURES project group had planned the route for the CAVE presentation (intensive care room – bathroom – nurse's front office – intermediate care room – bathroom). The architect presented the spaces with the same description to all the groups. The planned route took approximately 15 minutes. After that groups could return to the virtual rooms that they would like to evaluate more closely. The participants could interrupt and ask for details or comment at any time.

4.2.4 Evaluation

After the presentation, participants completed a questionnaire in which they could analyse the properties of the spaces more systematically and evaluate the virtual environment and collaborative design experience. Vivid conversations usually followed, where discussions focused on the function of spaces, changes to the function, and the number of healthcare staff that could be accommodated. On the whole visits lasted for one hour.

The first models of the rooms were based on a summary of their requirements, which was compiled by the intensive care unit. The summary included an illustration of single patient rooms designed abroad and the requirements set for the design of new units. The requirements were based on EBD-studies and examples of previous implementations of single patient rooms in ICUs abroad.

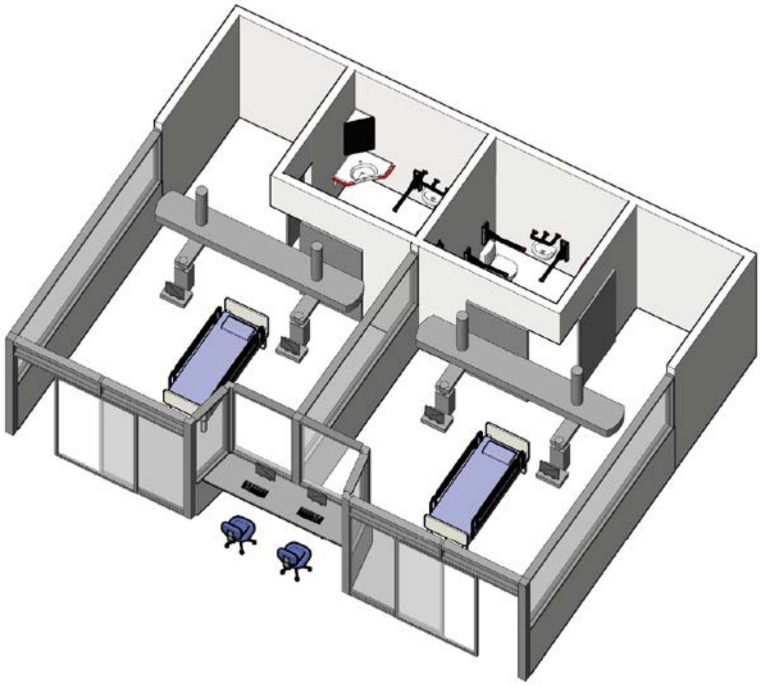


Figure 5. The first model of intensive care rooms.

The first models of rooms were rejected for basically two reasons. First the bathroom was difficult to reach with the patient. Second the participants preferred patient rooms with windows and a view outdoors. Evidence-based design also states the importance of natural light for patients and staff.

The second model appealed more to the participants (Figure 6). The bathrooms were moved to the sides of two patient room complexions. After the model was seen as satisfactory, the participants started to evaluate more details, such as the height of the glass between the two patient rooms, the visibility and equipment. A more detailed model was promised for the third phase.

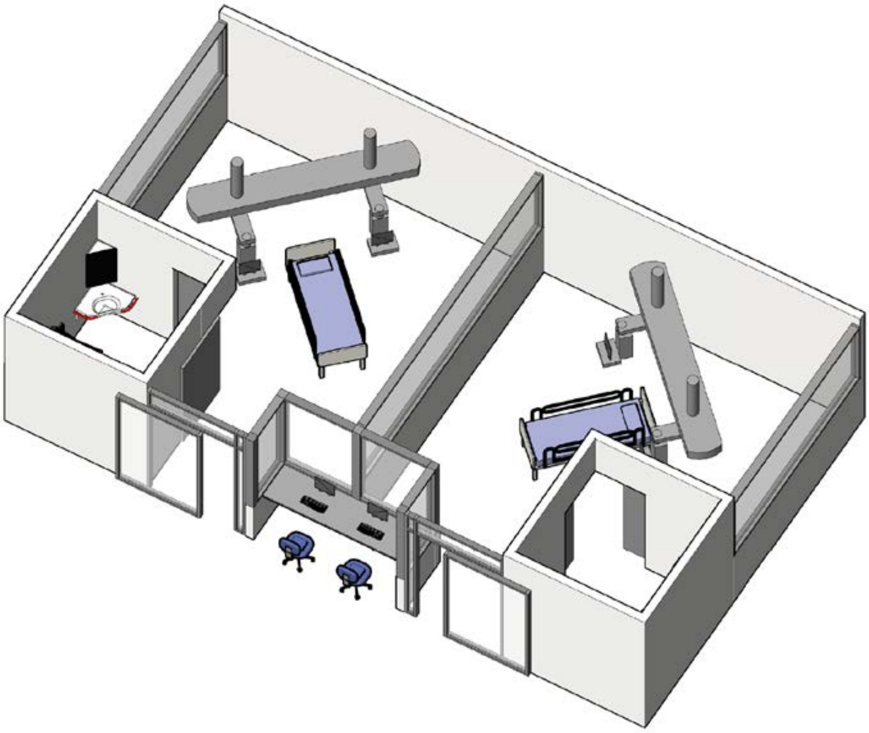


Figure 6. The second model of intensive care rooms.

The third model had colours, pictures on the walls, and a view from the window. The last model had also some additional functionality, such as door opening and movable ceiling mounted booms. Though the model was acceptable there was a lot of discussion about insufficient space to work, the amount of movable cabinets and other furniture, and should there be a sluice for fluid disposal instead of bathrooms.

Figure 7. The third model of intensive care rooms.

4.2.5 Discussion

The change to single patient rooms highlighted many of the challenges in the work processes of medical staff. The challenges focused on the visibility of patients, communication between medical staff, and the thread of social isolation in single patient rooms (Apple 2012, Friesen et al. 2008). These problems can be solved through changes in working, good spatial layout, and with new technology. The benefits of single patient rooms to patients and staff are bigger and research has demonstrated that single patient rooms are superior to multi-beds in terms of patient safety and privacy (Thompson et al. 2012).

The changes to models between these three phases were discussed and carried out by the project team. The final analysis of the questionnaires and videotapes concerning the spaces and their function will be examined by a researcher.

A limitation of the study was that only some room types were designed for the new unit and not the layout of the whole unit, though designing larger areas is today possible. The patient rooms, bathrooms and nurses' front office were selected because they were considered important. The layout and the disposition of the rooms are very important to an efficient way of working. The patient rooms will be located in groupings of six patient rooms in the final design of the forthcoming new unit.

Figure 8. The group of nurses evaluating the bathroom.

The participants were satisfied that they could take part of the design of their new unit and express their needs and experience. The virtual environment provides a scene were participants without any design background are in equal position with architects and other designers. The designers obtain information of the actual way of working, which helps them to design the spaces so that they support the actual way of working.

4.3 Experience of presence in the virtual environments

People in a CAVE-like virtual environment feel physically positioned in the mediated environment. This experience has been called a sense of presence, which can be defined as the person's subjective feeling of 'being there' in the virtual environment. Several psychological dimensions for presence have been identified, such as spatial presence and involvement. Post-test rating scales have been widely used in the assessment of the sense of presence, and there are several questionnaires available for measuring subjective experiences of presence in different types of media environments (for a review, see Laarni et al. 2015).

In the CAVE tests of the EVICURES project, a novel rating tool, the Spatial Presence Experience Scale (SPES), was used. The SPES has been developed by Hartmann et al. (2015), and is based on a process model of presence according to which participants first generate a mental representation of the presented physical space, and then they activate and test perceptual hypotheses concerning the acceptance of the mediated environment as their primary frame of reference (Wirth et al. 2007). The SPES measures people's self-location (SL) and perceived possible actions (PA) in the mediated environment. It is a quite short questionnaire comprising eight items, and it can be applied in different types of media environments (Hartmann et al. 2015).

All in all, it was expected that sense of presence would be stronger in the richer and more vivid virtual presentation of the care environments. Since in the EVICURES project, the richness and vividness of the virtual environment will increase across test phases, presence experiences should also become stronger over time. Preliminary results suggest that this seemed to be in fact what happened in the test sessions: the mean SP ratings increase across the three phases, and also PA scores in the third phase were higher than in the preceding two phases (Figure 9). Participants' subjective comments also support these findings. According to a one-way ANOVA, the PA scores of the three phases differed significantly ($p < 0.05$) from each other, but the differences between the SL scores were not statistically significant. The SL scores were also clearly higher than the PA scores.

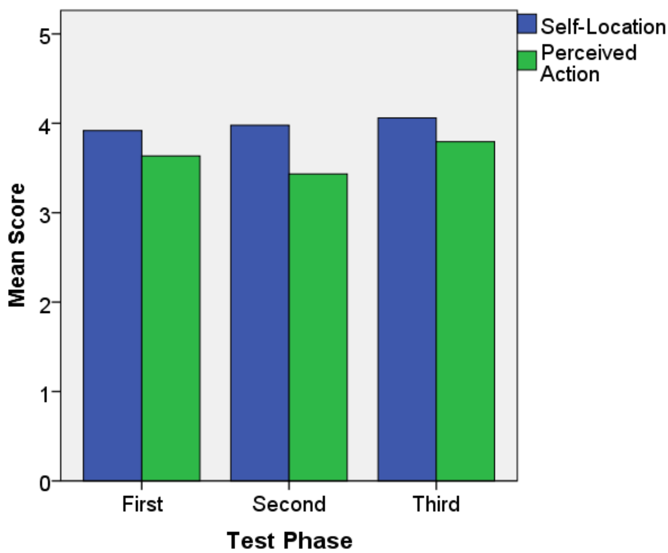


Figure 9. Presence (self-location, perceived action) scores in the three test phases.

Overall, the test results support the assumption that the participants experienced a higher sense of presence in the later versions of the virtual presentation of the care environment, which were more vivid and richer in details than the first version.

4.4 Game interface development

To provide a convenient and productive way of analysing the space [EVICURES ICU hospital block] a simple, cross-platform game-like application was developed. The following describes the development process.

To prepare the EVICURES model as a virtual playable environment, the pre-existing 3D model needed to be modified in some subtle ways.

The first part involved converting the model's materials to Unity materials or shaders. The complication was that the textures embedded with the model had pre-baked lighting effects. In order to preserve the textures, and having no access to the original diffuse maps, a self-illuminated/emissive material was employed in Unity. This severely limited the dynamic lighting possibilities (turning lights on/off, day–night cycles). However, it reduced the demand for computing power and increased mobile compatibility.

The next step was creating collision surfaces for the models that were already present in the scene. This would allow a playable character to navigate the environment without walking through walls and closed doors, or for that matter, falling through the floor.

Finally, some of the models were divided or modified in 3DS Max to allow finer control in the Unity game. After these changes were made, some significant features could be implemented.

4.4.1 Custom controller, interactive objects

The essential starting point was making a custom controller/camera to navigate the scene and interact with in-game objects. The main challenge here was to make a controller that worked on the PC as well as on android devices. While computer interaction is fairly straightforward, the mobile version has a small virtual joystick. While a 'gamer' will find this simple to use, the average user may still experience a learning curve and it is one of the limitations of touch screen interfaces that has no trivial solution.

To simplify things, the menu provides the user with options to jump to different locations in the ICU block effortlessly.

In addition, there is the possibility to navigate with the Kinect 2 if the user has a Windows computer.

4.4.2 Dynamic environment, generated characters

The scene, being navigable, needed some interactive objects. Some just react to the player's presence, such as the sliding doors, while others require explicit user interaction, such as sitting down on the nurse station chairs or turning the glass from transparent to opaque and back.

To add some life to the space, a few non-player characters were added. Some of these characters are dynamically generated and walk along the corridor. Others are stationary. The user can use the menu to add or remove these characters as they see fit.

Figure 10. Non-player characters.

4.4.3 Map mode with intelligent navigation

Along with the first person perspective, another way to observe the scene is available. From overhead, this can be similar to a map or layout view, but the camera can also be tilted and rotated to give an overall view from all angles. Within this 'map-mode', the user can click on a part of the floor and the player character (represented by a red sphere) will walk to the desired point while avoiding obstacles on the way.

Figure 11. Map mode.

4.4.4 Game versions

Finally three versions of the Game were made available: Windows (with Kinect 2), Mac, and Android. The game was used near the end of the project among personnel for the purposes of checking and discussion. In subsequent projects, the game development could be done at an earlier stage so as to be available to support the (non-CAVE) discussions.

Figure 12. The Game in Android Tablet.

5. Indoor environmental satisfaction and wellbeing

There is a lot of evidence showing that indoor environmental conditions have an impact on job satisfaction and wellbeing (for a review, see, e.g., Aaltonen et al. 2012). For example, there is strong evidence that working in open-plan office environments reduces employees' job satisfaction (De Croon et al. 2005). Therefore, there are good reasons to study indoor environmental satisfaction and its effects on different wellbeing indicators (e.g., job satisfaction, work engagement and work stress).

Interruptions are an inherent aspect of many work tasks, such as emergency services (Chisholm et al. 2001). Also, multitasking is growing steadily, and multitasking has become a normal condition in many work domains, such that it is even more difficult for workers to recognize that they are multitasking.

This chapter presents first a conceptual model of linkages between environmental satisfaction and various indicators of wellbeing. Secondly, it presents a brief literature review on multitasking and the impact of interruptions on work performance.

5.1 Conceptual model

The conceptual model links the physical environment through environmental satisfaction to job satisfaction and work engagement (see Figure 13). The model has been modified from several existing models and frameworks, such as Newsham's et al. (2009) conceptual model and a framework presented by Danna and Griffin (1999).

Based on the conceptual model, a detailed questionnaire concerning environmental and job satisfaction, job stress, multitasking, work engagement and personality has been developed.

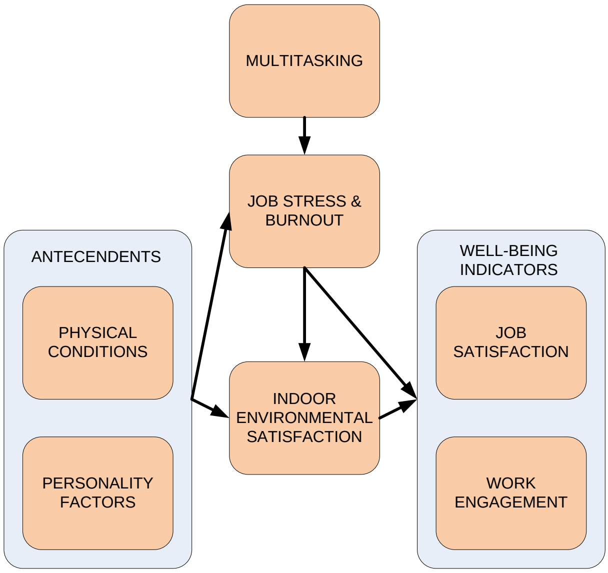


Figure 13. Conceptual model of linkages between antecedents, indoor environmental satisfaction and indicators of wellbeing. All the factors shown with a brown background are measured in our study.

5.1.1 Antecedent factors

The antecedent factors under consideration are physical factors and personality factors. Physical factors related to the work setting are described in detail in Chapters below.

Personality factors had an effect on the level of wellbeing in a given organizational environment. Personality factors that have been shown to play a role are Type-A behavioural tendencies and locus of control (Danna & Griffin 1999). Type-A behaviour will be measured by the Framingham scale (Haynes et al. 1978), which has been widely used in the evaluation of Type-A behaviour pattern. Locus on control will be measured by the Levenson's I, P and C scales (Levenson 1972).

5.1.2 Mediating factors

Factors such as thermal comfort, air quality, lighting, acoustic quality, office layout, furnishings and cleanliness are linked to overall environmental satisfaction. A set of items from the CBE's (Center for the Built Environment) occupant survey questionnaire was used to measure the above-mentioned aspects of indoor environmental quality.

Job stress and feelings of burnout have a direct effect on wellbeing. Stress and burnout were measured with the Shirom-Melamed Burnout Measure (SMBM).

5.1.3 Consequences

Well-being is a broad and encompassing construct including various satisfactions experienced by individuals (both work and non-work related) and general Health (health, affective wellbeing and subjective wellbeing). In this study, wellbeing was measured by the Job Diagnostic Survey (Hackman & Oldham 1974) and the Utrecht Work Engagement Scale (Schaufeli & Bakker 2003).

5.1.3.1 Job satisfaction

Some previous studies have shown a significant correlation between environmental satisfaction and some aspects of job satisfaction. According to Brill et al. (2001), various aspects of the physical workplace environment could account for about 24% of the variance in job satisfaction. Several studies have shown positive links between environmental satisfaction, job satisfaction and wellbeing. For example, Wells (2000) showed that higher satisfaction with the physical environment predicted higher job satisfaction, which in turn predicted higher employee wellbeing. In Veitch's et al. (2007) study, overall environmental satisfaction had a positive link to job satisfaction. According to Newsham et al. (2009), overall environmental satisfaction will be an important contributor to job satisfaction, mediated by satisfaction with factors such as management and compensation.

5.1.3.2 Work engagement

Work engagement is a positive and pleasurable affective state that has been considered as the opposite to job burnout (e.g., Schaufeli & Bakker 2003). Engagement is characterized by a high level of potency and attachment with one's work. Work engagement has been measured, for example, by the Work Engagement scale on the UWES – Utrecht Work Engagement Scale (Schaufeli & Bakker 2003) and the Employee Engagement Scale measured by GWA – Gallup Workplace Audit (Harter et al. 2002).

5.1.4 Multitasking and interruptions

Multitasking and interruptions are a natural part of work in health-care settings, and nurses are experts at managing task switching and interruptions. This section provides a short literature review on multitasking and the impact of interruptions and distractions on work performance in health care.

In multitasking the person is performing two or more overlapping tasks at one time. According to Benbunan-Fich et al. (2009), simultaneous tasks can be performed in a sequential, parallel or intermittent fashion. In multitasking, the person's attention is focussed partially to each task, which quite easily causes inattention (Benbunan-Fich et al. 2011).

Different definitions of interruptions have been used by different authors, which makes it difficult to compare findings (Grundgeiger & Sanderson 2009). Apparently, the concept is highly context-dependent and study-specific (Brixey et al. 2007). In fact, an interruption has been described in different ways in different contexts. Some common definitions are the following:

- Anything that disturbs the progress of the work
- Any disturbance/distraction that is not related to the main task
- Halting of the current activity for some reason
- Any event that requires the attention of the subject
- Any event that distracts attention from the ongoing task.

Most of the studies on multitasking and interruptions in work have been conducted in the health-care domain. Overall, multitasking is considered an essential element of work in many health-care sectors (Forsberg et al. 2014).

One of the main questions has been to find out how frequent are interruptions in health care. According to one state-of-the-science review, the average number of reported/calculated interruptions per hour for nurses ranged from 0.3 to 13.9 (Hopkinson & Jennings 2013). In Kalich and Aebersold's (2010) study, nurses were observed to be multitasking for 34% of their work time. Laxmisan et al. (2007) found that, on average, the attending physicians and nurses were interrupted every 9 and 14 minutes, respectively. Potter et al. (2005), in turn, showed that nurses had about 9 cognitive shifts per hour, so that they had to shift their focus from one patient to another every 6–7 minutes. It was also found that the nurses did not typically try to control the sources of interruptions during the medication preparation process. The time-weighted average for cognitive load for nurses in the Potter's study was 11 activities, that is, they had on average 11 tasks to perform at any given time.

Several causes for the interruptions in health care have been identified. Chisholm et al. (2001) categorized the interruptions in emergency departments and primary care offices into four main categories: care interruptions (referring to a patient under care), patient interruptions (relating to another patient), non-patient interruptions (interruptions not relevant to patient care) and telephone interruptions. In McGillis's et al. (2010) study, more than half of the interruptions were intrusions initiated by another person that interrupted the conduct of one's work. Sasangohar et al. (2013) studied interruptions experienced by intensive care unit nurses and found that other nurses caused nearly half of all interruptions, followed by interruptions caused by equipment and medical doctors.

Some of the conversations in medical care are irrelevant, and thus the interruptions caused by these conversations should also be avoided. For example, Spooner et al. (2015) found that 3.5 irrelevant conversations on average occurred in each surgical procedure that was studied.

According to Cook et al. (2000), the medical domain has gaps in care that must be constantly bridged by workers (e.g., shift handovers). Professionals may make errors in bridging these gaps, but in most cases they are successful. In order to understand these failures, we also have to understand how professionals do their work successfully.

5.1.4.1 Effects of multitasking and interruptions

Interruptions are not necessarily bad or good, and sometimes interruptions may boost performance (Grundgeiger & Sanderson 2009, Weigl et al. 2012). For example, interruptions may deliver valuable task-related information (Weigl et al. 2012): It is reasonable to tell a colleague that he/she is going to commit an error (Grundgeiger & Sanderson 2009).

According to Sykes (2011), employees must constantly balance the potential positive and negative consequences of interruptions, rather than try to avoid them completely. Moderate levels of multitasking may even increase performance in many tasks, even though excessive multitasking leads to a reduction of performance (Adler & Benbunan-Fich 2012). In fact, most existing research suggests that interruptions and excessive multitasking have harmful effects on performance and wellbeing (Baethge et al. 2014).

It has been found that interruptions increase the task completion time, hamper decision-making, and lead to more errors (e.g., Carayon et al. 2007). The effects that interruption has on quantitative task performance derive from factors such as increased memory load and task similarity (Lee & Duffy 2015). One of the drawbacks of interruptions is that their effects can last long after the interruption has expired (Dismukes et al. 1998).

O'Conaill and Frohlich (1995) showed that 40% of the time the disrupted task was not resumed immediately following the interruption, because it was difficult for the workers to resume. Czerwinski et al. (2004) identified the following factors that affect the perceived difficulty of switching back: task complexity, task duration, length of absence, number of interruptions, and task type.

Interruptions cause loss of time (e.g., Monk et al. 2004). The completion time of the task that is interrupted increases by two transition time intervals: interruption lag and resumption lag (Altmann & Trafton 2002). The 'interruption lag' is the switching time from the primary task to the interrupting task, and the 'resumption lag' is the return time from the secondary task back to the original primary task (Altmann & Trafton 2002). Both the accomplishment of the primary interrupted and secondary interrupting task may be delayed (Altmann & Trafton 2002).

In health-care settings an important question is to show whether there is a causal link between interruptions and errors. Overall, there is quite little evidence for a positive relation between interruptions and medical errors (Grundgeiger & Sanderson 2009). According to Grundgeiger and Sanderson (2009), this is because of the methodological approaches that have been used have their limitations, not because there would be evidence that the interruptions have no effect on error frequency.

A Canadian study (McGillis et al. 2010) showed that of over 5325 interruptions in medical care, only 115 of the interruptions were judged to have a positive outcome. According to Grundgeiger and Sanderson's (2009) survey, three cause-and-effect studies showed that there is a connection between interruption and error, one study provided evidence of no connection, and five studies provided inconclusive evidence for methodological reasons. Based on these findings, Grundgeiger and Sanderson concluded that under certain circumstances, interruptions may cause medical errors.

More recently, in Westbrook's et al. (2010) study, the occurrence and frequency of interruptions were significantly correlated with the occurrence of errors among nurses. Each interruption was associated with an increase of 12.1% and 12.7% of procedural and clinical failures, respectively (Westbrook et al. 2010). More specifically, if there were five interruptions during a medication round for an individual patient, it was almost certain that a failure will happen (Westbrook et al. 2010). It was also found that work experience provided no protection against errors and was even linked with higher rates of procedural failures (Westbrook et al. 2010). It was also found that only 11% of the interruptions were evaluated to have a positive outcome in their study.

Baethge et al. (2014) have proposed that cumulative interruptions may further increase the probability of errors and failures, because of lack of resources and because increased stress may lead to the use of sub-optimal strategies (Frese & Zapf 1994). The effect of cumulative interruptions can be subtle and difficult to notice: if the number of incomplete tasks is increasing, workers may change their strategy and try to accomplish their tasks with reduced effort (Baethge et al. 2014). This does not need to occur consciously: As Hockey (1997) has presented, attentional narrowing and reduced memory capacity can cause people to be careless regarding safety standards or avoid secondary tasks without noticing. Interruptions may, thus, hamper the quality of work, even though they do not cause clear-cut errors.

When people are interrupted, they tend to forget what they were doing in the first place. Prospective memory implies a recollection process at a certain point in time in the future, which is more challenging than remembering a particular fact (Czerwinski et al. 2004). In addition, if an employee's attention is constantly drifting from one information source to another, he/she may not be able to have a complete and coherent view of the event, when he/she has to recall the interrupted task (Chisholm et al. 2000).

In Weigl's et al. (2012) study, there was a significant correlation between interruptions and workload in addition to the contribution of other factors. Frequent interruptions were also correlating with increased frustration in their (2014) study. Interruptions by colleagues had the strongest link to workload (Weigl et al. 2012). And if the interruptions are cumulated, the effect may be further pronounced (Baethge et al. 2014).

The effect of interruptions on workload can be explained by the distractions-stress ladder model: Interruptions increase the demand upon an individual, demand exceeds resources, and thus increase his/her stress level (Sevdalis et al. 2008, Weigl et al. 2012). Similarly, Farrimond et al. (2006) have suggested that interruptions cause people to perform tasks faster, while needing to maintain the level of quality.

In addition to cognitive costs, interruptions may also have emotional effects (Janssen et al. 2015). Interruptions had a negative effect on emotion and wellbeing and increased feelings of stress and frustration (Farrimond et al. 2006; Kalich & Aebersold 2010; Mark et al. 2008).

Baethge et al. (2014) suggested that cumulative interruptions cause more severe and longer-lasting emotional reactions than isolated interruptions. They proposed that repeated cumulative interruptions may lead to emotional strain, and sequenced interruptions may lead to an accelerative increase of strain. Sequenced interruptions may also cause rumination about the tasks that cannot be interrupted voluntarily: individuals' thoughts are circling around the interruptions and all the tasks that have not yet been completed (Baethge et al. 2014).

However, sometimes interruptions and multitasking may lead to positive emotions, because of increased variability, an increased feeling of usefulness and the adoption of a new perspective on the work activities.

5.2 Satisfaction and wellbeing in emergency care – results of the survey

A survey regarding environmental satisfaction, work conditions, and job satisfaction was conducted in autumn 2015.

5.2.1 Methods

The development of the questionnaire was based on the theoretical framework presented above in Chapter 5.1. The questionnaire consists of the following subscales:

- Background demographic information (12 items)
- Environmental satisfaction scale, including two scales, a general part and a specific part with detailed questions about individual elements of the hospital environment (52 items)
- Job satisfaction scale (17 items)
- Work engagement scale (9 items)
- Work stress and burnout scale (14 items)
- Assessment of Type A personality scale (10 items)
- Locus of control scale (24 items)
- Questions about multitasking and interruption/distraction management (12 items).

The general part of the environmental satisfaction scale was partly based on the Workspace Satisfaction questionnaire developed by Kim and de Dear (2013). The detailed part was developed together with the experts of the Seinäjoki Central Hospital.

The Job Satisfaction scale was based on JDS – Job Diagnostic Survey (Hackman & Oldman 1974), and Work Engagement scale on the UWES – Utrecht

Work Engagement Scale (Schaufeli & Bakker 2003). Work stress was assessed by the SMBM – Shirom-Melamed Burnout Scale. A scale for the measurement of Type A personality was adapted from the Framingham scale (Haynes et al. 1978), and the scale for the measurement of Locus of Control from the Levenson IPC scale (Levenson 1972).

The final questionnaire includes 150 items that were presented in Finnish (APPENDIX A).

Thirty respondents filled in the questionnaire; 24 of them were nursing personnel at the Seinäjoki Central Hospital, 6 were support staff. In total, 48% of the nursing staff participated in the study.

5.2.2 Results

Due to the small number of participants, the original model presented in Figure 13 above could not be completely tested. As a result, our research approach had to be exploratory and descriptive in nature.

Descriptive statistics and the results of the analysis on correlations between some variables are presented in the following pages. Sum scores were calculated for most of the scales, and some item-level considerations were also made.

5.2.2.1 General environmental satisfaction

The overall results are presented in Figure 14, which shows a 100% stack bar chart displaying the full scale of the survey responses regarding environmental satisfaction. Figure 15 shows the average environmental satisfaction across all the factors included in the survey. As can be seen, the respondents were most satisfied with opportunities to interact and communicate with other workers and with the availability of cleaning services. They were least satisfied with inadequate sound insulation, bad indoor air quality, insufficient privacy, colours and patterns of surfaces, temperature, an insufficient amount of lighting, and lack of adjustability of the furniture.

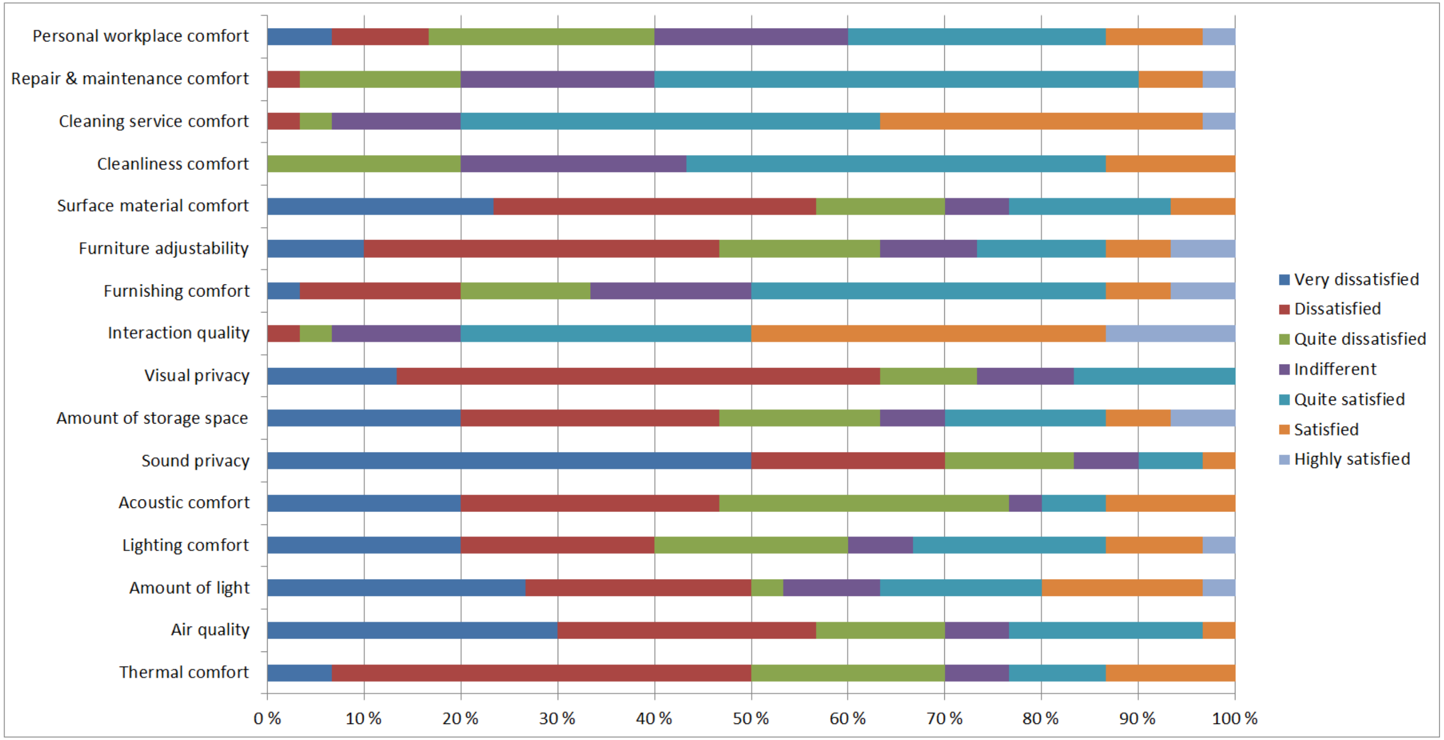


Figure 14. Distribution of responses regarding environmental satisfaction.

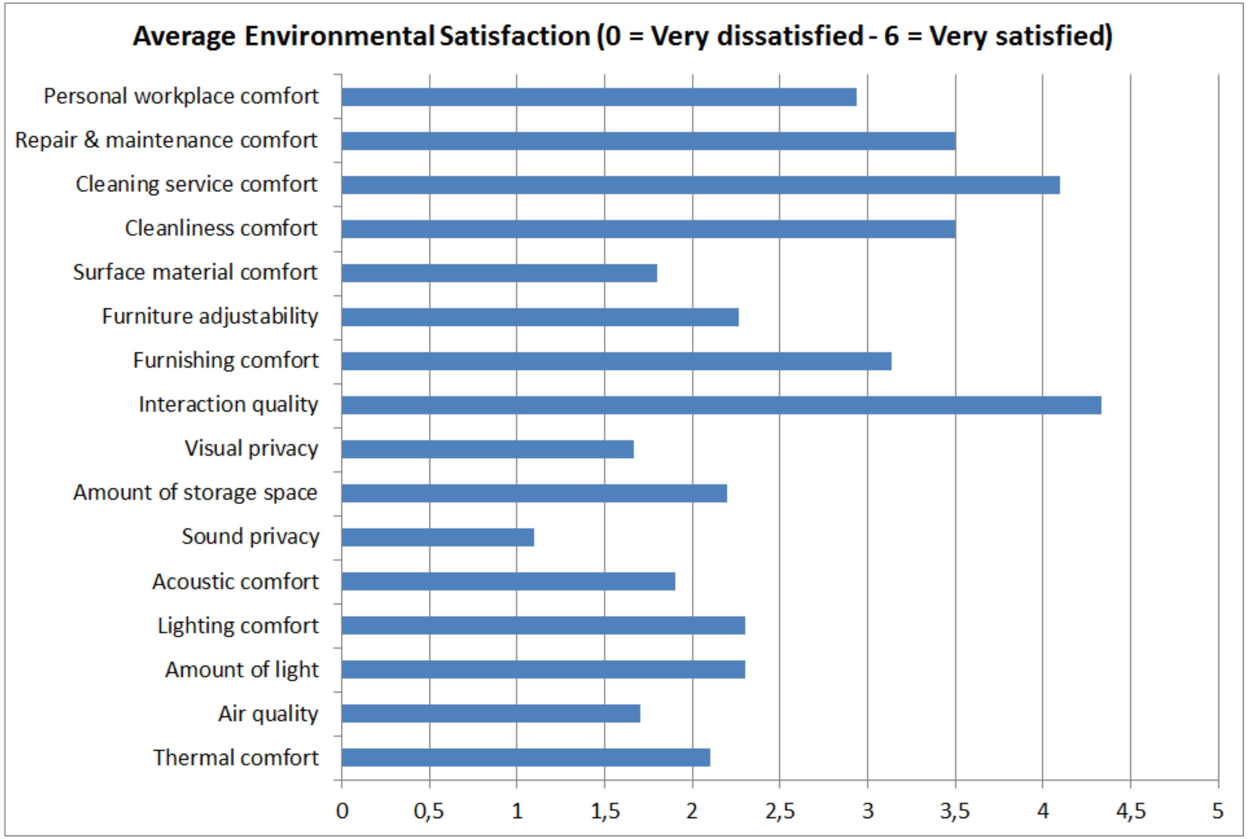


Figure 15. Average environmental satisfaction across the factors measured in the questionnaire.

As compared to the results of the pre-validation study, the results are quite consistent with regard to acoustics and sound insulation: sound insulation is insufficient, and noise impairs worker concentration. Regarding lighting and lighting comfort, the results are also consistent with the results of the pre-validation study: the amount of daylight is insufficient, and there is room for improvement in lighting comfort. Regarding air quality and temperature, the results of the present survey are somewhat more affirmative than the earlier results; that is, the problems related to air quality and temperature are somewhat less pronounced in the present study.

It was found that gender and profession were significantly correlated with environmental satisfaction. The finding is mainly caused by the fact that nurses were less satisfied with the environmental conditions, and most of them are female.

Regarding the correlation between environmental satisfaction and multitasking/interruption management, it was found that environmental satisfaction is significantly correlated with distractibility by noise, interruption management, and amount of multitasking. Those who were less satisfied with the environmental conditions were distracted by noise to a larger extent, were able to concentrate for a shorter period of time on a single task, and were multitasking more frequently than those who were more satisfied with their environmental conditions.

In the detailed part of the questionnaire, more specific questions about environmental satisfaction were asked. The respondents had the most positive attitude to the following features of the emergency care unit:

- Position of some of the main room spaces, such as the nursing office, own workplace, storage spaces
- Access to some facilities such as computers and printers
- Availability of some key facilities and services, such as computers, printers, Internet connections, and kitchen facilities
- Availability of break rooms and storage space for personal belongings.

The respondents thought that the following features were the least satisfying:

- Availability of sensory stimuli, such as drawings in patient rooms
- Width of corridors and doors
- Space available for beds, wheelchairs and other equipment
- Access to daylight
- Call and signal system of patient rooms
- Recreational space for nurses and other staff
- Furniture in the patient rooms.

5.2.2.2 Job satisfaction, work engagement and work stress

Job satisfaction was measured by three items from the JDS – Job Diagnostic Survey, developed by Hackman and Oldham (1974), which measured general satisfaction with work. Fourteen items addressed the respondents’ satisfaction with diverse aspects of work, such as job security, opportunities for personal growth, amount of salary, supervision quality, and human relations. As can be seen in Figure 16, the respondents were most satisfied with the amount of job security and challenge, the chance to help other people, and human relations in general. Respondents were least satisfied with the fairness and amount of salary they receive, the amount of support and guidance received from the supervisor, and the overall quality of the supervision.

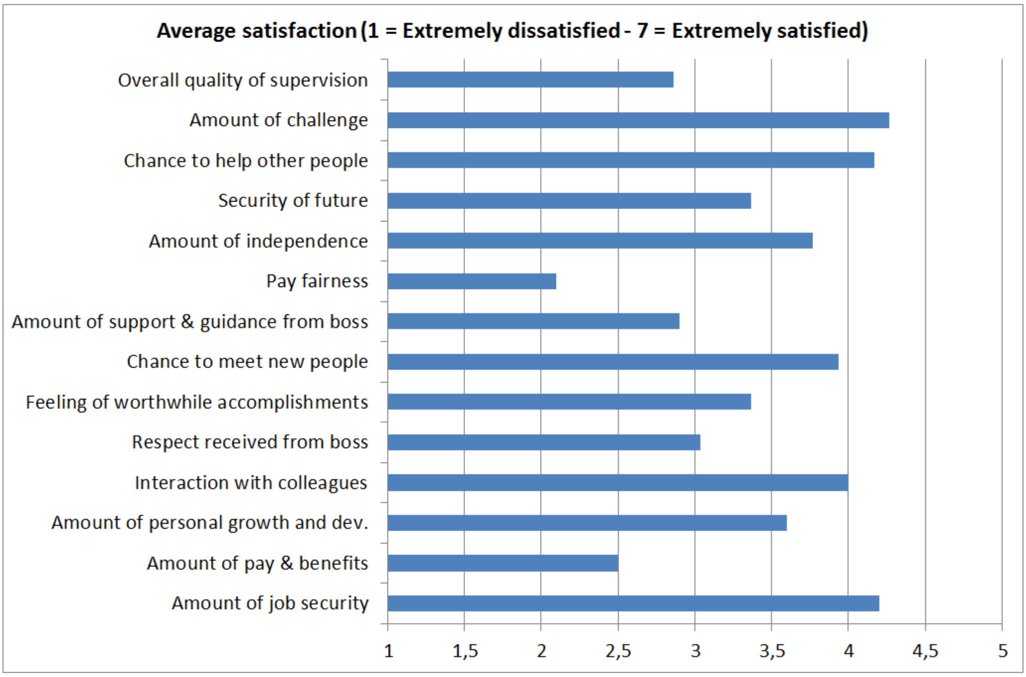


Figure 16. Average level of satisfaction with various aspects of work.

Work engagement was measured by the UWES (Schaufeli & Bakker 2003); work stress was, in turn, measured by the SMBM (the Shirom-Melamed Burnout Scale). Work engagement scores were significantly negatively correlated with work stress: those respondents who were more engaged with their work felt less stressed than those who were less engaged. However, a similar negative correlation was not detected between job satisfaction and work stress.

We also measured two aspects of personality: Type A behaviour patterns and Locus of Control. A partial correlation between scales representing Work engagement and the Chance aspect of the Locus of control was moderately negatively significant ($p = 0.02$); that is, those who are well engaged with their work do not think that their fate is controlled by chance.

Work engagement was significantly positively correlated with basic education: Those who had a higher level of basic education thought that they were more engaged than those who had a lower level of basic education.

Interestingly, Work engagement was significantly negatively correlated with interruptability by noise: Those who are more engaged with their work are less disturbed by environmental noise. This correlation may be caused by the fact that those who are less disturbed by noise are better educated and have an opportunity to work for longer periods in a more peaceful office environment.

5.2.2.3 Environmental satisfaction vs. general satisfaction/work engagement

One of the main objectives of this study was to investigate whether there is a positive correlation between environmental satisfaction and job satisfaction or environmental satisfaction and work engagement. A partial correlation between environmental satisfaction and general satisfaction, after controlling for the effect of work stress, approached significance ($p = 0.092$), but did not reach statistical significance. Neither was there a significant correlation between environmental satisfaction and work engagement in the present study.

5.2.2.4 Multitasking and interruption/distraction management

As can be seen in Figure 17, the respondents estimated that the average duration of their work tasks is about 28.5 minutes. They also estimated that they were able to concentrate on a single task without interruptions for about 7 minutes. Taking into account both of these results, on average, each task is interrupted 4 times. In addition, on average, according to the respondents’ estimations, they were interrupted about 7 times in each work shift. It was also asked how long it takes before the employee can resume a task after an interruption. The average resumption time was about 2 minutes.

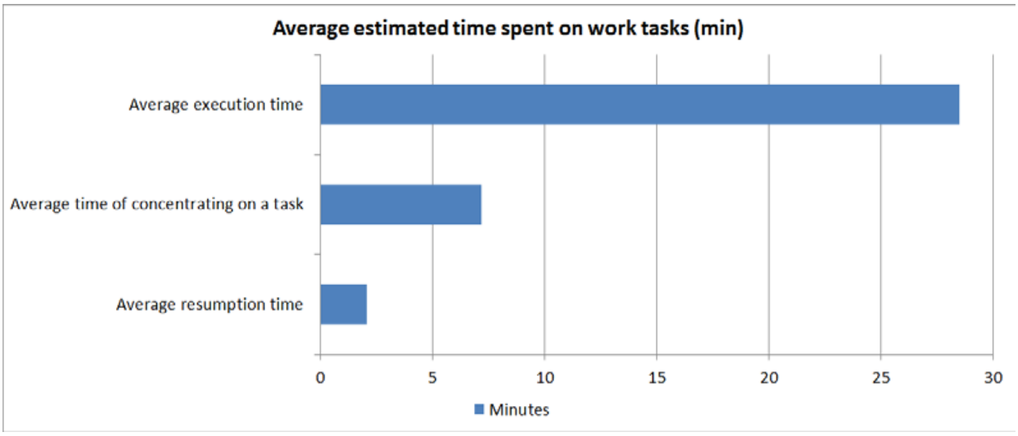


Figure 17. Estimated average time spent on the execution of work tasks and on resumption from interruptions. See text for details.

The number of interruptions was higher among those employees who were in a position of leadership and who were older. On the other hand, those who were in a position of leadership could also concentrate on a single task without interruption for a longer period of time than those where were not.

It is typical that people try to anticipate possible interruptions, and many of us have developed various strategies to manage the occurrence of interruptions. In our study, about half of the respondents tried to prevent harmful interruptions of a task. The employees tried to prevent the interruptions, for example, by:

- Putting the phone into silent mode
- Deciding to not respond to the phone
- Closing the door to the room
- Careful planning, scheduling and anticipating
- Consciously focussing on one task at a time.

It was asked whether the respondent had to perform several tasks simultaneously in his/her work. As can be seen in Figure 18, 43% of the respondents have to do several tasks simultaneously nearly all the time. The most common causes for multitasking that were mentioned were the following:

- Phone calls/phone ring sounds
- Colleagues
- Another patient needs help
- Alarm sounds of equipment
- Doctor’s rounds
- Patient’s relatives (entering, conversations).

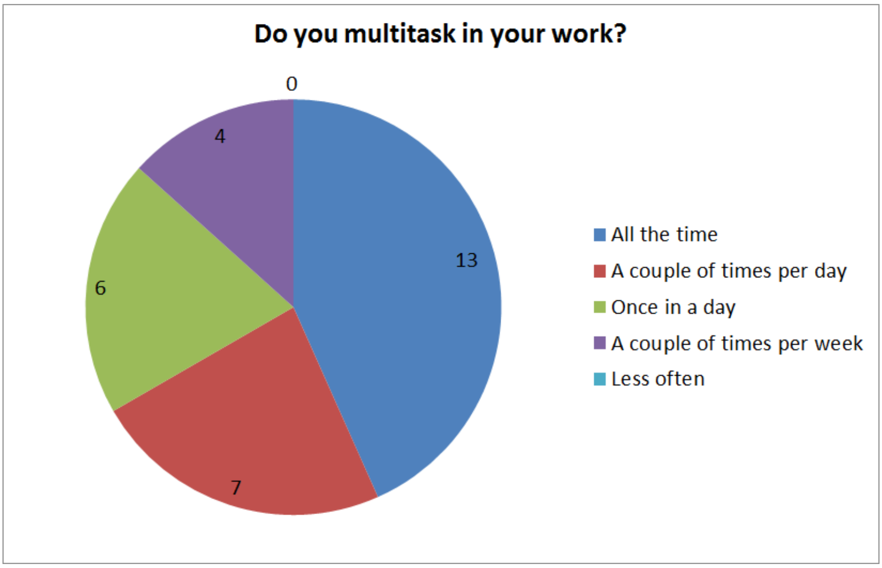


Figure 18. Estimated amount of multitasking in work.

It was asked how many tasks the respondent can perform simultaneously without a significant impairment of performance. As can be seen in Figure 19, the average number of tasks was 2.5. It was also asked that if the respondent has to perform several tasks at the same time, how many tasks he/she typically has to carry out simultaneously. According to their estimates, the respondents can perform, on average, 2.4 tasks simultaneously. Interestingly, they thus had to perform a greater number of tasks simultaneously than they thought they were capable of doing.

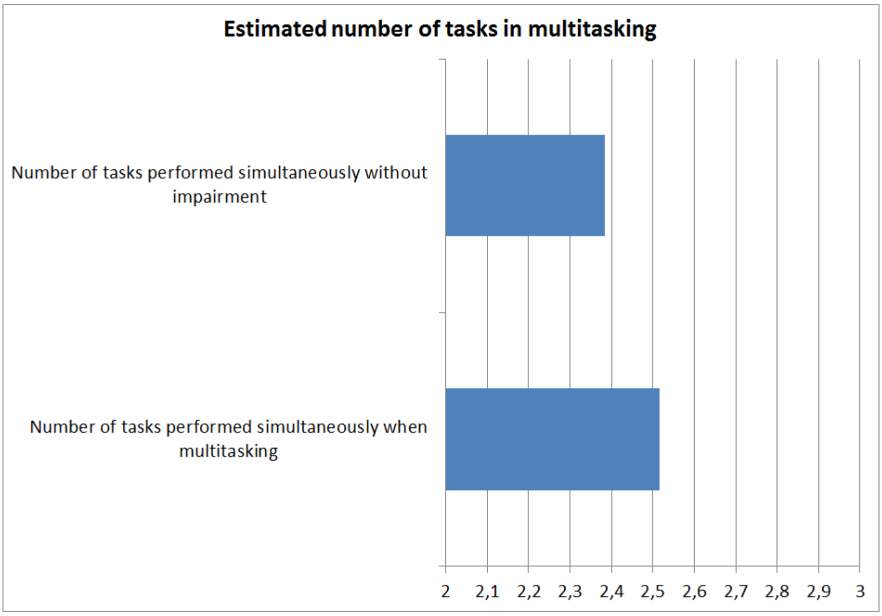


Figure 19. Estimated number of tasks performed when multitasking.

In response to being asked whether noises heard in the workplace impair concentration, 57% of the respondents thought that noises disturbed them quite frequently in their work (Figure 20). According to the respondents the following sounds seemed to impair their concentration:

- Background conversations, talking
- Noise from equipment
- Phone calls/phone ring sounds
- Air-conditioning
- Radio/TV
- Cleaning
- Noise caused by renovation work.

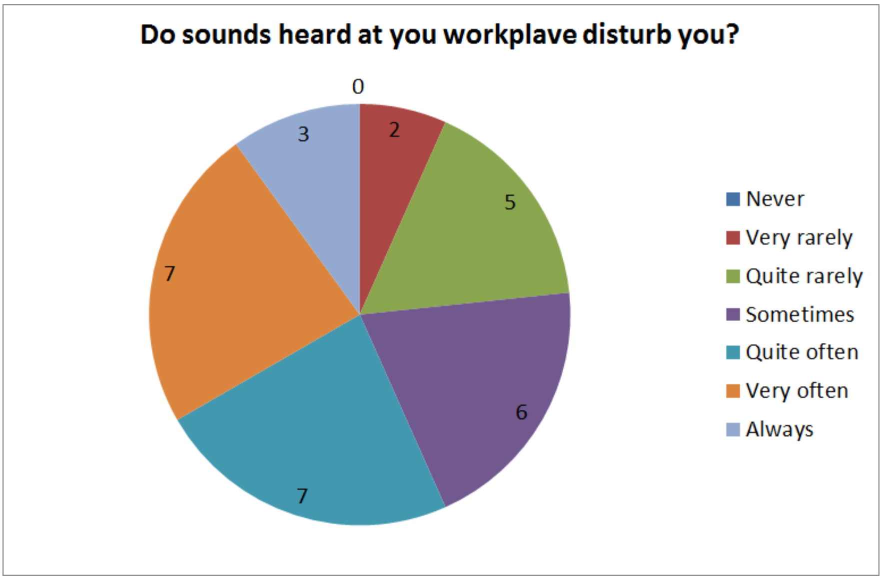


Figure 20. Number of participants distracted by sounds.

5.2.3 Discussion

One of the main findings of the survey was that there were several features in employees' work environment that caused dissatisfaction and possibly also stress. The harmful factors were mainly features of the physical work environment (e.g., environmental noise, lack of visual privacy and air quality), whereas the employees are overall quite satisfied with interactions with their colleagues and clients/patients. In addition, the respondents were quite dissatisfied with the tightness of spaces, a lack of sensory stimuli in the department and especially in the patient rooms and the lack of windows and daylight. On the other hand, they were quite satisfied with the position of, and access to, some main facilities and services, such as the position of the nursing office and storage spaces and access to computers and printers.

The results of the survey are quite consistent with the negative results of the pre-validation study in terms of acoustics, sound insulation and lighting comfort; on the other hand, the present results are somewhat more positive than the earlier results in terms of air quality and temperature.

Due to the small number of respondents, a multivariate analysis of the survey data could not be performed, and we could therefore not completely test the model presented in Chapter 5.1. Some associations between variables were tested, however. Figure 21 illustrates some associations between the variables. Statistically significant correlations are shown by solid lines; correlations that only approached significance are shown with dashed lines. For example, a positive correlation that approached significance was found between environmental satisfaction and job satisfaction. Further, a significant correlation between environmental satisfaction and some features of multitasking and interruption management were also found. For example, those who are more satisfied with their environmental conditions multitask to a lesser degree than those who are less satisfied. One possibility is that the less-than-optimal environmental conditions force the employees to multitask to a larger extent.

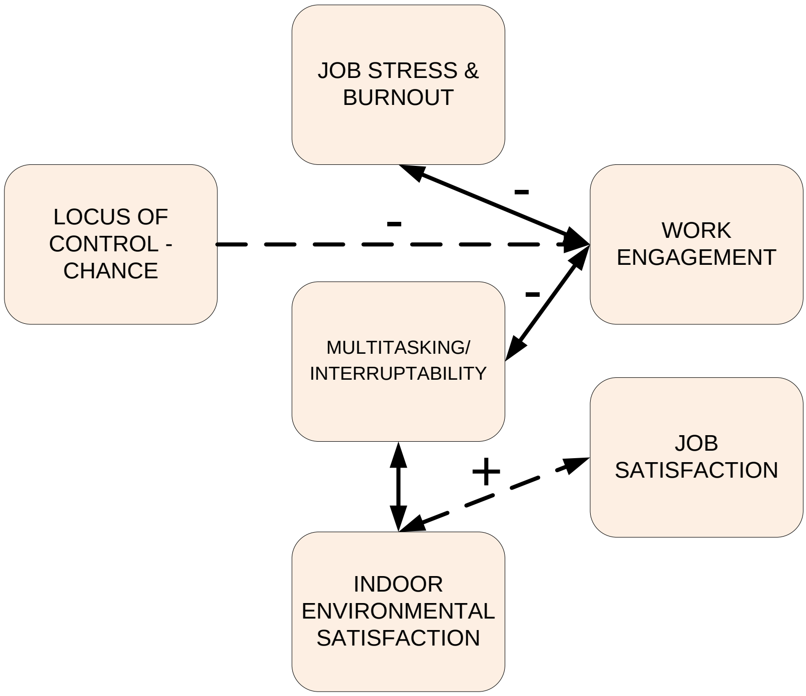


Figure 21. Some significant correlations between variables (solid lines) and correlations that approached significance (dashed lines). +/- sign shows whether the correlation is positive or negative.

Regarding job satisfaction, the employees seem to be quite satisfied with most aspects of their work. Pay fairness and the amount of pay and monetary benefits were one of the few aspects that were considered quite unsatisfactory. Work engagement as measured by the Utrecht Work Engagement Scale (UWES) was significantly negatively correlated with work stress and the Chance dimension of the Locus of Control. Those employees who were more engaged with their work felt less stress and seemed to have a stronger belief that they could control their life than those who had lower scores.

The work environment of most respondents seem to be quite hectic and stressful, in that many of them were frequently interrupted, and they also often had to perform multiple tasks at the same time. These results are quite consistent with earlier research among nursing personnel (for a review, see, e.g., Laarni 2015). It was, for example, found that over 40% of the respondents have to multitask nearly all the time, and nearly 60% of them were quite often distracted by sounds. An interesting finding was that the participants had to perform more tasks simultaneously than they thought they were able to do successfully.

5.2.3.1 Implications

The work environment and work conditions in general should be restorative, and they should help employees improve and maintain their wellbeing. According to our results, there seem to be elements in the environment that do not promote the maintenance of job satisfaction and wellbeing among nurses and other workers. In addition, there was a moderate, but non-significant, correlation between environmental satisfaction and general job satisfaction. Apparently, such factors as environmental noise, lack of visual privacy and air quality do really hamper job satisfaction to some degree, for some time, and for some employees. The effect of environmental factors on satisfaction and wellbeing may be mediated, for example, by how and to what degree nurses are able to regulate and manage emotions in their work settings and to recover emotionally.

In a poor work environment interruptions and distractions are apparently more frequent and disruptive, and as was suggested above, interruptions and distractions may increase the probability of errors and failures. They, in turn, may compromise patient safety, and further increase workload and stress. In order to promote resilience in health care, the conditions of hospital physical environments thus have to be better considered.

We have investigated the factors that contribute to the satisfaction and wellbeing of nurses and other employees in health-care settings. However, our study has not directly addressed the effect of environmental factors on patient safety and wellbeing. There is a lot of literature on evidence-based healthcare design in which strategies and recommendations are presented based on scientific evidence (e.g., Ulrich et al. 2008). We suggest that the reader consults the literature on evidence-based medicine to find a more detailed account of the effects of the physical environment on patient safety and wellbeing.

6. Nursing staff's individual stress-level measurements

6.1 Aim

In EVICURES project we studied the impact of the present work environment on stress levels on stress levels of staff working in intensive and intermediate care unit's at the Seinäjoki Central Hospital. The hospital premises were built in the 1970s and have been renovated only a little since then. The most remarkable environmental problems nowadays are noise, poor indoor air quality and room temperature, and a lack of space, natural light and privacy. Patient rooms are for multiple beds.

6.2 Methods

We co-operated with Firstbeat Technologies by using their heart rate variability analysis. This analysis uses collected data about a person's work, leisure and sleep to create a picture of health and performance, stress periods and recovering. With the help of this analysis we can recognize factors that improve stress management, quality of sleep and the effects of exercising.

Ten volunteers (9 females, 1 male, aged 28–59) measured their heartbeats over a four-day (three working days, one day off) period using Firstbeat Bodyguard 2 HRV recorders. At the same time, they kept a digital diary to indicate time spent working, sleeping, and in leisure activity, and noticing medication. Before the heart rate measuring, participants filled out a questionnaire concerning their present wellbeing (exercise, eating, use of alcohol, stress and recovering, and personal wellbeing). The official analysis was made by Firstbeat.

6.3 Results

The results were handled at the group level. The group mean age was 45 years and body mass index, 27.9 (23–35). Sixty per cent answered that they did not exercise enough to be healthy, 80% ate healthily and used alcohol moderately. Half felt themselves to be non-stressed, though 40% did feel stressed. Eighty per cent answered that they have recovery moments and breaks during day, and the same percentage felt themselves to be lively and vibrant; only 40% reported sleeping enough. Everyone felt that they could affect their health issues and 90% did manage to affect their health.

Participants' average heart rate was 76/min (61–90), at rest 52/min (44–57) and peak rate 140/min (98–192). The portion of time being stressed was 50% and for recovering 26% per day. According to Firstbeat's database, the recovery recommendation is 30% per day at least. Recovering during leisure time was good or fair (61% of all recovering). Mean recovery times when awake during the day off were 55 minutes and during working time 42 minutes (Figures 22 and 23). Recovering at work was mostly weak (60%).

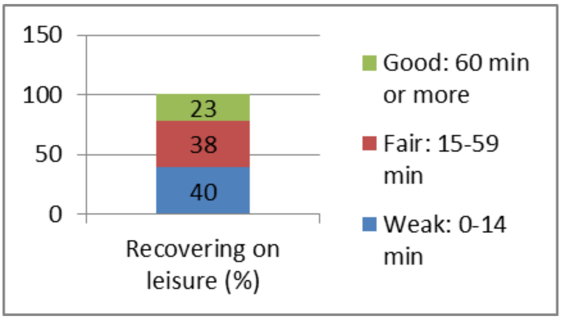


Figure 22. Recovering through leisure.

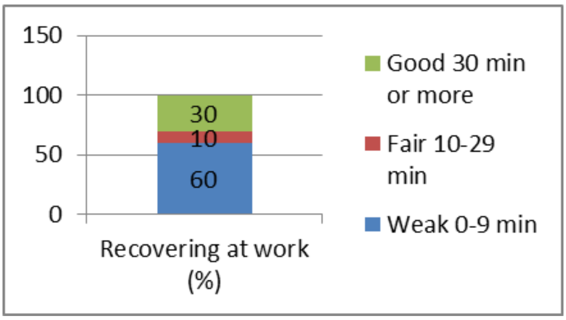


Figure 23. Recovering at work.

Participants slept on average 7 hours 21 minutes per day and the recovering part of sleeping was good (40%) or fair (35%). The quality of recovering was mostly good (58%) or fair (43%). The group exercised only 15 minutes per day. The American College of Sport Medicine (ACSM) recommends a minimum of 30 min/day regularly.

6.4 Discussion

In spite of the fact that a hospital as a work environment is broadly stressful for nursing staff, this group’s stress levels were not at an alarming level. No one had stress all the time without any moments for recovery. Quick changes in action and interruptions are typical for intensive care and intermediate nursing, which can be one reason for the staff’s weak recovering at work.

Designing the new intensive and intermediate care unit should take account of healing environment factors, such as acoustics, room temperature and lightning. In order to investigate the positive impacts of these work environmental changes, the wellbeing survey will be repeated one year after the new intensive and intermediate care unit has been operational, hopefully with the same participants.

7. Thermal sensation and comfort

This chapter deals with the personnel's evaluation of individual thermal sensation and comfort at the Seinäjoki Central Hospital Intensive Care Unit.

7.1 Comparison and selection of evaluation methodology

There are three parallel methods for evaluating the thermal sensation and comfort of individuals. The first and probably most straightforward is to arrange questionnaires in which all occupants are asked to evaluate the levels of their own thermal satisfaction. The second method is to measure individual skin temperature levels in order to estimate thermal sensation based on monitored data. The third method is to utilise a calculation methodology, by which thermal satisfaction can be predicted based on a more or less detailed human thermal model that mimics the true thermal behaviour of a human body.

7.1.1 Thermal satisfaction questionnaires

When arranging questionnaires for occupants, their thermal satisfaction is estimated by two fixed scales. In the first scale, *thermal sensation* is estimated by respondents according to nine basic levels, where a thermal sensation value of 0 corresponds to thermal neutrality (i.e., an occupant feels neither too warm nor too cool). Perceived deviations from this neutrality are estimated according to the scale presented in Figure 24 (e.g., a thermal sensation value of -1 corresponds to 'slightly cool'). In the second scale, thermal comfort is also estimated according to nine basic levels, where all positive values correspond to a comfortable and all negative values refer to an uncomfortable thermal perception (e.g., thermal comfort value +1 corresponds to 'just comfortable').

Figure 24. Thermal sensation and thermal comfort scales.

7.1.2 Skin temperature measurements

The most common locations for skin temperature measurements are presented in Figure 25. By adopting these measurement and monitoring locations, it is possible to compare the obtained results with previous similar measurements.

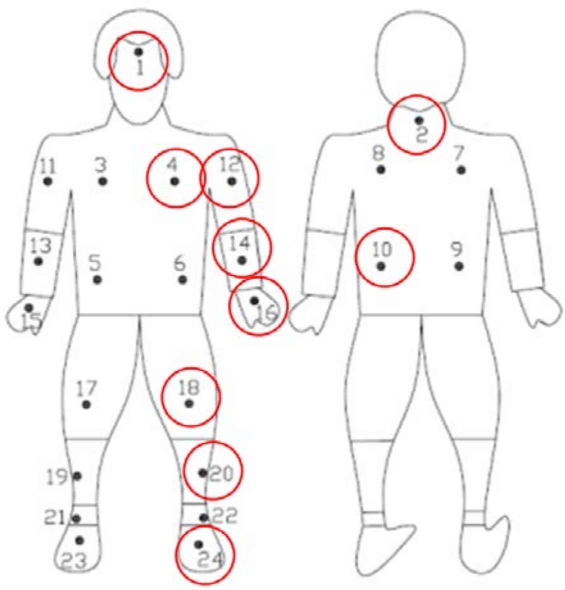


Figure 25. Typical skin temperature measurement locations (n=24).

7.1.3 Calculation methods for thermal sensation and comfort

Human thermal comfort can be estimated with several alternative methods. The widely used international standards ISO 7730 (1984) and ASHRAE 55 (2003) are based on Fanger's PMV (Predicted Mean Vote) method for the calculation of thermal comfort, and this method is a good starting point. However, the PMV method is applicable only to steady-state and uniform thermal environments. In order to estimate the impact of individual characteristics – such as age, gender, body-mass-index (BMI), and muscularity – on human thermal sensation, such human thermal models that take into account the effect of the human thermoregulation system and realistic transient heat transfer phenomena, need to be utilised. Therefore, the Human Thermal Model (HTM) has been developed to predict the transient thermal behaviour of a human body under realistic thermal interaction with a surrounding space (Tuomaala et al. 2014).

HTM is based on the true anatomy and physiology of a human body, and it estimates spatial and temporal temperature levels of body tissues. For the model, the body is divided into sixteen different body parts, such as the head, neck, upper arms, lower arms, hands, lower legs, etc. Each body part is further sub-divided typically into four realistic tissue layers (bone, muscle, fat, and skin) in concentric cylinders (Figure 26). The exact amounts of different tissue types on a body part level are based on typical tissue distributions given in previous studies (Smith 1991, Tuomaala et al. 2013), and on the individual boundary conditions presented above. Such an approach enables a realistic anatomy description for any individual, and HTM can be used to analyse the thermal wellbeing of different human groups, such as typical personnel and patients.

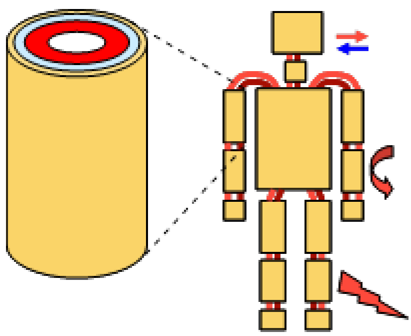


Figure 26. Anatomy model of Human Thermal Model (HTM).

The functional tissue layers are connected to adjacent body parts by the blood circulation system, which is used for physiological thermoregulation of the whole body (Holopainen 2012). HTM also estimates thermal interactions between the human body and the surrounding space by means of convective, radiation and evaporative heat transfer, which enables quantitative thermal sensation analysis under different boundary conditions.

When estimating human thermal sensation and thermal comfort, the influencing boundary conditions are usually divided into two groups of parameters: external and internal parameters (Figure 27). External parameters are related to the surrounding space, such as air temperature, surface temperatures, air velocity and humidity. Internal (or personal) parameters are related to the human being, i.e. clothing and metabolic rate. Furthermore, the metabolic rate depends on individual anatomy (i.e. amounts of different tissue types) and activity level.

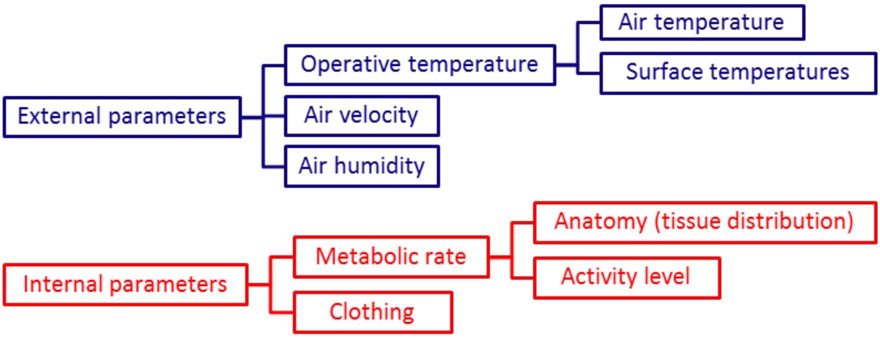


Figure 27. Space-related and occupant-related boundary conditions influencing human thermal sensation and thermal comfort.

After all the impacts of both external and internal parameters on human tissue temperature levels under the desired thermal boundary conditions have been calculated, the thermal sensation of an occupant can be estimated (Figure 28). The local (i.e. body part level) and overall thermal sensation and thermal comfort index values are calculated using Zhang's method (2003).

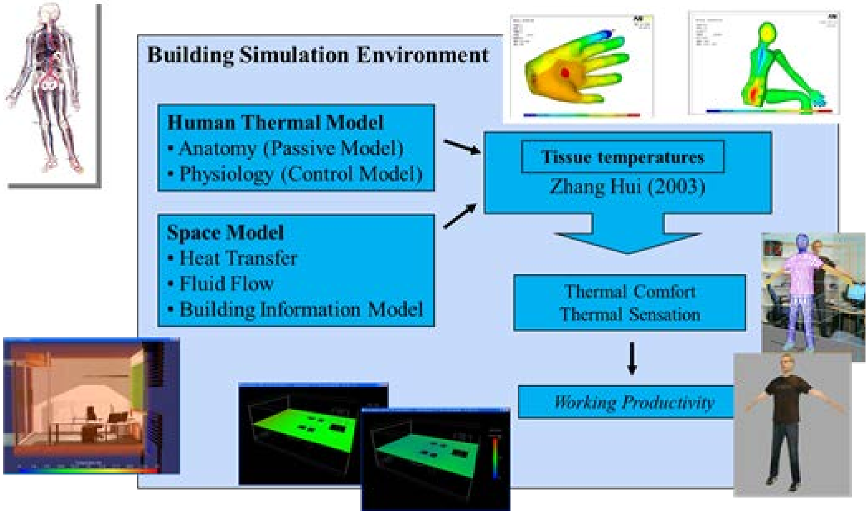


Figure 28. Simulation of tissue temperature levels, thermal sensation and comfort index values, as well as the level of potential hypothermia of an occupant spending his/her time in the studied space conditions.

7.2 Planning and preparation of thermal sensation evaluations

Thermal sensation and comfort evaluations were planned and prepared in close collaboration with the Seinäjoki Central Hospital personnel. Firstly, a questionnaire was organised for the personnel between March 17 and August 31 2015. In addition, skin temperatures of four personnel members were measured, and indicative Human Thermal Model calculations were conducted.

7.2.1 Questionnaire

When estimating perceived thermal satisfaction by a questionnaire, occupants were asked to fill the form presented in Figure 29. This form included background information (date, time, location, and name of a respondent), clothing description, perceived thermal sensation and thermal comfort index values, and perceived indoor air quality and lighting quality. The personnel were allowed to complete the formula whenever occupants were willing to.

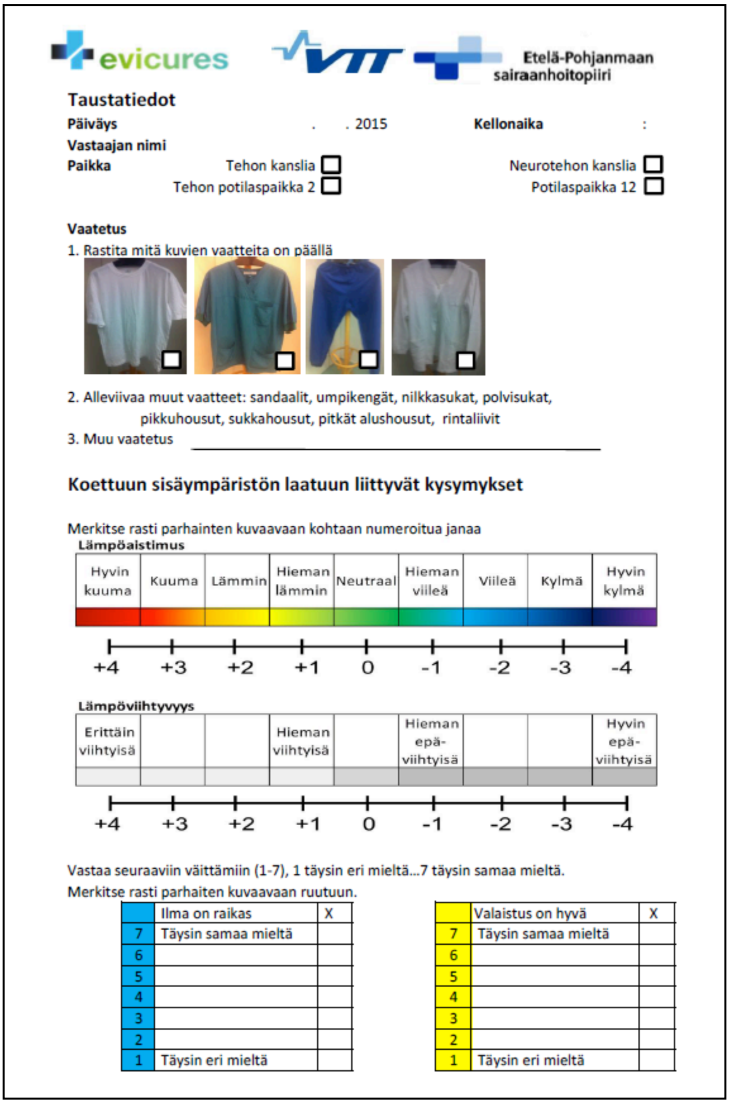


Figure 29. Questionnaire form for estimating the thermal perception of occupants at the Seinäjoki Central Hospital (Appendix B).

7.2.2 Skin temperature measurements

Skin temperature measurements were agreed to be made for sitting test persons in an open office space of the Intensive Care Unit. The uncertainty of skin temperature sensors was ±0.1 °C, and it was agreed to attach the sensors to the left side of each test person only (10 circled measurement locations in Figure 30) by means of medical skin tape.

Figure 30. Wired skin temperature measurement arrangement of a sitting person at the Seinäjoki Central Hospital.

7.3 Description of boundary condition measurements

Boundary conditions needed for thermal sensation and comfort evaluations were monitored in the agreed locations at the Seinäjoki Central Hospital Intensive Care Unit.

7.3.1 Monitored space temperature and humidity data

Thermal space conditions, temperature and humidity were monitored by small space monitor devices (TinyTag). These measurements were conducted in four locations (the patient places 2 and 12, intensive care unit office, and neuro-intensive care unit office).

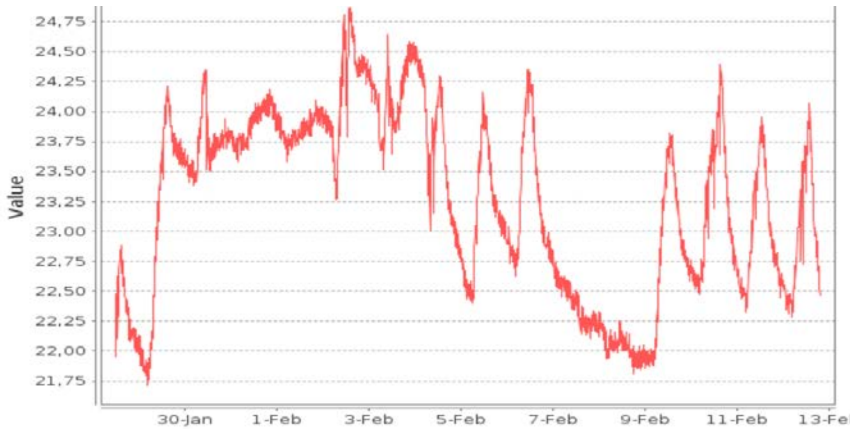


Figure 31. Example of monitored space air temperature data from the Intensive Care Unit at Seinäjoki Central Hospital.

7.3.2 Individual body composition data

Individual body composition data is needed as a boundary condition for Human Thermal Model calculations. The relevant tissue type masses were measured by BodyExplorer 2.0.

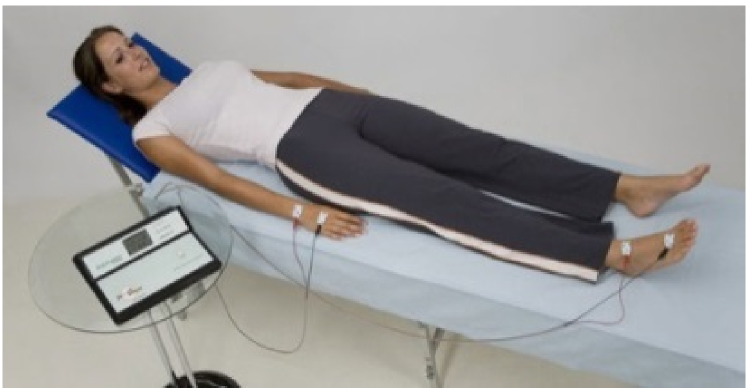


Figure 32. BodyExplorer measurement arrangements for the definition of individual body composition data required by Human Thermal Model calculations.

7.4 Thermal sensation and comfort evaluation results

7.4.1 Thermal satisfaction questionnaire results

Raw thermal sensation and thermal comfort data, obtained from the Intensive Care Unit questionnaire, are presented in Figures 33 and 34. Average values of thermal sensation and thermal comfort votes are -0.74 ('slightly cool' corresponds to value -1) and -0.64, respectively. However, there seem to be huge variations between individual votes: thermal sensation votes range from -4.0 to +3.6, and thermal comfort voles range from -4.0 to 4.0.

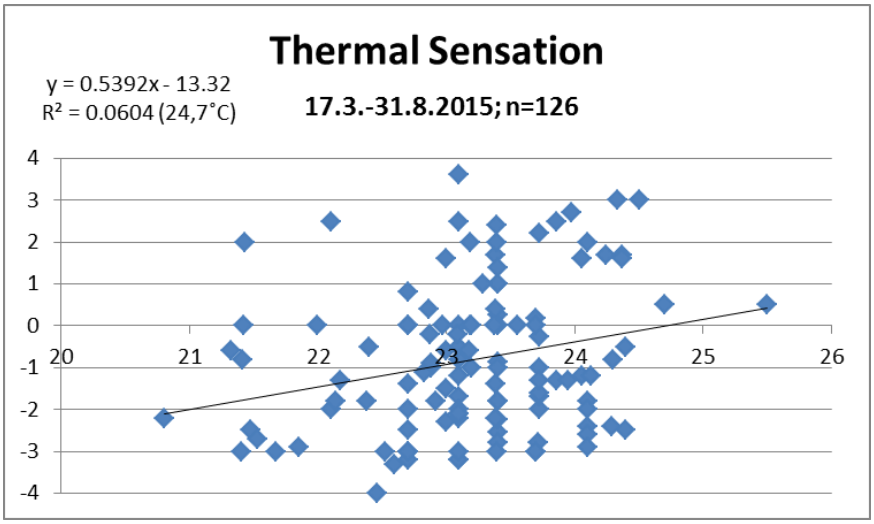


Figure 33. Questionnaire data on perceived thermal sensation from the Intensive Care Unit at Seinäjoki Central Hospital.

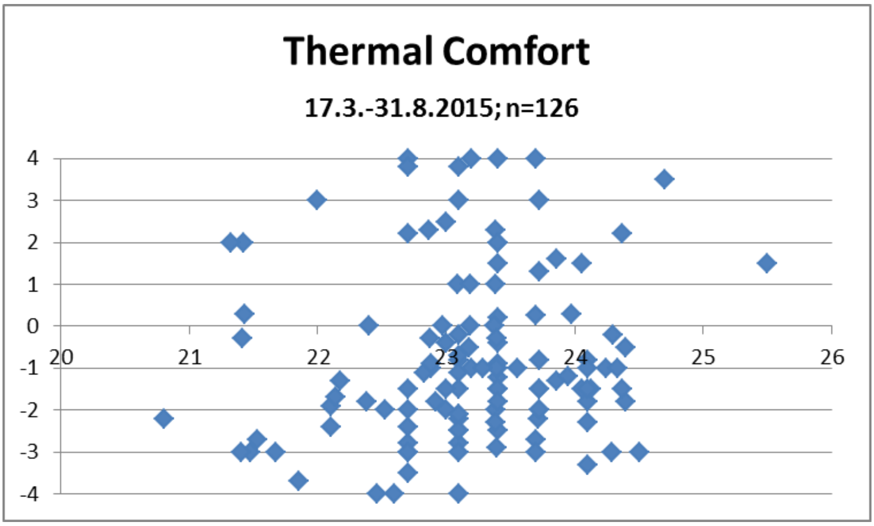


Figure 34. Questionnaire data on perceived thermal comfort from the Intensive Care Unit at Seinäjoki Central Hospital.

When analysing the correlation between indoor temperature and perceived thermal sensations by linear regression, a thermal sensation index value 0 (corresponding to thermal neutrality) is obtained at a temperature level of 24.7 °C for the whole population. However, there are significant individual variations between individuals, which becomes obvious when presenting correlations between temperature and perceived thermal sensation for individuals (subjects 1, 5, and 10) with different body compositions (BF = body fat and BMI = body-mass-index) presented in Figures 35, 36 and 37.

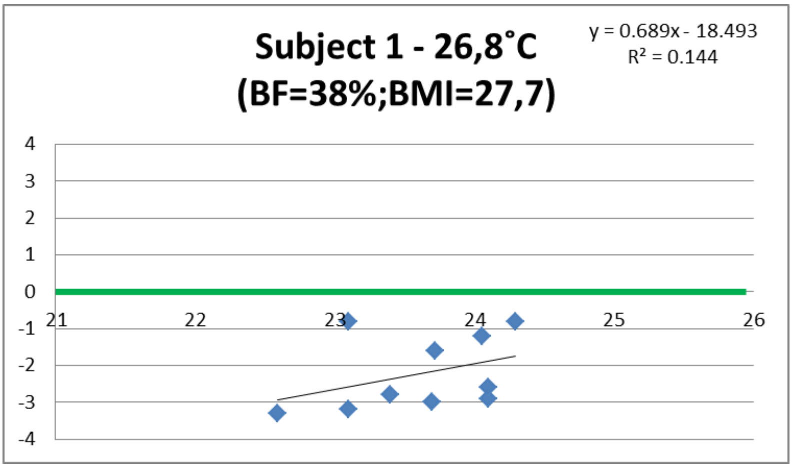


Figure 35. Perceived thermal sensation index values by subject number 1: optimal temperature level of 26.8 °C according to linear regression.

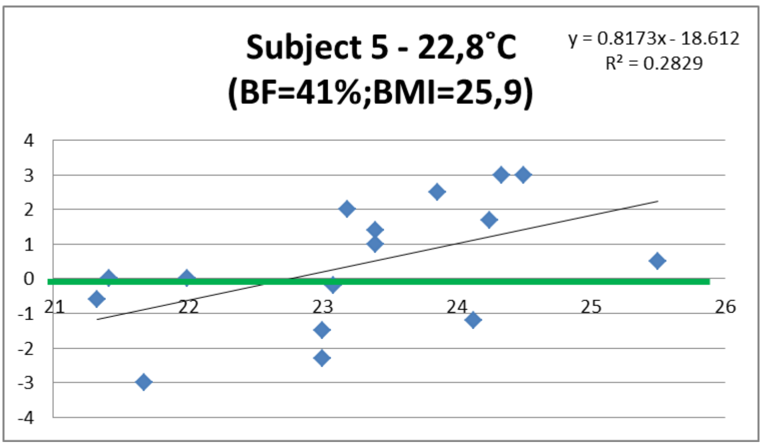


Figure 36. Perceived thermal sensation index values by subject number 5: optimal temperature level of 22.8 °C according to linear regression.

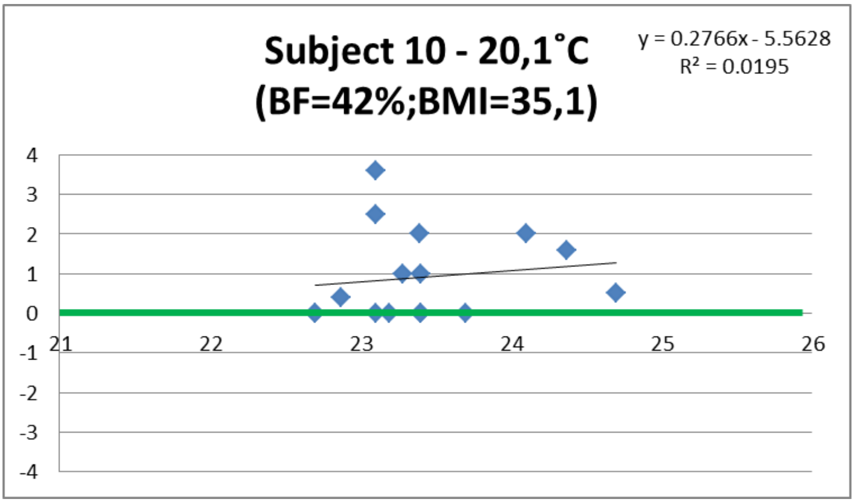


Figure 37. Perceived thermal sensation index values by subject number 10: optimal temperature level of 20.1 °C according to linear regression.

According to the results presented in Figures 35–37, there are obvious temporal variations in the individual thermal sensation index values, and most likely these alternations occur due to changes in activity levels. Nevertheless, there seems to be significant differences in optimal temperature levels for individuals (20.1 °C for subject 10 vs. 26.8 °C for subject 1).

7.4.2 Skin temperature measurement results

Skin temperature measurement results of the four subjects are presented in Figures 38–41 and also thermal sensation and thermal comfort votes at the end of the test period are shown in the top right-hand-side corner of each figure. These results indicate noticeable variations between local skin temperature levels within individuals (especially for subjects 1 and 3). On the other hand, relatively modest variations occurred for subjects 2 and 4. Based on the skin temperature measurement observations, it seems to be impossible to predict thermal sensation and comfort status based solely on skin temperatures. This phenomenon becomes even more obvious when local average skin temperatures are presented in the same figure. Figure 42 presents average skin temperatures in 10 locations for the four test subjects, with test subjects 1 and 4 perceiving the thermal environment to be too cool, and subjects 2 and 3 to be too warm. The measured local skin temperature values simply do not correlate with perceived thermal sensation index values, and most likely this is due to the complex thermos-regulation process of a human body in which both brain and inner organ temperature levels play significant roles in spatial and temporal thermal sensation.

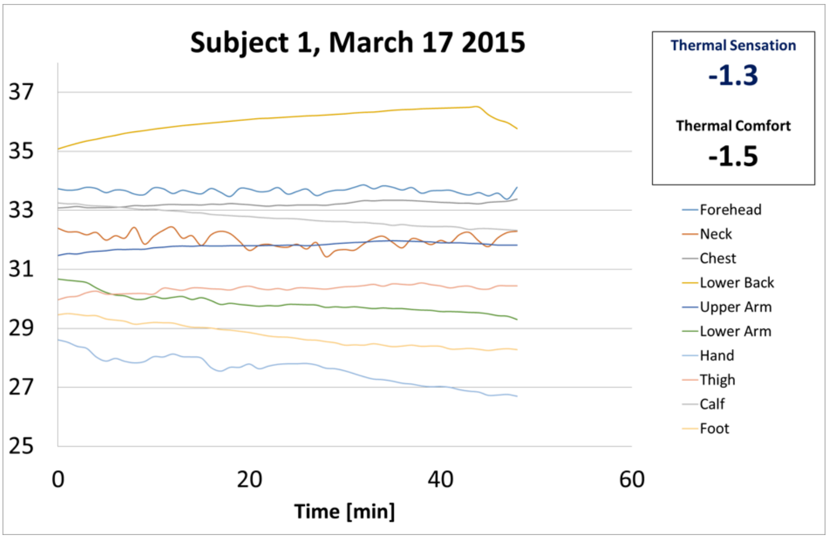


Figure 38. Measured skin temperatures from 10 fixed body locations, and thermal sensation and thermal comfort vote at the end of test period of the test subject 1.

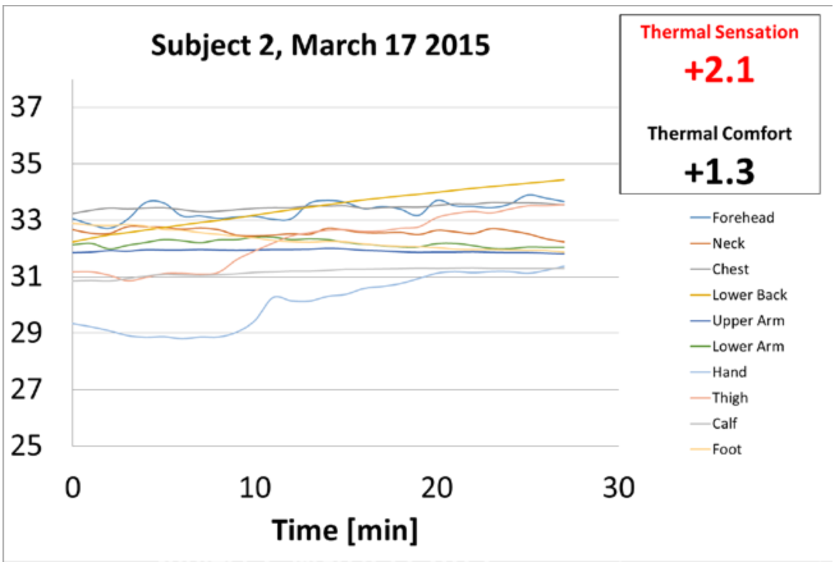


Figure 39. Measured skin temperatures from 10 fixed body locations, and thermal sensation and thermal comfort vote at the end of test period of the test subject 2.

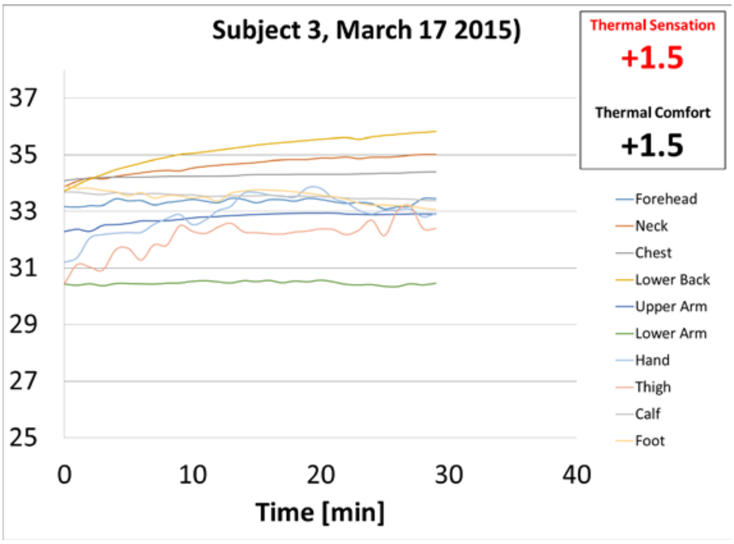


Figure 40. Measured skin temperatures from 10 fixed body locations, and thermal sensation and thermal comfort vote at the end of test period of the test subject 3.

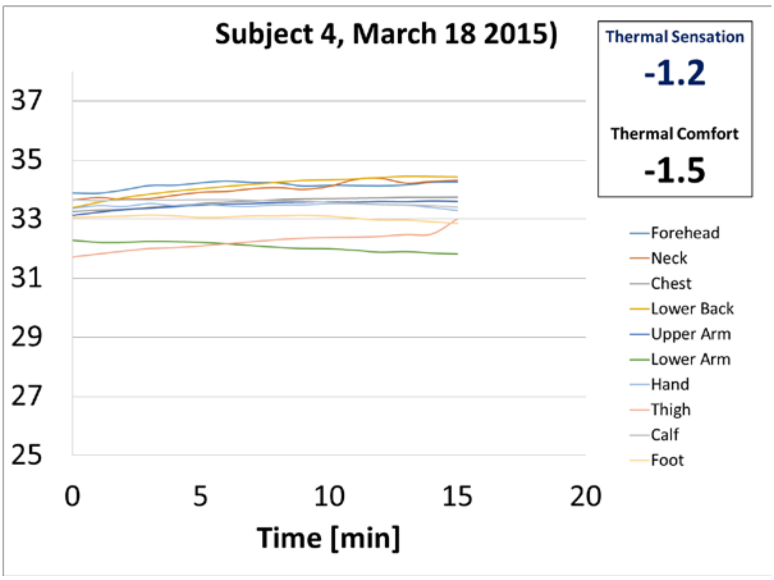


Figure 41. Measured skin temperatures from 10 fixed body locations, and thermal sensation and thermal comfort vote at the end of test period of test subject 4.

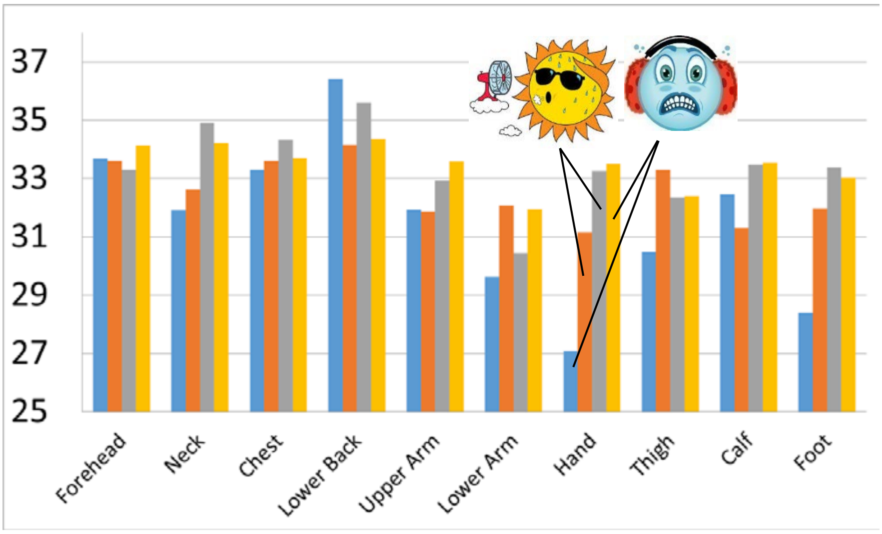


Figure 42. Comparison of measured skin temperatures from 10 fixed body locations of four test subjects, where test subjects 1 and 4 perceived the thermal environment to be too cool and subjects 2 and 3 too warm.

7.4.3 Human Thermal Model calculation results

Body composition measurements were conducted for 25 individuals (18 females and 7 males), and the results are presented in Figure 43 (body fat percentage vs. body-mass-index). The measured body composition data are aligned with the statistical data.

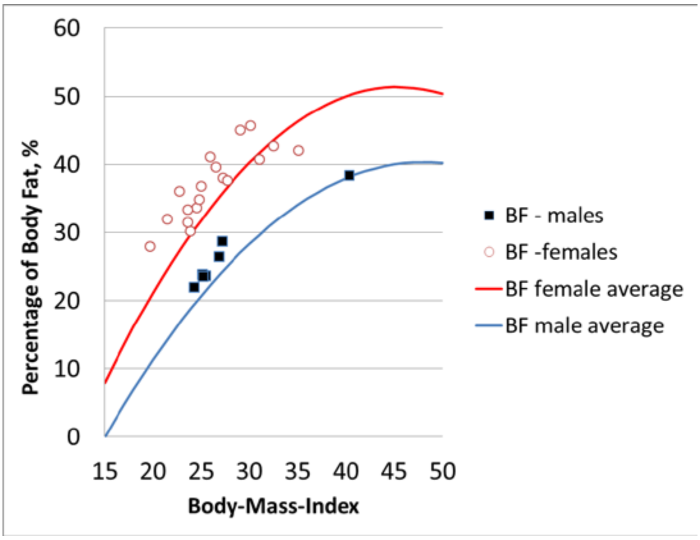


Figure 43. BodyExplorer measurement results (BF refers to Percentage of Body Fat).

When estimating individual human thermal sensation by HTM, operative temperature levels were varied systematically. All other *external* boundary conditions (i.e., air velocity, and humidity) were assumed to be constants. Activity level and clothing were kept constants (1.0 MET; 0.86 clo), corresponding to a seated person with typical nurse clothing. In order to clarify individual thermal sensation, three females and three males with different body composition data sets were adopted for these simulations. All males were assumed to have a body-mass-index of 25, and three muscularity index values were adopted: 1 (high muscularity) corresponds to a body fat percentage of 12%; 0.5 (average muscularity) 23%; and 0 (low muscularity) 34%. For the females, three different levels of body fat percentage were adopted: Low (BMI = 20, body fat = 13%), Average (BMI = 25, body fat = 30%), and High (BMI = 30, body fat = 49%). These body compositions are presented by markers (squares for males, and circles for females) in Figure 44.

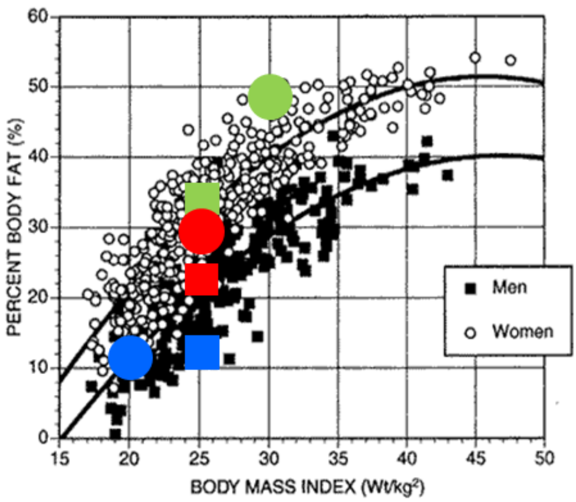


Figure 44. Large population correlation between body-mass-index and percentage of fat (Jackson et al. 2002), and adopted body compositions for HTM calculations shown by coloured markers.

When evaluating the impacts of different operative temperature levels on individual thermal sensation by the Human Thermal Model (HTM), it should be noted that overall thermal sensation index values depend systematically on both operative temperature and tissue type distribution. It is interesting to note also that Thermal Neutrality Temperature (TNT) values (i.e., the values at which individual occupant feels neither cold/cool nor hot/warm) depend on muscularity index values, being 20.7 °C, 22.6 °C, and 24.4 °C (for 50-year-old male occupants with a body-mass-index of 25) with muscularity index values of 1 (high), 0.5 (average), and 0 (low), respectively (Figure 45). Similar results can be obtained for female occupants with low, medium, and high percentages of fat tissue, and their TNT values are 22.2 °C, 25.2 °C, and 26.7 °C, respectively (Figure 46).

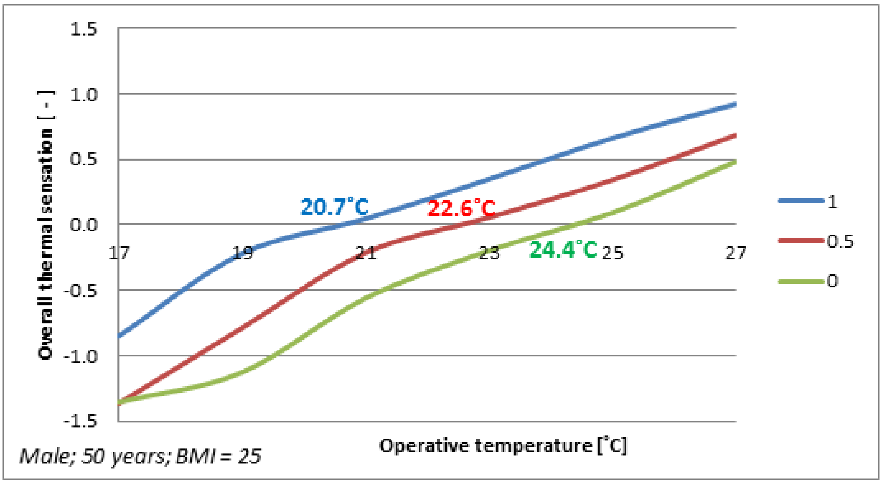


Figure 45. Impact of operative temperature on overall thermal sensation of male occupants with different muscularity index values (1, 0.5, and 0).

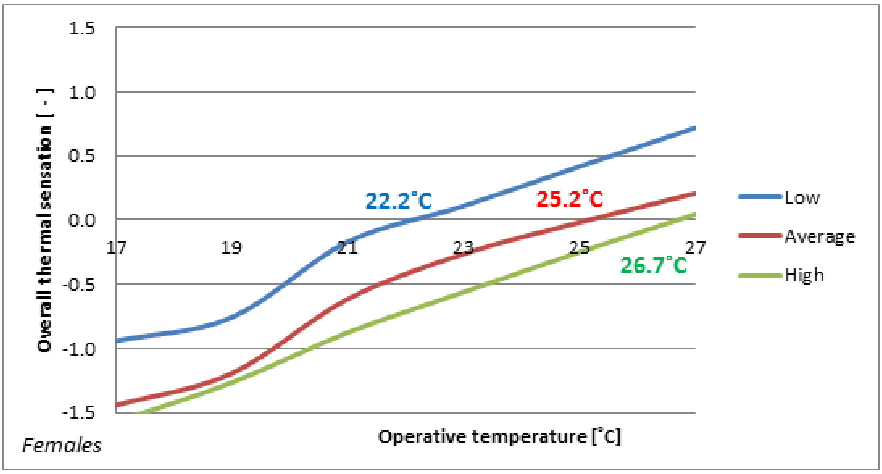


Figure 46. Impact of operative temperature on overall thermal sensation of female occupants with different proportions of fat tissue.

Based on the result obtained in this study, it is evident that individual characteristics have clear impacts on thermal sensation. This is most likely due to individual body fat and muscle tissue ratios, since there exist three orders of magnitude difference between the heat generation of muscle and fat tissues (2.02 W/kg_{muscle} vs 0.004 W/kg_{fat}). Especially gender and individual muscularity seem to have strong impacts on different tissue type distributions – and ultimately on thermal sensation.

7.5 Discussion

The questionnaire study, conducted at the Intensive Care Unit at Seinäjoki Central Hospital, introduced obvious deviations in optimal temperature levels for individuals. The lowest (statistical) individual optimal temperature level was 20.1 °C, and the highest value was 26.8 °C. Similar results have been obtained from Human Thermal Model calculations, in which different body composition data were adopted in order to identify variations in optimal temperature levels for individuals with different body shapes. For the three male test persons, the optimal operative temperature varied between 20.7 °C and 24.4 °C, and for the three female test subjects, the optimal temperature levels varied between 22.2 °C and 27.7 °C, depending on the individual percentage of body fat.

Based on the results obtained in this study, it is recommended that building service systems ought to be designed for and operated with a default indoor air temperature value of 23 °C. In addition, indoor temperature should be adjustable by ±3 °C in order to guarantee individual thermal satisfaction. However, these figures are valid for personnel activity and clothing levels, and patients with different activity and clothing insulation levels might have even broader requirements for optimal thermal environment. Anyhow, this controllability aspect ought to be taken into consideration not only in dimensioning building service systems, but also in designing the control systems of buildings.

In the thermal sensation and comfort field study conducted at the Seinäjoki Central Hospital Intensive Care Unit, an additional valuable piece of information would have been the activity level of a respondent prior to completing the questionnaire. Namely, the results indicate that such data might have brought credibility to the evaluation of temporal thermal sensation and comfort.

Currently, general physiological models from the medical literature are implemented according to the Human Thermal Model. However, there are indications that there might be age-related, seasonal, and individual features that could influence our individual thermo-regulation system. Therefore, more systematic laboratory and field measurements with different individual boundary condition parameter combinations are needed in the future. In addition, more thorough modelling of heat and moisture transfer in clothing and bedding materials would be beneficial when estimating thermal sensation and comfort of the most sensitive patients.

8. Promotion of patient safety and smooth care processes – preparing for change with the Foresight Framework Model

8.1 Background

This article focuses on describing how the Foresight Framework model can be used as a tool in collaborative workshops during the restructuring of nursing care. The purpose of the workshops discussed here was to support nursing staff preparing for work in a new care context, that is, in the new intensive and intermediate care unit to be introduced in Seinäjoki in 2018. The new unit with single patient rooms will be based on evidence-based design and it will bring together staff from three existing units.

Patient safety is a key concept in this article. It is an essential element in high quality care, for which clear objectives and standards have been defined. A number of international guidelines and recommendations, established on the basis of experienced experts' opinions, exist to define such objectives and standards and also to provide guidelines for architectural planning (Brilli et al. 2001, Haupt et al. 2003, Valentin & Ferdinande 2011). Besides quality and risk management, ensuring patient safety also requires making the best of the resources available (Publications of the Ministry of Social Affairs and Health 2009). The anticipation of safety risks becomes especially important during restructuring, or when there is a change in the care context. Nurses in charge of shifts may experience a pronounced change in their role and duties (Miller & Buerhaus 2013). To diminish risks and adverse events, it is necessary that the staff of the organization observe commonly agreed good practices and policies (Publications of the Ministry of Social Affairs and Health 2009). If we want to maintain and enhance high quality intensive and intermediate care, we must look at the challenge from the perspective of care processes and care co-ordination.

8.1.1 Challenges in patient safety in intensive care

Demand for critical care among adults seems to be increasing (Rhodes et al. 2011, Reinikainen 2012). From the patients' and family's perspective, critical illness and the environment at the ICU are a stressful experience (Engström & Söderberg 2004, Almerud et al. 2007). Similarly, caring for critically ill patients is challenging and demands expertise and ability to endure stress. The work is complex and fast-paced and nurses are often required to make urgent high-risk decisions based on incomplete data. There is thus a higher risk of medical errors than elsewhere (Beckmann et al. 2003).

Hospital-acquired infections are among the challenges that deserve special attention in the intensive care environment (Gerberding 2002). Deviations from safe practice standards have been found to be associated with higher infection rates (Burke 2003). Unfortunately, medication errors have also been found to occur, most commonly due to wrong dosage and most frequently associated with cardiovascular drugs, anticoagulants and anti-infective agents. Adverse incidents are most common during treatments and procedures, especially during the ordering or execution of medications used for treatment. Other common errors have been found to occur in reports or communication of clinical information. Care providers may also fail to take precautions or to follow protocols designed to prevent accidental injury (Rothschild et al. 2005).

Critically ill patients' overarching need to feel safe and feeling of safety are influenced by family and nurses caring for them (Hupcey 2000). As the presence of family members is reported to be important in the support of the critically ill patient (Bergbom & Askwall 2000, Hupcey 2001, McKiernan & McCarthy 2010), we should consider the perspectives of both patients and their families during the time in the unit (Eriksson et al. 2011). In the same way, the caring relationship has been repeatedly perceived as providing an important degree of comfort and security. Nursing care actions can therefore be seen as vital factors for patients overcoming the experiences to which they have been subjected (Granberg, et al. 1998).

The challenges concerning patient safety should be dealt with by increasing discussion between nursing and medical staff on factors that influence safety (Thomas et al. 2003). More effective communication, better functioning teamwork and reaching a common understanding of guidelines and practices can promote the welfare of patients, families and staff (Sexton et al. 2000, Pronovost et al. 2003). Good teamwork is essential to ensure patient safety (Manser 2009). The nurses in charge of shifts have a key role; they make daily decisions whose purpose is to ensure smooth patient care processes. Most decisions are related to staffing, know-how, the patients' situation, vital functions and various interventions (Lundgren-Laine 2013).

8.1.2 Challenges in restructuring Intensive Care Units

Merging of units, re-engineering and other restructuring is relatively common in hospitals (Aiken et al. 2001, Way et al. 2005, Nordang et al. 2010). According to a study, the merger of small units into larger ones in intensive care units is believed to enhance efficiency (Valentin & Ferdinande 2011). On the other hand, a number of studies report nurses' concerns about the quality of patient care due to restructuring (Laschinger et al. 2001, Wynne 2004, Vifladt et al. 2016). It is therefore important to draw attention to the safety culture, here defined as an integrated pattern of individual and organizational behaviour based on shared values that promote patient safety (European Union Network for Patient Safety 2010), when planning and accomplishing restructuring.

Restructuring of units can influence the safety culture 1–4 years after the change, as revealed by a study of Vifladt et al. (2016). According to another study, nurses' decreased perception of the care quality only improved seven years after the onset of restructuring (Way et al. 2005). Three dimensions of the safety culture that have been found to be most vulnerable during restructuring include manager expectations and actions promoting safety, staffing, and teamwork within hospital units (Vifladt et al. 2016). The first of these dimensions involved nurses' experience that in restructured units, there was less support from the management concerning daily problems and decreased feedback and positive rewards. (Aiken et al. 2001, Laschinger et al. 2001.) Nurses felt that they received less feedback when they suggested safety improvements. The second dimension, staffing, means a manageable workload and adequate use of staff. One of the studies discussed above (Vifladt et al. 2016) reported that nurses in restructures units were concerned about staffing and were busier than their peers in units that had not been affected by change. Thirdly, there was a negative development of the teamwork culture with less co-operation and opportunity for mutual support.

In conclusion, managers have a decisive role in the promotion of a safety culture, and they are also in a position to influence the outcome of the restructuring process (Corrigan et al. 2001, Salmela et al. 2013). In order to develop new, well-functioning teams, managers themselves require teamwork skills, for example, situation monitoring and communication skills, the ability to provide and receive support, as well as general leadership competence (Vifladt et al. 2016).

8.2 The purpose and objectives of the development project

In the workshops arranged for this development project, the ultimate objective was to promote intensive and intermediate care patients' safe, high quality care and smooth care processes by creating a theoretical model. The workshops aimed at identifying, anticipating and evaluating critical points in planning and introducing the new intensive and intermediate care environment. Any challenges or problems were named as systematically and concretely as possible in the model, so that human error and overburdening of staff could be prevented.

8.3 Collaborative workshop methods

All nursing staff members of the intensive care unit participated in the collaborative workshops, whose purpose was to create a foundation for multiprofessional teamwork in the future unit, but also to support and consolidate nursing staff's and the secretary's experience of being in command of their work. An effort was made to provide all staff members with an opportunity to express their ideas. Such dialogue was thought to be the best way to prepare for the changes and challenges brought on by the new single patient room model. Four rounds of workshops were arranged during 2015. Each round comprised 4–5 components, with 5–10 persons working together at a time.

8.3.1 The Foresight Framework Model as a tool in the workshops

The work carried out in the collaborative workshops was based on the Foresight Framework Model developed by Carleton et al. (2013). Foresight is a capacity that allows us to think ahead and respond to future eventualities through the consideration, modelling and creation of alternatives. In other words, the idea is to expand the perception of the range of options available to staff and organizations. It would be beneficial for staff and management to think about the future routinely. Ideally, this should take place in a climate where individual thoughts about the future can be freely expressed and collectively considered (Conway & Stewart 2005). To put it differently, foresight requires that thinking moves from the individual to the collective and from the implicit to the explicit (Voros 2003).

In workshops based on the Foresight Framework Model, groups are asked for their ideas and insights concerning the near future, for example, through brainstorming, mind maps or modelling of processes (Slaughter 1999, Voros 2003). Modelling means describing the future action processes in practical terms. Ideas will emerge and innovative solutions can be found if the organization acts in time and the management indicates an appreciation of the staff's competence and contribution. In this anticipatory and innovative process, clinical organizations can benefit from an outside perspective, such as provided by teaching staff in universities of applied sciences.

The Foresight Framework model includes five planning phases, designed to identify and assess new situations (for example new contexts and technologies) and to anticipate clients' or patients' current and emerging needs. The model is also useful in identifying and naming problematic areas rapidly, creatively and systematically. The five phases build on each other. The first phase is called Perspective, as here the aim is to develop a long clear view based on the organization's history. In phase 2 or Opportunity, participants focus on exploring new promising opportunities. In Phase 3, Solution, a practicable prototype is constructed for a future solution and in phase 4, Team, the focus is on uncovering participants' (hidden) abilities, strengths and creativity. The final phase is called Vision. Participants formulate and communicate an innovation vision that will guide their future actions (Carleton et al. 2013). Figure 47 illustrates how the Foresight Framework model was applied in this development project.

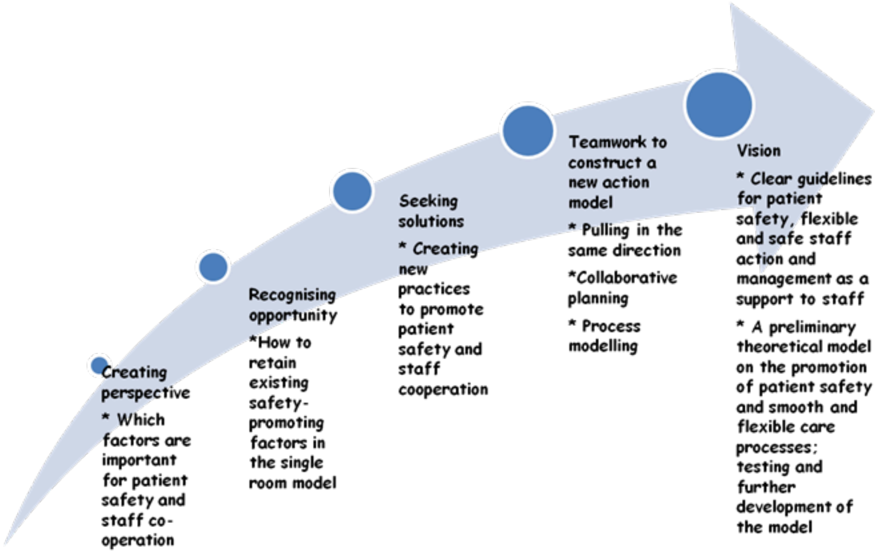


Figure 47. The Foresight Framework Model as a tool in the workshops.

8.3.2 The Pathfinders Method

Besides the Foresight Framework Model, the workshops applied the Pathfinders Method, recommended for use when new ideas need to create paths to success. The method uses knowledge of how a team likes to proceed and how past innovation ideas have established themselves in the organization. Pathfinders is based on the idea of wayfinding, which means that the idea of navigating physical space is applied, with visual maps, cues and landmarks. The map and its landmarks represent the team's journey based on explicit and implicit rules within the organization. A straight line stands for the recommended route for new ideas within the organization and the team should note which major milestones they must follow to gain successful approval (Carleton et al. 2013.)

8.3.3 Workshop objectives, implementation and main results

The first workshop of the development project concentrated on identifying patient safety factors that need to be considered before the introduction of the new unit. The following factors were listed as essential for ensuring patient safety:

- adequate staff resources
- a model for a clear division of work
- ensuring instant assistance in critical situations
- receiving help from colleagues in challenging nursing situations
- ensuring high quality reports and consultation
- logical division of patients into modules

- ensuring audibility and visibility of alarms in all patient rooms
- securing asepsis and patient hygiene
- ensuring that urgently required medicines and instruments are easily accessible and close to patients
- securing the proper function of equipment
- minimizing adverse events by the use of HaiPro, a Web-based tool for reporting patient safety incidents

The first workshop also aimed at gaining an overall perspective and a clear view of factors in the existing action model of the intensive care unit that have been essential to patient safety and smoothness of care processes and should be retained in the new model. The following features were appreciated as worth preserving:

- high quality team work
- mutual appreciation among colleagues and co-operation based on dialogue
- high standard of basic nursing care
- beginning the shift by checking infusions and equipment
- minimizing errors with the help of checklists and appointed areas of responsibility

In the second workshop, participants aimed at the identification and anticipation of challenges and options embedded in the new operating context and action model. Their task was to examine how the potential of the new context related to patient safety, development of expertise and command of work. The challenges and options discovered involved the following:

- having to make independent decisions
- challenges in communication
- managing sudden aggression in patients
- safety and functionality of patient rooms
- paying attention to family members

Secondly, during this workshop, participants concentrated on finding ways to promote nursing staff's smooth action and command over work. The following factors were found to be beneficial:

- increasing open dialogue
- developing the orientation of new employees
- more effective sharing of tacit knowledge
- developing a mentoring system
- developing 'a culture of offering help'
- continuous training on the use of equipment
- securing a shared documentation practice
- arranging various training events

Participants wanted to draw attention to the need to increase staff resources at the introduction of the single patient room model. The role of the ward manager and assistant ward manager will change, as they will be required to contribute more to ensuring patient safety and occupational safety. Staff members expect support, encouragement and their active presence in routine nursing situations. The importance of having an adequate number of experienced nurses in each shift was emphasised. The management is also expected to actively contribute to the creation of a daily safety culture. This would involve intensifying the flow of information during the transition period, promoting group spirit and preventing the formation of cliques. Workshop participants pointed out that the allocation of nurses might become challenging if the level of expertise is to be maintained throughout all shifts.

During the third workshop round, participants defined the essential components of the new action model and created preliminary process models to guide all nursing care in the unit. The work resulted in shared guidelines for the following duties and situations:

A) the patient's admission to the unit
B) obtaining assistance in basic patient care
C) obtaining assistance in emergencies/critical situations
D) the patient's transfer to another unit
E) optimal role of the nurse in charge of the shift
F) orientation of new employees
G) promotion of co-operation between modules

A summary was produced of the process descriptions based on the third workshop round and process modelling work. This preliminary theoretical model starts with the core idea of creating a safe, continuous care pathway for the critically ill patients from admission until transfer to another unit. The final version of the theoretical model will be published after confirming the staff structure and the alarm and communication systems of the new unit. The model will be refined and empirically tested in the new care environment.

The nurse in charge of the shift (henceforth the co-ordinating nurse) has a pronounced role in this model. Only an experienced nurse or assistant ward manager is able to function in this position. To be able to concentrate on co-ordinating the care, she or he should not have any primary patients. The co-ordinating nurse is responsible for patient safety and smooth care processes. This requires constant assessment and allocation of staff resources, as well as assignment of further workforce if required. The co-ordinating nurse selects the patients' primary nurses and supports the nurses' coping by updating their need for assistance repeatedly during the shift. The co-ordinating nurse also appoints colleagues to provide assistance and the members of the emergency teams for each shift. Finally, she or he receives communications about incoming patients, enters the information into the electronic data system, informs primary nurses of the new patients and actively updates the overall electronic system, entering information on beds, reasons for admission, diagnoses, current statuses and upcoming tests and examinations.

The new model will be helpful when new employees are recruited, as a thorough orientation is essential for patient safety and smooth care processes. A clear framework and orientation plan help both the newcomer and the mentor to reach the objectives. First, it is necessary to define the objectives of the orientation in clear terms and to choose appropriate assessment tools. A good mentor knows how to encourage and give the learner adequate time and an opportunity to ask questions. Open dialogue should be encouraged. The mentoring should take place gradually, according to the learner's ability to assimilate new knowledge. The orientation must include essential practices, care protocols and care processes, for example, the daily rhythm and the patients' general care and observation, which form the foundation for all other action in the unit. It is equally important that the use of instruments and equipment (monitors, respirators, infusion and dialysis equipment) and pharmacological care are studied carefully. The new employee needs to practise managing emergencies with emergency teams together. He or she should also be aware of the co-operation policy with important partners.

Lastly, the third workshop aimed at identifying critical points in the patient's safe care pathway. It was found that transfer to another unit poses risks to patient safety. This means that special attention must be paid to patient transfers, to changes in the care context, and to ensuring the flow of information between units. A clear model on the essential components of patient admission, care and transfers can help to ensure smooth care and minimise risks. The model can also make it easier to define areas of responsibilities and to ensure that all necessary action has been taken. Clearly defined roles and tasks result in more flexible action and also reduce staff stress. Figure 48 illustrates the critical points in the patient's care pathway.

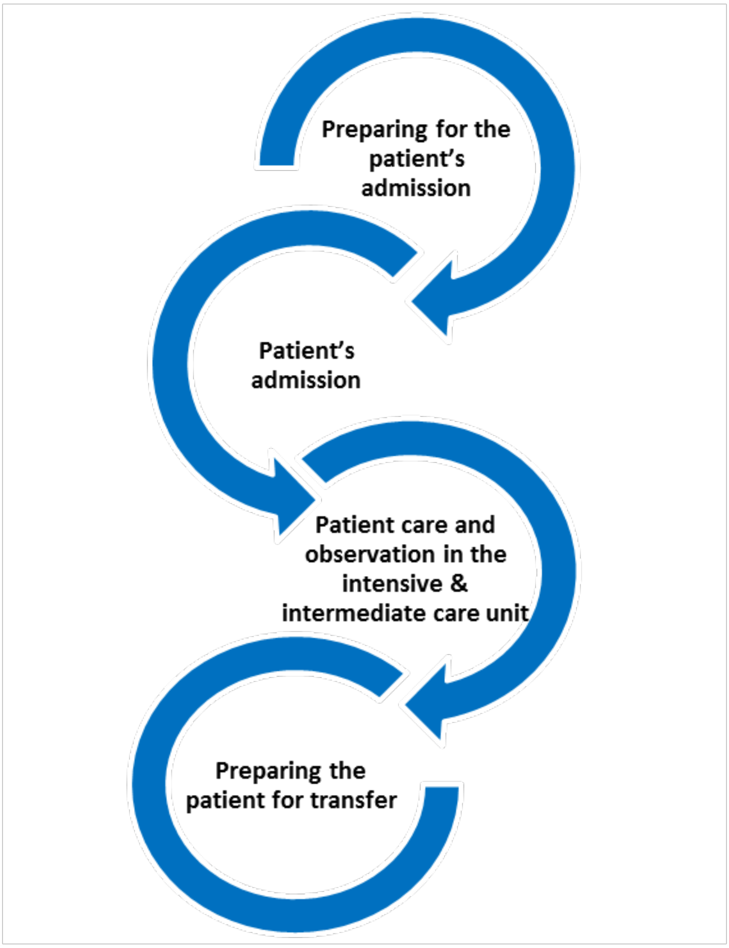


Figure 48. The critical points in the patient's care pathway in intensive and intermediate care.

The fourth round of workshops summarised the most important results of the earlier rounds. Participants discussed ideas for promoting co-operation and creating a positive work climate in the new unit, which brings together staff from three current units. Other important contributors to a good work climate include a flexible, encouraging atmosphere, support from management, appreciation of colleagues and arranging after-hours activities. Participants also wrote a short narrative or a visionary story on the expected challenges and peer support in the new care context. The narratives will be analysed using inductive content analysis and the results will be utilised in the further planning of work.

8.4 Conclusions and clinical implications

The collaborative workshops of nursing staff described above brought forth a great number of elements that should be considered when planning and launching new intensive and intermediate care units. Merging units, bringing their staff together, and working in a new context are major changes with multiple effects. In the project of Seinäjoki Central Hospital, where a new intensive and intermediate care unit based on evidence-based design will be introduced in 2018, the most concrete changes will occur at the level of patient care. The introduction of single patient rooms requires staff awareness and preparedness to work more independently, although still supported by team and module work. Effective alarm systems must be installed to ensure that primary nurses receive optimal assistance for both emergencies and basic care situations.

The workshops also produced a preliminary theoretical model on the essential care processes. The model will be tested, refined and published later. The core idea of the model is to ensure safe, continuous care throughout the patient's care pathway, that is, from admission until transfer to another unit. The model will help staff gain an overview of the care processes, clarify their roles and responsibilities and enhance co-operation. In will also be useful in the orientation of new employees.

Finally, the workshops produced a great deal of valuable information about areas still in need of further development. The identification of critical points will help management anticipate challenging situations that require more staffing. Open dialogue, appreciation of colleagues and a culture of offering help and support can improve the smoothness of all actions, promote staff welfare, and minimize stress.

9. Sensors as a service

Sensors are an essential part of many modern technical systems. In the hospital environment, the technical systems are not only the most common ones (like automatic ventilation) but also systems that support personnel work and increase patient safety.

9.1 Questionnaire

The questionnaire in this project was developed to be ICU specific and included 3 parts:

- **Background** info on the person habits (use of a phone, tablet, games)
- What are the **functions** the person would like to see happen automatically, if possible, that is, the 'service'.
- What is the **technology** that is in use for detection/action, that is, the 'sensor'.

The questionnaire (in Finnish) is included in Appendix C.

There were five response options:

- Definitely no
- Possibly no
- Possibly yes
- Definitely yes
- I don't know

There were also some free text questions.

The objective of the questionnaire was to find the 'top' list of services that personnel would like to support their work, as well as a 'top' list of the services they would not to have. The information is then made available in the design phase so that the designers can choose the best alternatives by default.

9.2 Results

The questionnaire was carried out in October 2015. The number of respondents was 25 persons (about 50% of ICU personnel). The average age of respondents was 31 years. All persons (100%) used a smart phone daily and over 90% used a tablet daily or occasionally.

Almost 50% of persons played computer games daily or 2–3 times per week. The rest (over 50%) never played computer games.

Figures 49 and 50 present the answers to the services questions (numbered 7–25) as a percentage by category (definitely no…I don't know).

From Figures 49 and 50 it can be seen that the top 4 services are:

- door opening (fully or partly),
- switching on a water tap,
- switching on/logging into the computer,
- setting the glass walls to be opaque

Next on the list with very high scores are the need to adjust the indoor air (temperature and quality).

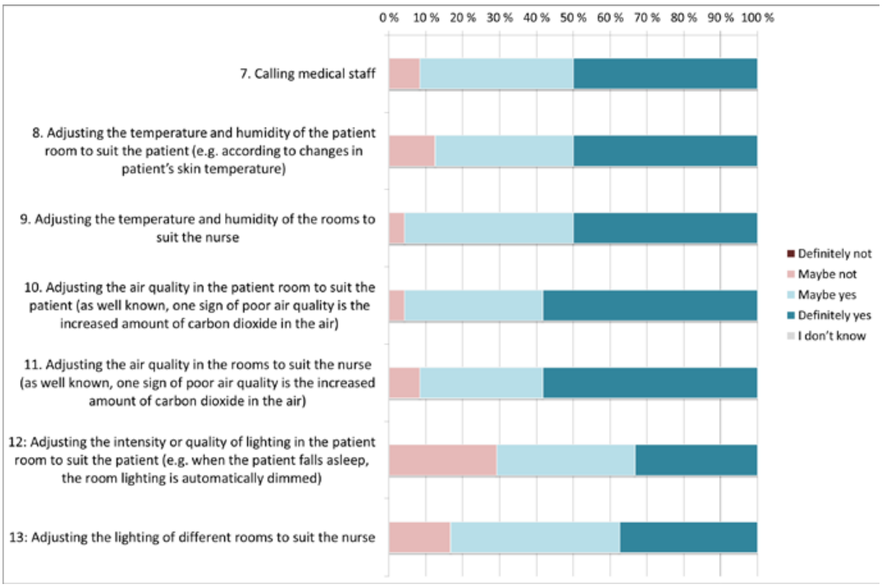


Figure 49. Services List 1.

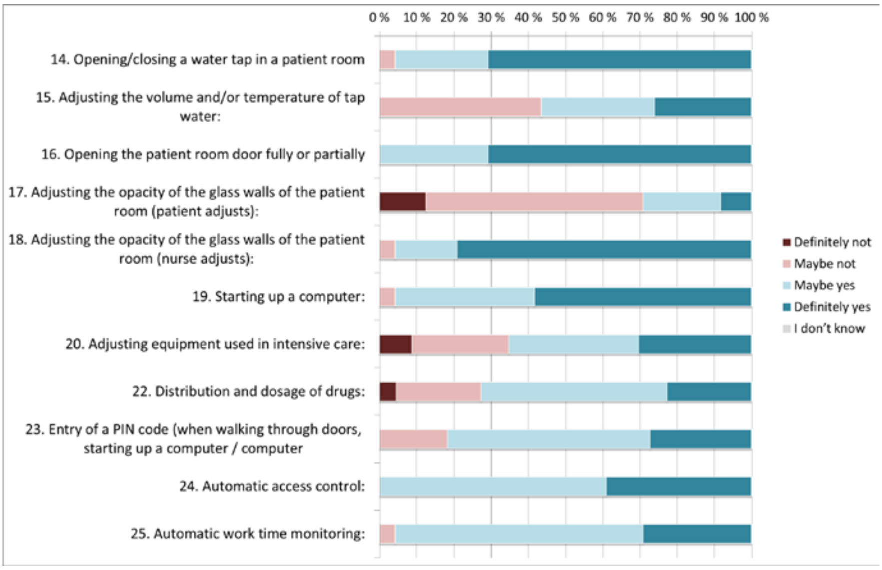


Figure 50. Services List 2.

- Figure 51 shows the answers to the technology questions (numbered 30...37) as a percentage by category (definitely no… Indifferent)

From Figure 51 it can be seen that the top 3 of the technology are:

- smartphone,
- ID card or access control token ('tag')
- smart wristband or other smart 'accessory'.

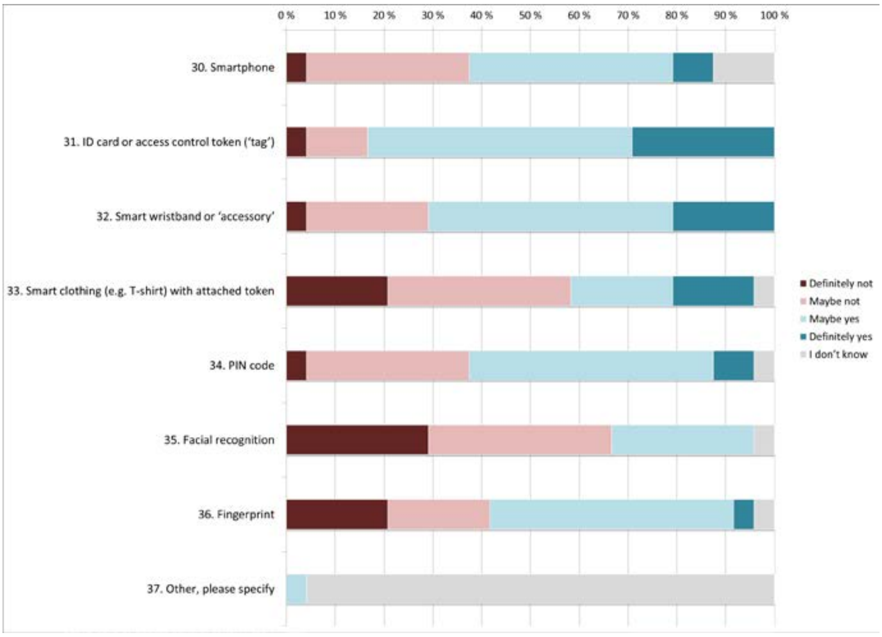


Figure 51. The means list.

In addition to the categorized questions there were a couple of open questions with free textbox. The most important open question was about what devices in the room you would like to see used / automated, if possible.

The top three devices mentioned by the respondents were:

- monitors
- infusion automation
- respirator

9.3 Discussion

The questionnaire showed clearly that there is a need and willingness to have automated actions as services to support ICU work and patient safety. The state-of-the-art offers several opportunities to exploit sensors for detection and control. Care equipment like infusion devices are likely to see more automation and control in the near future. However, automation of care equipment divided opinions most strongly.

10. Technical requirements and the design process

From a technological perspective – both HVAC and maintenance-wise – the current intensive care unit has been designed and implemented according to the views and know-how of its day, and is now at the end of its life cycle. The problems of the old technology have culminated in unpleasant ergonomic conditions for the staff and patients (e.g. ventilation, heating, lighting, acoustics, etc.). From a technological perspective, the largest culprits are the ventilation and temperature control, which as such was cutting-edge technology back in its day. The insufficiency of the ventilation's current implementation compared with today's requirements is emphasised in the pressure ratios of the rooms, the thermal load, feelings of draught, etc.

As an example of the current situation, the air from the intake ventilation machine is purposively very cool due to the thermal load on the premises. The purpose has been to manage the temperatures on the premises, while not allowing the temperature in the ICU to rise too high. Air is unevenly spread in the area, as air volumes are too small relative to the overall premises. This causes problems in the conditions in the ICU.

These issues have a significant impact on maintenance due to the placement of work orders by users looking to bring about an improvement in the conditions. To improve the overall conditions, the design of the new premises should take into account individual ventilation controls (e.g. air volume, temperature, pressure ratios, etc.). A very important facet of individual control is the even distribution of air in the space to minimise the feeling of draught, as the thermal load on the future premises can at times be significant, which poses a challenge for the building technology to create ideal conditions.

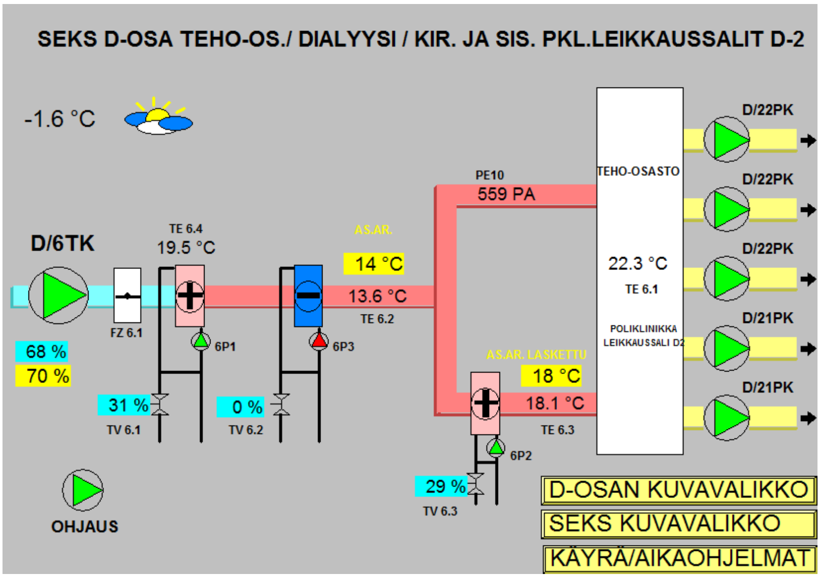


Figure 52. D6TK ventilation (building automation graphics of the current situation).

10.1 Requirements based on research

As an example of a research-based requirement, the need for room-specific individual temperature controls could be mentioned. According to research, the perception of ideal conditions can differ by as much as six degrees between people. This brings new perspectives and poses new challenges in the design of the new ICU with regard to the goal of having room-specific controls.

10.1.1 Temperature control and individuality

The purpose is to have room-specific temperature control, with an adjustment range of 23 degrees +/- 3. The objective is to achieve the desired temperature as evenly as possible in the room via controls and ventilation “terminals”, taking the surroundings into consideration. According to the recommendations, the best indoor condition class today, S1, is 21.5 degrees +/- 1.5, and the temperature must remain within this range for 95% of the time. This is used almost without exception as the design target when aiming for good indoor conditions.

10.1.2 Acoustics and noise conditions

For example, install a sufficient number of ventilation “terminals” so that the noise from the ventilation will not be a nuisance.

10.2 Requirements from a technical viewpoint

From a technical viewpoint, newer and more controls are needed in building automation, for example, aimed at bringing more individual controls to the premises. For example, several temperature sensors can be installed, with their average calculated and used to drive temperature control.

10.2.1 Functional requirements

By taking the requirements for lighting, ventilation, etc. into consideration in the implementation of the new ICU, it is possible to achieve an energy efficient solution. LED lighting with versatile adjustment is energy efficient and user friendly.

Ventilation and heating control that is as individual as possible will make maintenance easier and should significantly decrease the number of work orders.

Any malfunctions can often be detected before the user notices a problem. This can be achieved by investing in building automation and adding controls and sensors to it. If necessary, the technical staff can monitor/adjust the conditions from 'remote terminals', which in turn serves as preventive maintenance.

10.2.1.1 Door opening

The functional requirements for electric sliding doors are:

- opening sufficiently
- possibility for partial opening
- operation controlled without requiring touch
- hygiene

10.2.1.2 Water tap opening

Ensuring good hand hygiene among doctors, medical staff and visitors is without question the most important means of preventing the spread of infections between ICU patients; this is applicable also in units comprising single-patient rooms. Hand sanitizer dispensers and hand washing stations that are sufficient in number, correctly located with regard to functions, and usable aseptically without touching are essential for ensuring hand hygiene.

Even if hand hygiene is in order, the water stations in ICUs where large amounts of wide-spectrum antibiotics are used tend to become colonised by bacteria of the Pseudomonas family. When temperature and humidity are suitable, they can attach even to a steel surface as a biofilm. For healthy people, these pathogens are harmless, but for a gravely ill ICU patient there is a real possibility of developing severe infections from contaminated water. For this reason, the regular microbiological sampling, disinfecting of fixture components and replacement of water fixtures must be simple and quick.

10.2.1.3 Identification without touching

With regard to the spread of infections, smart medicine cabinets that open without touching with an ID card or an equivalent personal identifier are recommended for ICU environments.

For information security reasons, it is justifiable to increase the use of VR certificate cards when logging into the hospital network, and also the clinical information system of the ICU.

10.2.2 Heating and cooling

Washing rooms are taken into consideration in the design of the new ICU; their heating was previously implemented through ventilation. Floor heating is now installed in almost all washing rooms, with the aim of even temperature, controllability and a lack of draught.

10.2.3 Dynamic lighting

The patient rooms has planned to have dynamic lighting. Dynamic lighting is lighting that follows the daily cycle. Colour temperature is following the circadian rhythm. The research has showed that light can increase patient satisfaction, comfort, mood and quality of sleep thus supporting recovery.

10.2.4 Acoustics

In 1999, WHO released the technical report ‘Guidelines for community noise’ and it concludes that for most spaces within the healthcare segment, critical effects of noise are sleep disturbance, annoyance and communication interference. The guideline demands that the L_{Amax} (A-weighted, maximum sound level) should not exceed 45 dB(A) during the day and evening – and during the night the guideline value is 30 dB L_{Aeq} (A-weighted, equivalent sound level). But how is it in reality? Research (Busch-Visniak et al. 2005) has shown that from the 60’s to 2005 the sound levels in hospitals have increased on average 15 dB during the day and 18 dB during the night and the sound levels are way above the recommendations. In some cases the sound levels are measured to be above 60 dB during the night and 70 during the day. This noise level is so high that it is difficult to sleep and the recovery of the patients is threatened at the same time as the staff needs to stress their voices to be understood.

Sound levels were measured at Seinäjoki Central Hospital intensive care unit. Results are shown in Table 4. Measurements were done during normal activities at unit. They include sounds from staff, patients and equipment. Figure 53 shows measured L_{Amax} values during night (measurement no. 6).

Sound levels are high compare to above mentioned values and there is big risk that noise cause negative effects on patients sleep and recovery as well as staffs wellbeing and stress level.

Possibilities to reduce sound levels are:

- to use single patient rooms
- to reduce noise from equipment
- to improve room acoustics by using sound absorbing materials on ceiling and walls
- to improve sound insulation between different spaces

Table 4. Measured equivalent and maximum sound levels.

1.	measurement location	$L_{A,eq}$	$L_{A,max}$	duration; time
2.	intensive care (neuro), patient	52 dB	87 dB	12:20–13:20
3.	intensive care (neuro), office	55 db	81 dB	13:23–14:23
4.	intensive care, patient	59 dB	82 dB	14:32–15:32
5.	intensive care, office	53 dB	82 dB	15:34–16:34
6.	intensive care, patient, nigth	53 dB	87 dB	17:00–11:00
7.	intensive care, corridor	53 dB	93 dB	11:15–12:15

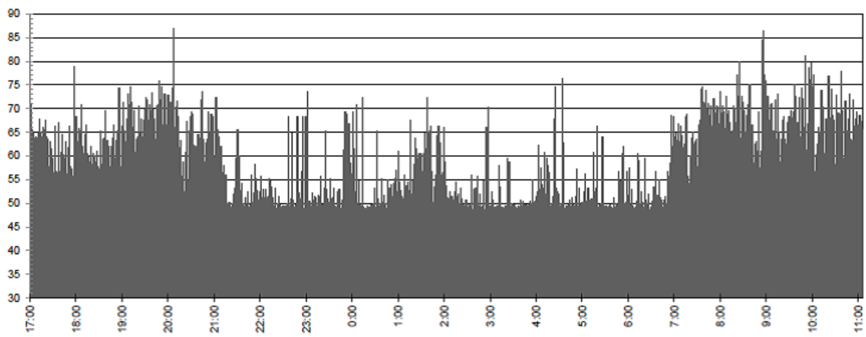


Figure 53. L_{Amax} values (dB) during measurement no 6.

10.2.5 Meters, sensors

For example, installing several temperature sensors in a room enables more accurate control of temperature adjustments. The locations of the sensors are designed according to the surroundings. Implement two model rooms with more sensors with the future in mind. Control can be implemented from different sensors for testing purposes, for example, from the exterior wall and a warm wall, while calculating the control value from their average.

10.2.6 Building automation

The entire system affecting climate control must be controlled from the same building automation system. The lighting and doors are controlled by different systems, but the HVAC systems are integrated into a single system.

10.2.7 Future and device control

Already a couple of years ago, the international research institute Forrester warned that the information security threats facing hospitals are constantly increasing, as more and more hospital systems are connected to various information networks. In addition to the building automation systems of hospitals, the information security of patient care information systems – even individual treatment devices – is estimated to be at least a decade out of date compared to the common standards in the field.

Hostile parties can hinder the operations of an entire hospital very extensively by attacking its building automation. A hospital with even a single critical part of its infrastructure disabled is practically non-functional.

When discussing the requirements to be set on the medical devices of a hospital and, in particular, the ICU, the need to arrange wireless data transfer between the patient, the devices, clinical information systems, the patient record system and the hospital's other information systems always comes up. This wireless requirement – as great as it would be if fully realised – involves not only major technical problems but also significant information security threats.

And this is no science fiction: a very recent news article from February 2016 reported that the American Hollywood Presbyterian Medical Center was recently held to ransom for USD 3.6 million after malware shut down its patient information system for several days. Even now, there is no certainty over whether patient information ended up in the wrong hands.

10.3 Design

The target temperature of the ICU rooms was set at +23 °C during the design process. This temperature was settled on based on individual thermal sensation measurements carried out by VTT. Users can also adjust the target temperature room-specifically by +/-3 °C according to their current needs.

The cooling and heating power needs of the ICU rooms were examined by means of simulations. The following Figures 54 and 55 present the results of cooling and heating simulations done with Granlund’s RIUSKA software. The simulations can be used to confirm both the cooling and heating power design values, so that on a warm day, the room can be cooled to 20 degrees (= 23–3 degrees) and, correspondingly, on a cold day, the room can be warmed to 26 degrees (= 23+3 degrees).

Figure 54. Cooling simulation with Granlund's RIUSKA software.

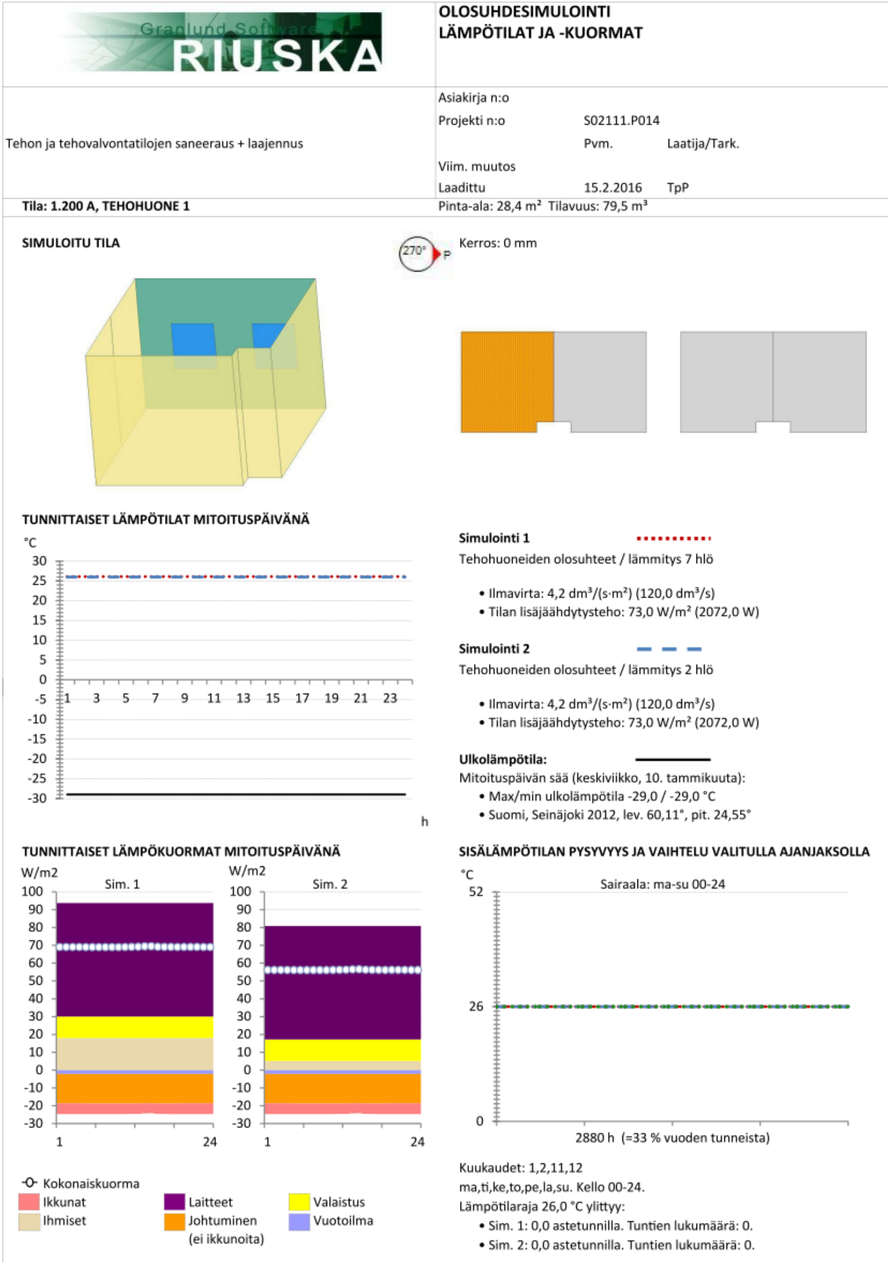


Figure 55. Heating simulation with Granlund's RIUSKA software.

10.3.1 Heating and cooling

The ICU rooms were designed to have active chilled beams of the PARASOL type. These beams feature both cooling and heating radiators. The radiators are easy to clean (see below for an image series of radiator cleaning).

Figure 56. Active chilled beams to be installed in the ICU rooms.

Furthermore, the rooms have heating radiators with actuators connected to the building automation system. Floor heating with water circulation is designed for the lavatories. The air volume in the room is also controlled with an air flow controller.

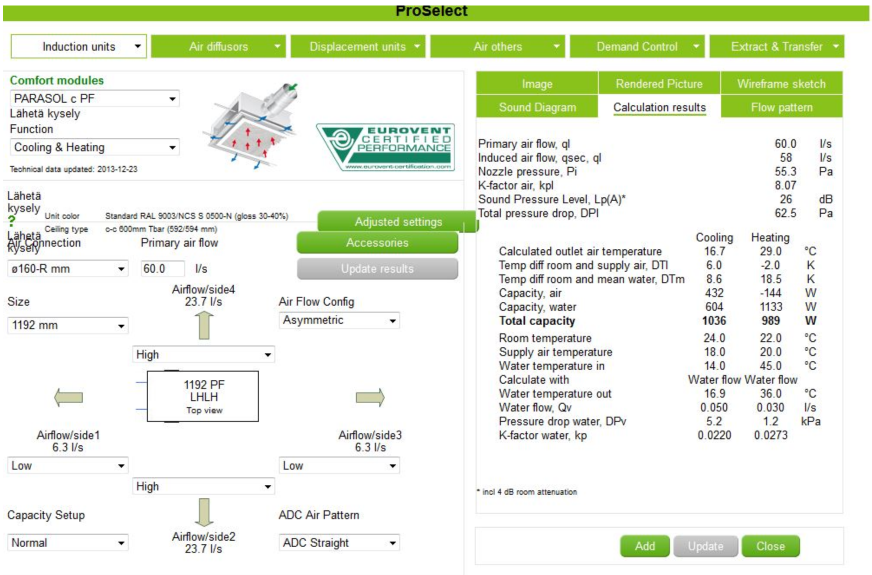


Figure 57. The design values of the chilled beams in the rooms were determined with the ProSelect software.

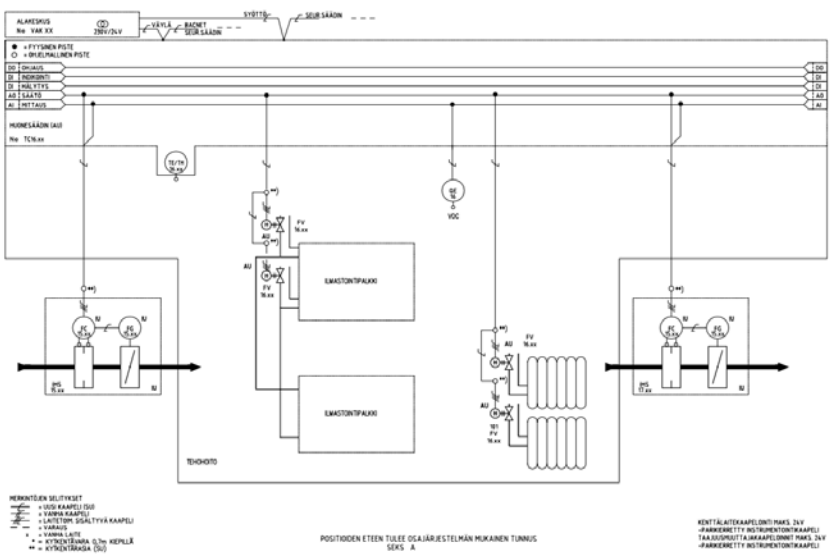


Figure 58. Control diagram of an ICU room.

The cooling of the property is partially handled with ‘free energy’ from cold wells. → When the cooling power requirement is at its highest, a water cooler installed on the roof will also be used. Bored wells are used in winter time for preheating the ventilation system.

11. Results & discussion

EVICURES is the first project to study *evidence-based design* (EBD) activities in Finland. The target has been to combine knowledge gained from EBD research, users' views, and the extensive intelligence of the multidisciplinary network regarding the functional requirements. Finally, the intention is that the design phase would contribute to the new ICU as built, thus improving the quality and effectiveness of intensive care and increasing patient and staff satisfaction.

In the **pre-occupancy evaluations** by ICU staff, patients and their relatives, the environmental effects (Chapter 1.4) were studied prior to the project. According to this evaluation the staff end-users (N=38) criticized the state of the acoustics, lighting, functionality, indoor air, and the lack of privacy in the existing intensive and intermediate care unit. Safety and security systems received the best appraisals. Changes in medical care have led to crowding in the current rooms and the extension of the hospital pharmacy in recent years led to the loss of windows. Several staff members commented that *'no windows, [means] no problems with glare or draught'.*

A shorter questionnaire survey administered to patients and their relatives (N=36) was carried out in November 2014. For their part, patients and their relatives rated the existing care environment as old-fashioned, uncomfortable and impractical, while they also criticized the lack of privacy. They were satisfied with the availability and presence of staff and security.

At the beginning of the project **an integrative literature review** of EBD research in intensive and intermediate care environments was carried out (Chapter 2). The literature search was conducted systematically (Whittemore & Knafl 2005) using the Medic, Medline(Ovid), CINAHL, Web of science and SCOPUS databases. The search was limited to works published 2005–2016. The time limit was set in order to focus on recent research. The studies were selected by one author of the integrative review according to the inclusion and exclusion criteria. The research data (N=50) consisted of quantitative (n=35) and qualitative (n=7) studies, with some studies using both methods (n=8).

One of the project methods **was computer supported co-operation work** (CSCW), that is, the collaborative design work in the cave-like virtual environment (CAVE)(Chapter 4.2). In the EVICURES project a virtual environment provided the surroundings for collaborative design work while permitting face-to-face interaction. Small groups of 5–6 participants had guided presentations of the designed spaces. An intensive care room, an intermediate care room, a single-patient bathroom, and a nurses' front office were modelled in the virtual environment.

Following the evolution in design (3 design versions), participants were satisfied that they could take part in the design of their new unit and could express their needs and experience. The virtual environment provides a situation where participants with no design background are in an equal position with architects and other designers. The designers obtain information about the actual way of working, which helps them to design the spaces so that they support the actual way of working.

In addition to the design development in CAVE, the **Presence experience** in virtual environments (Chapter 4.3) was studied using questionnaires after every CAVE visit. A novel rating scale tool, the Spatial Presence Experience Scale (SPES), was used. Overall, the test results supported the assumption that the participants experienced a higher sense of presence in the later versions of the virtual presentation of the care environment, which were more vivid and richer in detail than the first version.

The 3D model used in CAVE was used to develop **a Game interface** (Chapter 4.4). The first part involved converting the model's materials into Unity materials or shaders. One complication that emerged was that the textures embedded with the model had pre-baked lighting effects. In order to preserve the textures, and with no access to the original diffuse maps, a self-illuminated/emissive material was employed in Unity. This severely limited the dynamic lighting possibilities (turning lights on/off, day-night cycles). While a 'gamer' will find this simple to use, the average user may still experience a learning curve and it is one of the limitations of touch screen interfaces, which has no trivial solution. In addition, there was the possibility to navigate with the Kinect 2 if the user has a Windows computer. Three versions of the Game were made available: Windows (with Kinect), Mac, and Android. The game was used near the end of the project among personnel for the purposes of checking and discussion. In subsequent projects, the game development could be done at an earlier stage so as to be available to support the (non-CAVE) discussions.

An indoor environmental **satisfaction and wellbeing questionnaire for staff (Chapter 5)** was devised and administered to personnel in the middle of the project. Chapter 5 presents a conceptual model of the linkages between environmental satisfaction and the various indicators of wellbeing, as well as a literature review on multitasking and the impact of interruptions. Based on the conceptual model, a detailed questionnaire concerning environmental and job satisfaction, job stress, multitasking, work engagement and personality was developed.

The respondents were most satisfied with opportunities to interact and communicate with other workers and with the availability of cleaning services. The results of the survey are quite consistent with the negative results of the pre-validation study in terms of acoustics, sound insulation and lighting comfort; on the other hand, the present results are somewhat more positive than the earlier results in terms of air quality and temperature.

Regarding job satisfaction, the employees seemed to be quite satisfied with most aspects of their work. Those employees who are more engaged with their work felt less stress and seemed to have a stronger belief that they can control their life than those who had lower scores.

The physical **studies on stress** were carried out **as individual stress level measurements** (Chapter 6). In the test, 10 volunteers (9 females, 1 male, aged 28–59) measured their heartbeats over four days (three working days, one day off) using the Firstbeat Bodyguard 2 HRV recorders. Participants' average heart rate was 76/min (61–90), and at rest 52/min (44–57), with a peak rate 140/min (98–192). The percentage of time spent handling stress was 50% of the day (awake) and recovering 26% of the day. According to Firstbeat's database, the recommendation for recovery is 30% of the day at a minimum. Recovering during the day off was good or fair (61%). Mean recovery times when awake during the day off were 55 minutes and during the working time 42 minutes. In spite of the fact that a hospital as a work environment is broadly stressful for nursing staff, this group's stress levels were not at an alarming level. No one experienced stress whole day without any recovery moments.

Physical studies of **individual thermal sensation** (Chapter 8) used three parallel methods to evaluate the thermal sensation and comfort of individuals. The first, and probably the most straightforward method was to elicit information with questionnaires, in which all occupants were asked to evaluate the levels of their own thermal satisfaction. The second method was to measure individual skin temperature levels in order to estimate thermal sensation based on the monitored data. The third method was to utilize a calculation methodology, by which thermal satisfaction can be predicted based on a more or less detailed human thermal model that mimicked the true thermal behaviour of a human body. In the questionnaire scale, *thermal sensation* was asked to be estimated according to nine basic levels, where a thermal sensation value of 0 corresponds to thermal neutrality. Skin temperature measurements were made for sitting test persons in an open office space in the Intensive Care Unit. The uncertainty of the skin temperature sensors was ±0.1 °C, and the sensors were attached to the left side of each test person only by a medical skin tape.

The calculation was done using HTM. The Human Thermal Model (HTM) is based on the true anatomy and physiology of the human body, and it estimates the spatial and temporal temperature levels of body tissues. For the model, the body was divided into sixteen different body parts, such as the head, neck, upper arms, lower arms, hands, lower legs, etc. Finally,, based on the results obtained in this study, it was recommended that building service systems ought to be designed for and operated with a default indoor air temperature value of 23 °C. In addition, indoor temperature should be adjustable by ±3 °C in order to guarantee individual thermal satisfaction.

In **a series of workshops**, staff were encouraged to rethink the operations and supporting for change, using **Foresight Framework and Pathfinders methods**

(Chapter 7). The first collaborative workshops was based on the Foresight Framework Model developed by Carleton et al. (2013). Foresight is a capacity that allows us to think ahead and respond to future eventualities through consideration, modelling and creation of alternatives. In other words, the idea is to expand the perception of the range of options available to staff and organizations. The Foresight Framework model includes five planning phases, designed to identify and assess new situations (e.g. new contexts and technologies) and to anticipate clients' or patients' current and emerging needs.

Besides the Foresight Framework model, the workshops applied the Pathfinders method, which is recommended for use when new ideas need to create paths to success.

The workshops produced a great deal of valuable information about the areas still in need of further development. The identification of critical points will help management anticipate challenging situations that require more staffing. Open dialogue, appreciation of colleagues, and a culture of offering help and support can improve the smoothness of all actions, promote staff welfare, and minimize stress.

The **sensors-as-a-service** questionnaire (Chapter 9; Appendix C) set out to establish the key services that personnel would like to use in support of their work as well, as well as the key services they would not have. The top 4 services were: door opening (fully or partly), water tap opening, computer opening and setting the glass-wall opacity. For technology, the top three were a smartphone, ID card or access control token ('tag') and a smart wristband or other smart 'accessory'. Technology that would support the work or increase patient safety was also asked about, with the top three being monitors, infusion automation, and respirator. The questionnaire showed clearly that there is a need and willingness to include automated actions as services that would support ICU work and patient safety. However, discussions about support equipment divided opinions most.

At the end of the project, the results of the **technical requirements and design** (Chapter 10) are gradually being processed to create real design solutions. The final goal is to see the results of the user-oriented evidence-based design built into the new ICU.

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Appendix A: EVICURES questionnaire

Työympäristöä, työoloja ja työssä viihtymistä koskeva kysely – EVICURES-hanke

Tervetuloa vastaamaan EVICURES-hankkeeseen liittyvään työympäristöä, -oloja ja -viihtyvyyttä koskevaan kyselyyn.

Seuraavilla sivuilla on esitetty joukko kysymyksiä ja väittämiä. Kyselyn tarkoituksena on kerätä tietoa, jonka avulla työtäsi ja työympäristöäsi voidaan kehittää.

Varaa vastaamiseen tarpeeksi aikaa.

Useimpiin kysymyksiin vastataan ympyröimällä mielipidettäsi parhaiten kuvaava vastausvaihtoehto.

Kyselyn vastaukset tullaan käsittelemään **nimettöminä** ja **luottamuksellisesti**.

Taustatiedot

1. Syntymävuosi ________________________

2. Sukupuoli

Mies	1
Nainen	2

3. Peruskoulutus

Ammattikoulu/koulutaso	
(esim. perushoitajat, tekniikan puolen henkilöt)	1
Opistoaste	2
Alempi korkeakoulututkinto	3
Ylempi korkeakoulututkinto	4

4. Ammattinimike _________________________

5. Kuinka kauan olet yhteensä ollut mukana työelämässä?
   _________________ vuotta

6. Kuinka kauan olet työskennellyt tämän työnantajan palveluksessa?
   _________________ vuotta

7. Kuinka kauan olet toiminut nykyisessä työtehtävässäsi?
   _________________ vuotta

8. Millä osastolla / alueella / työpisteellä työskentelet?
____

9. Onko työsuhteesi

Vakinainen	1
Määräaikainen	2

10. Oletko esimiesasemassa?

Kyllä	1
Ei	2

11. Kuinka monta tuntia työskentelet yleensä viikossa?
_________________ tuntia

12. Mikä seuraavista parhaiten kuvaa työaikamuotoasi?

Päivätyö	1
Kaksivuorotyö	2
Kolmivuorotyö	3
Säännöllinen iltatyö	4
Säännöllinen yötyö	5
Jokin muu	6
Mikä?	___________________

Miten tyytyväinen olet sisäympäristön laatuun työpaikallasi? Lue jokainen väittämä huolellisesti ja päätä, miten koet väittämän esittämän asian. Ympyröi valitsemasi vastausvaihtoehto.

-3	-2	-1	0	+1	+2	+3
Erittäin tyytymätön	Varsin tyytymätön	Melko tyytymätön	En tyytymätön mutten tyytyväinenkään	Melko tyytyväinen	Varsin tyytyväinen	Erittäin tyytyväinen

		Erittäin tyytymätön	Varsin tyytymätön	Melko tyytymätön	En tyytymätön mutten tyytyväinenkään	Melko tyytyväinen	Varsin tyytyväinen	Erittäin tyytyväinen
13	Kuinka tyytyväinen olet työpaikan **lämpötilaan**?	-3	-2	-1	0	+1	+2	+3
14	Kuinka tyytyväinen olet työpaikan **ilmanlaatuun** (esim. tunkkaisuus, ummehtuneisuus, ilmanpuhtaus, hajut)?	-3	-2	-1	0	+1	+2	+3
15	Kuinka tyytyväinen olet **valon määrään** työpaikallasi?	-3	-2	-1	0	+1	+2	+3
16	Kuinka tyytyväinen olet työpaikan **valaistusmukavuuteen** (esim. häikäisy, heijastukset ja kontrasti)?	-3	-2	-1	0	+1	+2	+3
17	Kuinka tyytyväinen olet työpaikan **äänitasoon**?	-3	-2	-1	0	+1	+2	+3
18	Kuinka tyytyväinen olet työpaikan **äänieristykseen** (mahdollisuus keskustella ilman että muut kuulevat)?	-3	-2	-1	0	+1	+2	+3
19	Kuinka tyytyväinen olet **työ- ja säilytystilan määrään**, joka on käytössäsi?	-3	-2	-1	0	+1	+2	+3
20	Kuinka tyytyväinen olet **yksityisyyden suojaan**, jonka työpaikan näköesteet antavat?	-3	-2	-1	0	+1	+2	+3
21	Kuinka tyytyväinen olet siihen, miten pystyt olemaan **vuorovaikutuksessa muiden työntekijöiden kanssa**?	-3	-2	-1	0	+1	+2	+3
22	Kuinka tyytyväinen olet työpaikan **kalustuksen** (tuolit, pöydät, tietokoneet, laitteet ym.) **mukavuuteen**?	-3	-2	-1	0	+1	+2	+3
23	Kuinka tyytyväinen olet **mahdollisuuksiisi muunnella kalustusta** tarpeidesi mukaan?	-3	-2	-1	0	+1	+2	+3
24	Kuinka tyytyväinen olet työpaikan lattioiden, huonekalujen ja päällysteiden **väreihin ja pinnanlaatuihin**?	-3	-2	-1	0	+1	+2	+3

		Erittäin tyytymätön	Varsin tyytymätön	Melko tyytymätön	En tyytymätön mutten tyytyväinenkään	Melko tyytyväinen	Varsin tyytyväinen	Erittäin tyytyväinen
25	Kuinka tyytyväinen olet työpaikan **yleiseen puhtauteen**?	-3	-2	-1	0	+1	+2	+3
26	Kuinka tyytyväinen olet työpaikan **siivouspalveluihin**?	-3	-2	-1	0	+1	+2	+3
27	Kuinka tyytyväinen olet työpaikan **huolto- ja ylläpitotoimintoihin**?	-3	-2	-1	0	+1	+2	+3
28	Kokonaisuutena ottaen, kuinka tyytyväinen **olet henkilökohtaiseen työtilaasi**?	-3	-2	-1	0	+1	+2	+3

Tässä osassa voit kertoa, millaiselta **työsi sinusta tuntuu**. Alla on väitteitä työstä. Sinun tulee ilmaista omat henkilökohtaiset **tuntemuksesi** työstäsi merkitsemällä, kuinka samaa mieltä olet kunkin väitteen kanssa.

Ympyröi valitsemasi vastausvaihtoehto. Valitse seuraavista vastausvaihtoehdoista:

Kuinka samaa mieltä olen väitteen kanssa?

1	2	3	4	5	6	7
Olen täysin eri mieltä	Olen eri mieltä	Olen jossain määrin eri mieltä	Siltä väliltä	Olen jossain määrin samaa mieltä	Olen samaa mieltä	Olen täysin samaa mieltä

		Olen täysin eri mieltä	Olen eri mieltä	Olen jossain määrin eri mieltä	Siltä väliltä	Olen jossain määrin samaa mieltä	Olen samaa mieltä	Olen täysin samaa mieltä
65	Yleisesti ottaen olen hyvin tyytyväinen työhöni.	1	2	3	4	5	6	7
66	Harkitsen usein eroavani työstä.	1	2	3	4	5	6	7
67	Olen yleensä tyytyväinen tähän työhön, jota teen.	1	2	3	4	5	6	7

Tässä osassa sinun tulee ilmaista, kuinka tyytyväinen olet alla lueteltuihin työsi piirteisiin.

Kuinka tyytyväinen olet tähän työsi piirteeseen?

1	2	3	4	5
Erittäin tyytymätön	Melko tyytymätön	Siltä väliltä	Melko tyytyväinen	Erittäin tyytyväinen

		Erittäin tyytymätön	Melko tyytymätön	Siltä väliltä	Melko tyytyväinen	Erittäin tyytyväinen
68	Työsuhteeni jatkuvuuteen	1	2	3	4	5
69	Palkkaani ja muihin työsuhde-etuihini	1	2	3	4	5
70	Henkilökohtaiseen kasvuun ja kehittymiseen työssäni	1	2	3	4	5
71	Ihmisiin, joiden kanssa keskustelen ja työskentelen työpaikalla	1	2	3	4	5
72	Esimiehiltäni saamaani arvostukseen ja oikeudenmukaiseen kohteluun	1	2	3	4	5
73	Tunteeseen, että olen saavuttanut jotakin merkittävää työssäni	1	2	3	4	5
74	Mahdollisuuksiini tutustua muihin ihmisiin työssäni	1	2	3	4	5
75	Esimiehiltäni saamaani tukeen ja ohjaukseen	1	2	3	4	5
76	Palkkani oikeudenmukaisuuteen tälle organisaatiolle antamaani työpanokseen nähden	1	2	3	4	5
77	Mahdollisuuksiini ajatella ja toimia itsenäisesti työssäni	1	2	3	4	5
78	Tulevaisuuteeni turvallisuuteen tässä organisaatiossa	1	2	3	4	5
79	Mahdollisuuksiini auttaa työssäni muita ihmisiä	1	2	3	4	5
80	Työni haasteellisuuteen	1	2	3	4	5
81	Työssäni saamaani johtamisen laatuun yleensä	1	2	3	4	5

Kuinka usein sinulla on seuraavien väittämien kaltaisia tuntemuksia tai ajatuksia? Lue jokainen väittämä huolellisesti ja päätä, miten usein koet työssäsi väittämässä kuvattua tuntemusta tai ajatusta. Ympyröi valitsemasi vastausvaihtoehto.

1	2	3	4	5	6	7
En koskaan	Muutaman kerran vuodessa	Kerran kuussa	Muutaman kerran kuussa	Kerran viikossa	Muutaman kerran viikossa	Päivittäin

		En koskaan	Muutaman kerran vuodessa	Kerran kuussa	Muutaman kerran kuussa	Kerran viikossa	Muutaman kerran viikossa	Päivittäin
82	Tunnen olevani täynnä energiaa, kun teen työtäni.	1	2	3	4	5	6	7
83	Tunnen itseni vahvaksi ja tarmokkaaksi työssäni.	1	2	3	4	5	6	7
84	Olen innostunut työstäni.	1	2	3	4	5	6	7
85	Työni inspiroi minua.	1	2	3	4	5	6	7
86	Aamulla herättyäni minusta tuntuu hyvältä lähteä töihin.	1	2	3	4	5	6	7
87	Tunnen tyydytystä, kun olen syventynyt työhöni.	1	2	3	4	5	6	7
88	Olen ylpeä työstäni.	1	2	3	4	5	6	7
89	Olen täysin uppoutunut työhöni.	1	2	3	4	5	6	7
90	Kun työskentelen, työ vie minut mukanaan.	1	2	3	4	5	6	7

Alla on joukko väittämiä. Ne kuvailevat erilaisia tuntemuksia, joita sinulla voi olla töissä. Merkitse, kuinka usein viimeisten 30 työpäivän aikana **olet tuntenut seuraavia tuntemuksia**.

Kuinka usein sinusta on tuntunut tältä töissä ollessasi?

1	2	3	4	5	6	7
Ei koskaan tai ei juuri koskaan	Hyvin harvoin	Melko harvoin	Silloin tällöin	Melko usein	Hyvin usein	Aina tai melkein aina

		Ei koskaan tai ei juuri koskaan	Hyvin harvoin	Melko harvoin	Silloin tällöin	Melko usein	Hyvin usein	Aina tai melkein aina
91	Tunnen itseni väsyneeksi	1	2	3	4	5	6	7
92	Minulla ei ole energiaa mennä aamulla töihin	1	2	3	4	5	6	7
93	Tunnen itseni fyysisesti uupuneeksi	1	2	3	4	5	6	7
94	Minua tympii	1	2	3	4	5	6	7
95	Tuntuu kuin "patterini olisivat lopussa"	1	2	3	4	5	6	7
96	Tunnen itseni loppuunpalaneeksi	1	2	3	4	5	6	7
97	Ajatteluprosessini on hidas	1	2	3	4	5	6	7
98	Minun on vaikea keskittyä	1	2	3	4	5	6	7
99	Minusta tuntuu, että en ajattele selkeästi	1	2	3	4	5	6	7
100	Minusta tuntuu, että ajatukseni harhailevat	1	2	3	4	5	6	7
101	Minulla on vaikeuksia ajatella monimutkaisia asioita	1	2	3	4	5	6	7
102	Minusta tuntuu, että minulla ei ole herkkyyttä havaita työtovereiden ja asiakkaiden tarpeita	1	2	3	4	5	6	7
103	Tuntuu, että en kykene panostamaan työtovereihin ja asiakkaisiin tunnetasolla	1	2	3	4	5	6	7
104	Minusta tuntuu, että en pysty olemaan myötätuntoinen työtovereita ja asiakkaita kohtaan	1	2	3	4	5	6	7

Alla on joukko väittämiä. Ne kuvailevat erilaisia tuntemuksia, joita sinulla voi olla töissä. Ympyröi se vaihtoehto, joka parhaiten vastaa **omia tuntemuksiasi**.

1	2	3	4
Ei lainkaan	Toisinaan	Aika usein	Hyvin usein

		Ei lainkaan	Toisinaan	Aika usein	Hyvin usein
105	Olen hyvin kunnianhimoinen ja kilpailuhenkinen.	1	2	3	4
106	Minulla on aina kova kiire.	1	2	3	4
107	Olen kova komentelemaan ja määräilemään.	1	2	3	4
108	Minulla on kova tarve kunnostautua lähes kaikessa mitä teen.	1	2	3	4
109	Ruokailen turhan nopeasti.	1	2	3	4

		Kyllä	Ei
110	Minusta tuntuu usein siltä, että minulla olisi liian vähän aikaa.	Kyllä	Ei
111	Työasian pyörivät mielessäni työajan jälkeen.	Kyllä	Ei
112	Usein pinnistelen minkä pystyn ja annan kaiken työlle.	Kyllä	Ei
113	Minua kiusaa usein ajatus siitä, teenköhän työni tarpeeksi. hyvin	Kyllä	Ei
114	Onko sinulla tapana hermostua, jos asiat eivät tapahdu heti?	Kyllä	Ei

Mikä on mielipiteesi seuraavista elämäntilanteisiin liittyvistä väittämistä? Ympyröi vaihtoehto, joka parhaiten vastaa omaa käsitystäsi.

0	1	2	3	4
Täysin eri mieltä	Jokseenkin eri mieltä	Vaikea sanoa	Jokseenkin samaa mieltä	Täysin samaa mieltä

		Täysin eri mieltä	Jokseenkin eri mieltä	Vaikea sanoa	Jokseenkin samaa mieltä	Täysin samaa mieltä
115	Jokainen on oman onnensa seppä.	0	1	2	3	4
116	Ihmisen elämänkulku on suurelta osin sattumien sanelemaa.	0	1	2	3	4
117	Valtaapitävät henkilöt päättävät paljosta, mitä ihmisen elämässä tapahtuu.	0	1	2	3	4
118	Autokolariin joutuminen riippuu suurimmaksi osaksi kuljettajan omasta ajotaidosta.	0	1	2	3	4
119	Kun teen suunnitelmia, olen myös varma, että toteutan ne.	0	1	2	3	4
120	Huonoa tuuria on vaikea etukäteen välttää.	0	1	2	3	4
121	Kyvykäskään henkilö ei pärjää ilman oikeita suhteita.	0	1	2	3	4
122	Useimmiten asiat menevät niin kuin ovat mennäkseen.	0	1	2	3	4
123	Elämääni ohjailevat pääasiassa toiset ihmiset.	0	1	2	3	4
124	Tapaturmat johtuvat yleensä huonosta onnesta.	0	1	2	3	4
125	Tavallisella ihmisellä on hyvin vähän mahdollisuuksia puolustaa etujaan yhteiskunnassa.	0	1	2	3	4
126	Asioita ei kannata suunnitella kovin pitkälle etukäteen, koska kaikkia tekijöitä ei kuitenkaan voi ottaa huomioon.	0	1	2	3	4
127	Asioiden saavuttaminen vaatii yleensä vaikutusvaltaisten henkilöiden miellyttämistä.	0	1	2	3	4
128	Menestyäkseen on oltava tarpeeksi onnekas ollakseen oikeassa paikassa oikeaan aikaan.	0	1	2	3	4
129	Pystyn itse päättämään hyvin pitkälle siitä, mitä minun elämässäni tapahtuu.	0	1	2	3	4
130	Jos joudun liikenneonnettomuuteen, se johtuu melko varmasti toisista tiellä liikkujista.	0	1	2	3	4
131	Saavutukseni ovat yleensä kovan työn tulosta.	0	1	2	3	4
132	Saadakseni omat suunnitelmani toimimaan varmistan yleensä, että ne sopivat muiden toiveisiin.	0	1	2	3	4
133	Omat tekoni ja päätökseni määräävät elämästäni.	0	1	2	3	4

		Täysin eri mieltä	Jokseenkin eri mieltä	Vaikea sanoa	Jokseenkin samaa mieltä	Täysin samaa mieltä
134	Ystävien lukumäärä riippuu siitä, miten miellyttävä henkilö sattuu olemaan	0	1	2	3	4
135	Onnistumiseni johtuvat yleensä hyvästä tuuristani	0	1	2	3	4
136	Menestyäkseen on varottava ärsyttämästä ihmisiä	0	1	2	3	4
137	Pystyn yleensä valvomaan omia etujani	0	1	2	3	4
138	On kohtalon kysymys, miten minulla tässä elämässä menee	0	1	2	3	4

Seuraavat kysymykset koskevat monen työtehtävän samanaikaista suorittamista sekä työssä esiintyviä keskeytyksiä. Merkitse vastauksesi kysymyksen alapuolella olevalle riville/oleville riveille.

139. Työ koostuu yleensä erillisistä työtehtävistä, joiden kesto vaihtelee. Arvioi, paljonko sinulla menee aikaa yksittäisen työtehtävän suorittamiseen **keskimäärin** (minuuteissa) – toisin sanoen, mikä on työtehtävien keskimääräinen kesto työssäsi.

_______________ minuuttia

140. Arvioi, montako kertaa jonkin työtehtävän suoritus keskeytyy **keskimäärin** työvuorosi aikana.

_______________ kertaa

141. Arvioi, kuinka kauan **keskimäärin** voit yleensä rauhassa keskittyä tiettyyn työtehtävään, ilman että tehtävän suoritus keskeytyy välillä (minuuteissa)?

_______________ minuuttia

142. Arvioi, paljonko aikaa sinulla menee **keskimäärin** työtehtävän keskeytyksen jälkeen, että saat taas ”langan päästä kiinni” ja pystyt jatkamaan tehtävää normaalisti (minuuteissa).

_______________ minuuttia

143. Mistä syystä työtehtävän suoritus saattaa keskeytyä? Mainitse kolme yleisintä keskeytyksen syytä.

i. ______________________________

ii. ______________________________

iii. ______________________________

144. Pyritkö jollakin keinoin välttämään työtehtävien haitallista keskeytymistä?

Kyllä	Ei

145. Jos vastasit edelliseen kysymykseen 'kyllä', niin mitä keinoja käytät välttääksesi työtehtävien keskeytymisen?

____

____

____

146. Haittaavatko työpisteeseesi kuuluvat äänet keskittymistäsi?

Ei koskaan tai ei juuri koskaan	Hyvin harvoin	Melko harvoin	Silloin tällöin	Melko usein	Hyvin usein	Aina tai melkein aina

147. Mitkä työpisteeseesi kuuluvat äänet haittaavat keskittymistäsi? Jos mikään ääni ei häiritse, siirry kohtaan 148.

____

____

____

148. Teetkö työssäsi monia tehtäviä yhtä aikaa, vaikka mikään ulkoinen tekijä (esim. puhelinsoitto) ei vaatisikaan sinua siirtymään tehtävästä toiseen kesken tehtävän suorituksen?

Koko ajan	Muutaman kerran päivässä	Kerran päivässä	Muutaman kerran viikossa mutta en päivittäin	Harvemmin tai en koskaan

149. Jos ainakin toisinaan suoritat monta tehtävää samanaikaisesti, niin kuinka monta tehtävää **keskimäärin** suoritat tällaisessa tilanteessa yhtä aikaa?

________________ tehtävää

150. Arvioi, montako työtehtävää pystyt suorittamaan samanaikaisesti, ilman että suoritus näissä tehtävissä merkittävästi heikkenee.

________________ tehtävää

Appendix B: Questionnaire form for estimating thermal perception of occupants in Seinäjoki Central Hospital

evicures VTT Etelä-Pohjanmaan sairaanhoitopiiri

Taustatiedot

Päiväys . . 2015 **Kellonaika** :

Vastaajan nimi

Paikka Tehon kanslia ☐ Neurotehon kanslia ☐

Tehon potilaspaikka 2 ☐ Potilaspaikka 12 ☐

Vaatetus

1. Rastita mitä kuvien vaatteita on päällä

2. Alleviivaa muut vaatteet: sandaalit, umpikengät, nilkkasukat, polvisukat, pikkuhousut, sukkahousut, pitkät alushousut, rintaliivit
3. Muu vaatetus ____________________

Koettuun sisäympäristön laatuun liittyvät kysymykset

Merkitse rasti parhainten kuvaavaan kohtaan numeroitua janaa

Lämpöaistimus

Hyvin kuuma	Kuuma	Lämmin	Hieman lämmin	Neutraal	Hieman viileä	Viileä	Kylmä	Hyvin kylmä
+4	+3	+2	+1	0	-1	-2	-3	-4

Lämpöviihtyvyys

Erittäin viihtyisä			Hieman viihtyisä		Hieman epä-viihtyisä			Hyvin epä-viihtyisä
+4	+3	+2	+1	0	-1	-2	-3	-4

Vastaa seuraaviin väittämiin (1-7), 1 täysin eri mieltä...7 täysin samaa mieltä.
Merkitse rasti parhaiten kuvaavaan ruutuun.

	Ilma on raikas	X
7	Täysin samaa mieltä	
6		
5		
4		
3		
2		
1	Täysin eri mieltä	

	Valaistus on hyvä	X
7	Täysin samaa mieltä	
6		
5		
4		
3		
2		
1	Täysin eri mieltä	

Appendix C: Sensors-as-a-service questionnaire

Uusien sensoriteknologioiden mahdollisuudet ja hyödyntäminen uusissa tehohoidon tiloissa – EVICURES-hanke

Tervetuloa vastaamaan EVICURES-hankkeeseen liittyvään uusien sensoriteknologioiden mahdollisuuksia ja hyödyntämistä kokevaan kyselyyn.

Kyselyn tarkoituksena on kerätä tietoa, jonka avulla uusia tehohoidon tiloja voidaan kehittää.

Useimpiin kysymyksiin vastataan ympyröimällä mielipidettäsi parhaiten kuvaava vastausvaihtoehto.

Taustatiedot

1. Syntymävuosi ________________________

2. Sukupuoli

   Mies 1
   Nainen 2

3. Ammattinimike _________________________

4. Käytätkö älypuhelinta?

   Päivittäin 1
   Joskus 2
   En koskaan3

5. Käytätkö tablettitietokonetta?

   Päivittäin 1
   Joskus 2
   En koskaan3

6. Pelaatko tietokonepelejä?

   Päivittäin 1
   Pari-kolme kertaa viikossa 2
   Joskus 2
   En koskaan 4

Tiedetään, että sairaalaympäristössä on syytä välttää koskemasta tarpeettomasti paljain käsin eri pintoihin. Tiedetään myös, että ihmisen tunnistaminen erilaisten sensorien avulla on hyödyllistä, sillä se parantaa turvallisuutta ja helpottaa työtä.

Minkälaisia asioita haluaisit, mikäli se olisi teknisesti mahdollista, saada ‘toimimaan’ automaattisesti, siten että jokin sensori ensin tunnistaa ihmisen yleensä tai sinut henkilökohtaisesti, ja sen jälkeen automaatio tekee puolestasi jonkin toiminnon? Muutamassa kohdassa asiaa tarkastellaan erikseen potilaan ja hoitajan näkökulmasta.

7. Hoitohenkilökunnan kutsuminen:

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

8. Potilashuoneen lämpötilan ja kosteuden säätäminen **potilaalle** sopivaksi (esim. potilaan ihon lämpötilan muutosten mukaisesti):

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

9. Huonetilojen lämpötilan ja kosteuden säätäminen **hoitajalle** sopivaksi:

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

10. Potilashuoneen ilman laadun säätäminen **potilaalle** sopivaksi (tunnetusti yksi huonon ilmanlaadun merkki on lisääntynyt hiilidioksidin määrä ilmassa):

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

11. Huonetilojen ilman laadun säätäminen **hoitajalle** sopivaksi (tunnetusti yksi huonon ilmanlaadun merkki on lisääntynyt hiilidioksidin määrä ilmassa):

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

12. Potilashuoneen valaistuksen voimakkuuden tai laadun säätäminen **potilaalle** sopivaksi (esim. kun potilas nukahtaa, huoneen valaistus himmenee automaattisesti):

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

13. Eri huonetilojen valaistuksen säätäminen **hoitajalle** sopivaksi:

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

14. Potilashuoneen vesihanan avaaminen/sulkeminen:

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

15. Vesihanan veden määrän ja/tai lämpötilan säätäminen:

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

16. Potilashuoneen oven avaaminen kokonaan tai osittain:

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

17. Potilashuoneen lasiseinien läpinäkyvyyden säätäminen (**potilas** säätää):

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

18. Potilashuoneen lasiseinien läpinäkyvyyden säätäminen (**hoitaja** säätää):

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

19. Tietokoneen avaaminen:

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

20. Tehohoidossa käytettävien laitteiden säätäminen:

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

21. Jos vastasit edelliseen kohtaan ‘ehkä kyllä’ tai ‘ehdottomasti kyllä’, niin mitä laitetta/laitteita haluaisit säätää automaattisesti?

____

____

22. Lääkkeiden jakelu ja annostelu:

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

23. Henkilötunnuksen (PIN-koodi) antaminen (ovista kuljettaessa, tietokonetta/tietokoneohjelmaa avattaessa):

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

24. Automaattinen kulunvalvonta:

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

25. Automaattinen työajanseuranta:

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

26. Potilaan henkilö- ja terveystietojen jakaminen potilastietojärjestelmästä, siten että lukijan avulla saa rannekkeesta nopeasti ja vaivattomasti seuraavat tiedot:

a. Potilaan allergiat:

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

b. Ruokavaliotiedot:

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

c. Tieto eristystarpeesta ja/tai tarttuvista taudeista (esim. hepatiitti):

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

d. Potilaan toiveet vierailijoista tai omien terveystietojen antamisesta läheisille henkilöille:

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

e. Tieto apuvälineiden tarpeesta (silmälasit, kävelykeppi, pyörätuoli ym.):

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

f. Tieto siitä mitä omaisuutta mukana yksikköön potilaaksi tullessa (vaatii asioiden kirjaamisen ja tarkistamisen jo päivystyksessä):

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

g. Potilaan kirjaaminen tehon/tehovalvonnan potilaaksi tulovaiheessa ja uloskirjaaminen pois lähtiessä potilastietojärjestelmään (sisältää tiedot aiemmista hoitojaksoista kyseissä sairaalassa tai yksikössä sekä tiedon onko aiemmilla hoitojaksoilla ollut jotakin erityistä, joka tulee ottaa huomioon):

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

27. Potilaan sijaintitiedot hoitohenkilökunnalle toiminnanohjausjärjestelmän taululle (esim. onko potilas parhaillaan sängyssä, tuolissa, suihkussa, leikkaussalissa tai röntgenosastolla):

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

28. Hoitotilanteeseen mukautuva päätöksenteon tuki:

hdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

29. Muu mikä?

___

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

Mihin tietoon tai mihin välineeseen edellä mainittujen toimintojen käynnistymisen toivoisit perustuvan?

30. Puhelimeen:

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

31. Henkilökorttiin tai kulkuavaimeen (‘laku’):

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

32. Älykoruun tai -rannekkeeseen:

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

33. Älyvaatteeseen (esim. T-paita) johon on kiinnitetty tunnistin:

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

34. PIN-koodiin:

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

35. Kasvojentunnistukseen:

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

36. Sormenjälkeen:

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

37. Muuhun, mihin?

____

Ehdottomasti ei	Ehkä ei	Ehkä kyllä	Ehdottomasti kyllä	En osaa sanoa
0	1	2	3	4

Kiitos paljon kyselyyn vastaamisesta!

Series title and number

VTT Technology 252

Title	**A user-oriented, evidence-based design project of the first Finnish single room ICU** Results of EVICURES project
Author(s)	Esa Nykänen, Pekka Tuomaala, Jari Laarni, Krupakar Dhinakaran: VTT; Kari Saarinen, Tiina Yli-Karhu, Kati Hämäläinen, Tiina Koskela, Hannu Eerikäinen: The Hospital District of South Osthrobothnia; Mari Salminen-Tuomaala, Tapio Hellman: Seinäjoki University of Applied Sciences; Kari Rintamäki, Kai Vimpari: Granlund; Jyrki Kilpikari: Saint Gobain Ecophon; Jyrki Jääskeläinen: Jääskeläinen Architects Ltd; Heli Kotilainen
Abstract	The EVICURES project developed a new user-friendly design model for intensive and intermediate care facilities. In this model staff, management, patients and their families, and corporate, hospital district and other co-operation partners jointly participated in the design work from day one. EVICURES is the first project to study evidence-based design (EBD) activities in Finland. It draws on research information on EBD, users' views, and an extensive multidisciplinary network. In addition, the design of operations seeked to improve the quality and effectiveness of intensive care and increase patient and staff satisfaction. The project conducted a pre-occupancy evaluation in spring 2014. Questionnaire offered 106 statements on nine different topics, including entrances and courtyards, architecture, indoor conditions, durability, functionality, safety, comfort, accessibility and usability. Actual project started with an integrative literature review of EBD research in intensive and intermediate care environments. The following phase was computer-supported co-operation work (CSCW) i.e. the collaborative design work in a cave-like virtual environment (CAVE) followed by study of presence experience. Also a Unity3D game was developed from the 3D model. The indoor environmental satisfaction and wellbeing questionnaire as well as the physical studies of stress was carried out in the existing ICU. A series of workshops supported the change in work processes by means of the Foresight Framework and Pathfinders methods. Physical studies of individual thermal sensation (Human thermal Model) was carried out to ensure correct parameters for indoor air temperature design. In last phase a Sensors-as-a-service questionnaire was done to find out the employeees preferences to sensor technology and need to automated services to support nursing and patient safety. Ultimately, the project results were acting as functional requirements in the real design process of the new ICU.
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Julkaisun sarja ja numero

VTT Technology 252

Nimeke	**Suomen ensimmäinen yhden hengen huoneista koostuvan teho-osaston käyttäjälähtöinen, näyttöön perustuva suunnitteluprojekti** Tuloksia EVICURES-projektista
Tekijä(t)	Esa Nykänen, Pekka Tuomaala, Jari Laarni, Krupakar Dhinakaran: VTT; Kari Saarinen, Tiina Yli-Karhu, Kati Hämäläinen, Tiina Koskela, Hannu Eerikäinen: Etelä-Pohjanmaan sairaanhoitopiiri; Mari Salminen-Tuomaala, Tapio Hellman: Seinäjoen ammattikorkeakoulu; Kari Rintamäki, Kai Vimpari: Granlund; Jyrki Kilpikari: Saint Gobain Ecophon; Jyrki Jääskeläinen: Arkkitehtitoimisto Jääskeläinen Oy; Heli Kotilainen
Tiivistelmä	EVICURES-projektissa kehitettiin uutta käyttäjälähtöistä suunnittelumallia teho- sekä tehostetun valvonnan osastoille. Henkilökunta, johto, potilaat omaisineen, sairaanhoitopiiri ja yhteistyökumppanit osallistuivat kehittämiseen. EVICURES on ensimmäinen suomalainen näyttöön perustuvaa suunnittelua (EBD) tutkiva projekti. Projektissa yhdistettiin olemassa oleva tutkimustieto, loppukäyttäjien osallistuminen sekä laaja monitieteellisyys. Lisäksi projektissa pyrittiin parantamaan teho-osaston toiminnan laatua ja tehokkuutta sekä henkilökunnan ja potilaiden tyytyväisyyttä. Projetissa tehtiin pre-evaluaatio nykyisistä tiloista (2014). Kyselyssä oli 106 väittämää yhdeksässä eri aihealueessa sisältäen arkkitehtuuria, sisäolosuhteita, kestävyyttä, toimivuutta, turvallisuutta, esteettömyyttä ja käytettävyyttä. Varsinainen projekti alkoi EBD-tutkimuksien kirjallisuuskatsauksella liittyen teho- sekä tehostetun valvonnan osastoihin. Seuraava vaihe oli tietokoneavusteinen yhteissunnittelu (CSCW) käyttäen virtuaalitilaa (CAVE). Suunnitelman 3D-mallista tehtiin myös Unity3D-peli. Kyselyllä selvitettiin henkilökunnan tyytyväisyyttä (indoor environmental satisfaction) ja hyvinvointia sekä mitattiin fyysistä stressiä. Työpajoissa suunniteltiin uusia tehohoidon työtapoja (Foresight Framework and Pathfinders methods). Kyselyillä ja mittauksilla selvitettiin yksilöllistä lämpöviihtyvyyttä (Human Thermal Model). Tuloksena saatiin lämpötilojen raja-arvot lämpötekniseen suunnitteluun. Viimeisessä vaiheessa selvitettiin tarvetta ja valmiutta käyttää "sensoreita" hoitotyön sekä potilasturvallisuuden tueksi (Sensors-as-a-service). Tutkimuksessa kerätyistä tiedoista saatiin muun muassa toiminnallisia vaatimuksia uuden teho-osaston todelliseen suunnitteluun.
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Julkaisija	Teknologian tutkimuskeskus VTT Oy PL 1000, 02044 VTT, puh. 020 722 111

VTT TECHNOLOGY 252 A user-oriented, evidence-based design...

A user-oriented, evidence-based design project of the first Finnish single room ICU
Results of EVICURES project

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