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User-centric work environments in modular healthcare facilities

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Abstract

Purpose The challenges arising from the reform of the social and healthcare sector call for efficient, effective and novel processes in both public and private health and medical care. Facilities need to be designed to suit the new processes and to offer usable workspaces at different levels of healthcare services. Along with traditional construction, modular facility innovations could be one solution to these pressures.

Design/methodology/approach This case study analyzed the different usability characteristics of the work environment in modular and non-modular healthcare facilities. The qualitative research method was based on semi-structured interviews of employees and observations of the case buildings.

Findings According to the results, the usability characteristics were divided into four main categories: functionality, healthiness, safety/security, and comfort. The main differences between the modular and non-modular facilities appeared to be room size, soundproofing, safety issues, and the utilization of colors and artwork, which were all perceived as better realized in the non-modular facilities. The staff highlighted functionality as the most important characteristic in their work environment. They even considered functionality a feature of a comfortable work environment.

Originality/value This paper presents new knowledge and a detailed description of the opinions and experiences of healthcare professionals concerning a user-centric, usable environment in the context of modular and non-modular healthcare facilities.

Keywords user-centric, usability, healthcare, modular, work, environment, comfort, healing

Article type Research paper

Introduction

Finland, among other western countries, is currently facing major challenges due to a significant reform of the social and healthcare sector, which aims to become more efficient and effective in several ways. In addition, the growing population, particularly that of ageing people, is creating pressure to offer quick, effective solutions to this challenge. Healthcare services are moving from institutions towards user-centric environments, and different functions will be combined, which will render old facilities

dysfunctional. Patient care processes will eventually change from rigid activities based on the needs of clinical specialties into an effective flow, depending on client needs.

In order to achieve effective, high-quality patient care, the best knowledge regarding medical science and modern health technology has to be implemented in the design processes of future hospitals and healthcare centers. More importantly, hospitals should be more closely associated with local public healthcare organizations. The prevention of non-communicable diseases needs to be recognized as the most effective way of saving lives and money. This means better collaboration between primary healthcare and specialized medical care in hospitals.

Old healthcare facilities (HCFs) in many countries need to be replaced with new solutions that could more efficiently attract qualified employees, provide cost savings by improving medical outcomes for patients and staff, achieve space efficiency, and increase user satisfaction and the quality of care (e.g. Aalto et al. 2017; Berry et al. 2003; Ulrich et al. 2008). Services are restructured on the basis of customer-orientation, equality, easy availability, and effectiveness. Institutionalization is no longer a priority. Thus, new HCFs need to be designed accordingly, to speed up patient discharge. HCFs need to be flexible yet comfortable. In addition, healing environments have become a trend in today's healthcare design.

There is a global need for HCF solutions that can be designed for a specific purpose but which are also easy to purchase, construct, relocate and demolish rapidly. Furthermore, HCFs should be simple to renovate and modify according to changing customer needs. Along with traditional construction, modular facility innovations could be one solution to resolving these pressures. In modular facilities, a building is structured into self-contained modules with a standardized interface with another part of a building (Peltokorpi et al. 2018).

In addition to modular buildings, modular operation rooms are increasingly used in non-modular hospitals especially in renovation buildings. Modularity enables better use of standard solutions in design, prefabrication in construction, and adaptability and replaceability in the use phase. As well, hospital extensions are ideal situations for modular construction, when construction process should be done in a very limited period of time and without disruption of existing facility (Moiseenko 2017).

International and local standards and regulations guide hospital design in general, but as Staloch (2015) state, modular design strategies require disciplined and coordinated approach toward the design of structure grid patterns and layout planning. The structure must support the uniform placement of modular units designated as exam rooms, patient rooms, operating theatres, offices or other specialty areas within core structural and infrastructural systems.

The general benefits and challenges of modularity itself (Ulrich 1993; Ma and Kremer, 2016; Doran and Giannakis 2011; Choi and Song 2014; Da Rocha et al 2015) and prefabricated modules (Edelman et al. 2016; Peltokorpi et al. 2018; Johnsson and Meiling 2009) have been explored in several studies. Based on the literature, prefabricated modules set some limits to architectural design. Because of restrictions in height, width, length (Doran and Giannakis 2011; Edelman et al. 2016), and interfaces (Da Rocha et al. 2015), the use of modular solutions may be limited in specialized facilities and thus diminish user satisfaction. Modular, temporary solutions also suffer from image issues, as they may be perceived to be of poorer quality than permanent buildings (Peltokorpi et al. 2018). In addition, several knowledge gaps related to their suitability for work processes in the healthcare sector need to be filled.

Usable environment in HCFs

Usability includes all aspects of the users' experience when interacting with the product, service, environment or facilities (Alexander, 2007). The ISO 9241-11 (1998) standard describes three factors that determine usability. *efficiency* means that the artifact allows users to perform with ease and little use of resources. *effectiveness* describes the ability of the artifact to deliver a certain desired effect. The third factor, *satisfaction*, describes the users' feeling and attitudes towards the artifact and its effects (Alexander, 2006).

Some studies concerning the usability of HCFs have been conducted from the viewpoint of patients (e.g. Hignett & Lu 2009; Jensø & Haugen 2005; Mollerup 2009; Pati et al. 2008), but only a few have taken into account the viewpoint of healthcare personnel (e.g. Haron et al. 2012; Capodaglio 2014; Aalto et al. 2017). Research reports generally discuss the spaces without specifying the usability characteristics from the viewpoint of different user groups. Evidently this is a significant challenge, especially in HCFs, since both the patients and staff use the same spaces daily.

The efficiency requirements for work processes are important, but they should not be detrimental to the well-being of hospital staff. According to Aalto et al. (2017), it is essential to consider which usability characteristics enhance and which hinder the performance of various activities from the viewpoint of employees.

Aalto et al. (2017) have published a usability framework of hospital buildings (Fig. 1). Although the framework illustrates the situation of hospital buildings under renovation, five usability attributes: safety/security, functionality, orientation, comfort and healthiness, can be seen as generally relevant to HCFs.

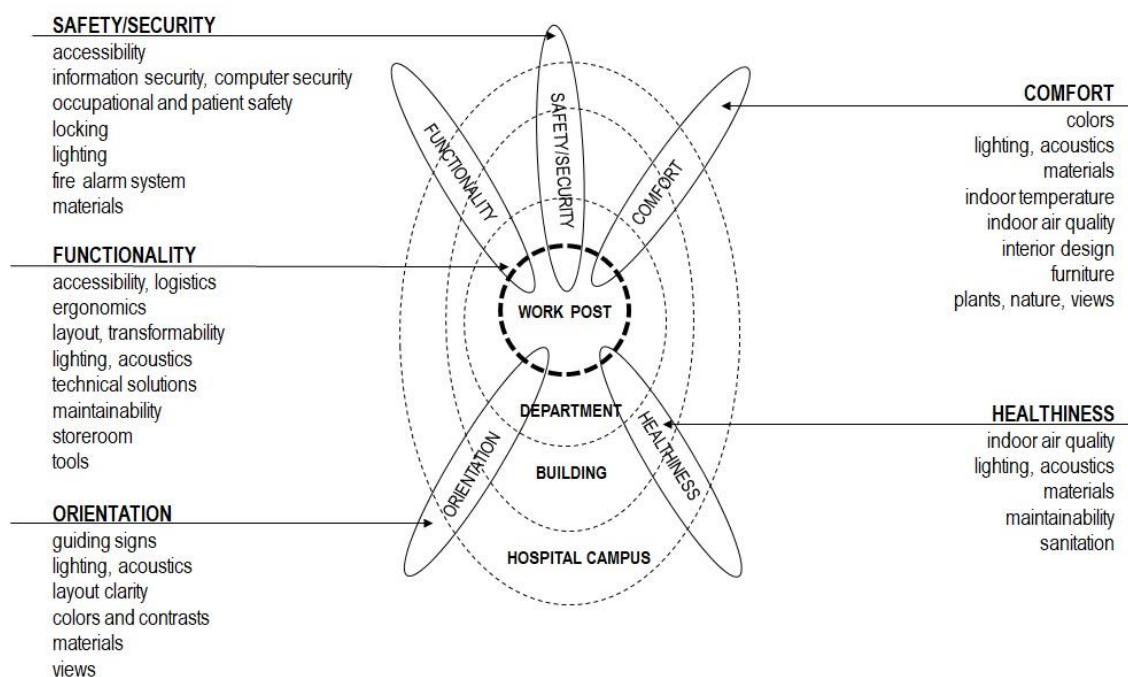


Figure 1 Usability framework of non-modular hospital buildings (Aalto et al. 2017).

Aim of the study

The main aim of this study was to formulate an extensive impression of the usability characteristics of HCFs, reflecting findings to the results of earlier investigations. Its multi-disciplinary approach focuses on the characteristics of user-centric, usable work environments in modular and non-modular HCFs from the viewpoint of the hospital personnel. The findings use the usability framework of Aalto et al. (2017) as a basis to expand the knowledge about usability characteristics that support fluent and effective work in HCFs.

The specific research questions were:

RQ1. How are usability characteristics considered in modular/non-modular HCFs?

RQ2. Which work environment characteristics enhance and which hinder usability in modular/non-modular HCFs?

Material and methods

Context of the study

This qualitative research was based on semi-structured interviews of employees (N= 16) in three modular and three non-modular HCFs. The interviewees included physicians and nurses but did not include patients. Although one case building (B3) was not yet in use, the interviewed individuals illustrated their viewpoints on the basis of the architectural plans. The interviews were conducted by four researchers, and the questions were:

- What are the main characteristics enhancing or weakening usability in your work environment?
- What kind of restorative, healing or comfort characteristics you have noticed in your work environment?
- How do you think about working in modular based buildings (if working in these buildings)?

The interviews were audio recorded and the duration of each interview varied between 30 minutes and two hours. The recorded interviews were transcribed in full (241 bytes) by a company specialized in transcription. For the analysis of the interviews the researchers used deductive content analysis (Bengtsson 2016). The study used the framework of Aalto et al. (2017) as its theory, and the findings were applied to the four attributes of the framework (safety/security, functionality, orientation, comfort, and healthiness). The same attributes came up in another usability study published by Haron et al. (2011).

In addition to the interviews, the researchers estimated the usability characteristics of four (A1, A2, A3 and B2) of all the six case facilities by walking through and observing the premises with one staff member. In accordance with Hansen et al. (2011), the walk-through as an evaluation method is a generic term for using onsite inspection of a building for evaluating various aspects of its usability. During the tour, the researchers took photos and posed defining questions. The findings of these tours were included in the analysis of the interviews.

Description of the case buildings

Three modular and three non-modular buildings were selected for this study. All the modular buildings were provided by the same company, which was specialized in relocatable, prefabricated and leased modular buildings, the leasing time of which can be up to 25 years.

The first two modular buildings (cases A1 and A2) were located in a hospital campus in Southern Finland. The existing buildings, built in the 1960–70s, had suffered from indoor air quality problems, and had become too small and outdated for their current use. Thus, the hospital had introduced two modular facilities to respond to contemporary healthcare practices. Building A1 (165 m²) was built in 2013 and had facilities for medical imaging such as ultrasonography and x-raying, and this 'satellite' building was connected to the main building by a corridor, the width of which was 2,8 m. Two storied building A2 (1000 m²) was built in 2012 and comprised offices and consulting rooms.

The third modular building - Building A3 (972 m²) - was a healthcare center in Eastern Finland. The building comprised one meeting room and consulting rooms for an outpatient clinic as well as for counseling services, home care, and child and maternity care. The building was relocated to the present site in 2015.

Two non-modular buildings – B1 (10 000 m²) and B2 (11 000 m²) – were private hospital facilities owned by an insurance company. B1 was located in the metropolitan area of Helsinki and B2 in Central Finland. Both hospitals focused on orthopedics as day hospitals. B1 was renovated in 2014 and B2 in 2016. B2 had three modular operating rooms, which were prefabricated in factories and installed at the building site. The modular operating rooms were assessed in the same way as the other modular buildings in this study.

The third non-modular case building – B3 (42 000 m²) – was a new building under construction, which will substitute an old hospital built in 1969. This hospital will be located in Eastern Finland and will be delivered in several phases to ensure the ongoing operation of the existing hospital. The first

building sections are estimated to be commissioned in 2019. The hospital is designed according to lean principles, emphasizing standard rooms, modular structures and adaptable solutions. One unique feature is the abundant utilization of wood material. The facade walls will be pre-fabricated wooden elements, as will the indoor decoration and visual materials.

Results

Usability characteristics in modular and non-modular HCFs

During the tours in the case buildings, the researchers highlighted the following usability characteristics in their observations: narrow corridors (width from 2.5 m to 2.8 m) and light rooms in the modular buildings, and high-grade interior design in the non-modular buildings. All the perceptions of staff members collected during the tours were consistent with the results of the semi-structured interviews.

According to the interviews and case tours, the main usability elements were: functionality, healthiness, safety/security and comfort. Functionality was divided into eight sub-categories, healthiness and safety/security were both divided into four sub-categories. In addition, comfort, with eight sub-categories, was highlighted as one of the usability elements (Fig. 2). Some of the descriptions fit several categories.

Comparing these results to the framework of usability by Aalto et al. (2017) the categories/sub-categories mainly included the same characteristics, although different words were used. However, two additional characteristics – functionality and the possibility to personalize spaces – can be added to the category of Comfort. In addition, orientation was regarded as a part of accessibility.

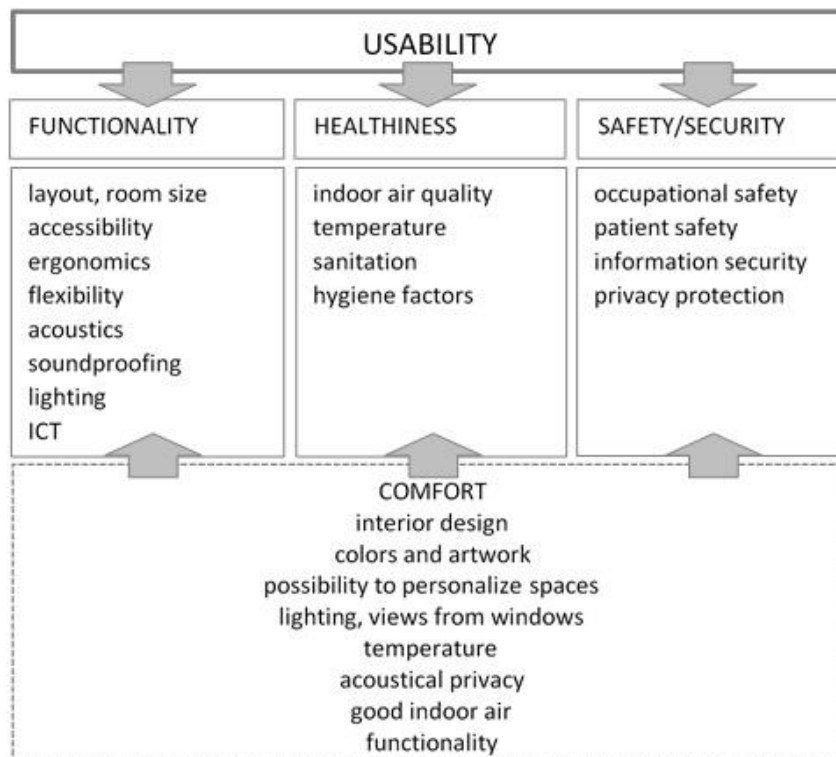


Figure 2 Usability characteristics based on interviews and case tours.

Functionality

The modular facilities were evaluated as mainly functional in their intended use, considering their temporary nature. The facilities were described as finished, new, and ‘like real buildings’. The non-modular facilities were described as very functional and successful. The premises were well

designed, even in renovated old building B2, and supported the care processes of the operation units (Table 1).

Table 1. Characteristics that enhance or hinder functionality in modular and non-modular HCFs.

Simple expression	Simple expression	Subclass
Modular-HCF	Non-modular HCF	
Functional facilities (considering their temporary nature) Appropriate room size Large space allows fluent patient care Easily perceived facilities, close assistance and short distances Possibilities for physical and visual accessibility of patients and nurses Separate lobbies and entrances	Functional facilities Appropriate room size Large space allows fluent patient care Easily perceived facilities, close assistance and short distances Space solutions supporting efficient care processes Possibilities for physical and visual accessibility of patients and nurses Separate lobbies and entrances	Functional layout and room size
Long distance from satellite module to main building Common routes of patients and staff Small and cramped spaces Narrow corridors Insufficient storage space, logistically in the wrong place Excessively small lobbies One of the three operating rooms too small	Insufficient storage space, logistically in the wrong place	Dysfunctional layout and room size
One-storied facilities Accessible entrances Clear signs supporting orientation Spacious toilet facilities Doors opening in the right direction Well-considered ergonomics Lifting gears and electrically controlled patient beds Electrically operated desks and adjustable chairs Clear, usable control panels in modular operating rooms. Enough space in the operating rooms for instruments on tables.	Accessible entrances Clear signs supporting orientation Spacious toilet facilities No cramped spaces Usable handles and automatic switches Well considered ergonomics Lifting gear and electrically controlled patient beds Electrically operated desks and adjustable chairs.	Good accessibility and ergonomics
Two-storied facilities with no elevators Narrow corridors Long distance from satellite module to main building Lack of power plugs resulting in extra wires lying on floors Dysfunctional ceiling systems due to modular operating room being too small	Doors opening in the wrong direction Dysfunctional furniture in waiting rooms and lobbies	Poor accessibility, achievability, ergonomics
Flexibility mainly accomplished by means of furniture Possibility to add or take down walls	Easily enlargeable operating rooms	Good flexibility
Facilities not very flexible Difficulties to enlarge modular operating rooms	Facilities not very flexible	Inflexibility
Good soundproofing in imaging spaces	Good soundproofing	Good acoustics and soundproofing
Problems with acoustics and soundproofing in the modular operating rooms. Voices heard from reception rooms.		Poor acoustics and soundproofing
High satisfaction with lightness of spaces Many windows in the rooms	High satisfaction with lightness of spaces Many windows in the rooms Lighting management controlled by touch panels	Sufficient lighting

Layout and room size. Layout and room size were considered one of the key factors of functionality. The layout form of all the modular buildings was rectangular. In all the studied modular and non-modular buildings, the layouts were perceived as mainly functional. Nevertheless, they had too little storage space which was often logistically located in the wrong place. Due to this, some of the instruments were kept in the offices in the healthcare center, which caused disturbances by people going in and out of the spaces.

Separate lobbies (for different patient groups) were highlighted as important in the healthcare center, since they prevented the spreading of infections, dirt and noise from one space to another. A door between the child welfare clinic and other clinics would have been a welcome additional feature. In the non-modular hospitals, separate entrances for acute care and elective care units were considered a good solution.

The layout and size of the inpatient wards in the non-modular hospitals were suitable. Room order was designed according to the care processes. Single-bed rooms had good privacy, and rehabilitation areas (in case B3) supported the principles of patients' quick discharge. The balance between standardized solutions and modification in the patient rooms and in the operating rooms was an important viewpoint in design, although it was challenging.

According to the users, healthcare facilities should always be large enough to ensure fluent patient work. Some of the premises were entirely smaller and some were larger than expected. Narrow corridors were a defect in all the modular buildings. Due to an information gap during the design phase, the satellite-based modular building was larger than planned and the premises were quite far from the main building. Spacious meeting rooms and recreation rooms were considered important for communication and recovery. Recreation rooms were mainly functional, yet in the modular healthcare center the small size of the recreation room was a defect. Due to this flaw, some workers had to use the meeting room

for their lunch break. During the rush hours, the waiting rooms of the healthcare center were too small, which caused disturbances, and customers had to stand in the corridors.

The staff offices and the consulting/reception rooms were mainly of an appropriate size in all the studied facilities. Single-room offices were considered more functional than open-plan offices, which were cramped and too noisy. Consulting/reception rooms had enough space for families.

Users of the non-modular hospitals (B1 and B2) indicated that the room height of the modular operating rooms should be at least three meters for the ceiling systems and other technical facilities to fit and function properly. In addition to this, the interviewees reported that at least one of the modular operating rooms should be bigger than the others, making it possible to change its function if necessary. Some of the investigated modular operating rooms were too small. One of the biggest operating rooms in renovated building B2 had a bearing beam in the middle of the ceiling, thus the ceiling systems and lights did not work flexibly. This resulted in poor usage of the room, which was a notable usability problem.

Accessibility and ergonomics. The importance of accessibility was emphasized in all the buildings. Both the one-storied modular buildings were estimated as the most functional, since the two-storied modular building A2 had no elevators. Entrances were accessible (flat terrains and functional ramps). In addition, the signs supporting orientation were sufficiently clear. The interviewees stated that all premises and especially toilets and corridors should be accessible and spacious enough for easy movement with assistive aids (patient beds, wheelchairs, walkers). The opening directions of doors should be correct, and door handles and automatic switches should be easy to use. Although the modular buildings were estimated as generally accessible, some problems did emerge. Long, narrow corridors in particular hampered the transmission of patient beds. The large number of electrical appliances in hospital work had not been sufficiently taken into account in the modular buildings. There were not enough power plugs, which resulted in wires lying on the floor, causing accessibility and safety problems.

All of the studied facilities, except the satellite model, were mainly evaluated as accessible. The facilities were easily perceived, assistance was close by, and distances were suitably short. Conversations and visual contact with patients and staff was considered important.

The users were mostly satisfied with ergonomics. Lifting gears and electrically controlled patient beds were widely used. The offices and consulting rooms were equipped with electrically operated desks and adjustable chairs. There was enough space for the instruments on the tables. In the non-modular hospitals, some chairs in the waiting rooms were dysfunctional.

Flexibility. Flexibility was highlighted as one of the key factors of functionality in today's HCFs, as activities are constantly changing. Moreover, all equipment should be movable and flexible. A sufficient number and suitable positions of power plugs and sinks should also be considered beforehand.

According to the interviewees, none of the modular and one of the old non-modular buildings were flexible, although some users found it difficult to estimate flexibility. Flexibility was mainly accomplished by means of furnishing. It was also possible to modify the modular facilities by adding or taking down walls or using unused spaces more effectively. The users of the modular operating rooms believed that easily enlargeable operating rooms would increase flexibility.

Acoustics and soundproofing. In HCFs, confidentiality requires that conversations are not heard by others. The assessments of soundproofing and acoustics varied. Soundproofing was mostly estimated as reasonably good. Yet some of the users of the modular facilities felt that voices could be heard from the reception rooms. Soundproofing of the modular imaging rooms was considered well realized.

Problems with acoustics emerged in the modular operating rooms especially, where much of the equipment makes humming and buzzing noises. Thus, communication between personnel was difficult during operations. Sometimes voices could also be heard from other operating rooms.

Lighting. The importance of lighting was emphasized in all the buildings. Suitable lighting is important in work tasks that require attention, and the users were highly satisfied with the lightness of spaces. The

rooms also had many windows. However, extra light was needed in some office spaces. In the modular operating rooms, the lighting was controlled by touch panels, which was considered highly functional.

ICT. The usability of information technology was an important issue, although the users only made a few comments about this. According to the interviewees, information technology generally worked well, but some problems occurred in remote access in the modular buildings.

Healthiness and safety/security

Healthiness was divided into four sub-categories. These were indoor air quality, temperature, sanitation, and hygiene factors. Both the modular and non-modular premises had good perceived indoor air quality, and the facilities and textiles were easily cleanable. Problems with temperature (too warm during the summer months and too cold in the winter) were reported in all the other modular facilities except in the imaging facilities. In the non-modular facilities, where temperature and air humidity were remotely controlled, the users were very satisfied.

The interviewees emphasized the importance of safety and security factors. Safety/Security was divided into occupational and patient safety, information security, and privacy protection. Although the premises were estimated as generally safe, some developmental needs arose, especially in the modular facilities. As the multiplicity of electrical devices was not considered, wires and extension cables lay on the floors, causing safety problems and difficulties in cleaning the premises. Due to inadequate storage, many devices were stored in the corridors. In the satellite-based module, the routes of the patients and staff were the same, which caused an information security risk.

Poor soundproofing caused problems with privacy protection. Security cameras and the ability to call for help were considered important safety factors. According to the staff, there were enough security cameras and possibilities to call for help. Only in the satellite module, the overly-narrow corridors and long distances from the main building weakened the feeling of security when the staff had to work alone, far away from colleagues (for example in the case of first-aid or a threatening patient). In the non-modular buildings, all the consulting rooms had two escape routes, which was considered a very important safety issue.

Comfort

The comfort characteristics were divided into eight sub-categories: Interior design, use of colors and artwork, the possibility to personalize spaces, lighting and views from the windows, acoustic privacy, indoor air, temperature, and functionality. Some of the descriptions fit into several categories (Table 1 and 2).

Interior design, use of colors and artwork, possibility to personalize spaces. Cozy interiors with harmonious furnishing, as well as easily cleanable surfaces were experienced as important in interior design. Wood was perceived as a healing and comfortable material. Use of colors and the possibility to personalize spaces by choosing materials, plants or artwork were considered important characteristics of comfort in both the modular and non-modular facilities.

According to the interviewees, no special attention had been paid to comfort in the modular facilities, as they were considered temporary solutions. The modular facilities were evaluated as quite 'sterile' and some users would have preferred more colors. In addition, they had no art, and very little had been invested in personalization, which was seen as a weakness. However, the users were satisfied with the new, clean interiors and materials.

The non-modular facilities were described as comfortable, and much effort had been put into comfort issues. There was a non-hospital-like atmosphere in both the existing non-modular buildings and a great deal was invested in interior design, individual colors and artwork. Warm and calming colors were used in the recovery wards, and art brought comfort into the facilities. The modular operating rooms in these facilities also had warm colors. Wood was used in the interiors and in facades, especially in

building B3. In B2, the staff were able to personalize the spaces during the design process, e.g. photographs of old workers were put on the walls.

Table 2. *Characteristics that enhance or hinder healthiness, safety and comfort in modular and non-modular HCFs.*

Simple expression	Simple expression	Subclass
Modular-HCF	Non-modular HCF	
No indoor air quality problems	No indoor air quality problems	High indoor air quality
Suitable temperature in imaging spaces	Suitable temperature Remote-controlled temperature and air humidity	Suitable temperature
Problems with temperature in all buildings except imaging facilities	No problems with temperature	Defects in temperature
No problems with sanitation and hygiene Easily cleanable surfaces and textiles Separate lobbies and entrances	No problems with sanitation and hygiene Easily cleanable surfaces and textiles Separate lobbies and entrances	Good sanitation and hygiene
Security cameras and possibilities to call for help	Escape routes in consulting rooms Security cameras and possibilities to call for help Wide corridors Enough space for electrical devices	Good occupational and patient safety
Long distance from satellite module to main building Lack of communication possibilities in satellite module Lack of communication possibilities due to poor acoustics in modular operating rooms Narrow corridors Lack of space for electrical devices Lack of power plugs resulting in extra wires lying on floors		Defects in occupational and patient safety
Good information security in most buildings	Good soundproofing supports privacy protection No common routes of patients and staff	Good privacy protection and information security
Lack of soundproofing causes problems with privacy protection Information security risk due to common routes of patients and staff in the satellite module	No privacy protection problems No information security problems	Defects in privacy protection and information security
New, clean spaces and materials Harmonious furniture	Cosy and non-hospital-like atmosphere Harmonious furniture High quality materials Wood as a healing and comfortable material	Good interior design
Rather sterile facilities, intimacy would increase comfort	Poor ergonomics of some furniture in lobbies	Defects in interior design
Some users would like more colors	Much effort put into colors and artwork Pleasant, harmonious and individual colors Warm and calming colors in operation rooms and recovery wards.	Use of colors and artwork
No art	No problems with colors and artwork	Lack of colors and artwork
Very little invested in personalization	Much effort on personalization by staff Photographs of old workers on the walls Non-hospital like work clothes	Possibility to personalize spaces
Functionality as a comfort/healing factor	Functionality as a comfort/healing factor	Functionality

Lighting, temperature, views from windows, acoustic privacy, and indoor air quality. Lighting, temperature, indoor air quality, and acoustics were considered usability factors, relating to a functional and comfortable work environment. In all the studied buildings, the staff were very pleased with the indoor air quality, lighting and views from the windows. However, some problems concerning temperature in the modular buildings were mentioned, as well as some problems in acoustics and soundproofing. All the users emphasized the importance of good soundproofing so that the staff could speak confidently and concentrate on their work.

Functionality. Surprisingly, functionality was considered a central comfort factor in every studied building (both modular and non-modular HCFs). Users of both modular and non-modular HCFs considered that the most important thing was that the premises supported work activities, and in their opinion, a functional building was also comfortable. The interviewees from both the modular and non-modular facilities stated that ‘As long as there are roofs and walls, lights and electricity and the work is done, other factors are irrelevant.

Discussion

In order to improve the efficiency of the healthcare processes, discharge of patients has to be quicker, and treatment should continue at home through home care or by a visiting nurse. Comparing the average length of stay in 2015 with the situation in 2010, a large majority of the EU Member States observed a reduction in the average length of time that patients spend in hospital, most notably in Finland, the Czech Republic and Bulgaria (Eurostat 2017). Since the patients stay in HCFs for a shorter time, it is

important that their care processes are efficient, and for the nursing staff it is essential that the patient care environment is functional and supports their work (Reijula et al. 2017, Aalto et al. 2017).

This study presents new knowledge and a detailed description of the opinions and experiences of healthcare personnel in terms of a user-centric, usable environment in the context of modular and non-modular HCFs. The paper discusses how usable and comfortable the modular HCFs are compared to the non-modular HCFs. Based on the results of this study, the differences were minor, although the scale and extent between modular and non-modular case buildings was notable. In addition, the results were quite consistent despite the age of the buildings. However, the temporary nature of modular facilities could be seen in the perceptions of the healthcare personnel; they did not emphasize the comfort aspects of the facilities in their interviews. The main differences between the modular and non-modular facilities appeared to be room size, soundproofing, safety issues, and the utilization of colors and artwork, which were all perceived as being better realized in the non-modular facilities. According to the interviews the main drawbacks in the modular buildings were long and narrow corridors, incorrect-sized spaces, and defects in room temperature and soundproofing. Similar results have also been identified in earlier studies (Da Rocha et al. 2015; Doran et al. 2011 and Edelman et al. 2016). This knowledge can be utilized in further design of modular relocatable laboratories and health care units like emergency medical care, mobile clinical units and up to redeployable trauma centers, which also Verderber (2015) mention in his book *Innovations in Transportable Healthcare Architecture* as suitable modular solutions globally.

According to the results of this study, both modular and non-modular facilities were perceived as non-flexible but mainly functional. In the case of the modular satellite-based solution, safety and accessibility were the most critical usability characteristics to consider. As regards the lay-out design of the modular buildings, structural limitations can result in long corridors, which in turn causes back and forth movement, which does not support effective work processes.

An earlier review study (Huisman et al. 2012) provided an overview of the evidence on the healing environments of HCFs (non-modular) and, for example, pleasant, comfortable and safe work environments for healthcare personnel. In their study, the outcomes concerning the staff were divided into three primary topics, which were Organization and Functionality (consisting of way-finding and lighting), Technical support (consisting of ergonomics) and Comfort (consisting of art, views, visual comfort, acoustic comfort, orientation). A comparison between the results of the present study and the primary topics of Huisman et al. (2012) shows that the main categories (functionality, safety/security, healthiness and comfort) and their sub-categories mostly highlight the same healthcare environment characteristics.

The results of the present study confirm that the earlier findings concerning the basic design elements of HCFs are relevant. In other words, lay-out solutions (Pati et al. 2015; Apple et al. 2014; Rashid et al. 2016) and visual accessibility (Nanda et al. 2015; Gharaveis et al. 2017) are considerable factors in the design assessment of HCFs. Salonen et al. (2013a, b) also state that the most beneficial design elements in HCFs are single-bed patient rooms, safe and easily cleanable surface materials, sound-absorbing ceiling tiles, adequate and sufficient ventilation, thermal comfort, natural daylight, control over temperature and lighting, views, exposure and access to nature, and appropriate equipment, tools and furniture.

Healing environments or comfortable workspaces

Along with a growing population with changing needs and the accumulating amount of research linking physical indoor environments to healthcare outcomes (Ulrich et al., 2008, Friedow 2012, Huisman et al., 2012, Ruohomäki et al. 2015), administrators and medical professionals have increasingly been recognizing the urgent need to create better HCFs. This means facilities with healing environments that provide both physically and culturally optimal support for the health, healing and well-being of patients, as well as for the hospital staff (McCullough 2010).

Earlier research has mainly focused on the healing environments of HCFs from the viewpoint of patients (e.g. Ulrich et al. 2004, 2008; Devlin & Arneill 2003; Laursen et al. 2014; Zahed et al. 2014;

Söderback et al. 2004; Abbas and Ghazali 2012; Schweitzer et al. 2004; Huisman et al. 2012; Dijkstra et al. 2008). Nevertheless, research shows that some characteristics of the indoor environment (Joseph 2007; Kaplow and Hardin 2007) and nature (Curtis et al. 2007; Korpela et al. 2014; Tang et al. 2015; Nejati et al. 2016) also affect the personnel working in these HCFs. In a recently published study, Salonen et al. (2017) showed that daylight, views of nature, and preferred art have a positive effect on the health and well-being of both patients and staff in hospitals. Bright light also helps individuals feel more vital and alert (Smolders et al. 2013), reduces blood pressure, increases oxygen saturation, has a positive effect on circadian rhythms and morning sleepiness (Zadeh et al. 2014), and improves performance of cognitive tasks (Smolders, de Kort & Cluitmans, 2012; Hadi et al. 2016).

Based on the results of the present study, all the abovementioned healing features of HCF environments are usability characteristics which have an influence on how comfortable staff members consider the spaces. Thus, healing features can also be considered characteristics of the usability framework in HCFs.

Nevertheless, as Salonen et al. (2017) state the effects of some design elements, such as lighting (e.g. artificial lighting levels) and layout (e.g. decentralized versus centralized nurses' stations) on staff and patients vary, and 'the best design practice' for each HCF should always be formulated in co-operation with different user groups and a multi-professional design team.

Conclusion

According to the present results, the healthcare personnel was mostly satisfied with both the modular and non-modular building solutions. The main usability characteristics of the work environment were functionality, healthiness, safety/security and comfort.

Based on the definition of usability (ISO 1998), three factors – *effectiveness*, *efficiency* and *satisfaction* – determine the usability of an artifact such as a built environment and workspaces. The results of this study can be presented as the usability factors above by distributing the main categories as follows: One of the main categories, functionality, with its sub-characteristics, can be presented as an expression of *efficiency*, since it enables staff to perform with ease and little use of resources. The healthiness and safety/security categories, with their sub-categories, can be presented as an expression of *effectiveness*, since healthy and safe spaces enable staff to deliver a certain desired care. The fourth category, comfort with its sub-categories, can be presented as an expression of *satisfaction*, as it describes the users' feelings and attitudes towards the workspaces.

The present study highlights two additional characteristics that affect the feeling of comfort: functionality and the possibility to personalize workspaces. Since functional and personalized workspaces increase the satisfaction of healthcare personnel, these features increase comfort and thus promote the usability of HCFs.

The results of this study show that more research is needed to clarify the kind of emphasis or compromises that are needed in order to design flexible user-centric healthcare spaces (modular and non-modular), which in tandem are healing environments for patients and usable work environments for staff. The concept of healing does not appear in a conventional way in the opinions of the staff. More often, the staff highlight functionality as the most important characteristic in a work environment; they even estimate functionality as a healing or restorative feature of the work environment. Thus, as modular HCFs can be leased for up to 25 years, it is essential to also consider comfort characteristics in the layout and interior design of workspaces.

This study enhances designers' and all stakeholders' understanding of the significance of taking into account usability characteristics in designing of HCFs, and also the importance of end-users' knowledge and needs concerning their workspaces as a part of design phase. As its best, the ongoing social and healthcare reform in Finland may also utilize the results and open the modular healthcare industry for international competition.

The practical contribution of this study is that it provides the staff's perspectives and experiences of the characteristics of environmental comfort and satisfaction that could be applied in future workspace design to both modular and non-modular HCFs. However, as the results derive from individual cases, they cannot be generalized as such.

In the future, the main challenge for research will be to explore and specify staff needs and to integrate these needs into the built HCF environment (Huisman et al. 2012; Aalto et al. 2017). We also need more research on the comprehensive impression of 'healing' from the viewpoint of staff.

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