Healthy Buildings Supporting Living and Working of the Ageing Population

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Abstract

The ageing population demands designing environments while considering their functional needs, desires and wishes. The ICF framework together with the gerontechnological principles can help to have focus on how to adjust or to (re)design the environment for this population. This paper focuses on building-related environmental factors including eHealth solutions. Knowledge and understanding of how the environment is perceived by older people help to set the building performance requirements and gives direction to improve our research to create healthy environments for future users.

Keywords: Gerontechnology; enriched environments; participatory design; ICF

Introduction

Buildings are just objects and cannot heal or cure people. Buildings though can be designed such that people can experience discomfort and their health and wellbeing are hampered. This phenomenon is observed for instance in an office building that has a poor-quality indoor environment. The complaints that office users experience are grouped under the term Sick Building Syndrome (SBS). SBS comprises several vague complaints and symptoms such as headache, dry skin, dry eyes, sore throats, without having a known aetiology. In the previous century, SBS was predominantly reported by office workers, leading to less work performance and sick leaves (Teeuw, 1992). In some studies, ventilation shows to affect the prevalence of SBS while others could not find an association at all (Sundell et al., 2011).

The societal challenges comprised in the social sustainable goals of the United Nations and especially Goal 3, *„Ensure healthy lives and promote well-being for all at all ages“,* established a paradigm shift from research on Sick Buildings to research on Healthy buildings. So, buildings that prevent people to become sick and or buildings that support those with a chronic disorder. The latter is very much relevant from the perspective of an ageing population. World-wide, the population is ageing according to the Global Age watch index. The Global Age watch index has compared the population in 2015 with the predicted one in 2050 when in a major part of the world 30% of the population will be 60 plus. Noteworthy is that not only Western countries are ageing but also so-called emerging markets, in Asia, as well as India and Brazil. Ageing even will occur in Africa (Global Age watch, 2015). Ageing will occur in these countries because people live longer, but also since young people migrate from (rural) areas to urbanized areas.

Furthermore, 70% of the population will be living in an urban environment (Prüss-Üstün et al., 2016). In the meantime, governmental policy demands working to a higher age when compared to the past century due to the relatively good health of the ageing population. Also, ageing people have desires and ambitions to participate in society and age-in-place. For all of this, focusing on how to create healthy environments will contribute to the described societal challenges.

Background

Before elaborating on healthy buildings, let us first look back into history. Before Christ, the philosopher Epicurus (341-270 BC) had a view on healthy

environments. Epicurus desired to have a happy, calm life characterized by ataraxia; peace and fearless and aponia; painless and enriched life by having friends around. To reach this goal, home and garden were designed. Healthy buildings for happy lives. Elements needed were to include space to relax with friends, self-management, and financial independence. Elements that can be found in the principles of healing environments concepts. In these concepts, the focus is on how environments can contribute to the healing of patients while supporting staff personnel in their wellbeing and work performance (Huisman et al., 2012). In analogy to the concept of the healing environment, we developed the concept of enriched environments. This concept was developed to be applied to long-term care facilities with residents of high age and frail health conditions. It relates to creating environments to support frail old people in their wellbeing and strive for meaningfulness while optimal supporting healthcare professionals to execute their work. Nowadays it is for example the famous architect Thomas Rau who works with the principles of healthy minds for healthy environments. In his view, we must be aware of the consequences of buildings for sustainability purposes. I translate this view and the view from Epicurus in creating healthy environments for healthy minds and bodies.

In this paper though the focus is on ageing people that have a life with desires and ambitions to be active alongside their possibilities. The public considers old people as having all kind of health conditions and as people who need support. However, older people have a different view, they consider themselves as the individual they desire to be at a certain moment in time. Older people vary divers. They can be highly physically active even at a higher age, or not at all. They may suffer from having cognitive disorders but still desires to participate and be meaningful and connect to people who they love. We must consider that being old is not a disease. The process of ageing can be thoroughly healthy, and illness is not a necessary part of ageing. There are frail older people but also very vital people; independent living able to execute daily activities, active in sports such as walking but also skating or just reading a book or working as a voluntary worker or in a paid job.

ICF Framework and Gerontechnology Principles

Building environments should be designed to support or compensate for the limitations older people experience while executing their tasks. This accounts for all buildings whether residential or offices or other working environments. The approach for creating healthy buildings and examining the interaction with users is by applying the WHO framework of the International Classification of Functioning and Disabilities (ICF) (WHO, 2001). In ICF environmental factors comprises from the perspective of the indoor environment, indoor environmental factors such as light, sound, air quality, temperature but also e-Health or e-assistive technologies (see Figure 1).

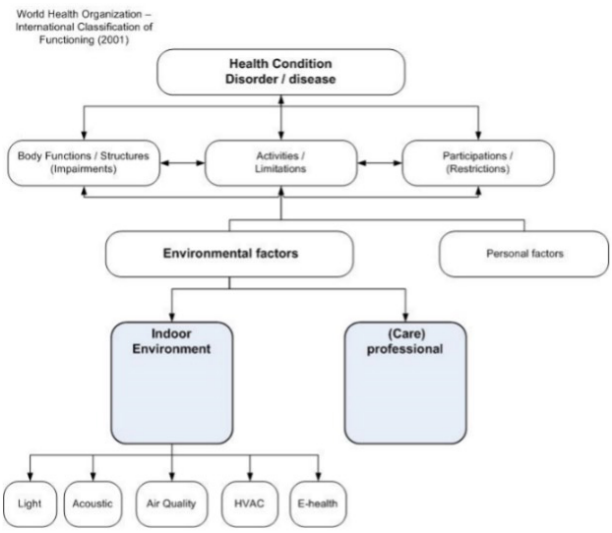

Figure 1: WHO-ICF framework with an emphasis on building-environmental factors (Kort, 2012).

Also, gerontechnological principles are relevant when creating healthy environments and for optimal implementation of eHealth or e-assistive technologies. Therefore, the age and technology generation matrix as well as the cross-fertilization matrix on gerontology and technology are relevant for the application of e-Health or e-Assistive solutions. The age and technology generation matrix illustrates the combination of stages of ageing with the different technology generation (Bronswijk van et al., 2009). To optimal embed an e-Health solution in the environment and for optimal use by ageing people it is relevant to consider the technology generation of the target group and to consider which gerontological conditions the technological solutions is aimed at.

		Target population			
		1st age Formative years	2nd age Main working phase	3rd age Active retirement	4th age Frailty & Dependence
Technology generation	Mechanical products, hierarchical organization				
	Electro-mechanical products, hierarchical organization				
	Menu driven products, layered software ('Microsoft generation')				
	Gaming software with proficiency levels, relational (non-hierarchical) organization at each level				

Figure 2 a) the Age and Technology (Bronswijk et al., 2009) generation matrix

		Technology					
		(Bio)Physics (Bio)chemistry	Architecture Construction	Information Communication	Mechatronics Robotics	Ergonomics Design	Management Economics
Gerontology	Physiology Nutrition						
	Psychology Social psychology						
	Sociology Demographics						
	Medicine Rehabilitation						

Figure 2b) the Cross fertilization matrix for Gerontology and Technology (Bronswijk et al., 2009)

With the ICF-framework and the Gerontechnological principles in mind we can start to design healthy environments for the ageing population.

Light, Vision and Sleep

For all people, light is relevant for our body and mind. (Day)light has effects on our visual and non-visual functioning. Light is electromagnetic radiation in the visible part of the spectrum that influences human performance (Boyce, 2014) and thus also older people. Ageing adults (60 plus) need three times more light than their younger cohorts (20 minus) for comfortable visual functioning due to the biological ageing of the eyes (Watson, 2001, Bouma et al, 2006). With age also colour discrimination (blue, green and violet) decreases due to the yellowing of the lens but also the amount of light that reaches the lens is less. Older people may suffer from Cataracts, Glaucoma, Macular Degeneration or Diabetic Retinopathy (Boyce, 2014), which limits their visual functioning and restrict their participation in society. A previous study by Sinoo et al showed that almost all the examined nursing homes did have lighting conditions below the threshold of 750lx and a correlated colour temperature below 5000K (Sinoo et al., 2011). This meant that the residents were living in a relatively dark environment. In some cases, an illuminance of 200lx was measured in the common rooms. Care professionals are still unaware of the benefits of daylight on frail people. Their perspective is to create a cosiness and ambience environment. Light though also might have negative effects; people with cataract are sensitive to glare and older people recover slower from glare; flickering and stroboscopic light effects may hinder the work performance whereas exposure to low correlated colour temperature negatively affects the non-image-forming effects that regulate the circadian system. Poor light conditions may also increase fall risks in combination with worse or uncomfortable visual functioning.

Exposure to daylight is also relevant for a good night sleep because lights regulate the circadian system (biological clock). Older people can experience poor sleep quality either due to a chronic condition (dementia syndrome) or due to the care burden that they have while taking care of their loved ones. More than 50 % of the family carers of people with dementia experience extreme care burden (Alzheimer Nederland, 2019). This contributes to suffering poor sleep quality (Ryuno, et al., 2020). Poor sleep quality is a risk for amyloid deposition in preclinical Alzheimer disease (Ju et al., 2013).

From the perspective of light and vision, older people need to be exposed to daylight to obtain an appropriate circadian rhythm, have light conditions with at least 750 lx for optimal visual functioning. Furthermore, poor light conditions need to be avoided for better sleep quality and reduction of fall risks. Currently, the adagio is light is medicine; to have a good night sleep, to be alert and motivated during the day, and for optimal visual functioning.

Sound and Hearing

When ageing, also hearing loss will occur. Therefore, it is highly relevant to design optimal acoustical conditions and avoid unwanted sound (noise) for daily functioning at work or home. Older people might not be aware of the deterioration of hearing functioning. They will develop personal strategies to cope with the hearing loss. Hearing loss can of course be compensated using hearing aids since not all environments (e.g., railway stations) can be modified in a way comfortable for older people. At home, work or at the residential care facility, though the environment can be adjusted or designed to fit for comfortable and functional hearing. A study by Huisman et al. showed that in long-term care facilities the acoustical condition is not as desired (Huisman et al., 2017). The averaged reverberation time, background noise and the STI were measured. The STI stands for the speech transmission index expressing speech intelligibility. A value below 0.3 results in unintelligible speech. The sound environment is being characterized by room acoustics and sound sources. Room acoustic parameters depend on the location of sound sources, receivers, space typology, source type and the behaviour (Reinten et al., 2017). Older people are sensitive to noise in their environment therefore, the acoustical climate should not be a barrier to their functioning. Reduce noise levels in health care facilities has been associated with reduced stress, fatigue, and increased satisfaction (Ulrich et al., 2008). So, this needs to be considered in working environments where older people work. In environments where older people work or live the speech transmission must be considered when designing a healthy environment. Speech transmission quality is highly relevant in spaces where social interaction takes place.

Illustration from Practice

In the project Creating enriched environments in long-term care facilities (Huisman et al., 2020; Huisman et al., 2017) the ICF framework was applied for the environmental factors light and acoustic in combination with the use of the mentioned gerontechnological principles. The project comprises two common living rooms in a long-term care facility. During the day approximately 12 residents with neurological disorders as dementia resided. The common rooms are mirrored rooms. One room was kept as such (reference room) while in the other interventions were made. Interventions included the change of the room layout to enhance the sightlines, the lighting and acoustical conditions. So light and acoustical conditions as environmental factors according to ICF were central, while from

gerontechnological perspective the focus was on the 4the age (frailty) and the mechanical generation (Figure 2a) while applying the cross-sectional matrix the focus was on the cross-section of architecture and construction (technology) and (social) psychology (gerontology) (see figure 2b). In figure 3a and b the two rooms are illustrated. Figure 3a is the reference situation whereas figure 3b is the room with the intervention. The results were that the horizontal illuminance (Ehor) was 3 times higher, the vertical illuminance (Ever) was 1.5 higher and the correlated colour temperature increased with 1.02 in the intervention room when compared to the reference room (Huisman, 2019) while the acoustical conditions for the reverberation time, was decreased with more than 50% and STI went from 0.62 to 0.74 in the intervention room (Huisman et al., 2017).

The acoustical conditions improved by installing sound absorption panels. Light conditions were improved by using innovative light ceiling panels as well as a smart daylight sensor to mimic the dynamic of daylight. After the interventions, observations showed that residents of the reference room were often present in the adapted room. Professionals indicated via interviews that they preferred this room over the reference room due to having a better eye on the residents and easier communication with the residents. So, the interventions had positive effects as expected. The only negative effect in the first week was that professionals reported that they cannot operate the daylight sensor. This was an omission at our sight. Though professionals did participate from the start of the project and shared their desires and wishes, the designed intervention did not include their technology generation level and skills. Furthermore, until now the gerontechnology matrixes focus on the needs of one type of user. We also should have walked through the intervention strategy from the perspective of the professionals.

HVAC

HVAC stands for Heating Ventilation and Air Conditioning. HVAC systems are installed to control the indoor air quality, ventilation, and temperature conditions. Aging adults perceive temperature conditions different than younger people due to changes in the circadian rhythmicity in body temperature, decline in basal metabolism and less physical activity. In most buildings these aspects are not considered.

Designing is focused on younger cohorts. Buildings where people with dementia live should also consider that people with dementia could have a delayed response on a certain thermal condition

Figure 3a: reference situation, Picture by Femke van den Heuvel (Huisman et al., 2020)

Figure 3b: the intervention room, Picture by Femke van den Heuvel (Huisman et al., 2020)

(Hoof van et al., 2010). Control of the Indoor air and temperature conditions can also be smart regulated. In offices devices can be installed according to the personal preference of a worker and or aligned with seasonal influences. At home people can have control on their environment. A study with healthy students about the influence of window opening on sleep quality showed that sleeping with windows or door opens has a positive effect on sleep quality (Mishra et al., 2018), whereas the study involving older people showed that there was no effect on the sleep quality. This could have been caused due to the lack of monitoring daytime sleep (naps). Our protocol followed the one for healthy students. In future, we need to focus on needs and lifestyle of older people before inviting them to participate in research.

e-Health

e-Health solutions, such as the use of apps on mobile phones, or tablets, or e-assistive technologies, or (social) robots are also environmental factors that can be used to close the gap of the functional threshold and the functional loss for optimal participation and execution of daily activities. These technological innovations can be embedded in building systems or be stand-alone solutions. Technological innovations for ageing people are though mostly not aligned with the technology generation of the targeted users. Furthermore, the users could be unaware of the level of technological innovations and or technology solutions are applied though users lack the skills for optimal use. For the use of e-Health solutions, ageing people need to have or obtain digital skills. They also should be willing to use e-assistive technology to not be limited in their activities or restricted in social participation. Ageing people seem to be willing to use e-Health. Also, these solutions should fit the design preference of older people's home- or working environment. Readiness to use e-Health technologies by older adults seems to be related to self-efficacy and older people's actual use of technology. Self-efficacy and digital literacy are playing a relevant role to use technology (Houwelingen van et al., 2018). Another study focusing on e-Health for people with COPD revealed that age, education degree, income, physical functioning (including arthrosis of the hands), and ethnicity are predictors for use. A higher physical functioning results in more ICT use (Vorrink et al., 2017). This shows that e-Health for physical functioning also will contribute to ICT use either in the home or working environment.

In the working environment, the use of robots contributes to keeping ageing adults in the workforce. Robots can be part of the work process to ease the way of working of (older) people as is the case for industrial/collaborative robots or they can compensate for the loss in functional capacity, or support functioning e.g. for lifting heavy weights or for the decline in cognitive capacity e.g. for the response latency. This is increased due to ageing and influences the lead time in production and distribution systems (Bogataj et.al., 2019). Other robots that may play a role in ageing people lives are social robots. This will be addressed in the second illustration for practice.

Before describing this the pyramid of technology will be discussed. The pyramid of technology, a model by van Mensvoort (Mensvoort van 2013), describes in analogy with Maslow's Hierarchy of needs for human requirements, the levels of technologies. The pyramid of technology model is developed as a tool for inventors, engineers, designers, and entrepreneurs to be aware of the playing field of technological development. We have experienced that it also works as an

excellent tool for researchers and health care workers to be aware of the level of a technological innovation. The lowest level being technology that is envisioned (ideas or incubators). The second level is the operational level concerning proof of concept or prototypes. The third level is the level in which technology gets from lab to society. In most cases, this is a level at which e-Health-related technology is being tested in health care settings. In practice, people are not always aware that when working on projects with technological innovations, these are still on this level. The other levels are illustrated in figure 4.

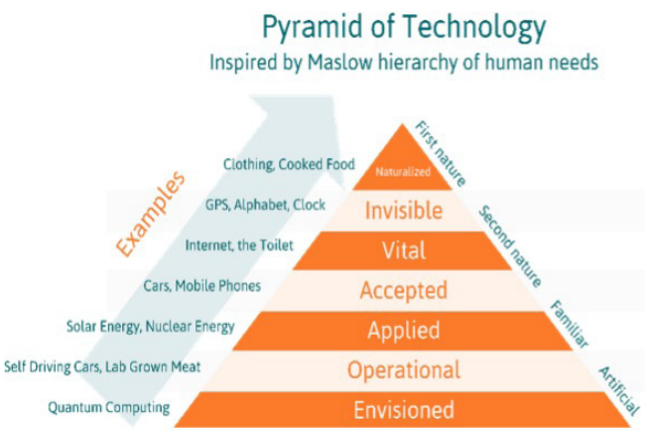

Figure 4: Pyramid of Technology (Mensvoort, 2013)

Figure 5: Care Robot ZORA (Chantal Huisman)

Illustration from Practice

In the project the social robot (NAO-type) ZORA (see figure 5) was evaluated for use in 14 nursing home organizations (15 locations) in the period from May 2016 – November 2016 and from April 2017 – December 2017. The robot was used for social activities and entertainment (Huisman & Kort, 2019). Care professionals were given all possible support (time, training, and ICT support) to present the robot to the residents. This was mostly done in group sessions and occasionally in a one-on-one session.

Applying the gerontechnological principles, the project targeted older people in the 4the age (frail and dependent) and the mechanical generation when looking at those using/playing with the robot. The purpose was to entertain resident while contributing to social participation and quality of life via given enjoyment with ICT (robots) see figure 2b. At the same time care professionals were also a target group. They varied in age and in technological experience. Some of the findings regarding the barriers were that at most locations there was poor Wi-Fi connection, software failures, poor speech intelligibility of the robot for the residents, and just too complicated to program activities on the ZORA. Facilitators amongst others were that clients liked ZORA's activities, pre-programmed music makes residence reminisce and the music encouraged residents to move. Staff highly appreciated the training and instruction sessions, the availability of the helpdesk, and the meetings with all the project leaders at a location (Huisman & Kort, 2019). While monitoring and evaluating the implementation of the robot in the nursing homes we noticed that board members and management did expect that the robot was on a level of acceptance according to the pyramid of technology. The perception of the company that delivered ZORA was though that the robot moved

back and forth from the operational level to the applied level. So, although both residents and staff were open to using the robot, the robot still went through some design iterations. That is what the company did expected that would happen, while the nursing home organizations expected to work with a robot ready for practice. Therefore, it is highly relevant to be aware of the level of the technological innovation, the target group(s), and have a mutual agreement of what is expected of an implementation project when also involving frail older people and care professionals that have a different experience in using technology. They might need special attention in training their digital skills.

To Conclude

Environmental factors influence (older) people performance. For older people, a better understanding is needed about the interaction between these factors and their daily activities. Furthermore, the ICF framework together with the gerontechnological principles help to have focus in creating healthy environments. From the presented findings guidelines can be developed for engineers, designers, installers, facility management and care professionals.

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