Steps towards an acoustical intervention in a nursing home for the benefit of residents and staff: A case study

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E.R.C.M. Huisman, N.H.A.M. van Hout, J. Reinten, H.S.M. Kort. Steps towards an acoustical intervention in a nursing home for the benefit of residents and staff: A case study. Gerontechnology 2017;16(4):249-256; https://doi.org/10.4017/gt.2017.16.4.007.00 **Purpose** In this case study, the focus is laid on the acoustical climate as potential indoor environmental aspect that contributes to organisations' ambition and real estate strategy. Currently, it is unknown how corporate real estate managers or facility managers can use functionalities in the physical environment to support their real estate strategy. This study is part of a larger project on how the indoor environment (light, indoor air and acoustics) affects the well-being of healthcare professionals and quality of life of older people with a frail health condition. The aim of this case study is to describe the steps in order to make the optimum real estate decision based on the best available evidence for the acoustical climate in nursing homes to add value for their users. **Method** Two locations (A and B) of a nursing home organisation were selected to execute the following steps (1) acoustic measurements, (2) interviews with healthcare professionals before the intervention, (3) the development and realization of an acoustic intervention, and (4) an evaluation of the intervention via acoustic measurements and interviews. **Results & Discussion** The acoustic measurement showed a difference in the averaged reverberation time and background noise levels measured at location A and B. All healthcare professionals mentioned that the room acoustics at both locations were acceptable. However, the healthcare professionals at location B mentioned they experienced the living rooms as acoustically hard, which implies a relatively long reverberation time. Therefore, the intervention was conducted in one of the living rooms at location B. The evaluation of the intervention showed a decrease of 50% in reverberation time and a 0.12 increase of the speech transmission index. The healthcare professionals (location B) remarked that they felt more comfortable and less tired and according to the professionals, the residents seemed more comfortable in the living room at location B. The findings show that an intervention to enhance the acoustical climate in nursing homes, has a positive effect on healthcare professionals and residents. In this case, the decision was made by the board members of the organisation to renovate all living rooms at that particular location aligned with the chosen intervention.

Keywords: facility management, corporate real estate management, health, speech intelligibility, sound sources

Introduction

The care sector in the Netherlands is changing rapidly due to changes in the care legislation. One of these changes is the deregulation with decreased public involvement and funding[1]. Due to this deregulation, nursing home organisations are themselves responsible for all real estate investments and costs of accommodation have become an integral part of the healthcare costs[1]. While this gives nursing home organisations more freedom in the briefing, design, and management of care buildings and real estate investment[2,3], decision making on nursing home real estate has increased in complexity with more opportunities and threats to consider[1]. Other important trends in the Dutch Healthcare sector are technological innovations (like home automation) and the design of healing environments[4].

These trends have influences on the design and management of nursing home real estate.

In this changing context, nursing home decision makers have to manage and design real estate in order to match the real estate supply and stakeholders' demand[1]. This requires a growing awareness and deeper understanding of the management and design of real estate by nursing home organisations. In addition, how the real estate strategy can contribute to the overall organisational performance[1,5]. Within this context, nursing homes in the Netherlands become more and more aware of the meaning of their real estate decisions in relation to organisation performance and user satisfaction[6]. For example, the decision creates a healing environment by adapting the indoor environment (via e.g. light, indoor air and acoustics adaptations) can contribute to increase the user satisfaction.

A nursing home is a place in which residents reside and healthcare professionals work. Both users have different demands regarding the environment. Therefore, nursing homes should be concerned with both residents and healthcare professionals in relation to their real estate decisions[7]. Currently, nursing home organisations aim to represent an organisation that focuses on both, the care and the functionalities of the indoor environment (like e.g. healing environment), in order to contribute to the quality of life of the residents and the wellbeing of healthcare professionals[8]. In order to achieve this, corporate real estate managers and facility managers need a better understanding of how to align their healthcare buildings to the trends and developments in the healthcare sector.

Aspects of the indoor environment are one of the steering mechanisms for real estate decisions. However, it is a challenge for corporate real estate managers and facility managers to make real estate decisions based on indoor environmental factors[9,10]. A clarification could be that it is unknown how aspects of the indoor environment can contribute to core business drivers such as increased client satisfaction or increased productivity of healthcare professionals.

In this case study, the focus is laid on the acoustical climate as a potential indoor environmental aspect that contributes to organisations' ambition and real estate strategies. The international classification of functioning, disability, and health (ICF) provides an overview of various aspects of health conditions in terms of influencing activities of biological, personal, environmental, and social factors[11]. Within the ICF model, the indoor environment (e.g. light, acoustics, indoor air) is seen as an environmental factor. In this case a focus is laid on the acoustical climate, the facility managers and technical staff can adapt the indoor environment and systems to improve the residents' and healthcare professionals' environment. All this could enhance the client and employee satisfaction of the residents with hearing problems.

The acoustical climate in a Dutch nursing home was measured to gain insight into the added value of the acoustical climate regarding healthcare professionals' work perception and the well-being of the residents. The aim of this case study is to describe the current acoustical climate and to examine how to enhance the acoustical climate in the nursing home in terms of residents' quality of life and the well-being of the healthcare professionals. Furthermore, steps to take real estate decisions with the acoustical climate as a case are elucidated. This case study is part of a larger project on how the indoor environment affects the well-being of healthcare professionals and quality of life of older people with a frail health condition. This project focuses on the alignment of real estate decisions in relation to building performance of nursing homes.

The acoustical climate in nursing homes

The acoustical comfort of buildings is the capacity to protect users from noise and to offer an acoustic environment that is suitable for the purpose of the building it is designed for[12]. The indoor sound environment is determined by room acoustics and sound sources (like music, traffic, HVAC systems, or the presence of distant people). Important acoustic parameters are the reverberation time and background noise level. Both parameters influence the speech intelligibility in the room[13]. The reverberation time of a room characterizes how long acoustic energy remains in a room. While the influence of the acoustical climate and room acoustics are considered as an important factor in building design[12], in our reading of the literature other targets group such as older people with a frail health condition residing in nursing homes are under-represented.

The acoustical climate in nursing homes could be a barrier for residents as they are more sensitive to the noise in their environment[14]. For example, hearing loss can cause problems in understanding speech and holding conversations in noisy environments[15]. For the acoustical design of rooms, where social interaction takes place, the speech transmission is relevant to be taken into account. Moreover, it is known that noise can cause stress, sleeping, and behavioural problems amongst residents in nursing homes.

Reduced noise levels in healthcare facilities have also been associated with reduced stress, reduced emotional exhaustion and burnout, re-

duced fatigue, increased satisfaction, increased effectiveness, increased productivity[16,17,18] and improved communications and decreased medical errors[19,20]. Additionally, improved acoustical conditions have been linked to a reduction in work demands experienced by healthcare professionals, as well as reported pressure and strain[21]. The above mentioned studies showed that for both user types, the residents and healthcare professionals, the acoustical climate is an important indoor environmental factor that should be considered in the initial phase of the design process. However, there is still limited research focusing on the effects of room acoustics on healthcare professionals and their caring tasks. The WHO defined general guidelines for acoustical climates, but none are specifically defined for older people with a frail health condition or residents in nursing homes[22]. Therefore, there is a need to examine the interaction between the indoor environment for nursing homes and the residents and healthcare professionals. A better understanding will support facility managers and corporate real estate managers in the operationalisation of their real estate decisions.

Method

The study setting

This case study was performed at a Dutch nursing home organisation in the western part of the Netherlands. This nursing home organization had the ambition to enhance employee and client satisfaction through increasing the environmental quality. For this ambition, theories such as the healing environment concept, Plane Tree, Mayo Clinic or Eden Alternative, can be used to determine relevant aspects to focus on in the real estate strategy[4]. Based on these theories the aspects, light, acoustics and indoor air quality were selected by the board of the organization to be investigated and improved to increase the quality of their buildings. In this case study, the aspect acoustics was elaborated. Two locations of the nursing home organization were examined to see how the acoustical climate could contribute to residents' quality of life and support the wellbeing of healthcare professionals (*Figure 1*). Location A is a 4-floor building with three wings. Location B is a single floor building. In total, nine living rooms were assessed in this case study (seven in A and two in B). The living rooms for the assessment were selected in corporation with the staff and based on the availability to execute acoustic measurements. The lay-out of the nursing home is such that six bedrooms are connected to one living room, a so called small living facility. During daytime, residents use the common living room that is connected to their bedrooms. Each living room has an open-plan kitchen, a large table, and a small seating area with a television. During the day, two staff members, including nurses, are available per living room.

Study design

In this case study, the following steps were taken: (1) acoustic measurements to measure the current acoustical climate condition, (2) interviews with healthcare professionals, (3) selection, development and realization of the intervention, and (4) evaluation of the intervention. In the following sections, the steps are described in more detail.

Step 1: Acoustic measurements

To describe the room acoustics of nine living rooms (7 in A and 2 in B) the following parameters were used: background noise level, reverberation time, and the speech transmission index (STI). The STI is an objective measurement predictor of speech transmission quality and is, amongst others, influenced by room acoustics. These measurements were performed according to ISO 3382-2/3 and IEC 60268-16 in an unoccupied situation. Depending on the lay-out of the living rooms the STI was derived from measured impulse responses between 9 to 13 sources and receiving points. Besides the measurements, in all common living rooms, an inventory of the acoustic finishes of all rooms was made.

Step 2: Interviews with healthcare professionals

Further information regarding the living rooms was obtained through interviews with healthcare professionals. The aim of the interviews was to get insight into the perception of the healthcare professionals on their well-being and factors facilitating or restricting their work activities related to the sound environment. Twenty-two healthcare professionals were invited by the team leader of the location to participate in the interviews. The healthcare professionals worked in different locations in different acoustical climates. They received a letter in which a clear description of the study was provided. In total nineteen healthcare professionals were willing to participate in the study. Seventeen healthcare professionals were women and two healthcare professionals were men (age range: 22 to 61). The interviews were held at both locations. The interviews took place at the workplace of the respondents. The topic list was developed together with the national organization for applied research TNO and based on the expertise of the research team. The topic list was pilot tested with students. All interviews were audio-recorded with the permission of the participants and were transcribed and entered into MaxQDA version 12. First, each transcript was read in its entirety. Then, they were read a second time to develop codes. Defining the codes was done through two processes of open coding and axial coding[23].

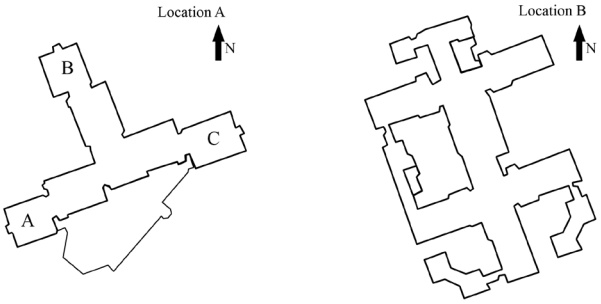

Figure 1. Location A (l) and Location B (r)

Step 3: Selection, development, and realization of the intervention
Intervention decisions were based on the outcomes of the acoustic measurements, interviews with healthcare professionals, an acoustic expert (the 2nd author), and the board of the healthcare organization. Based on the findings in step one and two, location B was selected for the intervention. At location B two mirrored living rooms next to each were part of this study; one served as a control location (no-intervention) and in the other, an intervention was conducted. The analysis of the measurement results of location B showed in this case the STI was mainly dependent on the reverberation time (RT) and not on the background noise level. The RT of both living rooms, averaged over the octave bands 125 Hz – 2000 Hz, was 0,86 s. The goal of the intervention was to see how much the STI would improve by reducing the RT by factor 0,5. A 3D raytracing model was used to determine the amount of sound absorbing material required to reach this reduction. The intervention contains the usage of 35 m^2 sound absorbing material. For the sound absorbing material the Ecophon solo rectangle panel in the size 2400 x 1200 x 40 mm with a weight of 11,5 kg was used. In total, twelve panels were positioned at the ceiling of the living room with an air gap of 200 mm between the panels and the ceiling.

Step 4: Evaluation of the intervention via acoustical measurements and interviews
After the intervention, room acoustic measurements (step 1) were conducted again to determine the effect of the intervention on reverberation time and STI. Additionally, interviews were held with the two healthcare professionals regularly working in the adapted living room to gain insight into the impact of the intervention on their well-being and performance. To gain more insight into the decisions a non-structural interview with the facility manager of the organization was held.

Ethics
In the organization, it is the policy to inform the client board about any research project. The client board approved the research project. Furthermore, the managers of the organization agreed on the measurements from the start of the project and were involved in the planning of the project. The professionals and family carers, along with the residents, were informed about the measurements. Daily activities were not disturbed nor hindered by the measurements procedure.

Results
In the following sections, the outcomes of the acoustic measurements, interviews, and the intervention are described.

The acoustic measurements
The averaged reverberation time of the living rooms of location A was approximately 0,2 s shorter compared to the living rooms of location B. Furthermore, the results showed a difference in the measured background noise levels in an unoccupied setting. The averaged background noise level of the livings rooms of location A was 5 dB higher than the measured level in the living rooms of location B (*Table 1*). Although the determined speech intelligibility index of the livings rooms of location A and B was almost equal a difference in the acoustic climate between the living rooms at location A and B was measured.

The interviews
The analysis of the interviews led to three main themes: sound sources, speech intelligibility and, reverberation. These themes were associated with six subthemes (*Table 2*). The perception of the acoustical climate at location A and B confirms the measured difference in the reverberation time. The healthcare professionals mentioned that the living room at location B was acoustically hard and mentioned reverberations. Although the living rooms at location B were acoustically hard, the healthcare professionals said that they expe-

Table 1. Overview of the acoustic assessments

	Location A (N=7)	Location B (N=2)
Reverberation time $T_{20,gem}$	0,67s	0,86s
Background noise L_{aeq}	41 dB	36 dB
Speech intelligibility index (STI)	0,62*	0,63*

*Average value determined over all source and receiving points.

Table 2. Identified themes, subthemes, and results before the intervention

Location	Theme	Subthemes	Results
Location A	Sound sources	Music/TV	Two healthcare professionals mentioned that they use the radio daily. In the morning, they use the radio to give the residents a good start of the day. Sometimes residents asked to turn the volume of the music. This could be related to their hearing aids. Another argument to use the radio was to break the silence in the living room.
		Contact noise	Eleven healthcare professionals mentioned that moving the furniture caused contact noise. This is clearly audible between the different floors. One healthcare professional mentioned the music between the bedrooms was audible but it was not experienced as a hindrance. This sort of noise belongs to the daily routine.
		Environmental noise	Six healthcare professionals mentioned that they experienced no hindrance from environmental noise coming from outside of the building. One healthcare professionals said *"the residents were more disturbed by each other than by other sound sources"*.
		Background noise	Two healthcare professionals mentioned the cooker hood as disturbing sound. It causes distraction and restlessness by the residents. One healthcare professional gave the height of the living room as an argument for background noise. Another professional was disturbed by the comings and goings of people.
Location A&B	Speech intelligibility	Have a conversation	Nine healthcare professionals experienced no difficulties regarding the communication with residents. The healthcare professionals related communication problems to the voice, the health condition of the resident, the stage of dementia, and the volume of the music.
Location B	Reverberation time	Reverberation	Two healthcare professionals mentioned the reverberations in the living room caused by the height of the living room.

rienced no hindrance from various sound sources. The sound sources in the living room were mainly caused by the activities of residents and healthcare professionals like: listening to (live) music, watching TV, moving chairs, cooking, and cleaning.

The acoustic measurements and evaluation

Figure 2 shows the living room with the sound absorption panels installed at the ceiling (left) and the living room without the sound absorption panels at the ceiling (Right). The colour of the sound absorption panels is white (left), while ceiling in the control living room (right) is wood. The results of the intervention showed a decrease of 50% in reverberation time and an increase of the STI of 0.12 (*Table 3*).

The two interviewed healthcare professionals received the new situation well. They experienced that the reverberation was less than before. They said, "there is an obvious difference between the two living rooms next to each other". The healthcare professionals gave remarks about the living room being more quiet and peaceful. They said, "I felt less tired than in the other living room". Another remark they made was: "I can do my work better". In addition, the healthcare professionals can have a conversation with the

Figure 2. The living room with the sound absorption panels installed (l) and the control living room (r).

Table 3. The Speech Intelligibility Index before and after the intervention.

	Before intervention	After intervention
Reverberation time $T_{20,gem}$	0,86s	0,44s
Speech intelligibility index (STI)	0,62	0,74

residents in a more comfortable way. Also, they mentioned that the residents were more comfortable in the new situation in their opinion.

Another aspect mentioned by the healthcare professionals was related to the colour of the sound absorption panels of the living room. As the panels where white, it seems brighter in the living room. They made the following remark: "It is not necessary to switch on the lights to distribute medication. I can read the list with medication better".

Discussion

The four steps of this study show the process of making a real estate decision regarding the acoustical climate in a nursing home based on best available evidence and from the perspective of the user. In the following sections, understanding the interaction between the environment and user and added value for residents and healthcare professionals are discussed.

Understanding the interaction between the environment and users

Understanding the physical characteristics of the indoor environment that affect health, comfort, and wellbeing is the key requirement underpinning the beneficial design of nursing homes[24]. Additionally, it is important to understand the physical characteristics that are most likely to optimize individual physical, mental, and emotional well-being[24]. From the literature, it is known that environmental factors such as temperature, noise, and lighting are related to the quality of life of the residents[25]. Even though our results relate to one living room and a particular location, they are in line with findings from the literature. The shorter reverberation time and improved STI positively influenced the experience of the acoustical climate of the living room by the healthcare professionals. Especially, in supporting the daily activities and increasing the communication between the healthcare professional and residents. Bradley et al, (1999) described in their study that the just noticeable difference of STI is 0,03. The just noticeable difference is the smallest difference that a person recognizes a variation in sensory experience[26]. In this study, the STI is increased with 0,12 and the two interviewed healthcare professionals regularly working in the adapted living room describe a difference in sensory experience as well. These results should be validated in further research. Therefore, it is relevant that future studies should investigate the acoustical environment of multiple nursing homes in order to define sufficient acoustical guidelines to prevent speech intelligibility issues among residents as well as healthcare professionals in nursing homes to support them in their daily activities. In this study, the acoustical measurements (before and after the intervention) and the interviews with healthcare professionals were useful to get insight into how the acoustical climate contribute to residents' and healthcare professionals' well-being in order to do an intervention, and the design of the intervention is dependent on different variables of the particular locations. In addition, the measurements (before and after the intervention) gave insight into how the acoustical intervention could support to the daily activities of the healthcare professionals and residents. The results of the intervention confirm these findings. This study might be used as starting point for the discussion to increase the awareness of the physical characteristics of the indoor environment that contribute to quality of life of the residents and well-being of the healthcare professionals. Furthermore, facility managers or corporate real estate managers should be aware that current acoustic guidelines are not specifically developed for older people with a frail health condition.

While this study gives insight into the added value of the acoustical climate regarding healthcare professionals' perception and well-being of the residents the focus was laid on the reverberations and speech intelligibility. More research in the field of perception and annoyance caused by noise among older people and nursing home staff should be conducted to get a better understanding between the environment and users.

Added value for residents and healthcare professionals

In this study, three relevant real estate decisions were taken in cooperation with the nursing home organisation. First, the nursing home organisation defines their ambition to increase well-being and comfort of their residents and healthcare professionals through the adaption of their real estate. The second decision was to enhance the quality of their building via building physics interventions with the emphasis on acoustics. The last decision was to adapt one living room based on the outcomes of the measurements and interviews. Decision one and two can be described as strategic management decisions and these decisions are often based on the core business drivers of an organization. The third decision is an operational management decision and is more specific. The four steps in this study gave valuable information and input

for the last decision to develop an acoustical intervention and implement this. Furthermore, the steps taken in this study gave also valuable information how to develop an intervention for the other indoor environmental aspects (like light and indoor air quality) from the residents' and healthcare professionals' perspective. Moreover, these steps gave relevant input for the decision-making process and the realization of the intervention for the corporate real estate manager and facility manager. The three decisions are needed to have a constant dialogue between strategic management and operational management to create benefits for the healthcare professionals and residents[27]. Although this study focused on the last decision, in future research the dialogue between strategic management and operational management could be investigated.

Furthermore, the findings of this study contributed to evidence-based design (EBD). The aim of EBD is to systematically translate research findings into design practice and to expose the best available evidence in order to help facility members, corporate real estate managers and designers to make design decisions based on users' needs[28,29,30]. The improvement of the acoustical climate at a particular location in this case study may lead to a better understanding of the physical characteristics of the indoor environment and real estate decisions that contribute to the ambition of the healthcare organisation which include an indoor environment that increase the comfort and wellbeing. However, it is still complex to quantify indoor environmental parameters for the entire nursing home organization. This is because the conditions and the perception per location are different. Therefore, it requires insight into the current conditions per location and it is necessary to gain information which parameters for redesign were relevant for each location. In addition, the interaction with the healthcare professionals and other stakeholders were important to provide guidance for design and to achieve the optimum indoor environment for all users of the nursing home organization[24,31]. Further research could be aimed at investigating the integrated effect of single environmental factors on the resident's and healthcare professionals comfort and satisfaction[31]. To define relevant aspects how the building or location affect human health and wellbeing the operational level of the indoor environment should be elaborated.

Conclusion

The steps taken in this case study showed that it is valuable to look at both, the acoustic measurements and the perception of the healthcare professionals and residents. The results showed that a small difference in the acoustical climate led to a benefit for the healthcare professionals and residents. The obtained results of this research show that the acoustical climate should be one of the factors to be taken into account in healthcare real estate decisions. The obtained results of this research can be used as starting point for further research.

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