MATERIALITY OF THE HEALING ENVIRONMENT

Empowering the efficacy of healthcare environments by experimenting with materials in the architectural design

A research paper by:
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Abstract

Due to developments in Dutch healthcare, questions arise about how to cope with the negative health impacts of urbanization. An answer to this is given by architecture in the form of so called 'healing environments.' Although not new as a concept, there is still discussion about the implementation of it into modern (healthcare) architecture. The classical recipe for the healing environment is given in literature which consists of four elements, to name: nature, daylight, fresh-air and silence (acoustic comfort). In this research paper, it has been researched how these key design elements are connected with their materiality and what that can provide for the efficacy of the healing environment. This formed the research question: In what ways can the materiality of healthcare environments improve patient care and well-being? Case studies and the creation of virtual mock-ups have been used to research how different iterations of rehabilitation spaces - on the spectrum of sterile to biophilic - can affect people's well-being. It has been shown that all iterations provide a positive influence on well-being although it should be taken into account in which type of function a certain setting, being it sterile or biophilic should be applied to empower the healing environment.

1. Introduction

The Dutch healthcare system is undergoing a lot of changes, for example the developments in human health and lifestyle, the advancements in healthcare coming from the care of people during the COVID-19 pandemic and the overall technological progress within the medical world. According to the Dutch National institute for Public Health and the Environment (RIVM, 2018), there will be an increasing amount of people suffering from chronic illnesses since the fatal illnesses of today will slightly become more chronic. Moreover, the healthcare system itself gets more decentralized. The generic hospital will become more specialized, while the post-treatment of patient will more occur outside the hospital, in other words this is called the 'zorg op maat' or customized care (RIVM, 2018). Another aspect is the growing attention to the effects of the environment on people's health. The latter one being more present in places where urbanization takes place at a significantly fast pace, results of such areas could result in 'unhealthy' consequences for the inhabitants (Flies. et al., 2019). This calls for an improvement of the urban environment. Side effects of this development could be the fragmentation of 'healthy' and 'unhealthy' neighbourhoods within cities as diversification of developments in combination with the diverse needs and economic prosperity within living environments could cause social-cultural segregation (RIVM, 2018).

It is this environmental development in which architecture can interfere. Especially in a current situation where e.g. hospitals were mostly build as strictly clinical and neutral with a focus on high productivity of treating sick people (van den Berg, 2005) which might not fit the needs for future projects and as well might not benefit the health of the users. A contemporary answer that architecture has been giving to this, is the growing demand in evidence based design. With this approach the potential is being investigated on how the architecture of a healthcare type building can be of value for the medical well-being of the users. This introduces the creation of a so-called healing environment. A term that houses some abstraction as it cannot be seen as a generic concept which can be implemented in every design project due to the abstract characteristic of the definition and its architectural design elements.

1.1 The Healing Environment

The healing environment is not an entirely new concept, it is actually rooted in long-standing traditions of the complementary medicine and holistic healing (van den Berg, 2005). This can be seen in contradiction with modern contemporary Western medicine which goal it is to cure the sources of the illnesses rather than that of complementary medicine which focuses on 'healing' and finding the causes of healthiness (RIVM, 2021).

Ultimate purpose of the healing environment itself can be seen as the creation of an environment in which certain conditions are provided that support and stimulate the inherent healing capacities of the people themselves. As well as their relations and surroundings. This can consist of general and specific behavioural, psychological, social and even spiritual components likewise the medical treatment itself (Jonas et al., 2003). Returning elements of a healing environments which seem to provide these previously mentioned conditions are the presence, and views, of nature; supply of fresh air; natural daylight; silence, as in low reverberation times or calming (nature related) sounds such as waves crashing or wind moving through a forest. These elements together could be seen as the 'classical recipe of a healing environment (Van den Berg, 2005). The idea of the building as an aspect of the healing process seems to be resurrecting since the 1970s of the twentieth century. Patients and working staff during that time advocated to create more healing environments who could provide an answer to the more chilly, sterile healthcare buildings (RIVM, 2021). Nowadays, the healing environment can be seen as an common accepted theme within healthcare architecture. Still there are some critical sidenotes on what exactly makes the healing environment 'healing'

(RIVM, 2021). Especially considering that an healing environment is different for every individual. This makes the definition of the healing environment an ongoing development in itself.

1.2 Evidence Based Design

Evidence-Based Design, or EBD, was first introduced in the 1990s to research architectural solutions for the design of healthcare facilities. The initiation for the EBD movement started with a research performed by Ulrich in 1984 who compared how patients recovered from a gallbladder surgery when patients had a view on nature or a stone wall. Results of this research showed that the patients who had a view on nature required less pain killers and had less post operative complications than the ones having a view on a stone wall. More research on the influence of the built environment of hospitals on the patient's health followed in the years after (RIVM, 2021).

EBD is based on the research method of Evidence-Based Medicine, which consists of performing clinical research to the effects and outcomes of studied new medicines with single-variable controlled trials. EBD can be seen as a form of architectural decision making which is based on scientific research and project evaluations related to a specific healthcare project. This should eventually result in better medical and psychological well-being of patients and staff as well as increased family involvement. Moreover, economic performance and productivity for the healthcare facility itself (Hamilton, 2003).

Currently the term Research-Informed Design, or RID, is also being used but also sometimes confused with EBD. Whilst EBD also focuses on the evaluation on the realized design, RID is only based on the scientific literature and is not being evaluated. It sometimes occurs that a project is labelled as being EBD while there has only been use of RID during the design process.

1.3 The healing environment within the rehabilitation process

An example of a case in which the healing environment could be of large value is that of the rehabilitation centre or sometimes even called rehabilitation hotel. It is in this kind of program where the architectural environment could potentially contribute to the clients healing capabilities as people are there to be encouraged and helped to recover and regain a form of autonomy (Ziekenhuis.nl, z.d.). Many practical functions could be linked to this rehabilitation environment such as physiotherapists, exercise professionals but also a more relatively new treatment concept, PMT.

PMT stands for Psycho-motoric therapy and can be seen as a relatively new form of psychical treatment to mental difficulties (UMCG, z.d.). Typical for these type of spaces is its multiple character. On the one hand calming to provide confidence with the therapist and gain body consciousness, but on the other hand tantalizing in a way that it motivates the client to cope with their incapability's
(M. van der Linden, personal communication, March 30 2022). This type of spaces specifically also could make use of the healing environment's potentials, although how to apply it seems to lack explanation.

1.4 Research question and scope

The common accepted term of the healing environment consists of four key elements that can be seen as the 'classical recipe'. A challenge for designers is how to implement these elements and in what form they are actually proven to stimulate the healing process. Moreover the translation of these elements to a basic principle of architecture, called by Vitruvius as *Firmitas*, is the materiality of the healing environment. How is the materiality connected to the four key design elements and how can a design element be connected to a certain materiality and potentially enhance it. In other words, this brings up the research question of this research paper: **In what ways can the materiality of healthcare environments improve patient care and well-being?**

This research is specifically focused on testing the application of the healing environment within a rehabilitation hotel design case with a focus on treatment by PMT. Taken the healing environment as an user-centred design approach, a specific aim with specific needs should be taken to test its efficacy as good as possible as it can be connected to certain demands from the users, moreover creating an experience close to the reality. In addition, this research focuses on the influence of the overall architectural experience rather than the technical elaborations of the applications of materials.

2. Method

In order to form an answer to the research question, this paper will be split up into two sections. The first part will be focused on the already existing literature and applications of the healing environment and its design elements mentioned in paragraph 1.1. To get more knowledge and understanding about the mentioned key elements of the healing environment, their applicability and how they are being used in contemporary architectural design projects is analysed. This is related to a formulated sub-question which will be answered in the conclusions section:
Which already known architectural design aspects from the healing environment are there to benefit the medical and psychological well-being of humans and how are they implemented into the realized design of existing projects? The second part of this paper focuses on the material aspect of the healing

environment. Eventually relating the outcomes to the key design elements which is described in the first part. The second part will be complemented by a practical research done with virtual mock-ups, this will also be explained in paragraph 2.2.

2.1 Methodology on elaborating design elements of the healing environment

This is also needed to describe the relationship between the design elements and their materiality, thus relating to the main research question.

The first part focuses on the elaboration of the term healing environment and its described key elements. Every key element will be elaborated by existing literature to form knowledge about already existing, and scientifically proven design elements and applications that can be used in the creation of an optimal healing environment. Moreover, the implementation of these elements into existing realized projects will be studied by performing case studies with attention to the previously mentioned design principles of the healing environment (nature, daylight, fresh air and silence). Certain spaces will be studied which are related to the practical studies which is described in 2.2, to name: the entrance/cafeteria space; common hallway spaces; the treatment or activity spaces. For each case study, it is analysed how they integrated the elements nature, daylight and acoustic comfort. Fresh air is left out in this case studies because it is not clear from pictures and floor plans in what way the air quality is regulated. Moreover, only pictures from the projects are used to compare as it was not possible to gain floorplans and sections from each studied project. In each project, the same three spaces were studied – i.e. the entrance/ cafeteria, a common hallway and treatment room – as these spaces would be used as basis for the virtual reality environments. In this paper, it will be described how the applications of the described design elements from the healing environment differ from each other. The projects that will be studied are:

- Domstate Zorghotel by Van Eijk& van der Lubbe
- Groot Klimmendaal by Van Velsen Architects
- Hotel Intermezzo by HD Group
- Neubau Aerztehaus by Sektor 3 Architekten
- Psychiatric Clinic Radboud UMC by EGM Architects
- Maggie Centre by Heatherwick Studios
- Maggie Centre by dRMM

Every project will be studied by looking at (if available) two perspectives of the entrance/cafeteria area, two perspectives of the hallway spaces and one or two perspectives of the treatment spaces depending on the available documentation. It will be hatched in what areas of the perspectives a specific element of the healing environment is applied. This will give insight about the relative amount of the applied design elements within a realized project and also how a certain project houses or lacks a design element of the healing environment and how it is applied as this can tell something about the efficiency of the healing environment. This can eventually help in finding ways of applying the design elements for the virtual reality tests but also in what way the applications could be improved, considering the analysed literature, to create a more optimal healing environment.

2.2 Methodology on material study and practical tests

Whilst the spatial analysis of the case study research shows the more 'general' elements and application of the healing environment, the second part focuses on the materiality of these design aspects. In short this will focus on how different materials can shape a certain experience and how it affects the well-being of people experiencing it, in this case the entrance, common hallway and PMT treatment spaces. The PMT-treatment space is chosen for this research because of the multiple character of the spaces as mentioned in paragraph 1.3.

What is needed for the creation of medical well-being will be complemented by interviews with experts from the medical field as well as potential examples of end users e.g. PMT clients, practitioners and therapists who are involved in the design program of the rehabilitation clinic from the graduation project. They will be asked to tell more about what they need in terms of providing treatment and what the patient or clients wants to feel at ease. Thus, focusing on the medical application rather than the architectural demands. The outcomes of these interviews will then be translated to design requirements. Subsequently, a material research is done by reviewing different projects on the spectrum of sterile to biophilic design and ranking which main materials are being used in the extreme sterile, balanced and extreme biophilic setting. Biophilic design in this case means an approach of designing in which nature is incorporated into building spaces (HMC Architects, 2019). Sterile design in this case means designing with conditions that generate an (almost) complete absence of e.g. bacteria, fungus (P.A.C., 2020). Lastly, a balanced setting in this case means a fifty-fifty situation in which elements from both the extreme- and sterile settings are being used to form an overall experience.

Materials are categorized in a spectrum of sterile to biophilic. These materials are then used as a basis to design three different virtual mock-ups for each space within the proposed project. These virtual mock-ups will be created within a software that provides the functionality to transform the modelled space into a VR-ready environment. This will be done in the software Enscape and then converted into 360 panoramas for SentioVR. Each determined room will get three different iterations which are tested as a total experience hence firstly showing the entrance, then the common

hallway, finally the PMT treatment spaces. The different iterations are based on the previously mentioned spectrum which consists of two extremes to name biophilic and sterile. For example: iteration 1 will contain a lot of sterile elements. Iteration 2 will then have an extreme biophilic look and iteration 3 will use elements of both the extreme sterile and biophilic atmosphere thus creating a more balanced ambiance.

The test-persons will consist of master's students from TU Delft and experts from the medical field who are involved in the program of a rehabilitation clinic and even rehabilitation patients, in this case PMT clients. These persons will be asked to fill in a survey which questions the generated experience or their experiences and feelings will be noted when this is not possible. The survey will be based on existing models of measuring well-being inside the built environment, specifically the multi-item scale by Watson (2018). Unconscious factors are also studied such as how long people want to stay in a certain test room. This can provide more direct input for the overall results.

Results from the virtual mock-ups will be described with tables and a schematic that show the outcomes of the experience and the executed survey. Eventually forming a conclusion on what type of setting fits the best for each type of space. Moreover, providing insight into the application of a set of materials as a setting in relation to a certain sub-item of well-being as this can also tell something about the desired setting for each space. This is related to the sub items of well-being mentioned in the multi-item scale by Watson (2018). See also figure 1 and 2.

The Building wellbeing scale Please answer based on your experience of spending time in this building					
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I feel optimistic when I'm in this building	–2	–1	0	+1	+2
I have purpose when I'm in this building	–2	–1	0	+1	+2
I feel rewarded when I'm in this building	–2	–1	0	+1	+2
I feel at ease when I'm in this building	–2	–1	0	+1	+2
I feel interested in other people when I'm in this building	–2	–1	0	+1	+2
I can be myself when I'm in this building	–2	–1	0	+1	+2
I feel worthwhile when I'm in this building	–2	–1	0	+1	+2
I deal with problems well when I'm in this building	–2	–1	0	+1	+2
I feel empowered when I'm in this building	–2	–1	0	+1	+2
I think clearly when I'm in this building	–2	–1	0	+1	+2
I feel inspired when I'm in this building	–2	–1	0	+1	+2
I feel useful when I'm in this building	–2	–1	0	+1	+2
I feel close to other people when I'm in this building	–2	–1	0	+1	+2
I feel successful when I'm in this building	–2	–1	0	+1	+2
I feel fulfilled when I'm in this building	–2	–1	0	+1	+2
I can make up my own mind about things when I'm in this building	–2	–1	0	+1	+2
I feel valued when I'm in this building	–2	–1	0	+1	+2
I can apply myself to what I'm doing when I'm in this building	–2	–1	0	+1	+2
I feel joyful when I'm in this building	–2	–1	0	+1	+2
I feel in control of my own decisions when I'm in this building	–2	–1	0	+1	+2
I feel energised when I'm in this building	–2	–1	0	+1	+2
I feel at my best when I'm in this building	–2	–1	0	+1	+2

Figure 1. The Building well-being scale by Watson (2018)

Satisfaction	
I feel useful when I'm in this building	WEMWBS
I have purpose when I'm in this building	QEWB
I feel fulfilled when I'm in this building	QEWB
Affect	
I feel Optimistic when I'm in this building	WEMWBS
I feel at ease when I'm in this building	WEMWBS
I feel energised when I'm in this building	WEMWBS
Competence	
I deal with problems well when I'm in this building	WEMWBS
I think clearly when I'm in this building	WEMWBS
I can apply myself to what I'm doing when I'm in this building	QEWB
Relatedness	
I feel interested in other people when I'm in this building	WEMWBS
I feel close to other people when I'm in this building	WEMWBS
I feel valued when I'm in this building	WEMWBS
Autonomy	
I can make up my own mind about things when I'm in this building	WEMWBS
I can be myself when I'm in this building	QEWB
I trust my own decisions when I'm in this building	QEWB

Figure 2. Selected items by Watson (2018) for the building well-being scale based on themes of well-being

3. Results

This chapter will describe the results from the research to provide an answer to the research questions. The results are split into two sections which correspond to each own research question, eventually forming an overall answer to the main research question. Thus first describing the existing proven design elements of the healing environment and their application into existing projects. Followed by the material research and the virtual mock-up test which will be supplemented with tables describing the results.

3.1.1 The classical recipe of the healing environment

As described in paragraph 1.1, the 'classical' recipe for the creation of the healing environment consists of four key elements to name: nature, daylight, fresh air and quiet. There have been many studies performed on these elements and their effects on (medical) well-being. This part will focus on how these elements can be applicated into architectural design an what their proven effects on (medical) well-being are. To start with the application of the element nature.

Van den Berg (2005), who reviewed different studies on the healing environment, divides the application of nature into three sub-applications to name: views, gardens and indoor plants. A famous study by Ulrich (1984) did already show the benefits of views on nature on patients recovery time. Van den Berg continues on this by mentioning the effect of nature on patient's pain tolerance as it seems that patients who have a view on nature gained a higher pain tolerance as well as relieved stress. The latter one also being connected to 'distraction therapy'. It is also described how there seems no difference in providing a realistic view on nature or a digital one according to already performed studies. Gardens could provide a place to exercise and interact with nature as well as it potentially fosters access to social support. Although there have been some examples, this application lacks rigorous scientific research. The third form of application described by Van den Berg is the application of indoor plants. It seems that this can purify the air and reduce stress levels within a building. However, especially in medical environments, this should be taken with the precaution that indoor plants could be the growing place of bacteria. Moreover, the reviewed studies show that a higher density of indoor plants can increase the positive mood of users but decrease their concentration thus within working environments this should be added in a moderate way. Sakallaris et al. (2015) states the application of nature as a key component of creating a healing space which

is there to enhance the healing potential of people. By Ulrich (1991) it is also mentioned that the application of pictures and screens of nature can reduce the feelings of anxiety and stress as well as the presence of natural colours and materials. Moreover, Park and Mattson (2009) also describe the implementation of plants within patient rooms resulting in higher satisfaction rates by patients.

The second element is daylight. Van den Berg reviews that natural daylight is preferred above artificial daylight. A balanced amount of (natural) daylight in combination with a balanced spectrum of colours can potentially provide positive outcomes for patients well-being. Luminance, colour and flickering of artificial lighting can have a positive or rather negative impact. It is shown in research done by Buchanan et al. (1991) that a luminance of ca. 1570 lx lowers medication errors by staff. But flickering of artificial lighting might increase stress (van den Berg, 2005). If there is bright indirect lighting, this can improve mood of patients, this is studied by Delvin & Arneill (2003) and Ulrich et al. (2008). The study by Ulrich et al. also shows that the presence of daylight can reduce pain and incidence of depression, especially morning light rather than evening light, thus facing east. An important theme to take within the application of daylight, is its relation to the circadian rhythm which is the biologic rhythm of one day (Van den Berg, 2005). Providing daylight in relation to this rhythm, can provide positive outcomes on the well-being. For example, the presence of sunlight during the day but also dimmed lights at night to create a more darker ambiance.

The next elaborated element is fresh air. This can be connected to the presence of natural ventilation within the building. Van den Berg (2005) describes that it is preferred to have no recirculation of the air when taken into mechanical systems. As well as the preference for natural ventilation instead of mechanical ventilation. Although within polluted contexts, natural ventilation should be filtered. Not only the quality of the air but also the odour should be taken into account as unpleasant odours from sanitary functions can produce increased heart rate and breathing. Thus these odours should be masked out to complement the air quality of the healing space. In other ways, specific flower and fruit scents can reduce blood pressure and heart rate as well as calm breathing (Herweijer-van Gelder, 2016).

The fourth key element is 'quiet', however the term 'acoustic comfort' and 'sounds' is more used within literature. Van den Berg describes that a reduction of reverberation times can provide positive outcomes on the satisfaction of patients. This can be achieved by the application of sound absorbing tiles for example. Ulrich et al. (2008) also bring up the application of furniture or with sound absorbing materials and designing single-patient rooms to prevent noise from other users. Rubin et al. (1998) furthermore mentions the application of wall-to-wall carpeting as noise reducing. Another aspect that could be implemented is the presence of music which has been studied by Delvin & Arneill (2003). It is studied that music can shut out unwanted sounds but also can generate reduced feelings of stress, anxiety and pain.

Besides the key elements, some of the researched literature also show the benefits of harmonious colours, the presence of art and certain aesthetics such as home-like decor. However these elements will not be discussed within this research.

3.1.2 Application of the key elements into realised projects

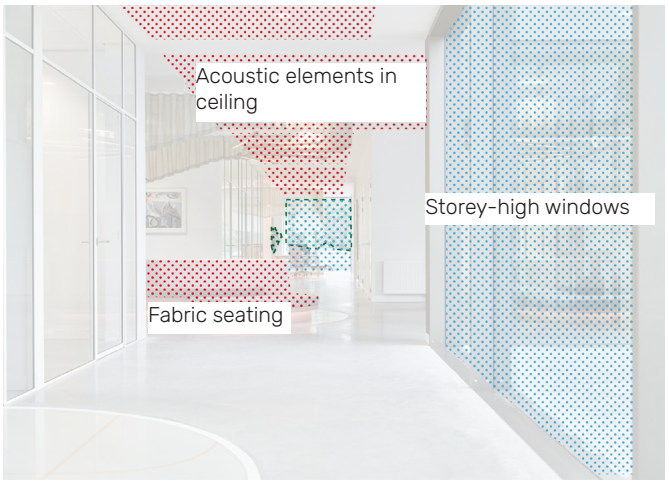
Figure 3.1 & 3.2 shows the comparison of hallways within the different case studies (see also the legend in figure 3.1 &3.2) It is clearly visible that nature is not present in the hallways of most projects as it seems they all use a sterile approach to the design. Only the Maggie Centres have nature as an present element in their design, with the one designed by Heatherwick even having it incorporated in the interior whilst the one designed by dRMM focusing on the views on the central nature element within the inner garden. Groot Klimmendaal has its advantage of a natural context which provides wide views of nature due to its window sizes in combination with situating the hallways across the facades instead of internally. A risk of incorporating nature within medical environments is the chance of higher infection rates, this could be why most studied medical spaces do not implement a significant amount of nature. In combination with the idea that implementing nature also requires treatment for the natural elements itself. The element (natural) daylight on other hand is clearly present in the projects. Every project is showing an implementation of indirect or direct natural daylight into the hallways by story high windows, skylights, atria or patios. Although the Intermezzo hotel and Radboud UMC shows some internal hallways which do not incorporate the natural daylight, probably due to its internal placement. Groot Klimmendaal is showing the use of a relatively higher hallway space to let more natural daylight into the spaces. Acoustic comfort is achieved in most projects by applying absorbing tiles into the ceiling or walls. The maggie centers do not show a clear implementation of acoustic applications although the timber materiality of the design and the furniture could potentially contribute to it. In addition, the Radboud UMC and Groot Klimmendaal also does not show a specific implementation of acoustic elements in the hallways.

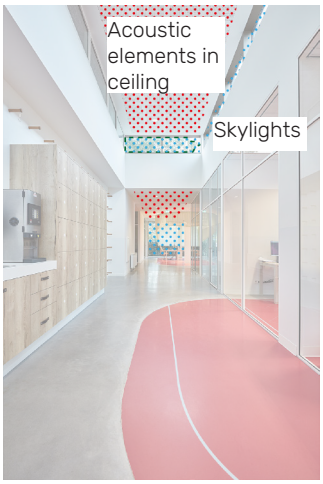
Figure 4.1 & 4.2 shows how the design elements of the healing environment are incorporated into the entrance area and/or cafeteria areas. It is again visible how the element nature is not significantly present into most projects. Some projects do show incorporation of indoor plants and have a view on nature, especially the Maggie Centres. As well as Domstate which is showing the application of indoor plants into the furniture of the spaces. Daylight is as well as in hallways achieved by mostly story-high windows or indirect skylights which is for example shown in the Radboud UMC cafeteria. In combination with light coloured elements, this natural daylight is highly diffused across the spaces. Acoustic comfort is then again mostly achieved by the application of sound absorbing tiles on the ceiling or the walls. For some projects, it is unclear how they achieved acoustic comfort although at the Radboud UMC, there seems to be an acoustic ceiling material in the cafeteria area which is used as a coating. Furthermore, the Maggie centres seem to make use of the acoustic characteristics of the materiality, mostly timber, of the spaces to achieve acoustic comfort.

Figure 5.1 & 5.2 shows how the treatment spaces are making use of the key design elements. Not every project does have a specific treatment space nor had documentation available, therefore in some cases the activity space has been studied or the project is left out in this part of the case study. It is clearly visible that again, the spaces do not show a significant presence of nature. Although some projects have a view towards nature or incorporate indoor plants mostly visible at the Maggie Centres. Noticeable, is the project by Sektor 3 which applied the element of nature by placing an indoor greenery wall element behind a glass wall to prevent bacteria into the treatment space. Daylight is achieved in all the studied project by story high windows, although the project by Sektor 3 does not seem to incorporate a form of natural daylight. At Domstate, indirect natural daylight is applied through the hallway connected to the activity space. The activity space within the Groot Klimmendaal is using its floor height to provide more natural daylight within the space. Acoustic comfort is again mostly applied by the use of sound absorbing tiles in the ceiling or walls. Both Maggie Centres seem to use their furniture as sound absorbing just as the timber materiality of the spaces.

It can be concluded that, although described as an important key element of the healing environment, nature is lacking from the researched projects. Only the Maggie Centres are showing a significant use of views to nature or implementation of indoor plants. Also Groot Klimmendaal is providing wide views to nature within the hallways by using its position in the floorplan. Daylight on the other hand is widely implemented into the design of the projects by using story high windows and/or skylights and atria. Acoustic comfort is mostly achieved through wall- or ceiling panels and by using furniture which is made from sound absorbing materials. Some of the projects do not clearly show how acoustics are being treated. More information about the exact used materials in the spaces is needed to analyse it.

Domstate zorghotel

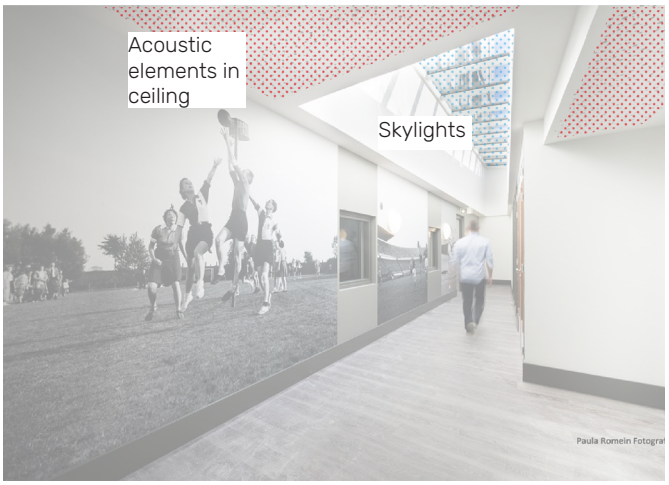




Legend

- Zones providing acoustic comfort
- Zones providing daylight
- Zones providing nature or views to nature

Intermezzo hotel



Neubau Aerztehaus

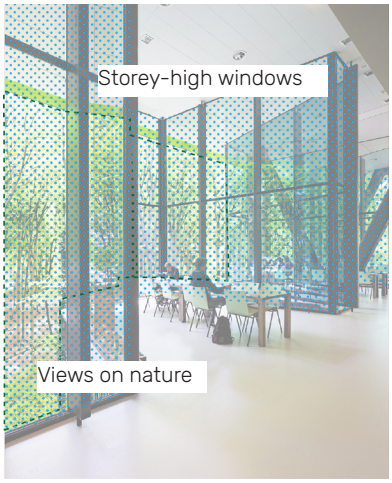
Psychiatric clinic Radboud

Figure 3.1 Comparison of healing environment architectural elements within the hallway spaces (see also figure 3.2)

Maggie centre Oldham

Maggie centre Leeds

Groot Klimmendaal

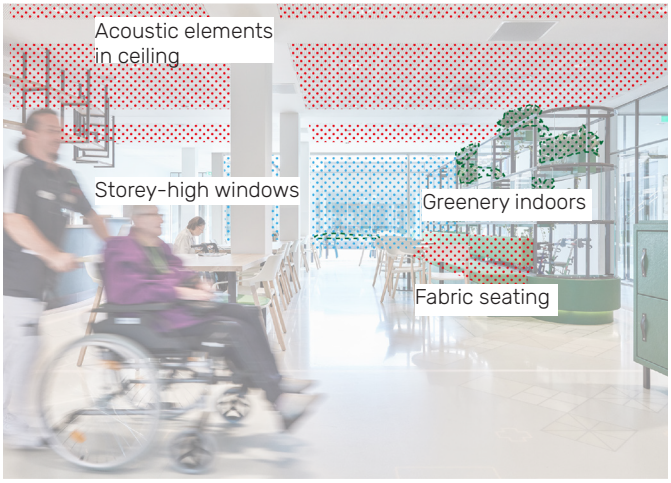


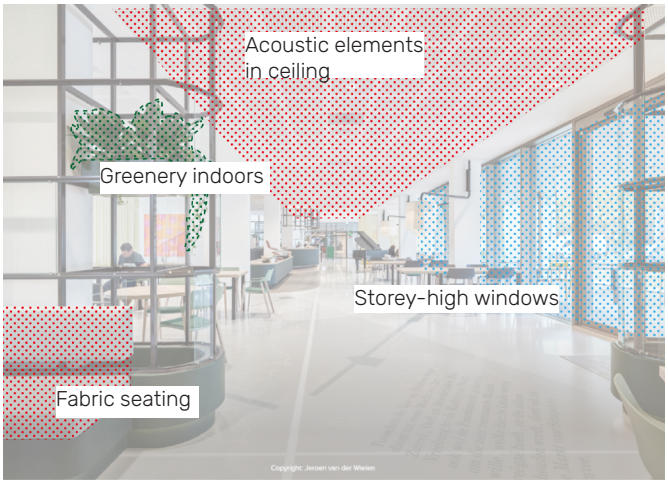
Legend

- Zones providing acoustic comfort
- Zones providing daylight
- Zones providing nature or views to nature

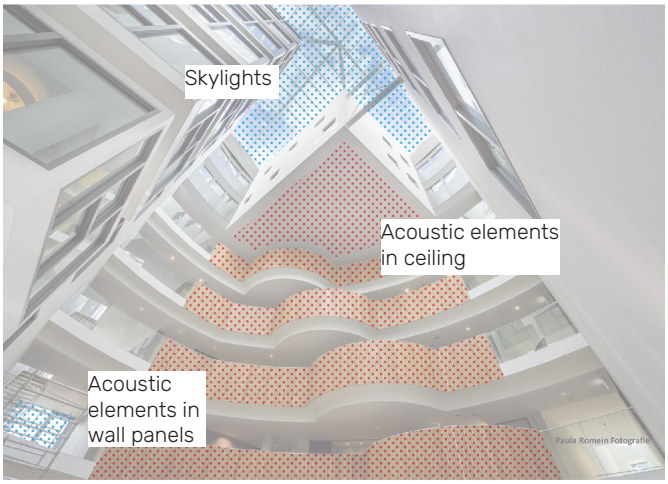
Figure 3.2 Comparison of healing environment architectural elements within the hallway spaces

Domstate zorghotel

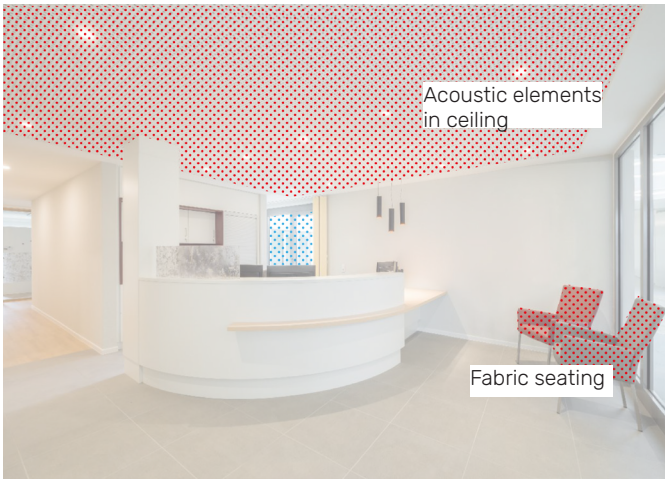




Intermezzo hotel



Neubau Aerztehaus



Psychiatric clinic Radboud

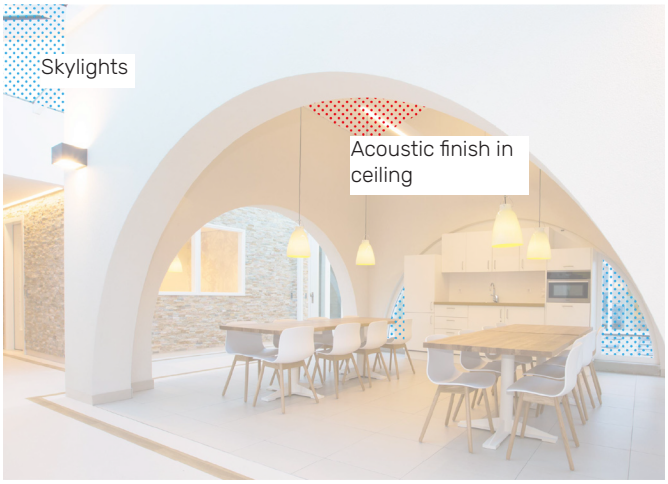
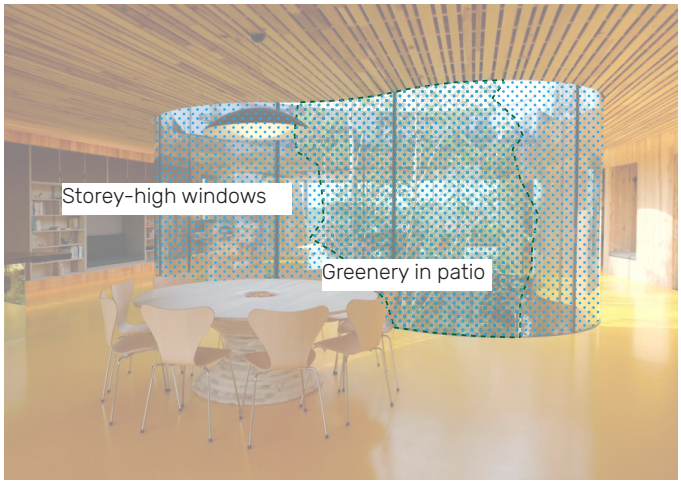


Figure 4.1 Comparison of healing environment architectural elements within the entrance/cafeteria spaces (see also figure 4.2)

Maggie centre Oldham



Maggie centre Leeds

Groot Klimmendaal

Legend

- Zones providing acoustic comfort
- Zones providing daylight
- Zones providing nature or views to nature

Figure 4.2 Comparison of healing environment architectural elements within the entrance/cafeteria spaces

Domstate zorghotel

Intermezzo hotel

Neubau Aerztehaus

Psychiatric clinic Radboud

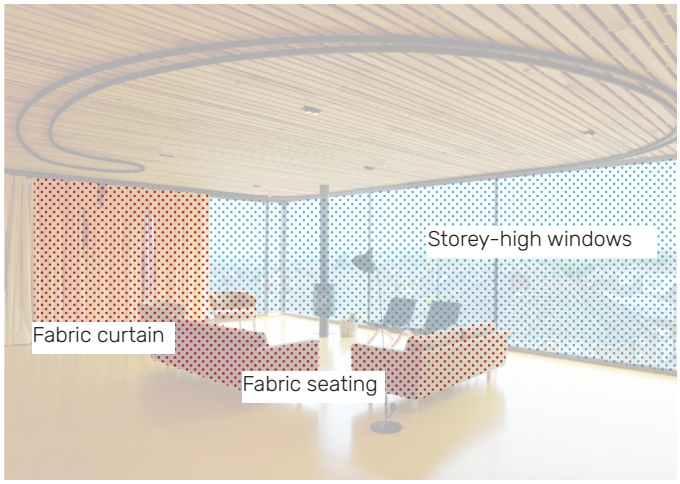
No documentation available

Legend

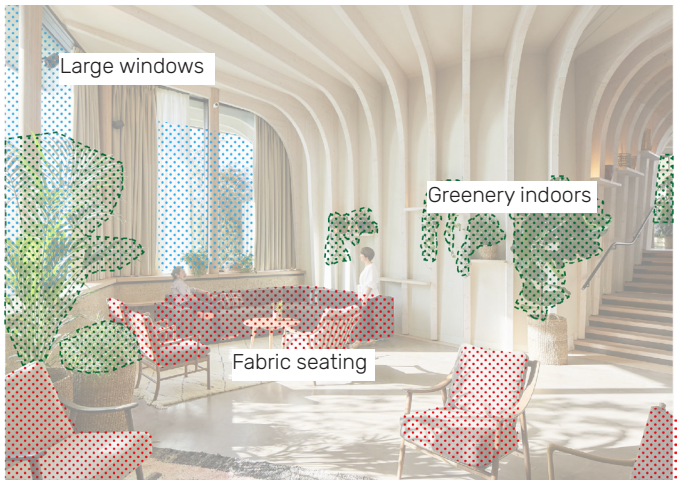
- Zones providing acoustic comfort
- Zones providing daylight
- Zones providing nature or views to nature

Figure 5.1 Comparison of healing environment architectural elements within the treatment spaces (see also figure 5.2)

Maggie centre Oldham



Maggie centre Leeds



Groot Klimmendaal

Legend

- Zones providing acoustic comfort
- Zones providing daylight
- Zones providing nature or views to nature

Figure 5.2 Comparison of healing environment architectural elements within the treatment spaces

3.2 Virtual mock-ups test and results

For the creation of the virtual mock-ups, a material palette is created on the basis of analysed projects within the spectrum of extreme sterile to extreme biophilic (see appendix A). It is analysed which main materials have been used for the floors, walls and ceiling. It is not about the added materials such as furniture but about the recurring element that is present within the designed space. In addition, the amount of main materials is also counted. The total analysis is put up into a graph (see figure 6) with the x-axis showing the projects placed on the spectrum of sterile - balanced – biophilic and the y-axis showing the amount of materials used. For example, project 1 (see appendix A) uses one main material throughout the shown space which is Corian. Although it seems that the floor is made from a different material, this is not clear from available documentation. Therefore, in total, this is counted as a 'synthetic material' making it only one main material type being used in the overall space. Recurring materials for each part of the spectrum are mentioned within the graph. The graph shows that the more biophilic a space is designed, the more materials are being used within the design of the space. Sterile using an average of 2 (2,5) main materials, balanced an average of 3 (3,55) main materials and biophilic 4 (4,5) main materials.

The described materials in each spectrum part of the graph are being used as the basis for the design of the virtual spaces. The sterile design is shown in figure 7, the biophilic design in figure 8 and the balanced design in figure 9. It is shown how every space within each iteration is designed. The spaces are designed within Skechtup and the 360 panoramas images are rendered in Enscape. The Oculus Quest is used as virtual reality goggles and the 360 panoramas are shown in the SentioVR app on the Oculus.

The spaces are also designed on the basis of overall practical requirements for the spaces given by professionals from the medical field involved within the design case of the research including PMT therapists, physiotherapist, exercise agog (a person who provides sport- and exercise activities within rehabilitation environments) and nurses. This was done to eventually provide an overall experience which comes close to reality as the research scope is linked to a certain purpose of the spaces. Recurring themes from the interviews were privacy, functionality, autonomy, space for exercise, generating self-confidence and consciousness and a choice of generating calming or tantalizing spaces. This themes were as well used as guiding for the creation of the virtual mock-ups.

Eventually the spaces for the virtual mock-ups were designed with the materials that came out of the material palette (figure 6) in combination with the practical requirements coming from the interviews with experts from the medical field. The material application is based on how materials have been applied within the different projects that were used to form the material palette as well as the projects from the case studies. Also, the key elements from the healing environment were as well incorporated into every iteration as much as possible. This is also based on the analysed case study projects as well as the projects reviewed for the material palette. This is all done to test the effects of the specific material applications rather than the difference between using and not using design elements from the healing environment. All the used materials and how the key elements of the healing environment are incorporated in the different designs are in the description of each iteration, figure 7,8 and 9.

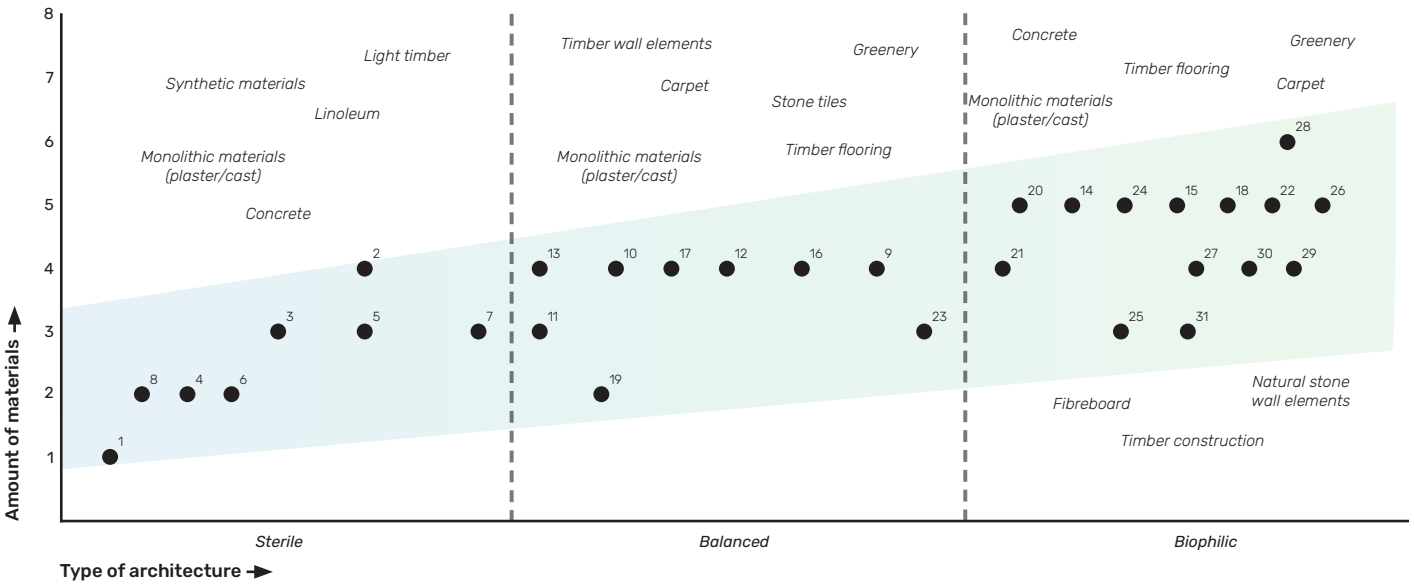


Figure 6. Spectrum graph showing the amount of main materials used for each project (black dot). Recurring materials are described in each spectrum. Every project corresponding to the numbers can be found in appendix A.

Entrance

Cafeteria

Hallway space

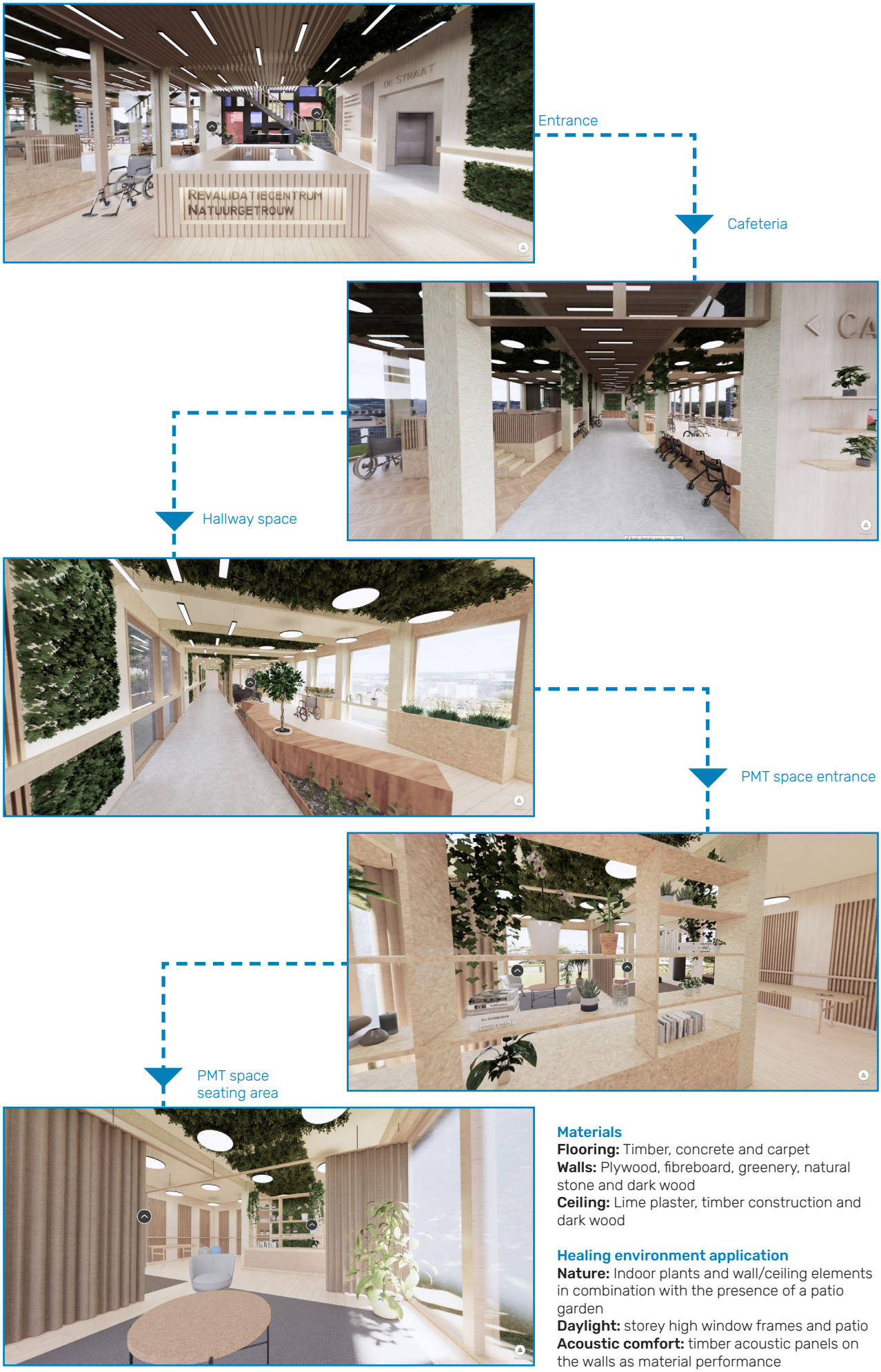
PMT space entrance

PMT space
seating area

Materials
Flooring: concrete and linoleum
Walls: Plaster and light window frames
Ceiling: Plaster and cast-suspended ceiling

Healing environment application
Nature: not specifically provided, outdoor viewing
Daylight: storey high window frames and light materials
Acoustic comfort: acoustic panels incorporated in suspended ceiling

Figure 7. Virtual mock-up of the sterile iteration



Materials
Flooring: Timber, concrete and carpet
Walls: Plywood, fibreboard, greenery, natural stone and dark wood
Ceiling: Lime plaster, timber construction and dark wood

Healing environment application
Nature: Indoor plants and wall/ceiling elements in combination with the presence of a patio garden
Daylight: storey high window frames and patio
Acoustic comfort: timber acoustic panels on the walls as material performance

Figure 8. Virtual mock-up of the biophilic iteration

Entrance

Cafeteria

Hallway space

PMT space entrance

PMT space
seating area

Materials
Flooring: timber and concrete
Walls: Plaster, light window frames, dark wood elements, plywood and greenery
Ceiling: Cast-suspended ceiling and dark wood elements

Healing environment application
Nature: Indoor plants in combination with the presence of a patio garden
Daylight: storey high windows and patio
Acoustic comfort: timber acoustic panels on the walls as well as panels incorporated in the ceiling as well as material performance

Figure 9. Virtual mock-up of the balanced iteration

In total, there were twelve persons who experienced the virtual mock-ups. However only six of them could fill in the survey (see appendix B) as the other people were mentally incapable to answer the questions although they were aware of why they were experiencing these spaces. Therefore notes have been made of the feelings that the test persons, who could not fill in the survey, described verbally when they were experiencing the virtual mock-ups to provide an idea of their well-being within the different iterations. The table in appendix C shows the direct average outcomes of the survey for each question. Figure 10 shows the average scores related to the sub-themes of the building well-being scale. A positive number indicates a positive influence on the sub-theme of the scale, a negative number indicates a negative influence. The test group consisted of GGZ therapists, PMT clients with mild intellectual disability, PMT clients with mental disabilities (PTSS, anxiety disorder), PMT clients with personality disorders, family doctor, practise nurse and personal relations.

The table is in general showing how biophilic elements improve the scores of the test persons well-being for both biophilic and balanced settings in comparison to a sterile materialised environment. Although, the sterile iteration has relatively low positive influence on well-being of the test persons, the only negative influence can be found in the theme of relatedness. Also remarkable is the difference between the scores of the biophilic and the balanced iteration which seems relatively low. This could be discussed as there were less people who have filled in the survey of the balanced iteration than the biophilic iteration. Looking to the differences between the two extremes of biophilic and sterile, the scores show that the biggest difference can be found at the subject of relatedness as the feeling of relatedness has been experienced as not really present (not agreeing) in the sterile setting whilst in the biophilic setting, it has been experienced as more present (agreeing). Relatedness refers to the social ties people experience when being in a space. Also the subject of affect shows a big difference in positive influence between sterile and biophilic. Affect in this case refers specifically to the presence of positive affect a space is creating and the lack of negative feelings a person is experiencing.

Looking to the notes made with the clients that could not fill in the survey (see appendix D), it becomes clear that the clients experienced the sterile materialised iteration as calming and relaxed but also related it to a clinical hospital-like environment. Furthermore, the biophilic environment seems much appreciated in terms of cosiness and a welcome and homely feeling but contradictory, the spaces are also being experienced as too tantalizing maybe due to the large amount of greenery present in the spaces. A recurring comment is about the therapy space. Whilst the therapy space within the sterile environment is experienced as relaxed or at ease, the biophilic iteration becomes too tantalizing to feel relaxed or at ease. The therapy space within the balanced iteration was experienced as less tantalizing but not for all clients.

	Sterile (n=6) Avg. time spent (n=4): **212 sec.**	**Biophilic (n=6)** Avg. time spent (n=4): **279 sec.**	**Balanced (n=5)** Avg. time spent (n=4): **255 sec.**
Satisfaction (average score)	+0,22	+0,83	+0,93
Affect (average score)	+0,45	**+1,39**	+1,27
Competence (average score)	+0,39	+1	+0,93
Relatedness (average score)	-0,11	+1,06	+0,87
Autonomy (average score)	+0,44	+1	+0,93

Figure 10. Table showing the results (average score of multi-item scale) of the survey related to their theme from the well-being scale by Watson (2018). The lowest score is marked in red, the highest score is highlighted in black.

4. Conclusions

Conclusions on this research can be divided into two parts, the conclusions of the case studies on healing environment design elements and the conclusion of the virtual mock-up test.

4.1 Conclusions on literature research and case study

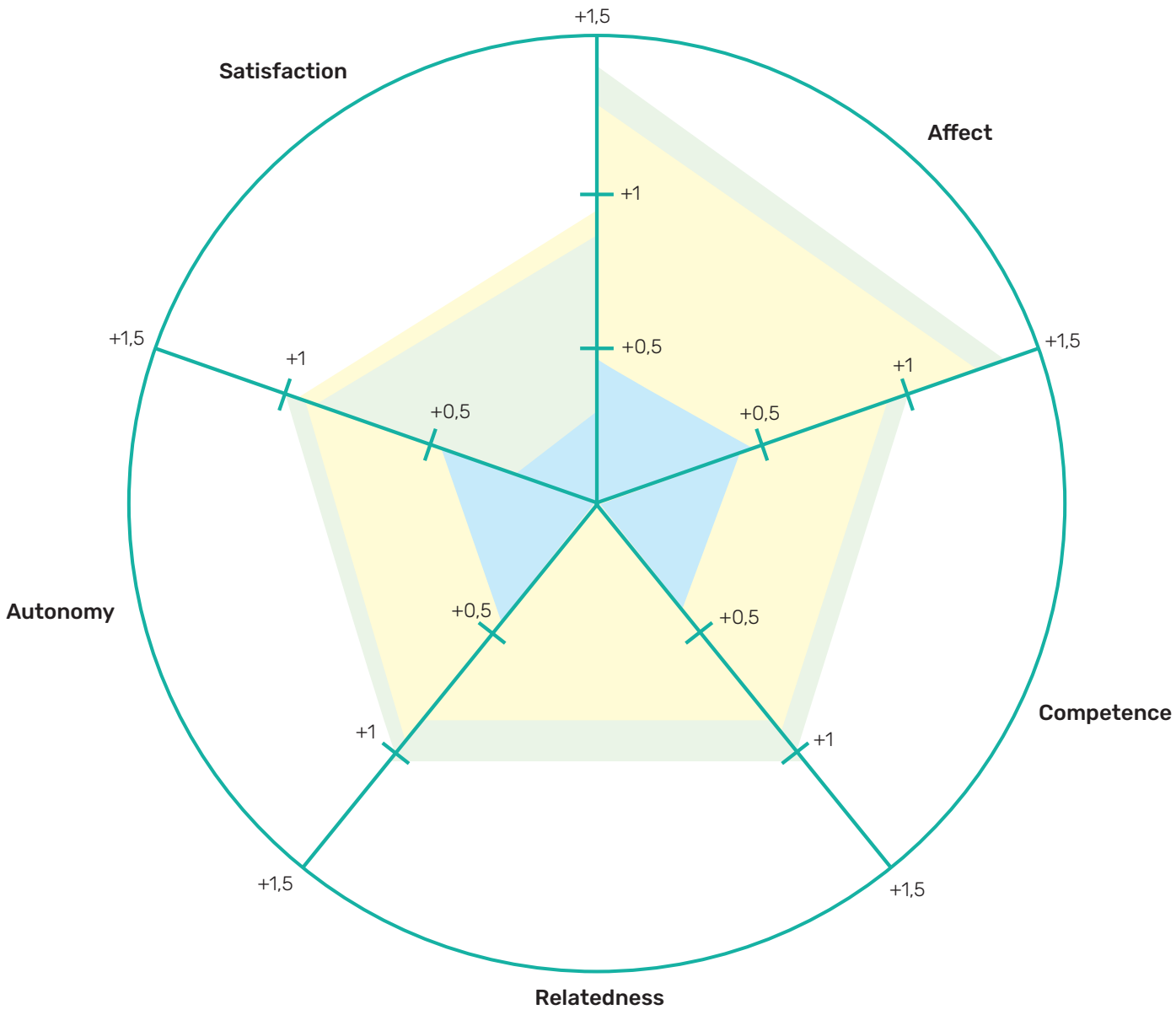
The research question related to this paragraph is: **which already known architectural design aspects from the healing environment are there to benefit the medical well-being of humans and how are they implemented into the realized design of existing projects?** The literature study showed in what way five key elements: nature (especially views of nature), daylight (natural), quiet (acoustic comfort) and fresh air can be implemented in the architectural design and how they should be used as a design tool to improve the well-being of humans. In addition, it has been described which applications are scientifically proven or require extra research. The case studies showed how these design elements were implemented in the design of the project, independently of the element 'fresh air'. Although all using the term of 'healing environment' as guiding for the design, most projects lacked some of the elements or applied it in a relatively low amount, specifically nature. This might be due to the clinical requirements a healthcare environment has to achieve, e.g. low infection chances. Moreover, the studied projects differ in function which could also cause the difference in implementation of the design elements, as well as the context the projects were situated in. Due to the lack of documentation with some projects, a detailed analysis of the projects could not be made which could provide more insight into the application of the design elements from the healing environment.

4.2 Conclusions on virtual mock-up tests

The research question related to this paragraph is: **In what ways can the materiality of healthcare environments improve patient care and well-being?** The VR tests showed how the application of a certain materiality based on the scale of sterile to biophilic can influence the experience of users and their feelings of well-being. Thus enhancing the efficacy of the healing environment. The tests were performed on people who are potential stakeholders of a healthcare-type building. It has been shown how the biophilic iteration increases the positive influence at every aspect the well-being of users in comparison to a sterile materialised environment. Also, a balanced iteration still generates a positive influence on well-being although the differences with the biophilic iteration are relatively small. People felt more relatedness within the biophilic iteration than within the other iterations.

It has also been described how clients, related to the tested healthcare environments, experience the space. Clients felt relaxed and calm in the sterile environment on the other hand describing the spaces as hospital-like. Clients felt welcome and homely within the biophilic environment although they sometimes experienced it as too tantalizing, especially in the therapy space. The balanced iteration showed many similarities in experience with the biophilic iteration. Despite the fact that some experienced it less tantalizing than the biophilic iteration, others did not and still described it as too tantalizing. It becomes clear that a biophilic materiality generates a relatively higher score of well-being on all factors, except that, especially within treatment rooms, it can be distracting.

Overall, it can be concluded that the more social-interacting or welcoming spaces, such as cafeteria's or entrances ask for a more biophilic setting to be more effective as a healing environment. The treatment spaces or spaces meant for specific intention and focus, require a more sterile setting when incentives are not desirable or a balanced form of both settings when a feeling of comfort is needed such as the hallways. Although the results can describe something about the effects of materiality on the efficacy of the healing environment and what type of setting would fit in which type of space, it would require more test persons to verify it more scientifically.
An overall conclusion schematic of the used sterile to biophilic elements in relation to the effect on the sub-items of the well-being scale is made visible in figure 11 on the next page.



Sterile materiality

- Concrete (flooring)
- Linoleum (flooring)
- Plaster (walls/ceiling)
- Cast (suspended ceiling)
- Light timber (window frames)

> Suitable for:

- Spaces without distraction of other people
- Low infection rate spaces
- Calming space for people with too many incentives
- Specific treatment spaces which do require not having any chances of infection or external incentives

Balanced materiality

- Timber (flooring)
- Concrete (flooring)
- Plaster (walls)
- Cast (susepended ceiling)
- Light timber (window frames)
- Dark wood (extra floor wall/ ceiling elements)
- Greenery (wall elements)
- Plywood (walls)

> Suitable for:

- Spaces demanding less distraction/incentives
- Welcoming spaces to feel at ease
- Treatment/exercise spaces

Biophilic materiality

- Timber (flooring)
- Concrete (flooring)
- Carpet (flooring)
- Plywood (construction/walls)
- Fibreboard (wall elements)
- Extensive greenery (walls/ ceiling)
- Natural stone (wall elements)
- Lime plaster (ceiling)
- Dark wood (extra floor/wall/ ceiling elements)
- Wood (window frames)

> Suitable for:

- Entrance spaces where people are introduced to the building
- Cafeteria/restaurant spaces
- Spaces where people can meet each other
- Patient rooms where people can feel at home

Figure 11. Conclusion schematic showing the used settings as part of an effect on the sub-items of the well-being scale by Watson (2018).

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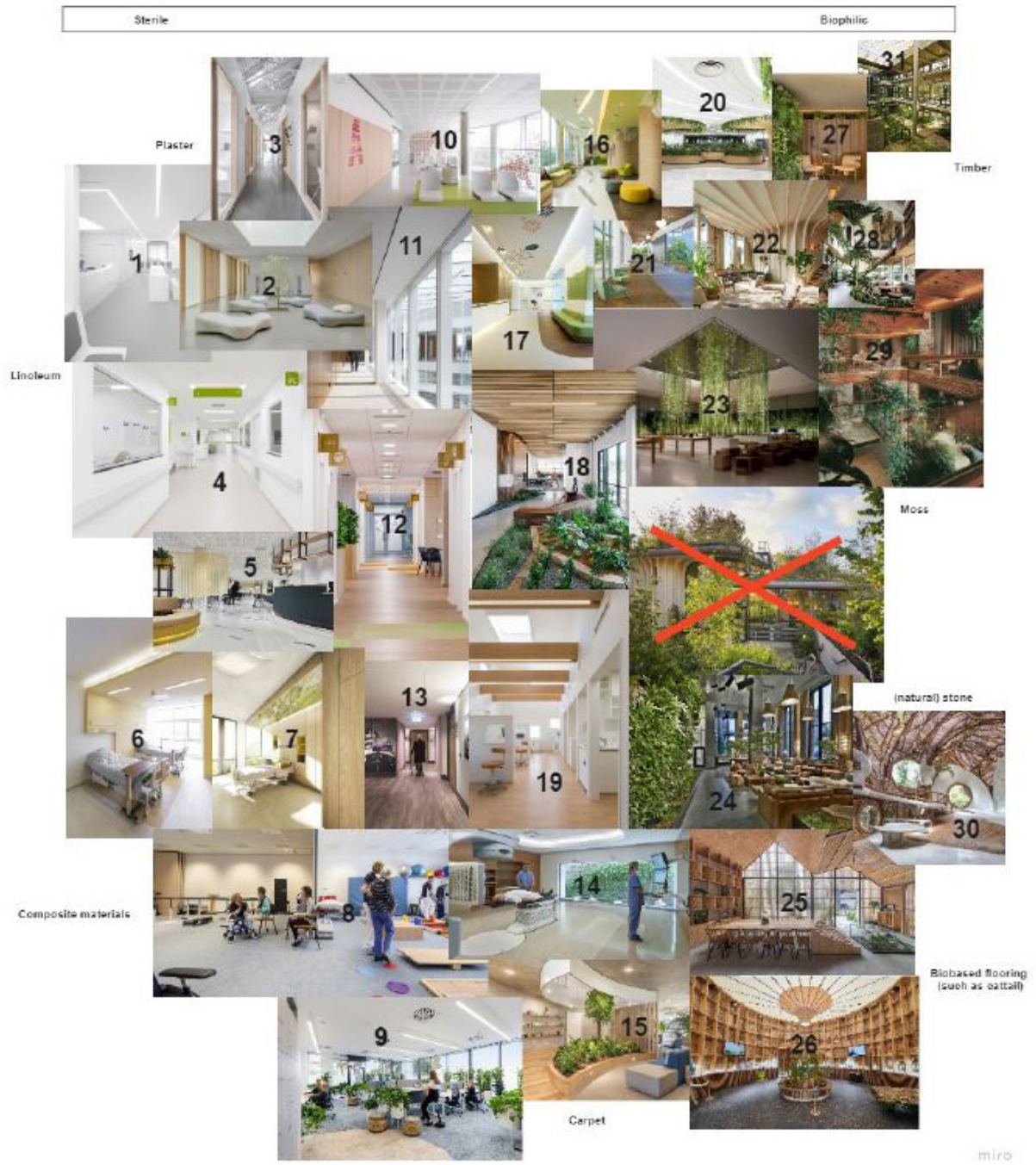
Appendix A: Reviewed projects on a scale of sterile - biophilic



Note: The moodboard is made with Miro (miro.com). The numbers correspond with the numbers in figure 6.

Project names and architects:

1: Orthodontic Clinic in Catania, Italy / Unknown
2: BIALMED Headquarters / 3XA
3: Lareau Insurance Office / Unknown
4: Unknown / Unknown
5: Domstate Zorghotel / Van Eijk & Van der Lubbe
6: Paris Hospital in Gilan / Unknown
7: Unknown / Unknown
8: Revalidatiehotel Intermezzo / HD Architects
9: The greenest office in Gdynia / Unknown
10: Hospital Sant Joan de Déu
11: Louis Dreyfus Headquarters / AZC
12: T-Mobile office / Unknown
13: Revalidatiehotel Intermezzo / HD Architects
14: Neubau Aerztehaus / Sektor 3
15: Hero Switzerland / Biopfilico
16: American International Hospital / Ong&Ong
17: American-Sino Hospital / Robarts
18: Alive + Well Austin / MF Architecture
19: Yokoi Dental Clinic / iks design + msd office
20: Al Zaydi Mall / Liqui Group
21: Unknown / Unknown
22: Maggie's Leeds Centre / Heatherwick Studio
23: Apple store Macau / Foster + Partners
24: 1 Hotels Brooklyn Bridge & Central Park / Sentient
25: Tropical Forest / Tayone Design Studio
26: The Growing Pavilion / Company New Heroes
27: Tartuferia San Paolo / MF+Arquitetos
28: Unknown / Unknown
29: Unknown / Unknown
30: Cultural Centre in Mayan Jungle (SFER IK)
31: Office building in India / CORE Architecture

Appendix B: Survey used with VR mock-ups test

Vragenlijst VR test
//De gebalanceerde ervaring

TU Delft
BK Bouwkunde

Totale tijd ervaren:
(in te vullen door onderzoeker)

Kruis het vakje aan wat het meest van toepassing is op jouw ervaring van dit gebouw
(1 vakje per stelling). Bedankt voor je medewerking!

	Zeer oneens	Oneens	Neutraal	Eens	Zeer eens
Ik voel mij optimistisch wanneer ik in dit gebouw ben	-2	-1	0	+1	+2
Ik heb een doel wanneer ik in dit gebouw ben	-2	-1	0	+1	+2
Ik voel mij op mijn gemak wanneer ik in dit gebouw ben	-2	-1	0	+1	+2
Ik voel mij geïntereseerd in andere mensen wanneer ik in dit gebouw ben	-2	-1	0	+1	+2
Ik kan mezelf zijn wanneer ik in dit gebouw ben	-2	-1	0	+1	+2
Ik kan goed met problemen omgaan wanneer ik in dit gebouw ben	-2	-1	0	+1	+2
Ik kan helder denken wanneer ik in dit gebouw ben	-2	-1	0	+1	+2
Ik voel mij geïnspireerd wanneer ik in dit gebouw ben	-2	-1	0	+1	+2
Ik voel mij nuttig wanneer ik in dit gebouw ben	-2	-1	0	+1	+2
Als mensen door dit gebouw zouden lopen, voel ik mij waarschijnlijk met deze mensen verbonden	-2	-1	0	+1	+2
Ik voel mij tevreden wanneer ik in dit gebouw ben	-2	-1	0	+1	+2
Ik kan zelf een beslissing of mening vormen over dingen wanneer ik in dit gebouw ben	-2	-1	0	+1	+2
Ik voel mij gewaardeerd wanneer ik in dit gebouw ben	-2	-1	0	+1	+2
Ik vertrouw op mijn eigen beslissingen wanneer ik in dit gebouw ben	-2	-1	0	+1	+2
Ik voel mij energiek wanneer ik in dit gebouw ben	-2	-1	0	+1	+2

Deze vragenlijst is onderdeel van een afstudeeronderzoek architectuur door Jaap Koopmans. De resultaten zijn anoniem en zullen enkel voor onderzoeksdoeleinden worden gebruikt. Mocht u vragen hebben, kunt u mailen naar: j.koopmans@student.tudelft.nl

Note: the questions were the same for every iteration, therefore only one question list is shown here.

Appendix C: Direct results from survey

	Sterile (n=6)	**Balanced (n=5)**	**Biophilic (n=6)**
Question number	Avg. time spent (n=4): **212 sec.**	Avg. time spent (n=5): **255 sec.**	Avg. time spent (n=5): **279 sec.**
1 (Af)	∑= +1 **Avg.: +0,17**	∑= +5 **Avg.: +1**	∑= +8 **Avg.: +1,33**
2 (Sa)	∑= +4 **Avg.: +0,67**	∑= +5 **Avg.: 1**	∑= +5 **Avg.: +0,83**
3 (Af)	∑= +4 **Avg.: +0,67**	∑= +8 **Avg.: +1,6**	∑= +10 **Avg.: +1,67**
4 (Re)	∑= -1 **Avg.: -0,17**	∑= +4 **Avg.: +0,8**	∑= +6 **Avg.: +1**
5 (Au)	∑= -1 **Avg.: -0,17**	∑= +6 **Avg.: +1,2**	∑= +7 **Avg.: +1,17**
6 (Co)	∑= +3 **Avg.: +0,5**	∑= +5 **Avg.: +1**	∑= +6 **Avg.: +1**
7 (Co)	∑= +6 **Avg.: +1**	∑= +5 **Avg.: +1**	∑= +5 **Avg.: +0,83**
8 (Co)	∑= -2 **Avg.: -0,33**	∑= +4 **Avg.: +0,8**	∑= +7 **Avg.: +1,17**
9 (Sa)	∑= 0 **Avg.: 0**	∑= +3 **Avg.: +0,6**	∑= +2 **Avg.: +0,33**
10 (Re)	∑= -2 **Avg.: -0,33**	∑= +4 **Avg.: +0,8**	∑= +7 **Avg.: +1,17**
11 (Sa)	∑= 0 **Avg.: 0**	∑= +6 **Avg.: +1,2**	∑= +8 **Avg.: +1,33**
12 (Au)	∑= 6 **Avg.: +1**	∑= +5 **Avg.: +1**	∑= +6 **Avg.: +1**
13 (Re)	∑= +1 **Avg.: +0,17**	∑= +5 **Avg.: +1**	∑= +6 **Avg.: +1**
14 (Au)	∑= 3 **Avg.: +0,5**	∑= +3 **Avg.: +0,6**	∑= +5 **Avg.: +0,83**
15 (Af)	∑= +3 **Avg.: +0,5**	∑= +6 **Avg.: +1,2**	∑= +7 **Avg.: +1,17**

Note: Af stands for affect, Sa for satisfaction, Re for relatedness, Au for autonomy and Co for competence.

Appendix D: Notes taken during VR mock-ups tests

	Sterile	**Biophilic**	**Balanced**
Client 1	Hospital-like; default; it tries to radiate tranquillity (-); therapy space feels at ease (+)	Beautiful (+); not a hospital-like feeling; you don't have to (+); domestic (+); safe (+); therapy space is too tantalizing (-)	Nice mix (+) ; piano is more present; soothing (+); very beautiful (+); therapy space looks to much like a sports hall (-), default (-), sad (-)
Client 2	Relaxed (+); not too tantalizing (+); therapy space not too tantalizing (+)	Too much (-); not happy (-); not yours (-)	Still too tantalizing (-); climbing wall is missing
Client 3	Boring (-); not cosy (-); clinical; therapy space relaxed (+); static	Cosy (+); did not notice the windows between entrance and cafeteria space; living room atmosphere (+); therapy space too tantalizing (-), because of greenery?	Also cosy (+); greenery less present; less living room atmosphere is being missed (-); therapy space is the best in this iteration (+)
Extra notes:	*Calming (+), pleasant (+), wide, height, quiet, relaxed (+)*	*Warmer, lots of green, makes life (+), homely (+), feeling welcome (+), a view of green is pleasant (+)*	

Note: Further comments that have been said during the tests but which have not been documented per person are added in italic at the iterations in the table. Every note has a ''(+)'' to mention a comment that can be seen as a positive influence on the well-being and a ''(-)'' for negative influence.