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Patient well-being, adaptation of/to indoor conditions, and hospital room design: Two mixed methods case studies

Research indicates that adaptation influences how people experience indoor conditions (ICs), and that the built environment influences both adaptation, via perceived control, and well-being. Their interlinkage is, however, not well understood. Therefore, we investigated how the design of hospital rooms can contribute to patients' well-being by supporting their adaptation of and to ICs via perceived control. Two mixed methods case studies were conducted at hospital wards in Belgium, each concurrently collecting qualitative and quantitative data. These included interviews with 16 (case 1) and 19 (case 2) patients, self-documentation by 8 patients, sensor measurements of indoor environmental quality indicators (e.g. sound, light and temperature levels) and questionnaires among 84 (case 1) and 238 (case 2) patients. Focusing on the built environment's role in adaptation allows characterizing known adaptation strategies in more detail. When perceiving control over adaptable building characteristics, patients can adapt ICs or adapt to ICs by choice. When not perceiving such control, they may still adapt sensations or their position. Without any perceived control, adapting to ICs is imposed. The built environment can support patients' adaptation by supporting their autonomy and competences. In this way it can foster both patients' eudaimonic as well as their hedonic well-being.

Keywords: adaptation; built environment; healing environment; indoor environmental quality; well-being

Introduction

The built environment affects occupants' comfort, health, productivity and well-being (Altomonte et al. 2020; Roskams and Haynes 2021; Woo et al. 2021). For hospitalized patients it impacts their healing process (Huisman et al. 2012). Its role, however, is not well understood (Andrade et al. 2017; Hanc et al. 2019; Altomonte et al. 2020).

This role has been the subject of inquiry in both healing environment (HE) and indoor environmental quality (IEQ) research. This article focusses on comfort, and its links with well-being (see below for a more in-depth discussion). In both fields, researchers have often focussed on how the built environment can help alleviate discomfort and provide comfort by assuming that it and its indoor conditions (ICs) are a given to occupants. However, when a change occurs that causes discomfort, people adapt, i.e. they react to restore their comfort (Nicol and Humphreys 2002). This adaptation is also affected by the built environment. Both are linked via perceived control, i.e., people's belief about influence on an outcome via changing the world or themselves to fit in with the world (Bryant 1989; Chipperfield et al. 2010). Little is known about how occupants adapt and adapt to ICs, how this adaptation influences their comfort and well-being, and how it is influenced by the built environment via perceived control. To advance this knowledge, we see potential in combining HE and IEQ research (Willems et al. 2020), both substantively and methodologically.

HE research

HE researchers have traditionally focused on healthcare settings. First, they have observed that perceived control has a positive impact on patients' comfort. According to Ulrich (1991), patient's lack of control is a major problem in healthcare settings, which increases stress and anxiety in patients. Ulrich's theory of supportive design advances three properties of healthcare settings that support patients' wellness: positive distractions, social support, but also perceived control over the built and social environment.

Second, HE researchers have focused on the role of the built environment in patients' experience. Huisman et al.'s (2012) systematic literature review indicates that patients' control over ICs can be enhanced by providing them with control over the temperature (air conditioning and heating), sound (music and television), lighting (including dimmers), and natural light.

Third, despite the above observations, in a study by Andrade et al. (Andrade and Devlin 2015; Andrade et al. 2017), questionnaire respondents' stress was predicted not by how much control they indicated to perceive over the lighting, temperature, windows and refrigerator, but by positive distraction and social support. These findings may be explained by the limited attention in HE research for the distinction between different ways in which patients adapt and adapt to ICs: typically data have been gathered about occupants' experience (e.g. through interviews or questionnaires (e.g. Jellema et al. 2020)), but not about the state of ICs (Willems et al. 2020). Andrade et al. have argued that the expected positive effect on the stress level of patients with a high desire for control may have been canceled out by the absent effect for patients with a low desire. Distinguishing between adaptation strategies might thus be needed.

IEQ research

IEQ researchers have traditionally focused on different settings, including healthcare settings. First, they have observed that perceived control and adaptation positively affect occupants' comfort. Some researchers have referred to the positive effect of perceived control (e.g. in offices: Boerstra et al. 2013; Sakellaris et al. 2019; Brackley et al. 2021, in schools: Yun 2018, and in residential buildings: Luo et al. 2014; Brown and Gorgolewski 2014; Xu and Li 2021), others to the positive effect of adaptation (e.g. de Dear and Brager 1998; Parkinson et al. 2020). This positive effect allows extending the range of ICs in which occupants feel comfortable.

Second, de Dear and Brager (1998) have provided insight into how occupants adapt and adapt to ICs. Based on literature, they have distinguished three adaptation strategies: behavioral, physiological and psychological. Even though these differences have been identified, IEQ research that considers adaptation has tended to treat these strategies as similar by treating adaptation as a ‘black box’ (e.g. Parkinson et al. 2020), or has attended to differences between them based on a limited understanding (Schweiker and Wagner 2015, 2017).

Third, some IEQ researchers have described, based on field studies, how perceived control and/or adaptation relate to the built environment (e.g. spatial layout) (Schweiker and Wagner 2016, Marín-Restrepo et al. 2019, 2020). Despite adaptive opportunities, i.e. contextual factors that offer possibilities to adapt behaviorally such as adaptable building characteristics or dress codes, which differ between settings (e.g. buildings or building uses), IEQ research has treated different settings as being similar to one another. An example of this is that threshold values for IEQ indicators (i.e. measurable quantities of ICs), developed by the use of sensor measurements and questionnaires, often apply for a combination of settings (e.g. Fanger 1970; Lazarov and Stranger 2017).

Combining IEQ and HE research

IEQ and HE research can complement each other to reduce their respective shortcomings. Substantively, an IEQ research perspective enables linking experiences with the state of ICs, while a HE research perspective enables understanding what is going on. This combination is needed to understand how occupants adapt, how this adaptation affects their comfort and well-being, and how it is influenced by the built environment via perceived control. Methodologically, insight is needed into variations in ICs via IEQ research that includes sensor measurements and research into occupants’ experience, not only via questionnaires, but also via HE orientated in-depth interviews.

In view of these observations, we aim to identify patients’ adaptation strategies, how this adaptation influences their comfort and well-being, and how it is influenced by hospital room design via perceived control. Central to our study is the research question: how does hospital room design influence patients' well-being through its impact on their adaptation of, and to, ICs via their perceived control? We address this question by linking well-being theories to the state-of-the-art of IEQ and HE research, and by further elaborating these links via observations from two mixed-methods case studies that combined the approaches of IEQ and HE research. Note that because we take into account both research approaches, we use the term ICs to denote characteristics of the indoor environment that can be quantified in terms of IEQ indicators as well as environmental characteristics that provide information about the environment to occupants (e.g. whether it is day or night).

Linking well-being theories to the state-of-the-art of IEQ and HE research

Well-being, comfort, adaptation and the built environment with its ICs are linked (see Figure 1). Psychologists have distinguished between two well-being perspectives: hedonic well-being and eudaimonic well-being (light and dark blue zone in Figure 1) (Delle Fave et al. 2010; Hanc et al. 2019). The former focuses on people's subjective belief about whether their life is desirable, pleasant, and good (Diener 2009); the latter on functioning well. Eudaimonia is concerned with living in a way, and within an environment, that aligns with one's *daimon* or true self (i.e. congruent with deeply held values), and that encourages expressing one's full potential (Waterman 1993; Ryan and Deci 2001; Ryff and Singer 2008). From this perspective, not all pleasure-producing desires would yield well-being when fulfilled, as some outcomes may harm people (Ryan and Deci, 2001). Ryff and Keyes (1995), who have adopted the eudaimonic perspective, have defined well-being in terms of six aspects. Related to adaptation is the aspect labelled as 'environmental mastery', which denotes the ability to manage effectively one's life and surrounding world. It parallels psychological constructs like ‘sense of control’ and ‘self-efficacy’, but unlike these it emphasizes finding or creating a surrounding context that suits one’s personal needs and competences (Ryff and Singer 2008). The self-determination theory (SDT) by Ryan and Deci (2001) defines three basic needs to foster well-being: autonomy, competence, and relatedness. It posits that fulfilling the basic needs typically fosters both hedonic and eudaimonic well-being.

Well-being has different connotations associated with comfort and health (big and smaller rectangle in Figure 1) (Altomonte et al. 2020). Across disciplines ‘comfort’ refers to subjective experiences, affected by various factors (physical, physiological, psychological) that result from the interrelation between an occupant and their surroundings (e.g. Ortiz et al. 2017; Looze et al. 2003; Vink 2005 p. 14). The Constitution of the World Health Organization (WHO) has defined health as "a state of complete physical, mental, and social well-being not merely the absence of disease ..." (World Health Organization 2020). Given our interest in the interrelation between the built environment and patients’ subjective experience, we focus on comfort and its links with well-being theories. However, ‘comfort’ has been defined differently by IEQ and HE researchers. The former have defined it as the ‘condition of mind that expresses satisfaction with the environment and is assessed by subjective evaluation (ASHRAE 55 2017). The latter have understood it as a concept with two dimensions (Ortiz et al. 2017): one consists of three states required to be comfortable: relief, ease, and transcendence; the other deals with the context of comfort focused upon: the physical (bodily sensations), psychospiritual (the inner self), social (interpersonal, family or cultural relationships), or environmental (light, noise, temperature, ambiance, colour, and natural versus synthetic elements) (Kolcaba 1994; Ortiz et al. 2017). Our understanding of ‘comfort’ covers both definitions.

IEQ and HE researchers have adopted perspectives related to hedonic and eudaimonic well-being. Most often their perspective links to hedonic well-being: ICs can alleviate discomfort and provide pleasure (de Dear 2011; Candido and de Dear, 2012; Rohde et al. 2020) (Figure 1: blue arrow in the light blue zone). ICs can also be linked to eudaimonic well-being: more perceived control has been considered to explain why people are satisfied with more variable and a wider range of ICs in some situations (Leaman and Bordass 1999; Nicol and Humphreys 2002; de Dear and Brager, 2002). More psychological adaptation occurs (Figure 1: orange arrow). When perceiving control over building characteristics, occupants can also adapt ICs (Nicol & Humphreys 2002). This behavioral adaptation can reduce discomfort and increase pleasure, and thus foster hedonic well-being (Figure 1: purple arrow).

Adaptation links comfort with ICs not only to both well-being perspectives, but also to the built environment (Figure 1: red colour). The built environment affects the ICs in the room (e.g. Rasmussen 2017; Carlucci et al. 2015), and the ICs affect whether a wish for adaptation is likely to arise (Figure 1: red frame around indoor conditions). The built environment also influences to what extent control is perceived, and thus behavioral and/or psychological adaptation occurs (Figure 1: red frame around occupant) (Leaman and Bordass 1999; Nicol and Humphreys 2002; Hummelgaard et al. 2006; Kim & de Dear, 2012).

Linking well-being theories to the state-of-the-art of IEQ and HE research highlights the need for investigating how the built environment influences well-being through its impact on adaptation of and to ICs via perceived control. As indicated in the introduction, we investigated this question with a focus on patients. Via two mixed-methods case studies the observed links were further elaborated into links between patients' comfort and well-being, their adaptation strategies, and hospital room design via their perceived control.

Figure 1: Adaptation model: links found within the state-of-the-art between well-being, comfort, adaptation and the built environment with its ICs.

Methodology

Multiphase, mixed methods case studies design

We conducted two mixed methods case studies in hospital wards. Quantitative and qualitative methods from HE and IEQ research were combined to gain more profound insight than each can offer in isolation (Creswell and Plano Clark 2011; Fetters et al. 2013). Integration occurred at the level of the research design, case study design, methods, interpretation and reporting (see Fetters et al. 2013 for further discussion). Figure 2 presents the research design. The research was approved by the ethics committee of the university (G-2018 08 1304).

The two case studies were combined within a multiphase design, with each case study covering one phase of the research and the cross-case analysis the third phase. Case study 1 improved our understanding of adaptation, which allowed informing and improving data collection for case study 2. The findings of both case studies informed the cross-case analysis.

Each individual case study has a convergent parallel design. Quantitative and qualitative data were gathered concurrently, in parallel and partly independently. Integration at the methods level occurred during data collection and analysis. We collected quantitative (questionnaires) and qualitative (interviews and self-documentation) data focusing on patients' perspective, and quantitative data about the state of ICs (sensor measurements). Integration during data collection occurred by connecting the methods to obtain qualitative and quantitative data. On the one hand, some interviewees, including those who participated in the self-documentation, constitute a subsample of the respondents of the questionnaire, further referred to as 'respondents'. On the other hand, some of the sensor measurements were conducted in the room of the interviewees and respondents. In the first instance, the different types of data were analyzed separately. Results from the separate quantitative and qualitative analyses were given equal priority, and integrated during the overall data analysis via merging. For reporting, we adopted the weaving approach, writing out findings from the qualitative and quantitative analyses together on a theme-by-theme basis.

Figure 2: Multiphase, mixed methods case studies design.

Cases

The case studies were conducted in Belgium. In consultation with hospital staff, we chose surgical wards as patients on those wards were expected to stay for several days and be physically and cognitively able to participate. Case 1 concerns a traumatology ward in a hospital building originating from 1984, and which was refurbished in 2010. ICs in patient rooms are regulated by mechanical ventilation (70 m^3/h in all rooms, supply temperature at outdoor air temperature during data collection), windows operable by occupants, indoor and outdoor shading devices operable by occupants (except for north-east oriented windows), individual fans, radiators with a thermostatic valve, and artificial lighting without dimmers. Case 2 investigated two wards in a building originating from 2018: one for abdominal surgery, urology and gynecological surgery; and one for neurosurgery, plastic surgery and ear, nose and throat. Patient rooms are equipped with mechanical ventilation (100 m^3/h in single room, 200 m^3/h in double room, supply temperature at 21°C), operable windows which are locked, a fixed sun shading, radiators with a thermostatic valve, and artificial lighting with dimmers. Except from top-cooling in summer, there was no cooling system in any of the patient rooms. Figure 3 shows the floor plans and the layout of a double room. For case 1 data were collected from May 14 to 30 and July 9 to August 1, 2019; for case 2 from September 29 to October 30, 2020 and December 8, 2020 to January 8, 2021.

Figure 3: floor plans of the wards where research was conducted for case 1 (left) and case 2 (right), and a picture of a respondent with in the background a VersaSense Wireless Device. The ‘x’ on floor plans indicates rooms where HOBO’s and VersaSense sensors were located during interviewees’ hospital stay in case 1 (left) and permanently during case study 2 (right); ‘h’ indicates those with only HOBO’s. (Plans case 2: based on the design of VK Architects & Engineers)

Data collection

A self-reported paper-based questionnaire quantitatively gauged patients’ assessments, causes of (dis)comfort, perceived control and, for case 2, states of adaptable building characteristics. Table 1 presents for the components this article focuses on the type of questions, the questions asked, the response scales and percentages of missing values per question.

The questionnaire was inspired by the CBE questionnaire (ASHRAE PMP 2010; Hyojin 2012; Peretti and Schiavon 2011), and adapted to hospitals based on insights from evidence based design research (EBD) in this context (e.g. Ulrich et al. 2008; Huisman et al. 2012). For case 2, questions about patients’ well-being were added, inspired by the WHO’s Quality of Life Questionnaire (WHOQOL-BREF) (De Vries and Van Heck, 1996). We turned the questionnaire into a right-now questionnaire inspired by ISO 28802 (2012), removed questions unrelated to IEQ indicators (e.g. about wayfinding), added questions about IEQ parameters (e.g. patients’ preferences and sensations), reformulated questions about IEQ indicators to questions about IEQ parameters for uniformity and to reduce response burden (e.g. thermal environment instead of indoor temperature), and added questions about causes of comfort and the state of adaptable building characteristics.

Within the wards, simple random sampling was adopted. The first author was at the ward one or two days a week to invite randomly selected (case 1) or all patients (case 2) to participate. In total 84 (case 1) and 238 (case 2) agreed to participate, provided informed consent, and responded. Table 2 lists the number of participants, the percentage of them that answered all questions, their personal and room characteristics, and dates the questionnaire was distributed.

To gain an in-depth understanding of patients' experience, perceived control and adaptation, we used semi-structured interviews, and, for case 1, self-documentation by the patients. The interviews addressed how participants experienced their hospital stay, especially related to their comfort with ICs and their actions to adapt them. Table 3 presents the topic guide. In between the interviews, participants could complete the questionnaire or participate in the self-documentation. The self-documentation consisted of a probe – a form of self-documentation that invites participants to express e.g. experiences and actions they might not think of during an interview (Gaver et al. 2004). It had the form of a timeline or booklet for taking notes and addressed participants' experiences and adaptations of and to ICs.

Convenience sampling was adopted. Interviewees were selected by nurses based on their ability and willingness to participate. They were interviewed until saturation in data collection was reached (i.e. new data repeat what was expressed in previous data (Saunders et al. 2018)). Interviews were conducted with 12 respondents and 4 others for case 1, and 15 respondents and 4 others for case 2. Eight interviewees participated in the self-documentation. All participants provided informed consent. All participants of case

1 and 10 of case 2 were interviewed twice, with about 3 to 4 days in between. Table 2 lists the number of participants, the number of them participating twice, their personal and room characteristics, and dates of participation.

Sensors were used to measure IEQ indicators in order to understand which ICs patients were experiencing, assessing, adapting and adapting to. Table 4 lists sensors used, the IEQ indicators measured and their unit, their accuracy or sensitivity, the sampling rate, their location in the ward and position in the room. Figure 3 presents for case 1 the rooms of interviewees where measurements took place during their hospital stay, as well as fixed sensor locations in patient rooms for case 2. For case 1, among the patients the nurses considered eligible for an interview during the days the first author was at the ward, we picked out patients who stayed in different room types (i.e. single versus double room and different window orientation) to maximize variety in measurement locations. For case 2, measurement locations were chosen so as to obtain an even spread of locations in both single and double rooms at each of the window orientations. To improve the measurements' reliability, sensors in patient rooms were calibrated for case 2 and HOBO's for case 1. For case 1, the minimum adjustment needed to calibrate case 2's light sensors was applied for all light sensors and only four different light and sound sensors were used.

Table 1: Overview of the questionnaire components this article focuses on, incl. type of questions, questions asked, response scale, and percentages of missing values per question when relevant. For case 2, questions ended with 'right now'.

Table 2: Overview of interviewed and questionnaire participants, their personal and room characteristics, and dates of participation.

Table 3: Topic guide of the semi-structured interviews.

Table 4: Overview of the sensor measurements.

Data analysis

Data were grouped according to differences in building characteristics (e.g. single versus double rooms) and conditions outside the room (e.g. regular weather versus an official heat wave (22/07/2019 and 26/07/2019)), as both turned out to influence patients' adaptation. For two opposing groups, we then compared experiences, causes of (dis)comfort, perceived control, satisfaction votes and measured values of IEQ indicators.

Quantitative analysis of questionnaire responses and sensor measurements, using the software RStudio (RStudio 2021) combined descriptive and inferential statistics. For the questionnaires, Mann-Whitney U tests and Wilcoxon Rank Sum tests allowed comparing satisfaction votes between groups. The significance level (α) is taken equal to 0.1 because of the limited number of participants per group for case 1. The extent to which multiple choice options were chosen was compared between groups via percentages. We considered only options chosen by at least 10% of the participants in one of both groups, and with a difference between both groups of at least 5%. The statistical methods applied work with unequal sample sizes. Only the non-missing values were analyzed. Measured values of the IEQ indicators were grouped in two steps.

(1) For each interviewee (case 1) or respondent (case 2), the distribution of measured values (mean, 1st quartile, 3rd quartile, 5th percentile, and 95th percentile) was calculated per 10-minute interval for the values measured in their room and during their hospital stay. This grouping ensured that the

measurements associated with each participant were given equal weight in the grouping of the second step.

(2) The measurements grouped for each participant were then grouped according to differences in building characteristics and conditions outside the room. For these grouped measurements, the distribution was again calculated per 10-minute interval.

The same process was undertaken to group measured air temperatures and global radiations outdoors. Influenced by the sampling rate, we used 10-minute intervals for case 1 and 15-minute intervals for case 2. Unless mentioned otherwise, measurements during the heat wave (case 1) were excluded from the groups, as this exceptional situation influenced the values considerably and was unevenly distributed over groups. The impact of differences in window orientations (see captions of Figure 5 to 7) and seasons were taken into account during data interpretation. The target values in Table 5 give an indication of how differences in measured values were expected to be experienced.

Table 5: Target values from norms, standards and guidelines

Interviews were audio-recorded and transcribed. Together with the data of the self-documentation, questionnaires and sensor measurements, transcriptions were analyzed qualitatively, roughly following the Qualitative Analysis Guide of Leuven (Dierckx de Casterlé et al. 2012) and using NVIVO software (Nvivo 2021). Interviews were analyzed per participant and per group. During data analysis, relevant concepts were looked up in existing literature: spheres of attention (Arvidson, 2006), perceived control (Chipperfield et al. 2012; Bryant, 1989; Rothbaum 1982), adaptive preferences

(Bovens, 1992; Teschl and Comim, 2005; Bruckner 2009) and theories about satisfaction (Oliver 1980). Insights from literature informed the adaptation model presented below. Quotes reported were translated to English by the authors.

The integrated analysis was done iteratively with the separate quantitative and qualitative analyses. For each of the compared groups, findings of the separate quantitative and qualitative analyses were merged via a joint display to draw out new insights beyond those gained from the separate analyses (see for instance Table 6 to 8 and Figure 5 to 7 below). Joint displays were set up for the analyses of the individual cases as well as for the cross-case analysis. When silence occurred during merging (i.e. findings about a certain theme were not present in a data set (O'Cathain et al., 2010; Uprichard & Dawney, 2019)), we first verified whether we overlooked something during the separate analysis. During the integrated analysis, attention was given to whether findings of the quantitative and qualitative data were congruent (i.e., correspond), complementary (i.e., clarify, explain, or more fully elaborate the observations), or discrepant (i.e., contradict).

Results

Merging data from interviews, questionnaires and sensor measurements offered insight into how participants adapt and adapt to ICs, how their adaptation is influenced by the built environment, and how both link to well-being. Figure 4 builds on Figure 1. It summarizes the interlinkages observed and will be referred to in the two sections below.

Figure 4: Adaptation model: the interplay between a patient and ICs through perceived control and adaptation, influences of the built environment on patients' adaptation of and to ICs, and how both link to well-being.

Patients' adaptation of and to ICs

The adaptation process observed is visualized in Figure 4. Some ICs catch participants' attention via sensations and environmental information they transfer. Participants attribute meaning to these ICs. Experiencing ICs that deviate from their preference in that situation can trigger a wish for adaptation.

When participants perceive possibilities to reduce the deviation, i.e., when they perceive control, they adapt behaviorally or psychologically. As indicated by the arrows in Figure 4, they (1) adapt ICs in the room (arrow pointing to ICs); (2) adapt sensations or the experienced environmental information via physical means (e.g. changing clothing) (arrow pointing to sensations and environmental information); (3) adapt their position by moving to more comfortable ICs (arrow pointing to sensations and environmental information); or (4) adapt by choice to ICs through choosing themselves to alter the attention given and meaning attributed to ICs (arrow pointing to meaning). Adaptation by choice to ICs occurs in two types of situations: when contextual factors take priority over comfortable ICs, or when some IEQ parameters take priority over others because the most comfortable condition of individual parameters cannot exist simultaneously. While perceived control improves participants' eudaimonic well-being (Figure 4: adaptation strategies within the corresponding zone), the former three strategies improve hedonic well-being as well (Figure 4: arrows pointing to the corresponding zone). Positive experiences of ICs are obtained and negative ones avoided.

When perceived control is lacking, participants are (5) imposed to adapt to ICs through altering the meaning and attention given to ICs (arrow pointing to meaning). This occurs in two types of situations: when actions taken to adapt ICs do not suffice, or when no action can be taken. This adaptation strategy does not foster hedonic well-being, and whether participants enjoy eudaimonic well-being depends on their psychological competence to adapt themselves (Figure 4: adaptation strategy within the corresponding zone).

Adaption of ICs

Adapting ICs fosters eudaimonic well-being. Perceived control and actions interviewees and respondents take positively affect how they experience ICs. Figure 5 shows the distribution of indoor and outdoor air temperatures, and illuminance, global radiation and sound levels in single and (at the window side of) double rooms or outdoors during the hospital stay of interviewees (case 1, top) and respondents (case 2, bottom). Table 6 presents their experiences, causes of (dis)comfort, perceived control, satisfaction votes and characteristics of the measured values. This section focuses on the findings from case 1. Rather than by the extent to which measured values of IEQ indicators meet target values (Table 6: target values), (the absence of) differences in actual satisfaction between single rooms and at the window side of double rooms can be explained by the fact that participants in single rooms perceive more control over ICs (e.g. have more privacy or control over sources that influence ICs) (Table 6: experiences and causes of (dis)comfort), perceive more control over building characteristics (Table 6: perceived control) and take more actions (Figure 5). How this shows itself for thermal, visual, and acoustic comfort is explained in more detail below.

First, the lower indoor air temperatures, at similar outdoor temperatures, indicate that in single rooms the window is opened more often (Figure 5). Despite the lower compliance with target values, satisfaction is not significantly different (Table 6: satisfaction votes and target values).

Second, as the global radiation outdoors is similar, higher illuminance levels in single rooms result from more actions on the lighting (Figure 5). This is supported by the horizontal patterns in the illuminance level and higher 95th percentile values during the night. Through the actions taken, compliance with target values is higher (Table 6: target values). Congruent with the higher compliance rate, satisfaction with the visual comfort is significantly higher (p=0,02) (Table 6: satisfaction votes).

Third, as causes of acoustic (dis)comfort, the respondents in single rooms mention more sources controlled by themselves, while those in double rooms mainly mention uncontrollable sources (Table 6: causes of (dis)comfort). In single rooms sound levels are slightly lower during the day, and slightly higher during the night (Table 6: measured values, Figure 5). Despite this limited difference in measured values, respondents in single rooms are significantly more satisfied with the amount of sounds (p=0,02), degree of tranquility (p=0,009), degree of sound privacy (p<0,001), and degree of privacy (p=0,002).

Respondents' higher satisfaction with the acoustic comfort in single rooms and the more positive experience of sound sources they can control (Table 6: satisfaction and causes of (dis)comfort) as well as interviewees' enjoyment of ICs that are adapted by themselves (Table 6: experiences) suggest that adapting ICs also fosters hedonic well-being.

Figure 5: The (10 minute average) mean, 1st quartile, 3rd quartile, 5th percentile and 95th percentile of the indoor air temperature (top left), illuminance level (top middle), and sound level at patients' bed (top right), and outdoor air temperatures (bottom left) and global radiation outdoors (bottom right) over the hours of the day during interviewees' (case 1) and respondents' (case 2) hospital stay in single or (at the window side of) double rooms. In case 1 window orientations are distributed as follows: 1x north-east, 1x east and 3x west for single rooms; and 4x south-east for double rooms. This difference explains the lower illuminance levels in the afternoon in double rooms. Horizontal dotted lines refer to target values of the Flemish Indoor Environment Decree (top left) and NBN EN 12464-1(2002) (top middle). (n: number of participants for which the measurements are included).

Table 6: Experiences, causes of (dis)comfort, perceived control, satisfaction votes and characteristics of the measured values for interviewees and respondents residing in single and (at the window side of) double rooms of case 1 and 2. (ni: number of interviewees; ns: number of respondents; n.s.: not significant; 1p: single room; 2p: double room).

Adaptation of sensations and environmental information

Having the possibility to adapt sensations or the experienced environmental information fosters eudaimonic well-being. Some interviewees preferred it to be slightly too cold instead of too warm so that they can adapt their clothing.

Adapting sensations or the experienced environmental information fosters hedonic well-being. Interviewees wear ear plugs to avoid annoying sounds, adapt clothing to increase thermal comfort, and, when the air feels dry, drink more, use moistening lotion, anti-dandruff shampoo and, especially those wearing contact lenses, eye drops.

Adaptation of position

Having the possibility to adapt one's position fosters eudaimonic well-being. Figure 6 shows for case 1 the distribution of illuminance and global radiation levels at the window and corridor side of double rooms during interviewees' hospital stay. Table 7 presents interviewees' and respondents' experiences, causes of (dis)comfort, perceived control, satisfaction votes and characteristics of the measured values. Several interviewees residing at the corridor side of double rooms move to the window when there is a nice view out. Having this possibility is expected to explain why respondents are significantly more satisfied with the view out than those residing at the window side of double rooms ($p=0{,}02$) (Table 7: satisfaction votes). This observation is discrepant from NBN EN 17037:2019's indication that the view out scores lower at the corridor side (Table 7: target values).

Participants' hedonic well-being would seem to be fostered at moments when they adapt their position. Interviewees residing at the corridor side refer with more enthusiasm to views on helicopter landings or the atmosphere at the window in the corridor (Table 7: experiences).

Figure 6: The (10 minute average) mean, 1st quartile, 3rd quartile, 5th percentile and 95th percentile of the illuminance level at the patients' bed (left), and the global radiation outdoors (right) over the hours of the day during interviewees' hospital stay at the window or corridor side of double rooms of case 1. The window orientations are distributed as follows: 4x south-east for the window side, and 2x south-west, 1x south-east, and 1x east for the corridor side. As the illuminance levels at the corridor side stay below those at the window side in the afternoon and evening, differences in window orientation do not cause bias in the interpretation of the measurements. Horizontal dotted lines refer to target values of NBN EN 12464-1(2002).

Table 7: Experiences, causes of (dis)comfort, perceived control, satisfaction votes and characteristics of the measured values for interviewees and respondents residing at the window or corridor side of double rooms of case 1 (w: window; c: corridor).

Adaptation by choice to ICs

Adapting by choice to ICs fosters eudaimonic well-being. This shows, for instance, when certain IEQ parameters take priority over others. Figure 7 shows for case 1 the distribution of indoor and outdoor air temperatures, and illuminance and global radiation levels during a heat wave and on other days during interviewees' hospital stay. Table 8 presents interviewees' and respondents' experiences, causes of (dis)comfort, perceived control, satisfaction votes and characteristics of the measured values. During the heat wave participants' attention goes mainly to the heat - it reduces their hedonic well-being most - and their main priority is keeping it outside (Table 8: experiences, causes of (dis)comfort, and perceived control). Although the actions they take reduce comfort with other IEQ parameters, the number of complaints about these is limited, as shown in more detail below.

On the one hand, interviewees and respondents close the sun shading during the heat wave (e.g. Table 8: perceived control) and use more artificial lighting, as indicated by the horizontal patterns in the illuminance levels and the higher illuminance levels with similar to lower global radiation outdoors (Figure 7). One would expect complaints about the visual comfort during the heat wave as daylight and a view out are appreciated by interviewees on other days. Contrary to this expectation, respondents complain only little more about causes of visual discomfort (Table 8: causes of (dis)comfort). They are not significantly less satisfied with the amount of light, visual comfort or view out (Table 8: satisfaction votes). An interviewee explains that, although he prefers a view out and daylight on other days, he accepts their reduction as this is the result of his own choices (Table 8: experiences). Neither did he consciously notice that during the heat wave the artificial lighting was on while before he complained about its intensity and atmosphere.

On the other hand, interviewees and respondents perceive more control over the window and the room's door during the heat wave (e.g. Table 8: perceived control). The interviewee closes the window to keep the heat out and opens the door to have some air circulation. Keeping the window closed, he expresses, involves accepting by choice that the indoor air cannot be refreshed with outdoor air, while keeping the door open involves accepting by choice the reduced privacy. During the heat wave respondents do not complain more about the amount of privacy, and they are not significantly less satisfied with the degree of sound privacy and privacy (Table 8: causes of (dis)comfort and satisfaction votes). They do complain more about causes of discomfort with the IAQ, yet they are not significantly less satisfied with it is (Table 8: causes of (dis)comfort and satisfaction votes).

Figure 7: The (10 minute average) mean, 1st quartile, 3rd quartile, 5th percentile and 95th percentile of the indoor air temperature (top left), and illuminance level at patients' bed (top right), and outdoor air temperatures (bottom left), and global radiation outdoors (bottom right) over the hours of the day during interviewees' hospital stay for those of case 1 who experienced the heat wave and the others. The window orientations are distributed as follows: 1x north-east, 2x east, 5x south-east, 2x south-west, and 3x west during moderate outdoor temperatures, and 2x north-east and 1x west during the heat wave. Horizontal dotted lines refer to target values of the Flemish Indoor Environment Decree (top left) and NBN EN 12464-1(2002) (top right).

Table 8: Experiences, causes of (dis)comfort, perceived control, satisfaction votes and characteristics of the measured values of interviewees and respondents hospitalized in case 1 during the heat wave and during other days of the field work (n.h.: not during the heat wave; h.: during the heat wave).

Imposed adaptation to ICs

When adapting to ICs is imposed, eudaimonic well-being can be fostered. During the heat wave, the indoor air temperature exceeds the target values of the Flemish Indoor Environment Decree more (Figure 7). Congruently, participants refer more to causes of discomfort related to the heat and perceive control over adaptable building characteristics that allow to reduce it (Table 8: experiences, causes of (dis)comfort, and perceived control). The actions they take do not allow creating thermal comfort. They are significantly less satisfied with the indoor temperature ($p<0.001$) (Table 8: satisfaction votes). An interviewee explains, however, that he knew in advance a heat wave was coming, and that this helps him to cope with the heat (Table 8: experiences).

How hospital room design affects patients' adaptation of and to ICs

Via its adaptable building characteristics and spatial layout, the built environment influences the experienced level of autonomy, competences and relatedness, and the experienced level of autonomy, competences and relatedness to what extent participants perceive control and which adaptation strategies they apply. Figure 4 presents these influences via the red frame. (1) Adapting ICs is stimulated when the built environment supports autonomy and competences to do so. (2) Adapting sensations and environmental information can occur independently from the built environment. However, it is stimulated when autonomy and competences to adapt ICs are lacking, or when relatedness takes priority over using this autonomy or these competences. (3) Adapting one's position asks for competences to move. (4) Adapting by choice to ICs is stimulated when the built environment supports autonomy and competences to do so, but it is also affected by relatedness that the built environment can stimulate. (5) Imposed adaptation to ICs is needed when the built environment does not support autonomy and competences to adapt ICs and when sensations or the experienced environmental information are not adapted.

Autonomy

The impact of the built environment on the level of autonomy participants experience shows when one compares findings in single and double rooms in case 1 and 2. In this situation it is the built environment which influences the experienced level of autonomy, rather than the number of patients in the room. In double rooms, participants reside next to each other in case 1 versus face-to-face in case 2 (Figure 3). Interviewees and respondents experience more autonomy in single rooms in case 1 and 2 and double rooms in case 2 than at the window side of double rooms in case 1 (Table 6: experiences and causes of discomfort related to the room's layout).

Differences in the experienced level of autonomy align with the degree of perceived control and number of actions taken to adapt ICs as well as with differences in satisfaction. For case 1 differences in perceived control (Table 6: perceived control) and actions taken (Figure 5) have been discussed earlier. For case 2 differences between both room types are less outspoken. Here still more control is perceived in single rooms, but the difference between both types of rooms is smaller compared to case 1 (Table 6: perceived control). Indoor air temperatures and (95^{th} percentile values of) the illuminance level are more similar between both types of rooms (Figure 5). Satisfaction with the visual comfort, tranquility and overall comfort differ significantly between single rooms and the window side of double rooms in case 1, and between the latter and double rooms in case 2, but not between single and double rooms in case 2 or between single rooms at both cases (Table 6: satisfaction votes).

These differences in perceived control, actions and satisfaction can be explained by differences in the experienced level of autonomy, rather than by differences in ICs. After all, the illuminance and sound levels differ more between the cases than between the two types of rooms per case (Figure 5). Taking into account the uneven distribution of window orientations of double rooms of case 1, we can assume that illuminance levels and the number of daylight hours are lower in case 2 due to seasonal differences. Sound levels are lower in case 2 in both single and double rooms (Figure 5). This can be partly explained by the fewer activities in the wards in case 2 due to the Covid-19 pandemic.

In double rooms in case 1, more autonomy and perceived control can also be noted at the window side than the corridor side (Table 7: experiences and perceived control). Interviewees residing at the window side enjoy this control. However, in this case it results in no differences in the number of experienced causes of visual and thermal discomfort and only a slightly higher satisfaction with the temperature (Table 7: causes of discomfort and satisfaction votes).

Competences

The impact of the built environment on the experienced level of competences, perceived control and actions taken shows through situations in which participants are imposed to adapt to ICs because competences are lacking. An interviewee in case 2 complains about looking straight at a slat of the sun shading while being unable to adapt position. Furthermore, adaptable building characteristics influence competences to adapt ICs. This shows itself in two situations. On the one hand, competences to adapt ICs depend on the adaptable building characteristics provided. Participants who stay long in case 2, for instance, miss the possibility to open a window. They miss the connection with outside, especially when being obliged to stay in their room due to the Covid-19 pandemic. On the other hand, competences to adapt ICs depend on the alignment of adaptable building characteristics with patients' physical and cognitive competences. An interviewee who is unable to leave his bed adapts himself to the lower amount of daylight when the sun shading is down although he prefers it to be open. Another interviewee does not understand how to turn the lighting off and thus leaves it on during the night, although he prefers darkness.

Relatedness

Even when having autonomy and competences to adapt ICs, in some situations participants give priority to their experience of relatedness. As discussed for adapting ICs, fewer actions are taken in double compared to single rooms, especially in case 1. Table 6 shows that interviewees and respondents residing at (the window side of) double rooms are more aware of other people's presence in their room (Table 6: experiences and causes of (dis)comfort). When interviewees in double rooms perceive control over adaptable building characteristics, several of them hesitate to adapt ICs and choose to adapt sensations or the experienced environmental information or adapt by choice to ICs (Table 6: experiences). For instance, an interviewee in case 2 chooses to wear an eye mask as her roommate prefers to keep some light on during the night. Several interviewees in case 1 hesitate to ask nurses to close the door during the night when they lack the competence to leave the bed. They do not want to disturb the nurses. Taking others into account is for some more important than comfortable ICs.

Discussion

Hospital rooms influence on patients' well-being

How can hospital room design foster patients' well-being in relation to ICs? Two ways can be distinguished from this research.

Architects and engineers can foster patients' hedonic well-being by alleviating patients' discomfort and increasing pleasure. Understanding how architects and engineers can achieve this goal has traditionally been pursued separately by IEQ and HE research. A downside of this perspective is that avoiding discomfort often results in neutral ICs. Also, pleasure is reduced. Compared to case 2, we found in case 1 more variation in experiences, causes of (dis)comfort, perceived control, satisfaction votes and measured values. This more outspoken variation is reflected in the findings discussed. In general, the lower variation in ICs in case 2, which is influenced by both the built environment and the limited number of activities in the wards during the Covid-19 pandemic, has the advantage that participants perceive more control over sensations and the environmental information experienced, but it can result in boredom too. Other IEQ researchers have voiced similar concerns (e.g. de Dear 2011; Candido and de Dear, 2012; Rohde et al. 2020). They have argued that besides avoiding negative stimuli, one should provide positive stimuli. Theoretical frameworks and literature reviews by HE researchers offer recommendations to do so (e.g. Ulrich 1991; Huisman et al. 2012; Andrade and Devlin 2015). Another downside is that what causes discomfort or pleasure can differ between patients. If there were no difference, adaptation by choice would, for instance, be less present in double rooms. Several other authors found differences between people as to which ICs they experiences as comfortable (e.g. Teli et al. 2015; Haddad et al. 2019; Bae et al. 2020, 2021). Designing built environments with ICs which contribute to hedonic well-being for all, might thus be impossible without providing adaptive opportunities, and thus without acknowledging that an approach that only aims to alleviate discomfort and increase pleasure via ICs does not suffice.

Architects and engineers can also foster eudaimonic well-being via design, with possibly a positive effect on hedonic well-being. From this perspective, the built environment can be designed as a means that patients can use to influence ICs, and in this way, their own well-being; in addition to a provider of ICs that contribute to hedonic well-being. More variable ICs can be combined with adaptive opportunities. The latter should be selected consciously. Perceived control needs to be restricted when ICs can harm patients' well-being (e.g. health), while support is needed for environmental mastery, one of the six dimensions of eudaimonic well-being (Ryff and Singer, 2008). To enable such mastery, the built environment has to fulfill the basic needs to foster eudaimonic well-being indicated by the self-determination theory via its adaptable building characteristics and spatial layout: autonomy and competences (Ryan and Deci 2001). By taking this perspective attention can be given to our observations and those from existing field work in offices, schools, and dwellings (e.g. Yun 2018; Brackley et al. 2021; Xu and Li 2021) that perceived control influences comfort with ICs positively. Furthermore, this perspective enables attending to variabilities in situations and people. The self-determination theory states that, when basic needs are fulfilled, people can choose how they influence their well-being (Ryan and Deci 2001). Patients are given an active role in influencing the IEQ within the possibilities offered to them. They can choose which of the feasible ICs align best with the true self. These can be those which foster hedonic well-being, but not necessarily. Fulfilling the basic needs allows accommodating differences in contextual, cultural and developmental factors, e.g., in the context we studied differences in outdoor conditions, self-rated well-being, length of stay or personal preferences.

While the second perspective seems promising, how to translate it into practice requires further research. The following two questions may help to guide future research, design practice, and hospital management.

Question 1; How to support autonomy? Differences found in the experienced level of autonomy between single and double rooms in case 1, for instance, align with observations that occupants of single offices perceive more control and/or take more actions than those in shared office spaces (Marín-Restrepo et al. 2019, 2020; Schweiker and Wagner 2016; Haldi and Robinson's 2010). Differences in the experienced level of autonomy between the window and corridor side of double rooms align with observations in shared office spaces that the distance between an employee and adaptable building characteristics affects perceived control (Marín-Restrepo et al. 2020). Future research should try to better understand patterns in the relation between (adaptable) building characteristics and autonomy. Hospital management needs to consider how much autonomy patients should be given.

Question 2; How to support competences? Adaptable building characteristics should be aligned with patients' physiological and cognitive competences. Differences between patients may exist in terms of mobility or cognitive abilities. The current IEQ approach has been criticized for designing for the average person (Bluyssen 2020). In line with this critique, our observations advocate for designing for those with the most limited competences, without reducing the comfort of others. Hospital policy can consider this as an important value. Future research should investigate similarities and differences in perceived control over ICs when competences vary.

Limitations

The methodology has shortcomings due to its explorative character. Part of the research was to investigate how IEQ and HE research can complement each other, both methodologically and substantively. Although this was demonstrated, limitations on resources and time need to be acknowledged.

Regarding data collection, the questionnaire's construct validity and reliability should be verified via further research. The questionnaire evolved during our study as our understanding of patients' comfort, perceived control and adaptation grew. The sampling procedure could be improved and the sample size should be increased in order to improve the generalizability for surgical wards. The representativeness of the sample can also be improved as patients with low cognitive and physiological competences were unable or refused to participate in this research. Selecting those participants for (short) interviews or interviewing them together with an assistant (e.g., a nurse or guardian) can be a direction for the future. Patients at other wards and occupants in other contexts should also be included to investigate whether the presented adaptation model is transferable to other contexts, each with their own specificities, and whether additional adaptation strategies can be identified. Furthermore, physiological adaptation could be taken into account simultaneously. Inspiration can be found in Goodhew et al. (2019). We can improve the mixed-methods approach by selecting the interviewees from the respondents using purposive sampling. To do so, online questionnaires are likely to be more convenient as, due to patients' short length of stay, purposive sampling should occur immediately after the questionnaire is filled in.

Regarding data analysis, groups were made based on one variable (e.g. single versus double rooms). An increased sample size would enable controlling for different variables simultaneously. We made some assumptions in this regard. Grouping the data of case 2 according to personal characteristics (age, gender, body mass index, length of stay and self-rated well-being) showed that these mainly impact on which control possibilities are perceived. We assumed that patients with different personal characteristics are randomly distributed across the compared groups. The season during which data were collected differs between both cases. Only single and double rooms are compared across both cases, and the difference in season is taken into account during interpretation. Comparing the two wards of case 2 suggests that differences in assessments, experiences and ICs between patients who undergo different types of surgery are limited.

Conclusion

Combining two mixed methods case studies in hospital wards in a multiphase design provided insight into how hospital room design influences patients' well-being through its impact on their adaptation of and to indoor conditions via perceived control.

The presented adaptation model, which was developed by linking well-being theories to the state-of-the-art of indoor environmental quality and healing environment research and empirical work, clarifies the relationships between the built environment, perceived control, adaptation strategies, and hedonic and eudaimonic well-being. Focusing on the built environment's role in perceived control and adaptation enabled characterizing known adaptation strategies in more detail. Strategies with perceived control were identified as adaptation (1) of indoor conditions, (2) of sensations or the environmental information, (3) of position and (4) by choice to indoor conditions; and without perceived control: (5) imposed adaptation to indoor conditions. The behavioral adaptation of the first three strategies contributes to both hedonic and eudaimonic well-being. The psychological adaptation of the fourth adaptation strategy contributes to eudaimonic well-being. For the latter strategy, patients enjoy eudaimonic well-being only if they are able to adapt psychologically themselves. The built environment affects which adaptation strategy is or has to be adopted via its adaptable building characteristics and spatial layout. Both affect whether the basic needs for eudaimonic well-being are provided: autonomy, competences and relatedness. To support patients' well-being, autonomy and competences should be provided so that patients can adapt indoor conditions, as well as competences to change position. Our observations suggest that the built environment should be designed as a means that patients can use to influence indoor conditions, and in this way their own hedonic and eudaimonic well-being; next to an environment that aims to provide indoor conditions that result in hedonic well-being.

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