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Thermal comfort and the integrated design of homes for older people with dementia

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Abstract People with dementia may have an altered sensitivity to indoor environmental conditions compared to other older adults and younger counterparts. This paper, based on literature review and qualitative research, provides an overview of needs regarding thermal comfort and the design and implementation of heating, ventilation and air conditioning systems for people with dementia and other relevant stakeholders through the combined use of the International Classification of Functioning, Disability and Health, and the Model of Integrated Building Design. In principle, older adults do not perceive thermal comfort differently from younger adults. Due to the pathology of people with dementia, as well as their altered thermoregulation, the perception of the thermal environment might be changed. Many people with dementia express their discomfort through certain behaviour that is considered a problem for both family and professional carers. Ethical concerns are raised as well in terms of who is in charge over the thermal conditions, and the protection against temperature extremes in hot summers or cold winters. When implementing heating, ventilation and air conditioning systems one should consider aspects like user-technology-interaction, diverging needs and preferences within group settings, safety-issues, and minimising negative behavioural reactions and draught due to suboptimal positioning of outlets. At the same time, technology puts demands on installers that need to learn how to work with customers with dementia and their family carers.

Keywords

Dementia, older adults, (in)formal care, thermal comfort, indoor environment, HVAC, design, Alzheimer's disease, integrated building

1. Introduction

According to Alzheimer Europe [1], there are an estimated 6 million -mainly older- people with dementia in the European Union. The vast majority of them lives at home, where they are largely dependent on (in)formal care [2]. Dementia is the loss of cognitive function of a sufficient severity to interfere with social or occupational functioning. Alzheimer's disease is the most important cause. Contrary to popular belief, loss of memory is not the only deficit in dementia. There are different kinds of symptoms in dementia, including (i) impairment in activities of daily life, (ii) abnormal behaviour, and (iii) loss of cognitive functions [3].

People with dementia are known to have an altered sensitivity to environmental conditions, and some may become increasingly reactive to their environment [4]. This in turn can result in behavioural problems, which form a serious burden for carers and are one of the reasons for long-term institutionalisation. The increased sensitivity seems to stem from the reduction of the individual's ability to understand the implications of sensory experiences [5]. In practice, about 90% of people with dementia show problem behaviour [6], which may be related to environmental stimuli. Apart from pharmacologic means, nonpharmacologic interventions can play an important role in managing problem behaviour [6,7].

The abovementioned changes in sensitivity imply that dementia has severe implications on daily life, and sets extra demands to living environments, including the thermal environment or indoor climate [8]. The thermal environment can be described as the characteristics of the environment that affect the heat exchange between the human body and the environment. Thermal comfort is described as 'the state of mind, which expresses satisfaction with the thermal environment' [9]. There exist extensive modelling and standardisation for thermal comfort, which depend both on physical and physiological parameters, as well as on psychology.

The home's indoor climate is not only the key factor in providing comfort to the occupants, but might even be a nonpharmacologic factor in managing problem behaviour accompanying dementia syndrome, and thus a yet largely unexplored and ill-known factor in care support and the reduction of the burden of care. Since people with dementia respond on a sensory level, rather than on an intellectual level [10], and given some of the cognitive and behavioural problems, extra attention should be paid to the indoor environment in relation to comfort and behaviour. It is, however, important to stress that cognitive impairment is not caused by environmental design, but problem behaviours may be exacerbated by inappropriate environments [11]. It is therefore of the utmost importance that the role played by the indoor climate is acknowledged by all relevant actors.

The design and maintenance of the indoor climate is the domain of various professions in the field of technology, not nursing in particular, such as building services engineers, architects and building physicists. Nursing literature in general often mentions the indoor climate in relation to people with dementia in various care settings, and provides clear indications in the form of anecdotal evidence that people with dementia are generally

very sensitive to (changes in) indoor climatic conditions. Professionals from the technological disciplines are the ones that build homes and install building services, using guidelines that are based on healthy, working-age adults. The integrated design of buildings in itself is a complex process; there are many stakeholders, it involves many disciplines and building systems, and aims at creating a range of stakeholder-related values [12]. People with dementia are the ones that are most affected when their actual needs are not considered in the design process and if a building cannot deliver its full potential of values to all users. A trend in society that makes the two professional fields come together is the emergence of air conditioning system in group-living and assisted-living facilities to protect older adults against the risk of increased mortality during long periods of (extreme) heat, as seen in the 2003 and 2006 heat waves in Europe. A good implementation of such technologies is crucial to not only protect people, but also to provide comfort to -and to maintain well-being of- older people with dementia. At the same time, there are important issues concerning the supply and costs of energy and fuel poverty, and the health risks of cold winters in community-dwelling people [13].
This paper, based on literature review and qualitative research, studies the needs regarding thermal comfort and the 'comfort-related' design and implementation of relevant building systems for community-dwelling people with dementia in an integrated way by focussing on the creation of building-related values for the relevant stakeholders: the person with dementia, family and professional carers, and professionals from the fields of technology, construction and housing.

2. Methodology

This study was based on (i) literature research, and (ii) reinterpretation of two data sets of qualitative research based on semi-structured interviews on the use of technology by community-dwelling older adults with dementia. Method and data triangulation was applied by combining these different research approaches. The International Classification of Functioning, Disability and Health (ICF) by the World Health Organization [14], and the Model of Integrated Building Design by Rutten [12] were chosen as frameworks for structuring and presenting the data (Figure 1).

2.1. Literature study

The literature study included both peer-reviewed articles and books on (i) ageing senses and perception of indoor environmental parameters by the aged and ageing, and (ii) housing for older people with dementia, (iii) behavioural problems among people with dementia in relation to indoor environmental parameters, and (iv) design guidelines for technology for people with dementia and the installers of such technology.
The search included databases as PubMed and databases of technological papers, without a limitation to the age of papers (up to March 2009). All volumes of the journals 'Dementia', 'American Journal of Alzheimer's Disease and Other Dementias', and 'Alzheimer's Care Quarterly / Alzheimer's Care Today', known for publishing on housing in relation to dementia, were searched manually for relevant papers. The reference lists were cross-referenced. Conference proceedings and books available in libraries in the Netherlands on dementia and design were also consulted. Also, the study included multiple sources from the Netherlands, to provide a counterweight for the large amount of Anglo-Saxon literature. The inclusion criteria did not only restrict to

publications on architectural modifications, technological solutions, building services including heating, temperature, and the indoor climate.
Literature included in this study does not only cover the home environment, but also institutional types of housing, such as nursing homes, small-scale group settings, and special care units (SCUs). International literature on SCUs is elaborate, and the knowledge is often directly applicable to the home situation.
The literature search was complicated by the large differences in vision and the way problems are conceptualised between nursing/occupational therapy, and the technological sciences. There are significant differences in the way professionals from both fields approach and perceive dementia syndrome and related health problems and challenges, as well as in the level of conceptual thinking when dealing with these challenges. Because nursing literature often reports of behavioural problems in dementia as a result of aspects of the indoor environment, most attention in these reports is given to the actual health problem instead of a good description of the actual environmental condition. A sort of forensic approach was needed to determine the exact underlying cause of the behavioural problems.

2.2. Qualitative research

The current study also makes use of two existing qualitative data sets on the use of technology by community-dwelling older adults in the Netherlands for a secondary analysis; the first data set is by van Berlo [15,16], and the second is by van Hoof & Kort [17]. These datasets concern the use of technology by community-dwelling older people. A phenomenological approach was used for the secondary analysis.
The van Berlo data set includes in-depth interviews (n=10) with primary carers (2 males and 8 females, often relatives) of community-dwelling people with dementia (4 males and 6 females). The interviews deal with the potential of technology in order to diminish the burden of care by limiting or partly taking over the various tasks of supervision. The interviews also deal with thermostats. Work related to this data set was published by Sweep [18] and Sweep et al. [19]. Many questions in the interviews were derived from an interview scheme for measuring the burden of care of family carers developed by Duijnstee & Blom [20].
The van Hoof & Kort [17] dataset includes data from an investigation of the expectations regarding technology and needs of a group of 18 older adults (care recipients) living in their own home with support of home care services. All 18 clients were entitled to receive institutional nursing home care. Seven clients coped with mild to moderate psychogeriatric health problems, including dementia. The others had (severe) somatic health problems. Some of the clients received back-up by family and/or professional carers during the interviews, using semi-structured questionnaires. These questionnaires covered a range of items, including (i) the use of assistive aids, (ii) the importance of ageing-in-place and accompanying challenges, (iii) the perception of safety and security, and (ix) the concerns regarding technology. The study was performed between December 2006 and September 2007. All interviews took place within the homes of the clients, since observation of the living environment plays an important part in the questionnaire.
The two data sets, consisting of transcripts of the interviews, were analysed as follows. First, each transcript was read in its entirety. Then, the transcripts were read a second time to develop codes, namely for (i) thermal comfort, and (ii) heating systems, (iii)

ventilation systems, and (iv) controls. Third, quotes that summarised the essence of each person's subjective experience were recorded, and translated from Dutch to English as closely as possible. These quotes are used to further illustrate findings from literature. In the text, the van Hoof & Kort subjects are shown as letters (Mr./Mrs. A to H, and J to S), whereas the van Berlo subjects are shown as Mr./Mrs. B plus a given number, for instance, Mrs. B5, Mrs. B12, etc.

2.3. Framework for the analysis

The data of the abovementioned literature review and qualitative studies is structured and presented using two existing frameworks: (i) the ICF [14] known from health sciences, and (ii) the Model of Integrated Building Design by Rutten [12] that has its origins in building sciences.

2.3.1. International Classification of Functioning, Disability and Health

The biological ageing process of persons may take place in good health and is not per se a precursor for dependency. It may also go along with an increased risk of the development of chronic diseases and impairments. Within the ICF, these health problems can lead to limitations or restrictions (Figure 1). ICF also lists external factors, such as environmental factors (specific products and services, technology, the (built) environment, social context, and care policies and welfare regimes), and personal factors (age, sex, education, profession, comorbidities and coping styles), which can be related to all the domains of the ICF. Within the ICF-model, the built or living environment can been seen as an environmental factor that influences people at the impairment level, and helps people to overcome limitations and restrictions posed by declining physical fitness and cognition. Relevant ICF domains for thermal comfort and the indoor climate are the domains b550 Thermoregulatory functions, and e225 Climate, which includes temperature and humidity [14].

2.3.2. Model of Integrated Building Design

Housing is one of the services that can be offered to older adults (with dementia) according to the concept 'integrated care'. In integrated care, packages of care and services are offered that fit into a daily rhythm or programme, or seamlessly follow the needs of users over time [21]. Integrated care may be seen as the process that is facilitated or supported through a fitting and integrated building process. Rutten [12] presented a Model of Integrated Building Design (MIBD) (Figure 1), which provides an overview of sub-aspects of the design process of a building and the desired building performance levels. In this model, a building derives its total value based on the quality of its relationship with its human environment. Although not necessarily mutually exclusive, the interests of different 'users' of a building can be quite varied [22]. Within the MIBD, six values and domains are distinguished, namely the basic, functional, local, ecological, strategic, and economical values. The ICF has a connection to three of these values, and therefore, emphasis will be on the basic value, functional value and economic value.

1. Basic value

The basic value is determined from a building's relationship with individual occupants and their sense of psychological and physical well-being. Thermal comfort (direct effect) and air quality (ventilation, indirect effect) are requirements under this category. Aspects

of safety as well as spatiality are also included within the domain of basic values. The person with dementia is the most important stakeholder in this section. The family carer is the one who knows the person with dementia best and can estimate the degree of psychological and physical well-being of this person. The starting-point is that the person with dementia stays in control and is accepted for as long as possible, even though there comes a point that the family takes over and becomes responsible. The basic value had a broad perspective; it can be regarded from a personal perspective and from the perspective of the building systems.

2. Functional value

The functional value is concerned with how activities taking place inside the building are supported. It relates to the organisation, which could be the organisation of care in the case of dementia, or the maintenance services of building systems. Underlying requirements include: support for production, manageability, operations and maintenance, and cleanliness.

3. Economic value

The economic value is based on the relationship with people concerned with the ownership and marketing of the building. This could be the occupants of the home as they own the dwelling, or a housing cooperation or care organisation that owns real estate. Sub-level requirements include: initial cost, life-cycle costs (operating costs & maintenance costs) and demolition costs.

The overall value of a building derives from how well it performs at all of the various human perspectives from which it is viewed. Defining total building quality therefore requires that the needs of all potential stakeholders be considered [22]. The building itself is made up of several systems or components, the six S's: stuff, space-plan, services, skin, structure, and site [23]. These components can be further sub-divided into sub-system components. The realisation of comfort is the resultant of various building systems. Each system has a specific set of functions that contribute to the achievement of a certain value. In this paper, various sub-systems as the façade system (skin), and heating, cooling and ventilation systems (services) and the controls are discussed in relation to the relevant stakeholder in terms of the provision of thermal comfort and a proper implementation in relation to safety and security. The heating, cooling and ventilation systems are further divided into: (i) heating systems (water-based systems and electrical systems), (ii) heating, ventilation and air conditioning (HVAC) systems, which deliver conditioned air, and (iii) ventilation systems (mechanical, natural and hybrid ventilation).

2.3.3. Combined model

The combined use of these models allows for an analysis of the current scientific problem that matches the mindsets of both scientific domains. From a practical point of view, this approach allows for a problem analysis from the viewpoint of the care recipient (i.e., person with dementia) which forms the basis of ICF, and to integrate the building process in such a way that it leads to a more fitting and appropriate use of a building (home), its rooms/spaces, and the technological and interior design. In this paper, only three values of the MIBD are considered for further analyses as they are the most relevant to the subject of this study: the basic, functional and economic values, although emphasis will be on the basic value. The connection between ICF and MIBD is as follows. The basic

value deals with the needs of the stakeholders as described in ICF terms, the functional value deals with answers and solutions to the needs of stakeholders, and the economic value deals with the fit between demand and supply.

3. Basic value

The domain of the basic value concerns the needs of the main stakeholder; the person with dementia. The next sections deal with standardisation and the impact of physiological changes that accompany biological ageing and dementia on the perception of thermal comfort, as well as directions for further thermal comfort research. This is followed by a discussion of the ethical aspects related to thermal comfort and relevant building systems.

3.1. Thermal comfort: standardisation, ageing and dementia

3.1.1. Thermal comfort models and standards

The most commonly used model for evaluating general or whole-body thermal comfort is the PMV-model (Predicted Mean Vote) by Fanger [24]. The PMV-model was created in the late 1960s by climate chamber research involving college-age students. It was validated for older people with 128 older subjects. The model expresses thermal sensation by Predicted Mean Vote, a parameter that indicates how occupants judge the indoor climate. PMV is expressed on the ASHRAE 7-point scale of thermal sensation (cold, cool, slightly cool, neutral, slightly warm, warm, hot). The outcome of the model is a hypothetical thermal sensation vote for an average person; i.e., the mean response of a large number of people with equal clothing and activity levels, who are exposed to identical and uniform environmental conditions. ASHRAE [9] defines thermal sensation as a conscious feeling, which requires subjective evaluation. The PMV-model is adopted by the (inter)national standards ISO 7730 [24], ANSI/ASHRAE Standard 55 [9], and EN 15251 [26]. These standards aim to specify conditions that provide comfort to a majority of healthy building occupants, including older adults. In practice, a selection of an acceptable percentage of dissatisfied is often made depending on economy and technical feasibility [27]. EN 15251 [26] mentions that for spaces occupied by very sensitive and fragile persons, PMV should be kept between -0.2 and +0.2 on the ASHRAE 7-point scale of thermal sensation.

Apart from general or whole-body thermal comfort, there is also local thermal discomfort, which is due to non-uniformity of the thermal environment. This includes uncomfortable vertical air temperature differences and floor temperatures, radiant temperature asymmetries, and draughts. Moreover, ANSI/ASHRAE Standard 55 [9], and EN 15251 [26] include models of adaptive thermal comfort [28] which are partly based on the expectancy of climatic conditions.

3.1.2. The effects of biological ageing

The abovementioned standards and models mainly focus on office situations, which are mainly populated by people roughly aged between 20 and 65 years old. Apart from a small percentage of people with dementia that are aged younger than 65 years old, most are aged 65 and over. The process of biological ageing may affect the perception of thermal comfort.

In principle, older adults do not perceive thermal comfort differently from younger college-age adults [27,29]. The effects of gender and age can be accounted for by PMV-model parameters, such as activity and clothing level [29]. The ability to regulate body temperature tends to decrease with age [29]. These changes vary widely among individuals and are related more to general health than age [13]. The circadian rhythmicity in body temperature tends to decrease with age [30]. Also, basal metabolism declines with advancing age leading to lower body temperatures, and on average older adults have a lower activity level than younger persons which is the main reason that they require higher ambient temperatures [29,31-33]. Many older persons complain they feel cold whether or not their actual body temperatures are lower [13]. Neurosensory changes tend to delay or diminish the older person's awareness of temperature changes and many impair behavioural and thermoregulatory responses to dangerously high or low environmental temperatures [13]. Moreover, high ambient temperature is found to negatively influence habitual physical activity [34]. However, according to Kenney & Munce [30], when the effects of chronic diseases and sedentary lifestyle are minimised, thermal tolerance appears to be minimally compromised by age.

Although 20% of older adults show no vasoconstriction of cutaneous blood vessels, not all of the remaining 80% have diminished control of body temperature [35]. Foster et al. [36] found a reduction in the sweating activity of aged men compared to younger age groups. The body temperature threshold for the onset of sweating was increased as well. These differences were even more pronounced in aged women. Moreover, pharmacological interventions may influence thermoregulation [13,37]. In general, older adults have a reduced (i) muscle strength, (ii) work capacity, (iii) sweating capacity, (iv) ability to transport heat from body core to skin, (v) hydration levels, (vi) vascular reactivity, and (vii) lower cardiovascular stability [29]. A number of studies have been conducted on older adults and their preferences of, and responses to, the thermal environment. Some studies found differences in heat balance, or preferences for higher or even lower temperatures between the old and the young, while others have given support to the PMV-model, which is based on the assumption that all age groups have the same thermal preference [27]. Some of the abovementioned findings for normal ageing are summarised in ISO/TS 14415 [38] as follows: "*Even among healthy aged persons, shifts of thermal circadian rhythms are often found. Vasoconstriction against cold environments, as well as vasodilatation and sweat secretion against hot environments, is weaker and starts later in an aged person. Thermal sensations become dulled and many cases of spontaneous hypothermia in the elderly are reported.*"

3.1.3. Dementia and thermal comfort

Apart from the ASHRAE definition of thermal comfort there is also a thermophysiological definition, which is based on the firing of the thermal receptors in the skin and in the hypothalamus. Comfort in this sense is defined as the minimum rate of nervous signals from these receptors [39]. Due to the pathology of many persons with dementia, involving damaging of brain tissue, the perception of the thermal environment, as well as the thermoregulation of psychogeriatric people might be different from their counterparts without dementia. Van Hoof [40] has postulated that more thermal comfort research is needed for older adults with dementia because of damages to the brain tissue and to problems expressing themselves.

In a study comprising 237 older adults, Sund-Levander and Wahren [41] have found that the variation in tympanic and rectal temperatures ranged from 33.8 to 38.4 C and 35.6 to 38.0 C, respectively. Dementia was significantly related to lower tympanic and rectal temperature. Much of the difference in the perception of thermal comfort is backed by anecdotal evidence. In a descriptive paper on the housing situation of his father with dementia, Steinfeld [42, p. 3] states that over time, his father's "*ability to sense thermal comfort seemed to deteriorate. There were many days when I would arrive to find the heat well near* [32 °C] *or more. And, in the summer, the opposite occurred with the air conditioning."*

The design process of building services for people with dementia, which is often based on the PMV-model, and thus thermal sensation, brings along risks since the traditional concept of thermal comfort is vague for people with an unknown 'state of mind' and who might lack the ability to express themselves reliably. Expressing satisfaction with the thermal environment, or dissatisfaction in particular, might take place via the expression of certain observable behaviour. Providing thermal comfort is important since a person with dementia may not be able to give an adequate reaction on the thermal environment and get or shed a sweater, or to ask for help or to complain [43]. Aminoff [44] adds that neglecting to dress warmly and to cover people with dementia occurs frequently; and although one feels the cold he or she cannot express the discomfort. Also, Cohen-Mansfield & Werner [45] studied behaviours in nursing homes and found that requesting for attention was associated with hot temperatures during daytime.

Cluff [46] stresses the importance of appropriate environmental quality including heating to benefit well-being, health and competence. The desired quality of building services for older adults with dementia, and their implementation in daily life, is likely to be different from that of other healthy groups. The current technical specification on thermal comfort of special groups, ISO/TS 14415 [38], does not provide any data on this matter.

Another problem, illustrated by Steinfeld [42], is that individual thermal preferences may differ greatly within the population of older adults with dementia. According to Fountain et al. [47], individual differences in healthy adults are frequently greater than one ASHRAE-scale unit when they are exposed to the same environment (inter-individual variance). In addition, how a person feels in the same environments from day-to-day can also vary on the order of one scale value (intra-individual variance). This scale value corresponds to a temperature range of approximately 3 K; the full width of the comfort zone in either summer or winter [47]. It is therefore not possible to exactly predict thermal comfort for individuals. That is the reason the comfort zone in standards is as wide as it is, and why it is unreasonable to expect all people to be satisfied within a centrally controlled environment, even when the thermal conditions meet current standards. In the case of older people with dementia, providing thermal comfort even when meeting current standards may be even more problematic particularly in group settings, due to even larger inter-individual variances.

3.1.4. Thermal comfort research for dementia

As most thermal comfort standards and guidelines are based on the PMV-model, this model should be investigated in terms of its applicability for people with dementia. Such an investigation would certainly bring along a lot of complicating factors. Apart from a person's cognition, underlying cause of dementia, age, the researchers have to use various

scales to investigate this matter, for instance, those stated in ISO 10551 [48]. According to this standard, subjects should rate the environment on a perceptual scale first, then an evaluative scale, followed by a preference scale, concluding with ratings for personal acceptability and personal tolerance. Since the validity of ratings and answers given by people with dementia is poor (some suffer from aphasia, others are happy to give any answer to the researcher in order to comply), family carers should be asked to rate the thermal perception of their partner/spouse with dementia as an additional measure, based on observations and knowledge of their partner/spouse with dementia.

According to Nygård [49], people with dementia may have considerable difficulties reasoning about abstract issues. Nygård also states that interviews largely rely on cognitive and verbal functions, which deteriorate as dementia progresses. At the same time, there may be discrepancies between statements of people with dementia and their family carers, which are more closely related to the actual burden of care than to a decline in cognitive functioning of the person with dementia [49]. Family carers, who are the representatives of people with dementia, often know the person with dementia best and their knowledge is often indispensable. Moreover, we do not know if people with dementia have thermal preferences that change over time, due to their progressing pathology. Still, not all is lost, in contrary. One might stress the importance of collecting information from both the person with dementia and the family carer in an early phase of the dementia process. Information may include whether someone feels warm or cold in certain conditions, and if someone is able to operate technology easily. Subsequently, it is important to observe changes in these patterns during the dementia process, in order to account for (shifts in) the preferences and abilities of the person with dementia as adequately as possible.

3.2. Ethical aspects

Within the domain of the basic value, the personal integrity of the person with dementia in relation to his/her surroundings and technology, and the accompanying ethical aspects form an important aspect, which is gaining importance as a field of discussion and study. According to van den Hoven [50], one obstacle to an adequate view of the relation between ethics and technology stems from Aristotle, namely the radical distinction between genuine action and production including engineering (*praxis* versus *poesis*). Praxis is the domain of ethics (*phronesis*), whereas poesis are the domain of instrumental reasoning (*techne*), not ethics. Van den Hoven [50] continues by stating that in modern times praxis and poesis are inextricably linked. The scope of the discussion on ethics, technology and dementia seems to be increasingly moving towards the field of architecture and design of technology and home automation for people with dementia [51].

3.2.1. Autonomy versus beneficence

Van Berlo [15, p. 69] describes an ethical dilemma about a 72-year-old woman with probable Alzheimer's disease Mrs. B12 cares for. In her current home, room temperature was controlled from a distance or was programmed, without letting the woman take control actions by herself, as the indoor temperature was often very high. Van Berlo [15, p. 70] states that the high temperature may be seen as a problem, but at the same time the resident may really like a hot indoor climate. The principle of beneficence would allow

control of room temperature because it seems often far too hot. But again, there is the principle of autonomy, which might outweigh the principle of beneficence here, since nobody is in direct danger due to a high temperature. In nursing homes, however, residents have no control over conditions in (group) areas. Staff needs to find a balance between 'dominating' residents and limiting damage residents might impose upon themselves.

3.2.2. Intelligent systems versus cognitive abilities

Fernie and Femnie [52] mention intelligent homes as a solution for community-dwelling people with dementia. These homes may 'turn up the thermostat a short time prior to the wake-up alarm and turning on the lights and coffee maker afterward'. The authors ask themselves four questions, which are relevant from an ethical point of view. What functions would be useful and acceptable? What functions would tend to trigger disorientation, confusion, anxiety or frustration? How could cognitively impaired individuals with Alzheimer's disease retain their ability to vary the environment? What special monitoring and control functions might enhance their independence, dignity and quality of life? In addition, Marshall [53] asks herself a number of ethical questions on the use of technology at home. One of these ethical questions is how can we know if the person with dementia consents to the use of technology. A second question is if people with dementia and their family carers have equal access to technology. A third question that needs to be answered is which person benefits from the technology? According to Marshall [53], 'the person with dementia ought to be the person who benefits at least as much as other people, but I am sure we can all think of situations where this would not be the case'. Similar ethical questions are posed by Bjørneby et al. [54] and van Berlo [55], who stated that the following questions should be considered in the use of technology: (i) the purpose of introduction, (ii) degree of involvement and consent of the person with dementia, (iii) who is to benefit most, (iv) is technology replacing human input, and (v) effects on the person with dementia. The final question by Marshall [53] that one should ask him/herself is if technology is being used because of poor design? This question is particularly relevant in relation to the indoor environment, which is dependent on passive architectural design, but which is often influenced by building services.

3.2.3. Control systems versus limitations to cognition

From an ethical point of view, people should have opportunities for control over the indoor climate and building services. In order to prevent problems with set-point temperatures of thermostats, control options should be easy and limited, even though abilities of people to operate equipment may vary considerably depending on the stage of dementia and past experience with technology. Technology should create an environment that is comfortable to both the person with dementia and the family carer.
Intelligent buildings may meet all criteria mentioned, in particular because the support devices are largely invisible to the user [51]. It is related to a building's strategic value, as it allows spaces to adapt to users over-time. The creation of conditions for thermal comfort and the control of ventilation systems are minimally invasive from a human-technology interaction point of view. One of the benefits of intelligent buildings is the possibility to work with user profiles. Set-point temperatures can be adjusted to people's

preferences and to the physical status of a person, for instance, whether someone is still active, largely involved in sedentary activity or bed-ridden. In situations with little physical activity and immobility, people with severe dementia may be unable to put off or add clothes and escape draughts created by forced air systems [56]. The resident profile may then adjust the heating and the method it is delivered.

Another issue that should me mentioned are economic conditions that often play a role in this vulnerability of older people, for instance, when someone can no longer afford air conditioning or adequate heating [13]. During winter months, the older person may try using little or no room heat to either reduce or eliminate high cost for fuel [13], which might lead to health problems as hypothermia and pneumonia. It is of the utmost importance that building services consume as little energy as possible to reduce energy costs. Also from the perspective of ecological and strategic values, such systems are desirable.

4. Functional value

Within the domain of the functional value, production support and reliability play a role as performance indicators. This can be both the impact in care giving processes of the family or professionals, as well as the production processes within the technological domain.

4.1. The role of carers and care organisations

Family and professional carers need to be aware of the consequences thermal discomfort can have on care processes, and how the good design and implementation of building services can lead to more efficiency in caring for someone with dementia. Even though dementia can significantly change how people interpret what they sense, the extent is highly individual and in constant flux, depending on neuropathological changes, sensory loss, time of day, medication management, and the social and physical environment [57]. All carers should be aware of this phenomenon too.

Many building services rely on controls. In order to implement technology successfully, all carers should be made familiar through training on how technology works and how to deal in case of malfunctioning. For instance, in an overview of special care units in Northern Europe and Australia, Judd et al. [58] described heating and HVAC systems installed per unit, but unfortunately did not go into operational details. It is likely that these systems were operated by staff only, not the residents. Information on the role of these building systems and thermal comfort should be made available via patient organisations and professional care organisations. Very old seniors with dementia are more likely to live alone or with a family carer in need of help him/herself, who cannot deal with the physical strain of caring. It is likely that such an aged family carer has difficulties with handling technology.

Occasionally, carers (particularly professionals) can have a misinterpretation of underlying problems. Bakker [57] states that at times, the loss of function of institutionalised persons with dementia is incorrectly blamed on dementia, when inappropriate design is at the basis. Bakker also provides an example of a person with dementia on a hot summer day, in a room without air conditioning. Although staff claimed that the person could no longer operate the HVAC equipment, which was said to be due to dementia, it turned out the lettering on the control panel was too small and

contrast was too low. Apart from operational restrictions, there are more concerns regarding air conditioning for older people with dementia.

In the Netherlands, some of the regional health care assessment centres take heating systems in account when assessing the need for care of a client living at home, for instance, whether occupants can handle the knobs, the thermostats and the central heating system itself. This means that these organisations acknowledge the importance of such a system in relation to being able to live independently.

4.2. The role of the technological professions

Dementia also calls for a more thorough approach from the technological domains. This approach is twofold.

First, installing technology puts demands on installers and their technological solutions. The complexity of technology can have a disabling effect on the person with dementia [59]. Ideally, technology and equipment should (i) not require any learning, (ii) look familiar, (iii) not remove control from the user, (iv) keep user interaction to a minimum, and (v) reassure the user [60,61]. Moreover, interfaces should be large in order for people with Parkinsonism, and various age-related limitations to motor skills, to be able to operate them.

Fozard et al. [62] have come up with a developmental view of human factors and ageing (Figure 2). They state that because biological ageing itself means change, the design of environments and equipment used over the lifespan should include the potential for changing requirements associated with ageing. Figure 2 represents the interaction between a person and the environment. People receive information from the environment (perception). This may lead to actions that may adjust or modify controls of the system that is operated. Within the model, age-associated differences in sensitivity to the thermal environment, as well as individual differences in, for instance, cognitive abilities, are the main things that determine whether it is necessary to age-adjust the relationship between the person and the system being operated [15]. The most important implication of the developmental view of human factors is that ergonomic interventions should emphasise adaptability of architecture and products as a design principle [15]. The model is very easy to apply to the design of building services for dementia, as it specifically incorporates cognition and perception, and focuses on displays and controls. Also, the so-called ‘technology generation’ [63] should be taken into account, as the type of technology people were familiar with before the age of 25 years plays a role in the ability to work with technology in later life.

When working with a person with dementia, he or she may not remember why an installer is working in a home, or who this installer is. This may be a cause of distress. Installers should preferably work in couples, which allows one of the two to leave the site, without loss of access upon return [64]. When equipment is installed, installers should answer user questions repeatedly, listen, and be sensitive to the state of mind of the client [64]. Some people with dementia are curious about new equipment and are often uninhibited about dismantling it to “find out how it works” [64]. Moreover, people with dementia need rapid responses to perceived difficulties, as they are often unable to understand the reason for a fault occurring, or work around it [64]. Gitlin & Kyung Chee [65] have come up with guidelines for introducing adaptive equipment, which include (i) making an observation of the home to determine needs, instalment considerations, and

use of space, and (ii) involvement of family members in the evaluation and decision-making process. Installers should proceed only with equipment that has been agreed upon by the family [65].

Second, technical professionals should be aware that current standards and guidelines for thermal comfort cannot be applied to persons with dementia without caution. In general, the quality of the indoor environment may be expressed as the extent to which human requirements that have a great interindividual variety are met. Some people are known to be rather sensitive and are difficult to satisfy [66], and this seems to be particularly true for people with dementia.
Other relevant building regulations tend to be primarily written for the needs older people with a physical impairment, rather than for people with mental or cognitive impairments [67]. It is worthwhile to investigate if design guidelines for older people with dementia are suitable for people with dementia younger than 65 years, who have not yet experienced the effects of high age.

5. Economic value

Within the domain of the economic value, initial costs and operational costs, as well as maintenance, play a role as performance indicators. These costs can be made by individuals with dementia and their relatives, by care organisations or stakeholders from the domain of technology.
As mentioned in the previous section, all carers should be made familiar through training about technology. Training, however, is costly and poses financial restrictions in the start-up phase, particularly when multiple systems are used simultaneously. The results however, may cut down on costs for the processes of facilitating care. If people with dementia are able to age-in-place, due to improved thermal comfort and building systems, instead of living in an institutional setting, this goes together with a reduction of costs for society. Van Hoof et al. [2] provide an overview of financial and societal costs of care for people with dementia. The costs of informal care in 2005 were an estimated € 4,700 per person with dementia per annum. The direct costs of dementia care were about € 14,200 per person with dementia per annum. The costs per person can vary considerably, even within the more developed countries and when considering the net domestic purchase power. Many family carers are older adults themselves, and health problems may arise from the stresses of caring for a loved-one, in particular when problem behaviours are observed.
Some of the Dutch regional health care assessment centres acknowledge the importance of heating systems and thermostats in relation to being able to live independently. At the same time, there are few commercially available solutions to assist people with dementia. One should keep in mind that what is available on the marketplace is not the same as what is or may be possible in practice. This brings us to the need for product development.
The technological domain is the ideal place for such product innovation, as many enterprises are focussing on the health care domain as potential growth market. This does however ask for investments from the industries for research and development, and requires serious investments in training and education personnel. At the same time, the technological sector could strengthen its market, while at the same time helping the

health care sector find a solution for present-day problems including the shortages in health care professionals. Maintenance and its costs are another issue. Well-kept equipment is less prone to failure, and in case of moving parts as in HVAC systems, maintenance can keep background noise down [11]. Money should be reserved for these necessary costs, including running costs. Operation and maintenance require service providers to innovate. New services should be developed to support the health care providers and recipients. Also, new low-energy systems could have a positive impact of both the environment and people's financial capacities.

6. Synthesis of building systems

The realisation and experience of comfort is the resultant of various building (sub)systems, i.e., the skin, the services and the control systems, which are discussed in the following paragraphs.

6.1. Skin: façade systems

There are both active and passive façade systems to maintain a comfortable indoor climate at home and to avoid large temperature rises in summer (risk of hyperthermia). Solar blinds can help limit the heating of the dwelling in summer [27]. Automated curtains and/or solar blinds installed to limit solar gains should be avoided, as Sweep [18] mentions that such technologies can be perceived as threatening.

Operable windows are important for ventilation. Ideally, windows should be manually operable as an easy way to let the resident have some control over the environment [68]. Ventilation openings should be designed so that residents cannot crawl through them [68]. Especially in high-rise buildings one should install security locks to prevent people from climbing out through open windows and balcony doors [69], or install home security systems to alert carers when doors or windows are opened. Locks may be necessary on windows to prevent them from being opened too far, or to keep residents from opening them throughout winter [68]. Moreover, ventilation grids should be easy to reach in order to prevent the risk of falls.

6.2. Services: heating systems

The bathroom is the room where a heating system is needed most. Bathrooms should be comfortably warm, since people undress in these rooms [70-72]. For institutional settings, Aminoff [44] states that in winter, if residents cannot complain that they are cold, undressing and later dressing in a cold bathroom, or allowing them to lie naked waiting to be washed with cold water, is 'cruel'. According to Warner [73], a person with dementia may not realise that a bathroom is too cold, only that he or she is uncomfortable, and may not associate the room's temperature with the experienced discomfort or have the ability to communicate it. This often results in frustration, anger or attempting to get away from the discomfort. Apart from discomfort and risks of hypothermia, there are other safety issues involved in relation to heating systems.

The diminished understanding of the surroundings also puts demands on the way heating systems are installed, and on safety requirements of separate, auxiliary electronic heating systems. These electronic systems should be kept out of the bathroom as much as possible [72]. An alternative solution to increasing comfort and providing heat is to install heat lamps in the ceiling [10,57,72]. Heat lamps cannot be knocked over, for

instance, into water, or touched by wet hands since they are out of reach [73]. A timer should be used to switch the heat lamps off, in case one forgets about the equipment [73]. In a study by Sloane et al. [74] the environmental modifications most commonly suggested by nursing staff (n=71) as elements of an ideal bathing area included installing heat lamps and sufficient heating of bathrooms (24.6%) and improved ventilation (13.1%).

Another safety issue is formed by hot radiator panels. Hot radiators should be blocked or covered, since people may have difficulty judging the temperature of the device and burn body parts [69,75,76]. Not only radiators, but also water pipes can cause burns [73]. When people are seated in a wheelchair, uninsulated piping and drains can cause burns to one's knees, without the person with dementia immediately indicating he or she is in pain. Radiators in general pose hazards in case of fall incidents [8,69]. This is illustrated by an example from qualitative research. Mrs. S (aged 83, widowed) has equilibrium disturbances due to Parkinson's disease. She shows that radiator panels can be a cause of serious injury when falling. During the interview, Mrs. S had several stitches in her forehead after she had fallen against the radiator panel.

A solution is to install radiant floor heating instead [8,10], which also help occupants to keep 'cold feet' warm. The temperature of such systems should not be too high because of the risk of developing oedema in the lower legs. Non-slip sheet rubber or a cushioned low glare vinyl on a bathroom floor can also replace tiles to keep feet warm [71]. Moreover, wall panels collect dust and thus require regular cleaning. On the other hand, radiators can play an important role in reducing stress. Radiators can be used to warm towels that can be used to pat one dry and to increase the sense of privacy [10,72], and help people dry used kitchen towels.

Bedrooms should be thermally comfortable [72]. Nocturnal unrest may be caused by people being too cold or too warm, and can along with medication and fluid intake contribute to people going out of bed to go to the toilet, which brings along the risk of fall incidents [77]. When (un)dressing, bedrooms should not be too cold [70]. Cold rooms may even put a physiological strain on older people and may lead to stress in the circulatory system. The aforementioned data on safety in bathrooms can of course, to some extent, be applied throughout the home.

6.3. Services: HVAC systems

In many countries, domestic HVAC systems that are often installed for cooling are a luxury item, whereas they are more common in warm countries, including large parts of the USA. As mentioned before, bedrooms should be thermally comfortable [72], and cooling provided via air conditioning may contribute to comfortable conditions, and even help prevent nocturnal unrest [77]. Especially in hot summers, silent air conditioning systems can help people fall asleep, which is both important to people with dementia and their family carers.

Also, there are some considerations to the positioning of outlets of HVAC systems. Systems that are installed to increase comfort, may, if not adjusted correctly, be a source of discomfort when people are unable to move aside or complain [44]. Naked people or those who had just been bathed should not be exposed to a draught, as they are unable to complain of cold, or ask to be moved or covered. Outlets directing air on curtains or papers on tables can cause them to move. Warner [73] states that such movement might

give the impression to the person with dementia that someone else, even a ghost or a thief, is in the room.

Given the uncertainties in comfort needs and possibly large inter-individual spread in preferences, special attention should be given to mass installation of HVAC systems (in particular, cooling) in light of recent hot summers as 2003 and the increased mortality rates of persons with dementia [78,79]. Dementia is a threat as people may not be conscious of certain risks during a heat wave, and as it can impair a person's perception of environmental conditions, threshold of suffering, and physiological defence mechanisms [79]. The protection from mortality by shielding people from heat could go hand in hand with more problem behaviour as people are exposed to cooler air and experience discomfort, and needs further elaboration.

6.4. Services: ventilation systems

Adequate ventilation is very important during bathing, in order to let fresh air in and to limit the amount of moisture that can cause unwanted mould growth. Brawley [80] mentions that steam-filled bathrooms may be stressful. Automated ventilation systems may be an option to get rid of excess moisture, but can problems of their own. Steinfeld [42] describes how his father with dementia got anxious by the noise generated by the fan that activated automatically when the light was turned on. The old man did not understand the source of the noise, as he turned on the light, not a fan. Warner [73] too mentions it is important to consider problematic sounds in the bathroom that may be confusing or irritating, including exhaust fans. Ceiling fans should be installed with care, as they may be a source of discomfort (draught, noise) when not adjusted properly, or when people with dementia are unable to move or complain [44].

Operable windows can cause draughts, which can cause curtains to move. This may lead to the aforementioned problems.

6.5. Services: control systems

Control systems form the most important sub-system component within the MIBD when considering the needs of people with dementia. This is illustrated by numerous examples from the qualitative data sets. The next paragraphs will focus on individual control of the environment for people with dementia, and the role of individual control in relation to an altered perception of environmental conditions.

6.5.1. Individual control

If cognition allows, thermostats give people the opportunity to control their environment to a certain extent. Marshall [53] states that very little attention has been given to technology to control the environment and thus help with problem behaviour. Marshall mentions the potential of technology, for instance, in reducing irritability when people with dementia are hot, by controlling temperature. The importance of temperature control for people with dementia at home is stressed by Gitlin [81]. According to Brawley [10], one could consider installing an independent temperature control for the bathroom as a means to optimally control the bathroom's temperature. If thermostats cause difficulty operating, covers can be placed over the controls [10,82], or thermostats can be pre-set and disguised [76], or simply placed out of sight.

Karjalainen [83] studied the usability problems with office thermostats and concluded that a substantial amount of information is needed even to use a seemingly simple thermostat. Hence, it is not a complete surprise that thermostats are known to be troublesome for people with dementia. Steinfeld [42] states that the system's delay in providing hot or cold air is one of the problems, since people forget that they manipulated the system's interface and then think the system is malfunctioning or broken. In his example, the person with dementia overcompensated, and would leave the room with the temperature set all the way up, resulting in extreme indoor temperatures. Those required the temperature to be set the other way, and caused frustration. Steinfeld [42] concludes that passive systems require far less intervention on the part of the resident, and that thermostat controls should only function within the optimal thermal comfort range.
Problems concerning how to operate thermostats and radiators knobs are also found from qualitative research. Mrs. N (aged 81, divorced) has a severely damaged short-term memory due to multiple strokes. Mrs. N had had a new thermostat, but due to her impaired short-term memory, she does not know how to operate it, even though the family put the instructions next to it on the wall. Her daughter explained:

> "*The instructions do not stick to her mind. Sometimes, the thermostat is turned on 34°C, and then you think it's rather hot in here. Today it was set on 18°C and you think it's rather chilly.*"

Mrs. N continued:

> "*O, well, to me it wasn't very cold.*"

Later, the daughter mentioned that the knobs of the radiator panels had been removed by the children.

> "*Mother turned the radiator knobs instead of using the thermostat, something she never did before. Then [mother] would say: 'It's not very comfortable in here, let me turn up the thermostat', which results in a very hot home and that is why we took off the knobs.*"

Mrs. B2 (aged 60), cares for her 65-year-old husband, who suffers from a mix of probable Alzheimer's disease and vascular dementia.

> "*Well, we used to have [some problems] with the radiator knobs; then it suddenly is very hot in here. The heating is then put around 30 to 35°C. And then I say: 'You can not touch it.' It then feels like you are about to suffocate in here, but well, then he touches [the knob] again, and then it is totally turned off, or he completely takes off the button and so on.*"

Mrs. B4 is in her fifties, and cares for her father (aged 80), who is diagnosed with probable Alzheimer's disease.

> "*He always turns up the heating very high. And he always says: 'It is so hot in here'. [The thermostat] is much too small. He turns [the button] but then he cannot see [the display] exactly. He thinks he turns the right way, but he turns it to [its limits]. He simply does not see the little letters, the temperature. So all that needs to be a bit larger, or something like it.*"

Mrs. B5 (aged 50) cares for her mother-in-law with an unmentioned type of dementia, aged 87. When asked if her mother-in-law can still operate the heating system:

> "*Yes. I always think […] it is so warm in here. Older people are cold so quickly. Then [my mother-in-law] says: 'Please turn it lower.' But well, I leave within the hour, so it has no use. But it is always very warm.*"

When asked if her mother-in-law can still operate the heating system:

> "*Yes, it is easy with a knob like that.*"

Galasko [84] provides a graphical overview of the correlation between MMSE (Mini Mental State Examination) scores and the ability to perform daily activities. Roughly between MMSE scores of 23 and 16 (early stage dementia), there is a loss of optimal (independent) performance to use the telephone. The ability to use home appliances disappears between scores of 19 to 9 (mid-stage dementia). This forms an important clue as to when people with dementia lose the ability to operate thermostats, as thermostats are part of the normal appliances found in homes too. Thermostats themselves are not explicitly mentioned by Galasko [84] though.

6.5.2. Altered perception and individual control

Fernie & Femnie [52] have also addressed the issue of thermal comfort and thermostats. They state that older adults with cognitive impairments are sometimes unaware of dangerous levels of heat and cold. In order to provide means for personal control, thermostat controls are available with a simple dial marked from 'cooler' to 'warmer'. "*Systems should be configured in such a way that the midpoint of the thermostatic stetting corresponds to the middle of the comfort zones and that the extremes lie within the safe physiological temperature limits.*" The findings by Fernie & Femnie [52] are supported by the qualitative research, particularly the disrupted perception of thermal conditions.

Mrs. B10 (aged 53) cares for her 55-year-old husband, who is diagnosed with probable Alzheimer's disease. He has lost his sense of the seasons. When asked if her husband still believes it is winter:

> "*Yes. I think he could not switch after winter. He also shuts the windows upstairs every night, even the ventilation grids. Everything needs to be closed. And in turn I open them all. And when I go to bed, everything is closed again. Before he goes to bed, I tell him not to close the windows, since it is so hot. Still, he closes everything. 'I won't close them', is what he says. I believe it is one of those habits. [His dementia has worsened fast during winter], he continues to carry out the same procedures. He kept on his winter coat for long, as well as his gloves. I put away the winter coat for a while, in order for him not to see it anymore so that he won't ask for it. There is only one coat on the coat rack, else it is too confusing. I put it away too, but he still asks for it. Then I think: 'Gosh, you're about to die from heat, and he still wants to wear gloves.'...*"

Mrs. B12 (aged 53) cares for her neighbour (female, aged 72), who has probable Alzheimer's disease.

> "*[This morning] it was scorchingly hot inside. She even had a colour on her face. I thought to myself that this was one of those situations. But well, I cannot just turn off the heater, because she will notice. So yes, I [...] went back home. Then the other neighbour stopped by [telling me that she was not well.] I responded by saying: 'Didn't you feel how hot it was inside?' It really was very hot. So, there probably is nothing wrong after all.*"
>
> "*It is rather chilly, to be honest. She says: 'It's cold.' She's cold so early. When it is warm, she says the weather is bad, and when it is cold [...] everything is wrong. It's never okay. So perhaps she is really cold. And then I would turn off the heater just because I am hot. I don't think that is fair, so I leave it on. So if she is really hot, she will turn it lower. Then she will do it herself. I can't go chasing after her all the time.*"

Warner [73] and Petersen [72] describe another consequence of someone with dementia misusing a thermostat, or uncomfortable temperatures. A person with dementia may start to undress as a solution to perceived warm discomfort. Undressing can be embarrassing both the person with dementia as to family carers and visitors. Some may even consider

the 'exhibitionist' behaviour as sexual disinhibition -this is a behavioural problem seen in a small percentage of people with dementia [7,85]- whereas the cause lies in thermal dissatisfaction. In case of cold discomfort, one may put on additional or inappropriate clothing. Warner explicitly states that the carer's views of a comfortable room temperature may not be the same as those of a person with dementia.

Also, there may be other problems concerning how to safely use heating systems and thermostats, illustrated by the following case. Mrs. B8 (aged 56) cares for her 88-year-old mother-in-law with an unmentioned type of dementia. When asked if her mother-in-law can still operate the heating system:

> "*She still knows well. We recently bought her a torch light. […] I think she went to bed at night and then she could not [read the display] well, and then she took matches. At a given moment, [someone] saw that there were matches near the [thermostat], and [that person] was scared by thought of the curtains that were near. [My mother-in-law] had said that when she went to bed at night, she wanted to check whether she had turned the heating system lower. You don't do such a thing with matches, you may get a fire. Despite the warning, she kept doing it, and then we bought her the torch light, which now stands on top of the television set. The matches have been removed. Now she uses the torch light; she only needs to take it and shine. You might say: 'Why don't you do it with the lights turned on, go check if the heating is turned off then….' I think she undresses first and only then she thinks about the heating. And instead of turning the lights on… I don't understand, because the electricity is for free, it is included in the rent. But she just took the matches; I really thought it was scary.*"

7. Conclusions and reflections

Integrated building calls for an integrated approach of the building process by considering the needs of the various stakeholders involved. This is not an easy task, as the needs of others may be overlooked in the complex process of constructing or refurbishing buildings, in particular the needs of stakeholders that do not reverberate strongly. The needs of people with dementia and their family carers are such a group of stakeholders that gets easily overshadowed. Thermal comfort and the relevant sub-systems -as a property or as part of housing- may impact health of people with dementia as an environmental factor, and may contribute to care support. Stakeholders from the domain of technology should shift their focus from installing and designing building systems to the creation of stakeholder-related values by integrating all sub-systems and user needs. Maximisation of the basic value is attainable and tenable as long as the functional and economical values are taken into account too.

In terms of the basic value, older people with dementia may perceive the indoor environment differently due to ageing and atrophy of parts of the brain involved in sensory perception. People with dementia may also respond to deviant or unexpected environmental conditions by expressing certain observable behaviours, as some are not able to complain or to take proper action to improve the environmental conditions. It is important to create increased awareness among family and professional carers about the effects the indoor climate may have on persons with dementia. At the other side of the spectrum, building engineers and installers should be aware that people with dementia are not just seemingly passive receptors of the indoor climate, but may actually respond to it in a very outspoken manner, and that the technology installed may actually pose challenges to the provision of care and well-being.

Fully controlled environments or environments where the subject seemingly is in control of the climatic conditions have been shown to pose limitations to people with dementia, which may stem from a broad range in interindividual thermal preferences and

experiencing difficulties in working with modern technologies such as control systems. These phenomena may cause ethical dilemmas, including matters of protection and being in control of the direct surroundings. The combined use ICF and the MIBD helps to better understand the needs of the most relevant stakeholders, and makes the total set of answers and solutions to the needs of stakeholders more transparent.

Given the results of this study, it is worthwhile to further investigate the impact of the indoor climate on older people with dementia along the lines indicated. Also, the extent to which the perception and sensitivity of people with dementia is different from counterparts without dementia deserves further research efforts. This included the question whether the preference for seemingly uncomfortable conditions stems from physiological changes witnessed in dementia, or stem from the inability to control the environment and the passive acceptance thereof. Until there is more evidence on the needs of people with dementia in relation to the indoor climate and relevant building systems, and as long as no suitable models and standards exist, the design and control of the indoor environment often relies on trial and error. This is captured in a quote by Warner [73, p. 20]:

"Try to discover [the] comfort zone. It's probably not the same as yours. Consider the home's temperature, lighting, and sounds [..]. Be extra-sensitive in doing so – even the motion or [draught] from a ceiling fan can be annoying. Your [partner] may not know what is wrong, only feel uncomfortable. [The] only means of expression may be agitation or desperate efforts to escape the discomfort".

On the other hand, it does not mean that the search for a new comprehensive comfort model that includes persons with cognitive limitations should be ceased. If we all try to understand the implications of dementia on daily functioning in relation to the indoor climate and related building systems, all can try their best to create a comfortable and enabling indoor environment for persons with dementia.

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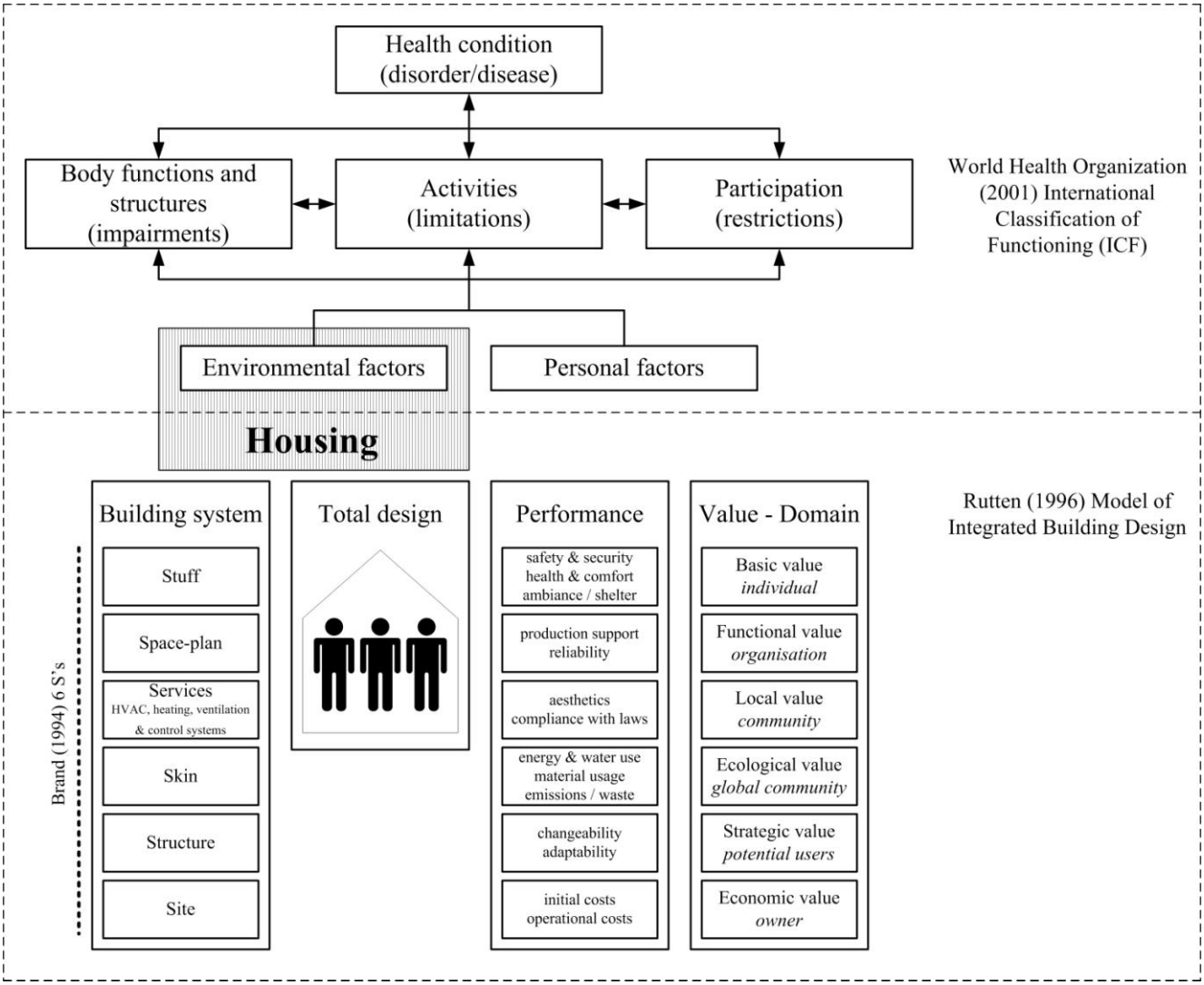
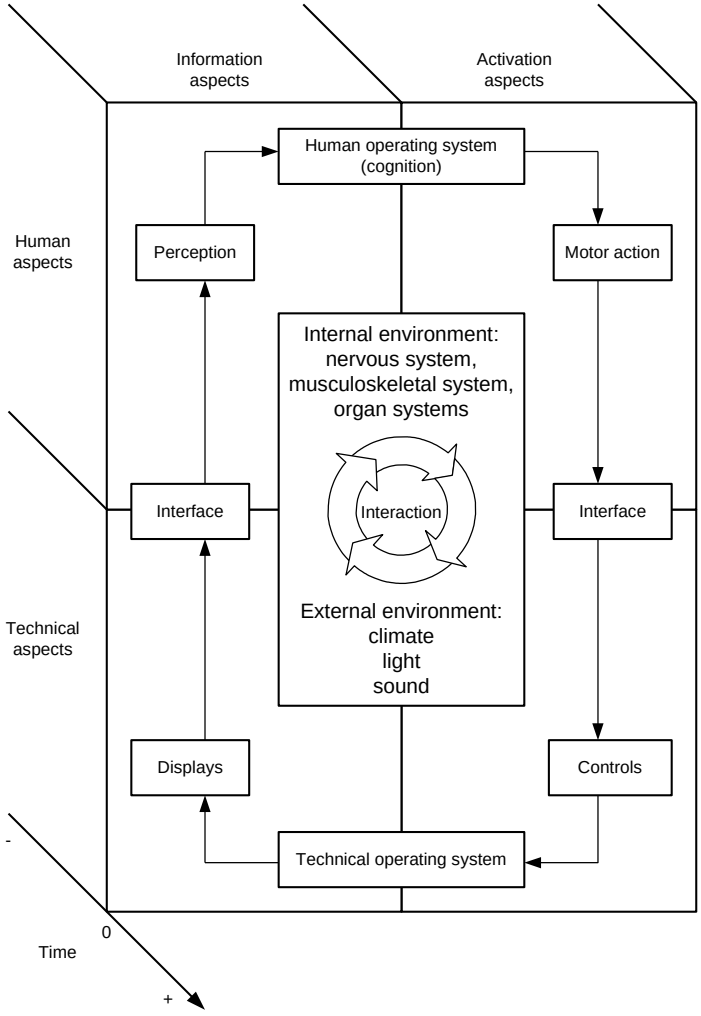
Figures and captions

Figure 1. Interactions between the components of ICF by the World Health Organization [14], and the integration of the Model of Integrated Building Design by Rutten [12].



1165 Figure 2. The developmental view of human factors and ageing [62].



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