Thermal comfort and HVAC design for people with dementia

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SUMMARY
Thermal comfort, described as 'the state of mind, which expresses satisfaction with the thermal environment' is one of the parameters important in building design for which extensive modelling and standardisation exist. People with dementia have an increased sensitivity for indoor environmental conditions, which can induce problematic behaviour that forms a serious burden for professional and informal carers day and night. The creation of supportive and comfortable home environments for both people with dementia and their carers is a non-pharmacological strategy to increase well-being and to combat the negative effects of hot summers. 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 (HVAC) systems for people with dementia.
In principle, older adults do not perceive thermal comfort differently from younger college-age adults. Due to the pathology of people with dementia, as well as their altered thermoregulation, the perception of the thermal environment might be different from that of their counterparts without dementia. Moreover, many people with dementia express their discomfort through certain behaviour that is considered a problem for both the person and people around him/her. Fortunately, a lot can be done to create a comfortable environment. When implementing systems one should however consider aspects like user-technology-interaction, diverging needs and preferences within group settings, safety-issues as electrocution, falls, and wandering, and minimizing negative behavioural reactions as fear 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 costumers with dementia. Moreover, HVAC systems also raise ethical concerns in terms of who is in charge over the thermal conditions, and the protection against temperature extremes in hot summers.

KEYWORDS
Dementia, older adults, senses, indoor environment, care

1. Introduction

Senses are the primary interface with our environment. With biological ageing, a number of sensory changes occur as a result of the intrinsic ageing process in sensory organs and their association with the nervous system (Ebersole et al., 2004). The age-related changes to our senses can be an even greater problem when coping with symptoms of dementia syndrome. Dementia is the loss of cognitive function of 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 three kinds of symptoms in dementia: (i) impairment in activities of daily life, (ii) abnormal behaviour, and (iii) loss of cognitive functions (Ebersole et al., 2004).

People with dementia are known to have an increased sensitivity to environmental conditions, and they may become increasingly reactive to their environment rather than acting upon it (Weaverdyck, 1991). This in turn can result in behavioural problems, which form a serious burden for carers and are often a cause of long-term institutionalisation. The increased sensitivity seems to stems from the reduction of the individual's ability to understand the implications of sensory experiences (Sloane et al., 2002). In practice, about 90% of people with dementia show problem behaviour at some point in their course (Ritchie & Lovestone, 2002), irrespective of the level of cognitive impairments, that may be related to environmental stimuli or sensory input. Apart from the large range of pharmacologic means, nonpharmacologic interventions can play an important role in managing problem behaviour (Ritchie & Lovestone, 2002; Desai & Grossberg, 2001).

Dementia has severe implications on daily life, and sets extra demands to living environments, including the thermal environment or indoor climate. 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 factor in reducing carer burden. Since people with dementia respond on a sensory level, rather than on an intellectual level (Brawley, 1997), and given some of the cognitive and behavioural problems, extra attention should be paid to the indoor environment inside the homes of this group of older adults 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 (MCSS, 1990).

In practice, 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 various indoor environmental parameters 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 environmental conditions. A trend in society that makes the two professional fields come together is 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.

This paper studies the needs regarding thermal comfort and the design and implementation of heating, ventilation and air-conditioning (HVAC) systems for people with dementia.

2. Methodology

This study was based on three pillars (i) general knowledge of indoor environmental sciences and dementia among the authors, (ii) literature research, and (iii) 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.

2.1. Literature study

The literature study included both books and peer-reviewed articles 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 June 2008). All volumes of the journals 'Dementia', 'The American Journal of Alzheimer's Care and Related Disorders'and its preceding volumes, and 'Alzheimer's Care Quarterly / Alzheimer's Care Today', known for publishing on housing in relation to dementia, were searched manually for relevant papers. 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 search covered 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. This means that the modifications are to the benefit of people with early and moderate stages of dementia. The literature search was complicated by the large differences in writing style 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 physical 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; the first data set is by van Berlo (1997a;1997b), and the second is by van Hoof & Kort (2008). These datasets cover community-dwelling older people only, and deal with problems concerning

technology. A phenomenological approach was used for analyses.
The van Berlo data set includes in-depth interviews (n=10) with primary carers (2 males, 8 females) of community-dwelling people with dementia (4 males, 6 females), of which results were published by Sweep (1998) and Sweep et al. (1998). A large amount of questions in the interviews was derived from an interview scheme for measuring the burden of care of primary carers developed by Duijnstee and Blom (1995). The field study was conducted to yield more insight into the potentials of technology to diminish the burden on the primary carer of a person with dementia by limiting or partly taking over the various tasks of supervision. The interviews occasionally deal with thermostats and lighting equipment.
The van Hoof & Kort dataset includes data from an investigation of the expectations regarding technology and needs of a group of 18 older adults living in their own home with support of home care services, who were receiving a home automation system to support ageing-in-place. 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 (in)formal carers during the interviews, using semi-structured questionnaires. 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 heating systems, including ventilation, and (ii) lighting. Third, quotes that summarised the essence of each person's subjective experience were recorded, and translated from Dutch to English as closely as possible. In the text, the van Hoof & Kort subjects are shown as letters, for instance, Mrs. A, whereas the van Berlo subjects are shown as Mrs. B plus a given number.

3. Indoor climate and thermal comfort

Thermal comfort is described as 'the state of mind, which expresses satisfaction with the thermal environment' (ASHRAE, 2004). The thermal environment can be described as the characteristics of the environment that affect the heat exchange between the human body and the environment. There exist extensive modelling and standardisation for thermal comfort, which depend both on physical and physiological parameters, as well as on psychology.
General or whole-body thermal comfort is evaluated using the PMV-model by Fanger (1970), which is adopted by the (inter)national standards ISO 7730 (ISO, 2005a) and ANSI/ASHRAE Standard 55 (ASHRAE, 2004). These standards aim to specify conditions that provide comfort to all healthy adults, including older adults, while in practice, a selection of an acceptable percentage of dissatisfied is often made depending on economy and technical feasibility (van Hoof & Hensen, 2006). The model is found to be valid for use in air-conditioned buildings (van Hoof, 2008). 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 (PMV), 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 (2004) defines thermal sensation as a conscious feeling, which requires subjective evaluation (ASHRAE, 2004). The following six parameters are involved in calculating PMV, of which the first two are estimated and the last four are measured: clothing insulation; activity level (metabolism); air temperature; mean radiant temperature; relative humidity; and air velocity.

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.

4. Ageing and thermal comfort

In principle, older adults do not perceive thermal comfort differently from younger college-age adults (Havenith, 2001; van Hoof & Hensen, 2006). The effects of gender and age can be accounted for by model parameters, such as activity and clothing level (Havenith, 2001). On average, older adults have a lower activity level, and thus metabolic rate, than younger persons which is the main reason that they require higher ambient temperatures (Havenith, 2001; Tsuzuki & Iwata, 2002). The ability to regulate body temperature tends to decrease with age (Havenith, 2001). Although 20% of older adults show no vasoconstriction of cutaneous blood vessels, not all of the remaining 80% have diminished control of body temperature (Collins & Exton-Smith, 1983). Foster et al. (1976) 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. In general, older adults have 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 (Havenith, 2001). 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 (van Hoof & Hensen, 2006).

5. 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 (Mayer, 1993). Due to the pathology of many dementia patients, involving atrophy 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 (2008) 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 (2002) 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 (2002, pp 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 90 degrees* [32 °C] *or more. And, in the summer, the opposite occurred with the air-conditioning."*

The design process of HVAC systems 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 without an unknown 'state of mind' and without the ability to express themselves reliably. Expressing satisfaction with the thermal environment, or dissatisfaction in particular, could be expressing certain observable behaviour.

The desired quality of HVAC systems 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 (ISO, 2005b), does not provide any data on this matter.

Another problem, illustrated by Steinfeld (2002), is that individual thermal preferences may differ greatly within the population of older adults with dementia. According to Fountain et al. (1996), 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 approximately 3 K; the full width of the comfort zone in either summer or winter (Fountain et al., 1996). It is therefore not possible to exactly predict thermal comfort for individuals, and that is the reason the comfort zone 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 larger inter-individual variances.

6. Thermal comfort and domestic heating systems in practice

The positive aspects of good thermal comfort are often mentioned, particularly in bathrooms and bedrooms. Bathrooms should be comfortably warm, since people undress in these rooms (Ponzetto et al., 1998; Brawley, 2002; Petersen, 2002). For institutional settings, Aminoff (2007) even states that in winter, when patients 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 (2000), 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 to the carer. This often results in frustration, anger or attempting to get away from the discomfort. Aminoff (2007) 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. Cluff (1990) stresses the importance of appropriate environmental quality including heating to benefit well-being, health and competence. Providing thermal comfort is important since a person with dementia may not be able to get or shed a sweater, or to ask for help or to complain (Hyde, 1989).

6.1. Bathrooms and radiators

The diminished understanding of the surroundings also puts demands on the way HVAC systems are installed and safety requirements of separate, auxiliary electronic heating systems. These should be kept out of the bathroom as much as possible (Petersen, 2002). An alternative solution to increasing comfort and providing heat is to install heat lamps in the ceiling (Brawley, 1997; Warner, 2000; Bakker, 2003). Heat lamps cannot be knocked over, for instance, into water, or touched by wet hands since they are out of reach (Warner, 2000). A timer should be used to switch the heat lamps off, in case one forgets about the equipment (Warner, 2000). In a study by Sloane et al. (1995) 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%). One could consider installing an independent temperature control for the bathroom (Brawley, 1997). Hot radiators should be blocked or covered, since people may have difficulty judging the temperature of the device (Silverstein et al., 1993; Mace & Rabins, 2006, Lach et al., 1995). Not only radiators, but also water pipes can cause burns (Warner, 2000). Radiators in general pose hazards in case of fall incidents (Mace & Rabins 2006). A solution is to install radiant floor heating instead (Brawley, 1997), which also help occupants to keep ‘cold feet’ warm. Non-slip sheet rubber or a cushioned low glare vinyl on a bathroom floor can also replace tiles to keep feet warm (Brawley, 1992). 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 (Brawley, 1997; Petersen, 2002).

6.2. Bedrooms and the need for ventilation

As with bathrooms, bedrooms should be thermally comfortable too (Petersen, 2002). 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 (Blom et al., 2000). When (un)dressing, bedrooms should not be too cold (Ponzetto et al., 1998). In hot summers, silent air-conditioning systems can help people fall asleep, which is both important to people with dementia, and their caregiving partners.

In order to maintain thermal comfort at home, and to avoid large temperature rises in summer, one can choose from both active and passive systems. In the home as a whole, solar blinds can help limit the heating of the dwelling in summer (Nouws 2001; van Hoof & Hensen, 2006). Windows should be easily operable to allow for fresh air to enter, and many people in Western Europe prefer to sleep with bedroom windows opened. Especially in high-rise building, where one can open windows and balcony doors, one should install security locks to prevent people from climbing out (Mace & Rabins, 2006), or home security systems to alert carers when doors or windows are opened.

6.3. Thermostats

If cognition allows, thermostats give people the opportunity to control their environment to a certain extent. Marshall (1995) 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 (2007). If thermostats cause difficulty operating, covers can be placed over the controls (Zgola, 1990; Brawley, 1997), or thermostats can be pre-set and be disguised (Lach et al., 1995), or simply placed out of sight. Thermostats are known to be troublesome for people with dementia. Steinfeld (2002) 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 (2002) 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.

Fernie & Femnie (1990) 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.*"

Warner (2000) and Petersen (2002) 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 partners and visitors. Some may even consider the 'exhibitionist' behaviour as sexual disinhibition, a behavioural problem seen in people with dementia (Desai & Grossberg, 2001), 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.

6.4. Positioning of outlets and draughts

If homes are equipped with air-conditioning systems or mechanical ventilation, one should pay extra attention to the position of the outlets, as well as ceiling fans. Systems that are installed to increase comfort, may, if not adjusted correctly, be a source of discomfort when people are unable to move or complain (Aminoff, 2007). Naked patients or a patient who had just been bathed should not be in a draught, as they are unable to complain of cold, or that they want to be moved, or covered. Outlets directing air on curtains or papers on tables can cause them to move. Warner (2000) states that such movement might give the impression that someone else, even ghosts and thieves, is in the room. The same could happen with operable windows that cause draughts, or automated

curtains, used to keep the sunshine out, as seen in smart homes. Sweep (1998) mentions that this latter type of technology can be perceived as threatening.

7. Findings from qualitative research

Many of the results from the literature search are further supported by data from the two qualitative data sets.

Mrs. N, aged 81, divorced, has a severely damaged short-term memory due to multiple strokes. She lives in a semidetached home, and assisted by her daughter during the interview. Mrs. N had had a new thermostat. 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 explains:

> "*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 continues:

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

Later, the daughter mentions that the knobs of the radiator panels had been removed.

> "*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. S, aged 83, widowed, has equilibrium disturbances due to Parkinson's disease. She has a flat in assisted-living. Mrs. S shows that for people with equilibrium problems, radiator panels can be a cause of serious injury when falling. She has several stitches in her forehead at the time of the interview, after she had fallen against the radiator panel.

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.

> "*One moment, he believes that he needs to inspect all [things in the house]. The stairs are open and [located] in the hallway. The central heating boiler is upstairs, and it breaks down once in a while. And so he strolls upstairs occasionally and back downstairs again. I say to myself that he can still manage, but you never know with his dizziness…*"
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> "*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.*"

When asked if the heating is always set on 20°C:

> "*Then you would get a sort of block heating, like in flats, where you have no control [over the thermal environment and] to say it want it to be 24°C; just like in care homes. There, temperature is centrally controlled too.*"

Mrs. B5, aged 50, cares for her dementing (cause not mentioned) mother-in-law, 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.*"

Mrs. B8, aged 56, cares for her dementing (cause not mentioned) 88-year-old mother-in-law. 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.*"

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.

"*He is not warm either, because I may not open the door. Then I do open the door. He does not feel it, because there is no cold air coming in; it was very hot last week. Then he enters the kitchen and closes the door again, and I tell him to leave the door open. [He says:] 'No, it is costly!'…*"

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 I in turn 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] the gas heater was completely turned up. 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 still notice that. So yes, I turned on the washing machine and 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.*"

When asked if she turns of the gas heater, like she did this morning:

"*No, I don't turn of the gas heater. I mean, she just came to my place. 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 she will turn it lower. Then she will do it herself. I can't go chasing after her all the time. […] She can only*

turn the gas heater in the kitchen up or down, or turn it off completely. The other day she stopped by, when the gas heater is turned off completely, she cannot light it again. Then she stops by for help."

8. Discussion

8.1. Sensitivity and group differences

People with dementia may react and respond different to the indoor environment in comparison with counterparts without dementia. Current standards and guidelines do not provide sufficient data on this group of people, and it seems that the demands set to the indoor environment should be a lot stricter. In general, the quality of the indoor environment may be expressed as the extent to which human requirements that have great interindividual variety are met. Some people are known to be rather sensitive to an environmental parameter and are difficult to satisfy (CEN, 1998), and this seems to be particularly true for people with dementia.

Building regulations tend to be primarily written for the needs older people with a physical impairment, rather than for people with mental of cognitive impairments. A similar conclusion was already drawn by Maslow & Mace (1991) for the many building regulations affecting nursing homes, as well as for homes that are claimed to facilitate the needs of impaired older adults, in the United States of America. Another question that arises is if design guidelines for older people with dementia are suitable for younger adults with dementia, who form a group of considerable size that does not yet experience the effects of age.

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 (Bakker, 2003).

8.2. Improper or poor design

Bakker (2003) states that at times, the loss of function of residents with dementia is incorrectly blamed on dementia, when inappropriate design is at the basis. Bakker 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.

The installation and operation of technological systems that control the indoor environment require special attention when dealing with older adults with dementia due to physical and cognitive impairments. The complexity of technology can have a disabling effect on the person with dementia (Hagen et al., 2004). In case of users with dementia, 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 (Orpwood et al., 2004; Orpwood et al., 2005). Moreover, interfaces should be large in order for people with rheumatoid arthritis, Parkinsonism, and various age-related limitations to motor skills, to be able to operate them.

Installing technology puts demands on installers. A person with dementia may not remember why an installer is working in at home, or who this installer is, which can cause distress. Installers should preferable work in couples, which allows one of the two

to leave the site, without loss of access upon return, or make a phone call while the other talks (Adlam et al., 2004). When equipment is installed, installers should answer user questions repeatedly, listen, and be sensitive to the state of mind of the client (Adlam et al., 2004). Some people with dementia are curious about new equipment and are often uninhibited about dismantling it to "find out how it works" (Adlam et al., 2004). Moreover, this group of older adults needs rapid responses to perceived difficulties, as they are often unable to understand the reason for a fault occurring, or work around it (Adlam et al., 2004).
In order to successfully implement technology, carers should be made familiar through training on how technology works and how to deal in case of malfunctioning. Training, however, is costly and poses financial restrictions in the start-up phase, particularly when multiple systems are used simultaneously. Maintenance is 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 (MCSS, 1990).

8.3. Ethics in designing the indoor environment

Ethics in dementia care is an important field of discussion and study. The scope of this discussion seems to be increasingly moving towards the field of architecture and design of technology and home automation for people with dementia (van Hoof et al., 2007). Van Berlo (1997a, p. 69) describes an ethical dilemma about a 72-year-old woman with probable Alzheimer's disease. She lived alone in a detached home, and had been on a waiting list for nursing home placement. In her current home, room temperature was controlled from a distance or was programmed, without letting the woman interfere by herself. Van Berlo (1997a, p. 70) states that the high temperature may be seen as a problem, but maybe the resident really likes a hot 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.
Fernie and Femnie (1990) 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 (1995) 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 carers have equal access to technology. A third question that needs to be answered is which person benefits from the technology? According to Marshall (1995), '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. (1999) and van Berlo (2005), 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 (1995) 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 HVAC-technologies and other building services.

From an ethical point of view, people should have opportunities for control over the indoor climate and HVAC systems. 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 caring partner.
Ambient intelligence may meet all criteria mentioned, in particular because the support devices are invisible to the user, and since ambient intelligence forms a self-learning part of the environment where one lives itself (van Hoof et al., 2007). Ambient intelligence is very suitable for creating conditions for thermal comfort and control of ventilation systems, which are minimally invasive. One of the benefits of ambient intelligence 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 may be unable to put off or add clothes and escape draughts created by forced air systems Calkins (2005), and the ambient intelligence resident profile may then adjust the heating and the method it is delivered.

8.5. Good thermal comfort as a first step towards excellence

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. 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.
Given the uncertainties in comfort needs and possibly large inter-individual spread in preferences, special attention should be given to massive installation of HVAC systems in living environments for people dementia in light of recent hot summers in relation to the ongoing discussions on climate change and global warming. Although environmental engineers start to understand the mechanism of ambient temperature and mortality, there is no golden standard for guaranteeing thermal comfort for the older population. 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, as set-point temperatures are chosen to comply with whose needs? It is a good example that there is a need for more indoor environmental research in relation to older adults and people with dementia for both home and institutional settings. Until there is more evidence on the needs of people with dementia in relation to the indoor environment, the process of modifying the indoor

environment often relies on trial and error. This is captured in a quote by Warner (2000, 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".*

If we all try to understand the implications of dementia on daily functioning in relation to the indoor climate, we can do our best to create a comfortable and enabling indoor environment for this group of people.

9. Conclusions

Older people with dementia may perceive the indoor environment differently due to ageing and atrophy of parts of the brain involved in sensory perception. There seems to be a larger interindividual range of comfort and tolerance, compared to older adults without dementia. People with dementia may also respond to 'extreme' or unexpected environmental conditions by expressing certain behaviours, as some are not able to work around it or make complaints. Difficulties in working with modern technologies, for instance, controls of HVAC-systems and lighting may cause people with dementia to be unable to influence their direct surroundings. These phenomena may pose ethical dilemmas in practice, including matters of protection and being in control of the surroundings.

It is important to create increased awareness among professional and informal carers about the effects of the indoor climate on their clients/loved-ones. 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 to provide comfort and ease may actually pose challenges to the provision of care and well-being.

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, we should try to find out to what extent the perception and sensitivity of people with dementia is different, and if the liking of seemingly uncomfortableconditions stems from different preferences and not from the inability to control the environment and the passive acceptance thereof.

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