

The indoor environment and the integrated building design of homes for older people with dementia

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1 **The indoor environment and the integrated design of homes for older people**
2 **with dementia**

3
4 Authors: J. van Hoof^{1,2*}, H.S.M. Kort^{1,3}, M.S.H. Duijnste^{1,4}, P.G.S. Rutten², J.L.M.
5 Hensen²

6
7 ¹ Hogeschool Utrecht University of Applied Sciences, Faculty of Health Care,
8 Research Centre for Innovation in Health Care, Bolognalaan 101, 3584 CJ Utrecht,
9 the Netherlands

10 ² Eindhoven University of Technology, Department of Architecture, Building and
11 Planning, Den Dolech 2, 5612 AZ Eindhoven, the Netherlands

12 ³ Vilans, Catharijnesingel 47, 3511 GC Utrecht, the Netherlands

13 ⁴ Academy of Health Sciences Utrecht, Bolognalaan 101, 3584 CJ Utrecht, the
14 Netherlands

15

16 Corresponding author:

17 J. van Hoof

18 Hogeschool Utrecht University of Applied Sciences, Faculty of Health Care

19 Bolognalaan 101

20 3584 CJ Utrecht, the Netherlands

21 Tel. +31 30 2585268

22 Fax. +31 30 2540608

23 e-mail: joost.vanhoof@hu.nl

24

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27

28 **Abstract** There are currently about 6 million -mainly older- people with dementia in
29 the European Union. With ageing, a number of sensory changes occur. Dementia
30 syndrome exacerbates the effects of these sensory changes and alters perception of
31 stimuli. People with dementia have an altered sensitivity for indoor environmental
32 conditions, which can induce problematic behaviour with burdensome symptoms to
33 both the person with dementia and the family carer. This paper, based on literature
34 review, provides an overview of the indoor environmental parameters, as well as the
35 integrated design and implementation of relevant building systems. The overview is
36 presented in relation to the intrinsic ageing of senses, the responses of older people
37 with dementia and the impact on other relevant stakeholders through the combined
38 use of the International Classification of Functioning, Disability and Health, and the
39 Model of Integrated Building Design. Results are presented as indicators of the basic
40 value, functional value and economic value, as well as a synthesis of building-related
41 solutions. Results can help designers and building services engineers to create optimal
42 environmental conditions inside the living environments for people with dementia,
43 and can be used to raise awareness among health care professionals about of the
44 influence of the indoor environment on behaviour of the person with dementia.

45

46 **Keywords** Indoor environment, dementia, behaviour, older adults, senses, light,
47 noise, sound, indoor air quality, family care, integrated building, technology

48

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99 **1. Introduction**

100 Senses are the primary interface with our environment. With biological ageing, a
101 number of sensory changes occur as a result of the intrinsic ageing process in sensory
102 organs and their association with the nervous system [1]. Over time, the accumulated
103 atrophy of sensory receptors substantially reduces the quality of environmental
104 impressions [1]. The age-related changes to our senses can be an even greater problem
105 when coping with symptoms of dementia syndrome. Dementia is the loss of cognitive
106 function of sufficient severity to interfere with social or occupational functioning.
107 There are about 100 known causes of dementia syndrome, of which Alzheimer’s
108 disease (AD) has the highest incidence. Contrary to popular belief, loss of memory is
109 not the only deficit in dementia. Impairment in activities of daily life and abnormal
110 behaviour are common symptoms [1]. The intensity of symptoms may differ over
111 time [2]. Many people with dementia have an altered sensitivity to environmental
112 conditions, which can result in behavioural problems [3]. These form a serious burden
113 for family carers and are one of the reasons for long-term institutionalisation. The
114 altered sensitivity seems to stem from the reduction of the individual’s ability to
115 understand the implications of sensory experiences [3]. This is aggravated by the age-
116 related deterioration in sensory acuity that affects vision and hearing steadily over the
117 years [4].

118 Dementia sets special demands to the design of housing facilities and the home’s
119 physical indoor environment and technology [5-8]. The physical indoor environment
120 comprises the thermal environment, the indoor air quality (IAQ), lighting, and the
121 acoustic environment. In a broader sense, it constitutes all that the individual hears,
122 sees, feels, tastes, and smells [9], and all together, these parameters have an impact on
123 whether someone feels comfortable. Comfort is a state of mind, which expresses
124 satisfaction with the total indoor environment or one of its parameters. In case of
125 persons with dementia, this definition is difficult to apply as these persons have an
126 unknown ‘state of mind’, and as these persons might lack the ability to express
127 themselves reliably other than by expressing (dis)satisfaction via certain behaviours
128 [7]. Tilly and Reed [10] state that in case of behavioural problems, environmental
129 techniques should be among the first strategies used as a treatment, rather than
130 beginning with pharmacologic interventions. The home’s physical indoor
131 environment is thus not only the key factor in providing comfort, but might even be a
132 nonpharmacologic factor in managing problem behaviour in dementia. It may thus be
133 a yet largely unexplored factor in reducing carer burden. According to Aminoff [11],
134 poor indoor environmental quality may have a role in the suffering of people with
135 dementia. Also, Florence Nightingale [12, p. 5] was well aware of the influence of the
136 indoor environment on the progress of disease and recovery, and her messages do not
137 go unnoticed [13].

138 *“In watching diseases [...] in private houses [...], the [...] symptoms or the*
139 *sufferings generally considered to be inevitable and incident to the disease are*
140 *very often not symptoms of the disease at all, but of something quite different – of*
141 *the want of fresh air, or of light, or of warmth, or of quiet, or of cleanliness, of*
142 *each or of all of there.”*

143 Van Hoof et al. [7] already concluded that nursing literature in general provides clear
144 indications in the form of anecdotal evidence that people with dementia are generally
145 very sensitive to (changes in) indoor environmental conditions and that their
146 perception differs from healthy subjects. Unfortunately, such studies have not yet
147 resulted in the development of practical guidelines for the building sector how to
148 create optimal indoor environments for people with dementia, and protocols for care

149 professionals for signalling building-related behavioural and other health problems.
150 The design and maintenance of the indoor climate is the domain of various
151 professions in the field of construction and technology, not nursing in particular.
152 Good design calls for an integrated approach. The integrated design of buildings in
153 itself is a complex process; involving numerous stakeholders, disciplines and building
154 systems, which aims at creating a range of stakeholder-related values or benefits [14].
155 When considering housing for older adults with dementia, it is this specific group of
156 people that is most affected when the actual needs are not considered in the design
157 process and if a building cannot deliver its full potential of values to all users.
158 Therefore, the goal of this paper is to present a literature review of the indoor
159 environment, in particular (i) air and odours, (ii) light and lighting, and (iii) the
160 acoustical environment for older people with dementia in relation to the ageing of
161 senses and dementia. The review focuses on the building-related basic, functional and
162 economic values for the relevant stakeholders and provides a synthesis of building-
163 related solutions. Although the perception of the thermal environment is affected by
164 biological ageing and dementia syndrome [7,15-18], the thermal environment is not
165 within the scope of this paper, as van Hoof et al. [7] presented a complementary paper
166 on thermal comfort and dementia.

167

168 **2. Methodology**

169

170 **2.1. Literature study**

171 The literature study included both peer-reviewed articles and books on (i) ageing
172 senses and perception of indoor environmental parameters by older adults, and (ii)
173 housing for older people with dementia, (iii) behavioural problems among people with
174 dementia in relation to indoor environmental parameters, and (iv) design guidelines
175 for technology for people with dementia and the installers of such technology.

176 The search included all relevant sources without a limitation to the age (up to October
177 2009). As persons with dementia are living in a continuum of housing [6], including
178 institutional types of housing, such as nursing homes, small-scale group settings, and
179 special care units (SCUs), the literature covers the whole range of living
180 environments. Although the main focus of this paper is on the home environment,
181 literature concerning institutional settings provide important information that are
182 relevant to the own home, and are therefore included in this study. Quotes appearing
183 in qualitative studies, which summarise the essence of a person's subjective
184 experience, are included in the literature review only for further illustration of certain
185 topics.

186 The literature search was complicated by the large differences in the way problems
187 are conceptualised between nursing/occupational therapy, and the technological
188 sciences. For instance, a different meaning is given to the term physical environment:
189 (i) the indoor environment as a whole, or (ii) the whole of the thermal, visual, and
190 acoustical environment and IAQ. There are also significant differences in the way
191 professionals from both fields approach and perceive dementia syndrome and related
192 health problems and challenges, as well as in the level of conceptual thinking when
193 dealing with these challenges.

194

195 **2.2. Framework for the analysis**

196 The data of the abovementioned literature study are structured and presented using a
197 novel combination of two existing frameworks: (i) the International Classification of
198 Functioning, Disability and Health (ICF) [19] with its basis in health sciences, and (ii)

199 the Model of Integrated Building Design (MIBD) by Rutten [14] that has its origins in
200 building sciences. This combined model was first presented in van Hoof et al. [7].
201 Such a combined framework is needed as this study tries to bring together demand
202 and supply, namely the needs of the stakeholders and the solutions offered in the field
203 of construction and technology.

204

205 **2.2.1. International Classification of Functioning, Disability and Health**

206 Within the World Health Organization's ICF [19], health problems are described as
207 well as limitations and/or restrictions that result from diseases and disorders (Figure
208 1). The overall aim of this classification is to provide a unified and standard language
209 and framework for the description of health and health-related states. ICF has two
210 parts, each with two components: Part 1: Functioning and Disability: a.) body
211 functions and structures, b.) activities and participation, and Part 2: Contextual
212 Factors: c.) environmental factors and d.) personal factors. Each component can be
213 expressed in both positive and negative terms.

214 Impairments are problems in body function (physiological functions of body systems)
215 or structure (anatomical parts of the body) such as a significant deviation or loss.

216 Within ICF, the severity of a disorder is described, which provides insight into
217 treatments, medication or adjustments of activities, as well as participation or
218 environmental factors. Activity is the execution of a task or action by an individual.
219 Activity limitations are difficulties an individual may have in executing activities,
220 such as domestic work and personal care. Participation is involvement in a life
221 situation. Participation restrictions are problems an individual may experience in
222 involvement in life situations. Within the ICF, the built or living environment can be
223 seen as an environmental or contextual factor that influences people at the impairment
224 level, and helps people to overcome limitations and restrictions posed by declining
225 physical fitness and cognition. The indoor environment as treated in this paper is
226 characterised by the ICF factors e155 (technical aspects of a private building), e240
227 (light), e250 (sound), e260 (air quality). These factors may hinder or support the
228 activities or participation of a person with dementia. To analyse the hindrance or
229 support posed by any of these factors, the MIBD is used.

230

231 *INSERT Figure 1 HERE*

232

233 **2.2.2. Model of Integrated Building Design**

234 Rutten [14] presented the MIBD (Figure 1), which provides an overview of sub-
235 aspects of the design process of a building and the desired building performance
236 levels. In this model, a building derives its total value based on the quality of its
237 relationship with the human environment or how well it performs at all of the various
238 human perspectives from which it is viewed, i.e., it fulfils needs. A performance
239 specification describes performance goals for each human-building relationship.
240 Rutten [14] suggests that by considering the combined performance of top-level
241 requirements (the six so-called value-drivers that represent various stakeholders), one
242 can determine a building's total value. This total value is realised through the
243 integrated functioning of a number of building systems on the demand side via a
244 system engineering approach. Such an approach implies that an overview of dominant
245 building systems is made, which in turn are distinguished in several levels in such a
246 way that functional integration is achieved with consideration of the various
247 disciplines involved in the building process. The MIBD tries to achieve value

248 integration, in which all values and stakeholders are integrated in order to achieve
249 functional integration.

250 Within the MIBD, six values and domains are distinguished, namely the basic,
251 functional, local, ecological, strategic, and economical values. In this study, the scope
252 of MIBD is extended to the analysis of living environments. The ICF has a specific
253 connection to three of the values of the MIBD when looking at housing facilities for
254 older adults (which is explained in the following section), and therefore, emphasis
255 will be on the basic value, functional value and economic value.

- 256 • The basic value is determined from a building's relationship with individual
257 occupants and their sense of psychological and physical well-being. The
258 person with dementia is the most important stakeholder in this section. The
259 family carer is the one who takes care of the person with dementia, and
260 therefore their needs are incorporated as well.
- 261 • The functional value is concerned with how activities and processes (including
262 facilitating care) taking place inside the building are supported. In short, how
263 facilitatory and supportive is a living environment to the activities that take
264 place inside, and the person with dementia and the family carer? The person
265 with dementia should be able to lead the life he/she wants to lead -within the
266 constraints posed by dementia- with the help of a living environment that
267 facilitates for the deficits seen in dementia.
- 268 • The economic value is based on the relationship with people concerned with
269 the ownership and marketing of the building. When the economic value is
270 maximised in relation to the needs of people with dementia and their partners,
271 a home should facilitate ageing-in-place and the provision of care, and should
272 minimise the burden of family and professional care. At the same time, a well-
273 tailored home increases in value on the real estate market.

274 As many aspects of the functional value and economic value are described by van
275 Hoof et al. [7], the main focus in this paper is on the basic value.

276 The building itself is made up of several systems or components, the six S's: stuff,
277 space-plan, services, skin, structure, and site [20]. These components can be further
278 divided into sub-system components. Each system has a specific set of functions
279 (which can be seen as solutions) that contribute to the optimisation of a certain value.
280 In this paper, various sub-systems such as the floor (structure), façade system and
281 curtains (skin), interior design, floor covering and finishings (stuff), and technological
282 systems and controls (services) are discussed in relation to the needs of relevant
283 stakeholders.

284

285 **2.2.3. Combined model**

286 The ultimate goal of this study is the creation of living environments which optimally
287 account for the actual situation of a person with dementia and his/her family carer. In
288 order to retrieve how and to what extent integrated building design can contribute to
289 improving living conditions of people with dementia, a framework for further analysis
290 is necessary. Such a framework should allow for the identification of needs of persons
291 with dementia and other relevant stakeholders, and subsequently should help to
292 identify which types of design solution are present in relation to a specific need. This
293 should then be followed by looking at the fit or gap between the demand and supply
294 (need and solution). Within the scientific domains of construction and health care,
295 such a framework for analysis that matches the mindsets of both scientific domains
296 did not exist. This led to the combined use of ICF and MIBD [7]. Following from the
297 purpose of this study, the connection between ICF and MIBD is as follows. ICF

298 characterises external factors, which may hinder or support activities or participation
299 of a person with a (chronic) disease or impairment. The MIBD has the tools to analyse
300 which external (environmental) factor causes hinder or support for a person with a
301 chronic disease/impairment.

302 With the basic value of the MIBD the individual needs of the stakeholders as
303 classified in ICF terms can be described. Also, hinder or support from external factors
304 on the level of the individual can be identified. The functional value of the MIBD
305 deals with answers and solutions to the needs of the organisation (in order to support
306 individuals). This value allows for the identification of hinder or support on the level
307 of an organisation. The economic value of the MIBD deals with the fit between
308 demand and supply (cost-benefit analysis), and in this way hinder or support for
309 individuals on a macroeconomic level is described. From a practical point of view, the
310 novel approach allows for a problem analysis from the viewpoint of the care recipient
311 (i.e., person with dementia), which forms the basis of ICF, and to integrate the
312 building process in such a way that it leads to more fitting and appropriate outcomes
313 for persons with dementia and other stakeholders. The combined model puts the
314 human being (occupant or stakeholder) and his/her needs in the centre, not the
315 building itself.

316

317 **3. Basic value**

318 This section deals with the domain of the basic value, which concerns the needs of the
319 main stakeholder; the individual person with dementia, and in line with this
320 stakeholder, the family carer, in relation to the indoor environment. In this paper,
321 focus is on those body functions that diminish due to biological ageing or dementia
322 syndrome, namely a person's sensory organs and their association with the human
323 brain, and perception. This analysis is followed by three more in-depth overviews of
324 (i) changes to the olfactory sense in relation to indoor air, (ii) changes to vision and
325 the eye in relation to the visual environment, and (iii) changes to hearing in relation to
326 sounds and the acoustical environment. These changes are related to ageing and to the
327 incidence of dementia.

328

329 **3.1. Health condition and body functions: ageing, dementia, senses and** 330 **perception**

331 A person's cognitive functioning can be seen as a path along which information is
332 processed through five types of functioning or phases: sensory phase, perception and
333 comprehension phase, executive phase, expressive phase, and motoric phase [9]. The
334 age-related sensory changes, involving sensory receptors in the eyes, ears, nose,
335 buccal cavity, and peripheral afferent nerves [1], frequently affect the sensory phase
336 [9]. Apart from the sensory changes, incorrect or malfunctioning visual aids and
337 hearing aids may have a negative effect too [9]. Sensory losses or impairments,
338 together with cognitive deficits, make it difficult for the individual to interpret and
339 understand the environment (perception and comprehension phase) [1,9,21,22].
340 Perception arises from the integration of sensory signals into percepts that give
341 meaning to raw data, which depends both on sensations and on experience [1].
342 Dementia is characterised by an impaired identification of incoming stimuli
343 (perceptual deficits), resulting in distorted perceptions [23]. These can lead to
344 illusions or delusions, which in turn elicit paranoid or aggressive response. Perceptual
345 deficits are present even at early stages of dementia and progressively worsen [23].
346 Some people with dementia have hallucinations, which seem real to the person
347 experiencing them and can be frightening to relatives [2]. According to Turner [24], a

348 person with dementia may spend hours fussing at a shadow ‘that has come to life’.
349 Misinterpretations of inappropriate lighting, shadows, and even distorting of floors,
350 walls and furniture are reported [25], which can cause people with dementia to fall.
351 Moreover, many people with dementia have short attention spans and are easily
352 distracted [23]. People with dementia may become increasingly reactive to their
353 environment rather than acting upon it [9]. Pynoos et al. [26] state that persons with
354 AD can be affected by their environment, particularly in the early and middle stages
355 of the disease. These people may be more sensitive to environmental frustrations,
356 including glare and noise, which negatively affect behaviour. Senses can be both
357 overloaded and understimulated leading to a number of problem behaviours or to
358 sensory deprivation [2,27]. Sensory overload is most often caused by abrupt,
359 unexpected environmental changes. For instance, an abundance of stimuli can cause
360 agitation and anxiety for people with dementia, which further heightens disorientation
361 and confusion [28].

362
363 The abovementioned findings can be illustrated by a number of practice-based
364 studies. Cohen-Mansfield and Werner [29] studied associations between behaviours
365 and environmental characteristics in nursing home facilities by observing 24 residents
366 for a period of 9.5 months. They found that (i) pacing increased under normal light
367 conditions and normal temperature during daytime, that (ii) noise levels were
368 associated with a decrease in picking at things and strange movements, and that (iii)
369 requesting for attention was associated with hot temperatures during daytime. Cohen-
370 Mansfield and Werner [29] conclude that even though there have been suggestions
371 that persons with dementia manifest agitation as a result of overstimulation in the
372 nursing home, and need a low stimulation and a quiet environment to reduce their
373 agitation, their own results do not support that hypothesis. They state that boredom
374 and lack of activity seemed the true source of agitation. Zeisel et al. [30] measured
375 associations between environmental design features of special care units and the
376 incidence of problem behaviours. In facilities where sensory input was more
377 understandable and input was more controlled, residents tended to be less verbally
378 aggressive. According to Lucero [31], exit-seeking wandering behaviour in middle-
379 stage dementia residents may be a reaction to discomfort or overstimulation. Price et
380 al. [32] also suggest that wandering behaviour may even be a way to escape
381 discomfort. In a study in two dementia clinics, Victoroff et al. [33] found that
382 particularly agitation is associated with burden and depression among family carers,
383 whereas no significant association between delusions and hallucinations was reported.
384 The reduction of environmental stressors can help to minimise agitation.

385
386 ***INSERT TABLE 1 HERE***

387
388 Since people with dementia respond on a sensory level, rather than on an intellectual
389 level [34], and given some of the cognitive and behavioural problems, extra attention
390 should be paid to the indoor environment in relation to comfort and behaviour. It is,
391 however, important to stress that cognitive impairment is not caused by environmental
392 design, but problem behaviours (Table 1) may be exacerbated by inappropriate
393 housing facilities [23]. Cohen and Weisman [21] stated that one of the design goals
394 for dementia should be to provide opportunities for stimulation and change, carefully
395 regulating sensory stimulation to avoid either deprivation or overload. Bowlby Sifton
396 [38] calls for sensory stimulation without stress; the environment of institutional
397 settings should feel, smell, and sound like home. According to Zeisel [39], an entire

398 environment should be designed so what people see, hear, touch and smell all give
399 them the same, consistent, information about the environment in a holistic manner to
400 understand the environment around us. Healthy persons balance the good features
401 against the bad to reach their overall assessment of the indoor environment [40], and
402 not all aspects are equally important in this subjective averaging process. It is likely
403 that this finding applies to persons with dementia too.

404

405 **3.2. Air and odours**

406 Indoor air quality deals with the content of indoor air that could affect health and
407 comfort of building occupants [41]. IAQ is related to building materials, ventilation,
408 and activities carried out in the home. Our awareness of the presence of airborne
409 chemicals in our environment relies on two sensory systems: olfaction and
410 chemesthesis or the common chemical sense [42]. The first sense gives rise to the
411 perception of odours, and the second gives rise to the perception of pungent
412 sensations [42]. Olfaction is closely linked to the sense of taste. These senses
413 intertwine to provide links to the environment, and allow appreciation of good tastes
414 and smells [1].

415

416 *INSERT TABLE 2 HERE*

417

418 **3.2.1. Ageing-related changes in olfaction**

419 Age-related losses of smell and fine taste normally begin after the age of sixty (Table
420 2) [1]. Age-related sensory changes to smell and taste include a decrease in the
421 number of olfactory cells, and a possible decrease in size and number of taste buds.
422 These changes may lead to decreased appetite and poor nutrition, as well as a
423 decreased protection from noxious odours and the intake of tainted food.
424 In the human forebrain, the olfactory bulb is a structure involved in olfaction, the
425 perception of odours. Changes in smell are attributed to loss of cells in this bulb, and a
426 decrease in the number of sensory cells in the nasal lining [1]. In addition, a history of
427 upper respiratory infections, exposure to tobacco smoke and other toxic agents
428 negatively influence olfactory function, as well as changing levels of hormones. There
429 is strong evidence that smell perception declines markedly with age [1].

430

431 **3.2.2. Dementia-related changes in olfaction**

432 The olfactory sense in older adults with dementia is affected by ageing and specific
433 pathologies. This directly influences the perception of indoor air quality and smells,
434 and poses restrictions to the way IAQ is maintained. Moreover, the specific lifestyle
435 of older people with dementia influences the IAQ.
436 Olfactory dysfunction is a common feature in several neurodegenerative disorders,
437 including AD, Down's syndrome, and Parkinson's disease. Neurofibrillary tangles
438 and senile plaques in the olfactory system have been reported in AD [44]. Researchers
439 even purport that the inability to recognise smells, combined with the lack of
440 awareness that olfactory sense is impaired, may be useful as a predictor for AD [1].
441 There is other research that suggests the impairment is primarily in odour
442 identification, not detection [45]. Diesfeldt [46] mention that in some people with AD
443 the ability to smell decreases before memory disturbances become noticeable. Only in
444 AD, the elementary odour detection is lowered, i.e., differences between odours. All
445 types of dementia affect 'meaningful odour recognition', for instance, that a certain
446 odour smells of fruit. In people with AD, this association problem was related to any
447 particular odour. People with semantic dementia had difficulty with all associative

448 tasks, even if these tasks were not related to any particular odour. Persons with this
449 type of dementia do no longer recognise the meaning of words and objects, and may
450 perceive inedibles as edible.

451 The olfactory bulb is linked to the thalamus-cortical region and the limbic system via
452 the olfactory tract [47], parts of the brain affected by AD. The limbic system affects
453 behavioural reactions associated with smell, whereas the thalamus-cortical region is
454 responsible for the conscious perception and fine discrimination of smell [47]. The
455 sense of smell often seems to have a strong hold on human emotions, because of the
456 connection to the limbic system, which is associated with emotion and memory
457 processing [34,47].

458

459 **3.3. Light and lighting**

460 Of all indoor environmental factors in the homes of older adults with dementia,
461 lighting is the most important and promising in terms of improving health and quality
462 of life. The best-known benefits of lighting are visual, i.e., being able to see, and
463 prevention of falls [48]. Falls in dementia result from cognitive and behavioural
464 disorders, visuospatial impairment and motor apraxia, gait and balance disturbances,
465 malnutrition, adverse effects of medication and fear of falling [48,49]. Moreover,
466 lighting plays an essential role in managing numerous biological and psychological
467 processes in the human body, including disturbed sleep patterns.

468

469 **3.3.1. Ageing-related changes in vision**

470 Ageing negatively affects vision. In general, the performance of the human eye
471 deteriorates at early age. Many people aged 45 and over wear glasses to compensate
472 for impaired vision due to presbyopia, the significant loss of focussing power. Older
473 people are known to have vision impairments stemming from the normal ageing
474 process, which include (i) an impaired ability to adapt to changes in light levels, (ii)
475 extreme sensitivity to glare, (iii) reduced visual acuity, (iv) restricted field of vision
476 and depth perception, (v) reduced contrast sensitivity, and (vi) restricted colour
477 recognition [34]. Changes in vision do not happen overnight, and depend on the
478 progress of age. After the age of 50, glare and low levels of light become increasingly
479 problematic. People require more contrast for proper vision and have difficulty
480 perceiving patterns. After the age of 70, fine details become harder to see, and colour
481 and depth perception may be affected [34,50]. An overview of age-related changes to
482 vision is given in Table 2. Apart from the influence of ageing, there are pathological
483 changes leading to low vision and eventual blindness, such as cataract, macular
484 degeneration, glaucoma, and diabetic retinopathy [50,51].

485 Impaired vision does not only influence independence, but also has severe
486 implications to social contacts, which in term can lead to loneliness. Research by
487 Aarts and Westerlaken [52] in the Netherlands has shown that light levels, even
488 during daytime, are too low to allow for proper vision and biological effects, even
489 though the semi-independently living older persons were satisfied with their lighting
490 conditions. A similar study was carried out among 40 community-dwelling older
491 people in New York City by Bakker et al. [53]. Even though nearly all of them had
492 inadequate light levels, subjects rated their lighting conditions as adequate.

493

494 **3.3.2. Dementia-related changes in vision**

495 Dementia has a severe impact on the human visual system, and the effects of
496 biological ageing often aggravate the visual dysfunctions stemming from dementia.
497 Persons with AD frequently show a number of visual dysfunctions, even in the early

498 stages of the disease [54]. These dysfunctions include impaired spatial contrast
499 sensitivity, motion discrimination, and colour vision, as well as blurred vision. Altered
500 visual function may even be present if people with dementia have normal visual
501 acuity and have no ocular diseases [54]. Another dysfunction is diminished contrast
502 sensitivity, which may exacerbate the effects of other cognitive losses, and increase
503 confusion and social isolation [50]. Impaired visual acuity may be associated with
504 visual hallucinations [55]. According to Mendez et al. [56], persons with AD have
505 disturbed interpretation of monocular as well as binocular depth cues, which
506 contributes to visuospatial deficits. The impairment is largely attributed to
507 disturbances in local stereopsis and in the interpretation of depth from perspective,
508 independent of other visuospatial functions.

509

510 **3.3.3. Ageing and non-visual effects of light**

511 Moreover, light plays a role in regulating important biochemical processes,
512 immunologic mechanisms, and neuroendocrine control (for instance, melatonin and
513 cortisol), via the skin and via the eye [43,57]. Light exposure is the most important
514 stimulus for synchronising the biological clock [58], suppressing pineal melatonin
515 production [59], elevating core body temperature [60], and enhancing alertness
516 [60,61]. The circadian system, which is orchestrated by the hypothalamic
517 suprachiasmatic nuclei (SCN), influences virtually all tissue in the human body.

518

519 ***INSERT FIGURE 2 HERE***

520

521 In the eye, light activates intrinsically photosensitive retinal ganglion cells [62], which
522 discharge nerve impulses that are transmitted directly to the SCN [63] (Figure 2), and
523 together with the photoreceptors for scotopic and photopic vision participate in
524 mammalian circadian phototransduction. These ganglion cells [65] have a different
525 action spectrum from rods and cones, and show short-wavelength sensitivity [66]. In
526 older adults, the orchestration by the SCN requires ocular light levels that are
527 significantly higher than those required for proper vision are. An additional problem is
528 formed by the ageing of the eye that leads to opacification and yellowing of the
529 vitreous and the lens, limiting the amount of bluish light reaching the retinal ganglion
530 cells [43]. This can be as much as a 50% reduction in 60-year olds compared to 20-
531 year olds. Many older adults are not exposed to high enough illuminance levels, due
532 to decreased lens transmittance, poorly-lit homes (up to 400 lx), and the short periods
533 of time spent outdoors [52,67].

534 Light also has an effect on the pineal gland that secretes melatonin. The secretion of
535 this hormone depends on the availability of (day) light. Sufficient amounts of light
536 (particularly the lower wavelength part of the spectrum) [66,68], suppresses melatonin
537 secretion, while during darkness, melatonin secretion is stimulated. This melatonin
538 secretion is related to the exposure to light during daytime [69,70]. A high exposure to
539 light during daytime, increases the nocturnal secretion of melatonin [71-73], and
540 makes older adults less sensitive for light exposure at night, for instance, when going
541 to the toilet. Being exposed to light at night may reduce the level of melatonin and
542 therefore reduce the time it takes to fall asleep. Exposure to light during daytime
543 should in turn positively impact sleep, both quantitatively and qualitatively.

544 Sufficient daily sleep is indispensable for restoration of body and brain. A lack of
545 good sleep slows reaction time, decreases alertness and attention, and affects mood
546 and performance in a negative way [74]. About 40 to 79% of older people suffer from
547 chronic sleeping problems and insomnia [52]. Changes in the timing of many

548 circadian rhythms in the body are related to that of sleep. The lessening of the
549 amplitude of the 24-hour rhythm in body temperature means that the lowering of body
550 temperature in the evening is less pronounced. This lessening can be a random
551 combination of a decreased functioning of the body clock, decreased physical activity
552 during daytime, and a decreased nocturnal secretion of melatonin [64].
553

554 **3.3.4. Dementia and non-visual effects of light**

555 In people with AD, the SCN are affected by the general atrophy of the brain, leading
556 to nocturnal restlessness due to a disturbed sleep-wake rhythm, and wandering
557 [64,75]. The timing of the sleep-wake cycle can show a far wider variation; times of
558 sleep and activity can vary substantially from day to day, or can be temporarily
559 inverted [64], which has great implications to both the person with dementia as its
560 family carer. Restlessness and wandering form a high burden for caregivers, and are
561 among the main reasons for institutionalisation [67,76,77]. Marshall [78] stated that
562 lighting technology deserves more attention as a means to help with managing
563 problem behaviour. Hopkins et al. [79] have suggested a relation between illuminance
564 levels and this type of behaviour before, and today light therapy is used as a treatment
565 to improve sleep in people experiencing sundowning behaviour [80].

566 It is hypothesised that high intensity lighting, with illuminance levels of well over
567 1,000 lx, may play a role in the management of dementia. Bright light treatment with
568 the use of light boxes is applied to entrain the biological clock, to modify behavioural
569 symptoms, and improve cognitive functions, by exposing people with dementia to
570 high levels of light (for instance, [81-84]), requiring supervision to make them follow
571 the total protocol and may cause a bias in the outcomes of the therapy. The results of
572 bright light therapy on managing sleep, behavioural, mood, and cognitive disturbances
573 show preliminary positive signs, but there is a lack of adequate evidence obtained via
574 randomised controlled trials to allow for a widespread implementation in the field
575 [85-87].

576 Another approach that is gaining popularity, both from a research, ethical and
577 practical point of view, is to increase the general illuminance level in rooms where
578 people with dementia spend their days to a high level [50]. Studies by Rheaume et al.
579 [88], van Someren et al. [89], Riemersma-van der Lek et al. [90], and van Hoof et al.
580 [91,92], that exposed institutionalised people with dementia to ambient bright light
581 through ceiling-mounted luminaires showed short-term and long-term effects as
582 lessened nocturnal unrest, a more stable sleep-wake cycle, possible improvement to
583 restless and agitated behaviour as well as sleep, increased amplitude of the circadian
584 body temperature cycle, and a lessening of cognitive decline. A cluster-unit crossover
585 intervention trial by Sloane et al. [93] on the effects of high-intensity light found that
586 nighttime sleep of older adults with dementia improved when exposed to morning and
587 all-day light, with the increase most prominent in participants with severe or very
588 severe dementia. Hickman et al. [94] studied the effects on depressive symptoms in
589 the same setting as Sloane et al. [93], persons with dementia. Their findings did not
590 support the use of ambient bright light therapy as a treatment for depressive
591 symptoms. To date, it is unknown how long effects of bright light last and how to
592 predict which persons respond positively to light treatment [76]. More relevant is how
593 to implement these preliminary results in the home situation, for instance, when trying
594 to improve vision.
595

596 **3.4. Noise and room acoustics**

597 The sense of hearing is related to the perception of sounds. When considering noise
598 and room acoustics, the most important parameters are sound pressure level and
599 reverberation time. These parameters are crucial in creating supportive environments,
600 both in terms of supporting hearing, as well as reducing negative effects associated
601 with sounds and noise.

602

603 **3.4.1. Ageing-related changes in hearing**

604 In addition to sight, one of the first senses to be affected by age is hearing, and this
605 begins to occur by the age of 40 (Table 2). High frequency pitches are the first to
606 become less audible, with a lesser sensitivity to lower frequency pitches [1]. The
607 ability to understand normal conversation is usually not disturbed at first, but when
608 combined with the presence of background noise comprehension may be affected. In
609 the United States, about one third of the community-dwelling older people are hearing
610 impaired [1]. A laboratory study from Japan [95] involving 20 younger and 20 older
611 subjects using various speech tests showed that speech recognition (intelligibility)
612 scores of the older listeners were 25% lower than those of young adults for any kind
613 of speech test. The effect of this difference is equal to the 5 dB increase of ambient
614 noise.

615

616 **3.4.2. Dementia-related changes in hearing**

617 Apart from the effects of biological ageing, there are no reported effects of dementia
618 on hearing, apart from the occurrence of acoustical hallucinations (Table 1). Most
619 older people lose hearing ability, and can compensate by a combination of lip reading,
620 increased attention, and extrapolation from the parts of sentences they can hear [96].
621 For a person with dementia, this compensation becomes problematic, and that is why
622 it is important to minimise meaningless background noise [97]. It can be hard to sort
623 meaningless cues and stimuli from those that are meaningful or important [97].
624 Hearing aids may magnify background noise. People with dementia often cannot learn
625 to compensate for this [2] or perceive the sounds as offensive [34]. Burton and
626 Torrington [28] mention that sudden loud noises often frighten people with dementia.
627 Hearing aids are crucial for people with hearing loss, since they contribute to
628 communication abilities that are already negatively affected by dementia. They may
629 prevent a state of sensory deprivation [98].

630 In institutional settings, noise has been associated with poor sleep, reduced ability to
631 perform tasks, distraction from completing a task, agitation and fear [3,11,99]. In a
632 qualitative study by Hyde [96] involving Alzheimer's facilities staff, one unit director
633 advised the following in relation to unnecessary auditory stimulation: "*Listen to the*
634 *noise level. The phone ringing, the intercom, it's a necessary evil, but they think God*
635 *is talking to them.*" It is unclear whether this apparent confusion is a source of fear or
636 other negative feelings, or reassurance, or a combination of both. Apart from the
637 confusion, sounds may cause a wide range of negative side effects. Often noise is an
638 accepted part of the routine of people with dementia [11].

639

640 **4. Functional value**

641 The domain of the functional value deals with the needs of the organisation. Within
642 this domain, production support and reliability play a role as performance indicators.
643 This can be both the impact on care giving processes of the family or professionals, as
644 well as the production processes within the domains of care, housing and technology.
645 Based on the needs of the organisation and those of their clients, raising the level of
646 awareness of the stakeholders of the impact the indoor environment may have on

647 persons with dementia is of the utmost importance. The requirements within the
648 domain of the functional value have a significant overlap with those stated in relation
649 to thermal comfort [7], in particular the aspects related to the professionals from the
650 technological domain. Therefore, only some of the highlights are described.

651

652 **4.1. Raising awareness**

653 Relevant organisations, family and professional carers need to be made aware of the
654 consequences the indoor environment can have on the behaviour and functioning of
655 person with dementia care processes. Also, increased awareness should be raised on
656 how the good design and implementation of relevant building services and systems
657 can lead to more efficiency in dementia care processes. Even though dementia can
658 significantly change how people interpret what they sense, the extent is highly
659 individual and in constant flux, depending on neuropathological changes, sensory
660 loss, time of day, medication management, and the social and physical environment
661 [100]. All relevant actors should be aware of this phenomenon too.

662 Raising awareness is also needed in terms of design and the operation of technology.
663 The sensitivity of people with dementia stretches beyond sensitivity for actual
664 physical conditions, for instance, to operational factors. Invasive technology, like
665 lights switching on seemingly spontaneous, automated movement of curtains, and
666 noisy ventilation systems can cause distress. Systems installed with the best of
667 intentions, which are unfamiliar, are not understood by people with dementia and
668 should therefore be left out of a dwelling. The complexity of technology can have an
669 unwanted disabling effect on the person with dementia [101]. Bakker [100] states that
670 at times, the loss of function of residents with dementia is incorrectly blamed on
671 dementia, when inappropriate design is at the basis. This is the point when specialised
672 knowledge from designers and installers is wanted.

673 Tilly and Reed [102] provide an example of wrong design, applied to alarm systems
674 used to alert the staff when a wandering resident is attempting to leave the facility.
675 One should choose the system that is the least intrusive and burdensome. For some,
676 alarm systems are a burden and may even lead to agitated behaviour, as evidenced by
677 the resident's protests or attempts to remove it. Furthermore, alarms that are audible to
678 the resident may discourage any movement. The implementation of a seemingly good
679 solution may turn out detrimental.

680

681 **4.2. Standards and guidelines**

682 Current standards and guidelines for indoor environmental quality should be applied
683 with caution when working with persons with dementia. Current standards and
684 guidelines do not provide sufficient data on this group of people, and it seems that the
685 demands set to the indoor environment should be a lot stricter. In general, the quality
686 of the indoor environment may be expressed as the extent to which human
687 requirements that have great interindividual variety are met. Some people are known
688 to be rather sensitive to an environmental parameter and are difficult to satisfy [103],
689 and this seems to be particularly true for people with dementia. Other relevant
690 building regulations tend to be primarily written for the needs older people with a
691 physical impairment, rather than for people with mental or cognitive impairments.
692 When recommendations are made for people with dementia, even these can have
693 shortcomings. The light levels recommended in Table 3, for instance, are generally
694 higher than the 300 to 500 lx recommended by Marx et al. [106] for institutionalised
695 people with dementia. New guidelines and standards that explicitly include older

696 people with dementia can also be used to raise the aforementioned awareness among
697 professionals and managers.

698 Apart from the abovementioned standards and guidelines, used for the design of
699 buildings, indoor environmental parameters and accompanying technology are also
700 applied in the field of multi-sensory stimulation or ‘snoezelen’ [107-110], a therapy
701 developed in the Netherlands around 1975 [111]. Multi-sensory stimulation is applied
702 in a special room using numerous tools that offer sensory stimulation by light, sound,
703 touch, smell and taste [108-110]. Apart from the therapeutic goals to make contact
704 [110], multi-sensory stimulation also aims to offer pleasurable sensory experiences
705 tailored to the needs of older adults with dementia [110]. Although Chung and Lai
706 [112] have concluded in a Cochrane review that there is not evidence showing the
707 efficacy of this therapy, multi-sensory stimulation is applied worldwide and appears
708 in numerous handbooks and guidelines.

709

710 ***INSERT TABLE 3 HERE***

711

712 **5. Economic value**

713 The domain of the economic value deals with the fit between demand and supply of
714 solutions and cost-benefit analysis of improved indoor environments. Within the
715 domain of the economic value, initial costs and operational costs, as well as
716 maintenance, play a role as performance indicators. Apart from direct economic
717 benefits to society that are the results from an integrated building design (macro
718 level), there are the human benefits to individuals (micro level).

719

720 **5.1. Raising awareness**

721 One of the requirements for maximising the economic value is making all family and
722 professional carers (and for that matter, managers in the health care sector too) aware
723 about the role indoor environment might play in relation to behaviour and well-being.
724 These persons can be made familiar through training as well as brochures, websites,
725 handbooks, standards and guidelines, which have been shown to be lacking or
726 incomplete at present. Training is costly and poses financial restrictions in the start-up
727 phase. The results of training however, may cut down on costs for the processes of
728 facilitating care. Raising awareness can lead to emancipation among carers and
729 persons with dementia alike, which in turn should lead to requesting supportive indoor
730 environments. In addition, managers in health care have an important role to play in
731 the creation of such indoor environments.

732

733 **5.2. Design**

734 The economic benefits of good indoor environmental quality can also be threatened
735 by new or emerging views in terms of the design of the home environment, such as
736 the example of new healthy lighting systems provided by Calkins [113]. Such systems
737 have obvious benefits to the residents of institutional settings. Calkins [113] stated
738 that there is a shift away from discrete behaviours and single environmental
739 ‘solutions’ to a more holistic approach. In her view, this represents a step forward in
740 terms of understanding the larger, more complex set of relationships found in
741 dementia care settings. Calkins [113] continues by providing an example of this more
742 holistic approach, namely the creation of so-called home-like care environments,
743 which include the absence of ceiling-mounted fluorescent lighting. At the same time,
744 fluorescent lighting is used in healthy lighting systems [88-92], which have non-visual

745 health benefits to the residents unlike the more home-like and dim incandescent lights
746 that provide a pleasant atmosphere.

747 Another issue related to providing solutions to existing demand is the availability of
748 specialised technology. For instance, there are few commercially available solutions
749 to assist people with dementia at home. One should keep in mind that what is
750 available on the marketplace is not the same as what is or may be possible in practice
751 [114,115].

752

753 **5.3. Costs**

754 There are economic aspects related to the creation of supportive indoor environments,
755 which manifest in terms of benefits related to ageing-in-place and the reduced need
756 for institutional care, the lessened burden on family carers, and the costs of home
757 modifications.

758 Duijnsteet [116] showed that practical housing can decrease the objective burden of
759 family carers, and thus lead to human benefits, which also represent an economic
760 value. Most family carers have an intrinsic motivation to provide care for a relative,
761 but it is not a free choice. Moreover, many family carers are older adults themselves,
762 and health problems may arise from the stresses of caring for a loved-one, in
763 particular, when problem behaviours are observed. When family carers can no longer
764 keep up with providing care due to all the stressors, people with dementia are
765 institutionalised. New initiatives in the field supportive housing may offer
766 opportunities for delaying the need for institutional care, which has economic
767 consequences for both society as a whole as on an individual level. It was shown that
768 for the Netherlands, € 6,000 to € 16,000 could be saved per person, depending on the
769 health status, if people aged-in-place instead of being institutionalised (2004 price
770 level) [117]. The human benefits of supportive living environments include increased
771 well-being among people with dementia, support of family carers in the provision of
772 care, as well as the opportunity that family carers do no longer have to cope with
773 building-related or building-induced problem behaviours of their loved-ones.

774 If people with dementia are able to age-in-place, due to improved indoor
775 environmental quality and building systems, instead of living in an institutional
776 setting, this goes together with a reduction of costs for society. Van Hoof et al. [6]
777 provide an overview of the financial and societal costs of care for people with
778 dementia for the Netherlands. The costs of informal care in 2005 were an estimated €
779 4,700 per person with dementia per annum. The direct costs of dementia care were
780 about € 14,200 per person with dementia per annum. The costs per person can vary
781 considerably, even within the more developed countries and when considering the net
782 domestic purchase power.

783 The availability of supportive home environments, in combination with adequate
784 professional care, services and telehealth, is not only much wanted by people in the
785 community, but also a necessity from an economic point of view [114,115].

786

787 ***INSERT TABLE 4 HERE***

788

789 **6. Synthesis of building-related solutions in the domain of the basic value**

790 In the preceding sections basic value indicators were analysed which result from the
791 needs of people with dementia. There are many building-related solutions available
792 within the domain of the basic value that deal with the symptoms of dementia:
793 impairments in activities of daily life, behavioural problems, and loss of cognitive
794 functions. These solutions in relation to (i) air and odours, (ii) light and lighting, and

795 (iii) the acoustical environment (Table 4) are described per building system (Brand's
796 six S's [20]: stuff, space-plan, services, skin, structure, and site) in the following
797 paragraphs. The majority of the solutions presented are generic and may help the total
798 population of persons with dementia, whereas other solutions provide an answer in
799 specific cases that depend of the health status, home environment and financial
800 situation of the person with dementia. In practice, needs of the persons with dementia
801 may vary due to differences in the stage of dementia, the incidence of problem
802 behaviours, and health effects of biological ageing. All the aforementioned factors
803 play a role when choosing and implementing a certain solution.
804

805 **6.1. Air and odours**

806 There are many building-related solutions available to the homes of older people with
807 dementia to deal with odours and indoor air quality.
808

809 **6.1.1. Stuff**

810 Building-related solutions on the stuff level can be found in the field of floor covering
811 and upholstery. Aromatherapy activities are part of this system, as well as artificial
812 deodorisers.

813 Unpleasant smells (urine, strong cleaning products) are known to cause
814 overstimulation [118], and should be removed from the home as much as possible.
815 Textile floor covering and furniture upholstery, often chosen to create a home-like
816 atmosphere, should be easy to clean when dealing with incontinence and leakage. At
817 the same time, textile floor covering is also recognised as a source of volatile organic
818 compounds, and is a dust reservoir containing biological contaminants like mites and
819 moulds [119].
820

821 The sense of smell often seems to have a strong hold on human emotions, because of
822 the connection to the limbic system, which is associated with emotion and memory
823 processing [34,47]. Smells can therefore be used for reminiscing and aromatherapy
824 activities. Aromatherapy has emerged as promising treatment for behavioural
825 problems in dementia in institutional settings, since it is claimed to reduce stress and
826 affect mood. Previous studies have found improvement in agitation, and motor
827 behaviour [107]. During bathing, people with dementia could enjoy the smell of nice
828 soap or bathwater with fragrance [100,120], which can alleviate stress. Perfumes as
829 well as non-poisonous plants and flowers in and around the home can be used to
830 alleviate stress, for example by reminiscing. People with dementia may be unable to
831 recognise inedibles, and in some cases may even try to eat these items not intended as
832 food. This probably results from damage to perception and memory [2,120]. Artificial
833 deodorisers are no substitute for good ventilation, and may even pose dangers, for
834 instance, when people with dementia mix up a bowl of potpourri for savoury snacks
835 [36].
836

837 **6.1.2. Space-plan**

838 As smells can be used for reminiscing, pleasant odours can be a positive aspect of the
839 home. Olfactory cues could even serve as orientation aids [121]. Some even claim that
840 smells can improve wayfinding, for example, locating the kitchen via cooking smells
841 [23]. Olfactory sense activation, for instance, by exposing people to cooking smells
842 from the adjacent kitchen [2,118,122], improves appetite and food intake by
843 stimulating the salivary glands [45], and hence can result in weight gains.
844

845 **6.1.3. Services**

846 Building-related solutions on the services level can be found in the field of ventilation
847 systems and alarm systems.

848 A study by Coelho et al. [123] revealed that many older adults (without dementia) use
849 many different cleaning products, spend a long time cooking (moisture and
850 combustion products), and spend a great deal of the day indoors. This exposes them to
851 many indoor air pollutants. Homes for older people with dementia can greatly benefit
852 from an adequate ventilation system [121]. At the same time, cooking odours can
853 have beneficial effects and should not all be taken out through the hood.

854 Ventilation is very important during bathing, in order to let fresh air in and to limit the
855 amount of moisture that can cause hazardous mould growth. Brawley [124] mentions
856 that during bathing, steam-filled rooms may be stressful for people with dementia.

857 Automated ventilation systems may be an option to get rid of excess moisture, but can
858 problems of their own. Steinfeld [125] describes how his demented father got anxious
859 by the noise generated by the fan that activated automatically when the light was
860 turned on. The old man did not understand the source of the noise, as he turned on the
861 light, not a fan. The anxiety was thought to increase by the acoustics of the bathroom.
862 In this example, improvements to IAQ can lead to problems caused by inexplicable
863 and loud sounds.

864
865 Smell and fine taste serve as a warning of environmental hazards [1]. A decreased
866 sensitivity to odours may be dangerous for the older person, and can contribute to the
867 inability to detect the odour of leaking gas, a smouldering cigarette, or spoiled food or
868 something inappropriate [1,36]. Therefore, alarms may be helpful in the home
869 environment. When the fridge's temperature control knob has been handled, leading
870 to too high a temperature inside, a temperature alarm may alert the carer [36]. In
871 kitchens that have gas cookers installed, gas alarms may be helpful. The same goes
872 for smoke and fire detectors [2,25,120]. Other alarms, for CO, CO₂ and NO_x are
873 available too. These measures give early warnings in case of danger, but it is not
874 always clear if the alarms are understood as a warning signal.

875 876 **6.1.4. Skin**

877 Building-related solutions on the skin level can be found in the field of ventilation
878 systems in façades. When installing these systems, attention should be paid to the
879 safety of the person with dementia and the family carer.

880 Opening windows and doors for ventilation purposes allow people with dementia to
881 escape or climb out [2]. Openings should be small enough so residents cannot crawl
882 through them to the outside [126]. Locks may be necessary on windows to keep them
883 from being opened too far, or to keep residents from opening them throughout the
884 winter [126]. Bars and locks may form restraints to residents, whereas ideally some
885 windows in a home should be operable by the residents as an easy way to have a
886 certain degree of control over the environment [126] and to allow for ventilation.
887 Moreover, ventilation grids should be easy to reach, in order to prevent the risk of
888 falls.

889 890 **6.1.5. Structure**

891 Building-related solutions on the structure level can be found in the field of a
892 building's floors. Olfactory dysfunction can also have social implications, with
893 disadvantages to the person with dementia, relatives, carers and the social network.
894 Ebersole et al. [1] and Diesfeldt et al. [46] state that people experience habituation to,

895 and unawareness of, the own body odour. In case of incontinence, people may be
896 unaware of the smell of urine that accompanies them [1]. In case of severe leakage
897 due to incontinence, the concrete slab or sub-floor may be sealed in order to prevent
898 odours from penetrating [127].

899

900 **6.2. Light and lighting**

901 The older individual is not static in the environment [43], and this is very important in
902 creating supportive visual environments. People often look away from a visual task;
903 areas that may be brighter or darker than the task and which affect visual comfort.
904 Schiff et al. [99] state that excess visual stimulation can distract people from
905 focussing on what they need to do in order to complete a task. In order to carry out
906 visual tasks comfortably, attention should not only be paid to light levels, but also to
907 luminance ratios, light colour, and colour rendering index.

908

909 **6.2.1. Stuff**

910 Building-related solutions on the stuff level can be found in the field of floor covering
911 inside the living environment.

912 Highly polished floors are a common source of glare and should be avoided or
913 replaced by matt surfaces [23,27,28,118]. Brawley [128] mentions that carpets can be
914 used to control glare. Qualitative research by Hyde [96] involving Alzheimer's
915 facilities staff, found that glare caused by bright overhead lights on overly waxed
916 linoleum tiles caused 'puddles' of light that more than one informant reported
917 residents walk around. The choice of floor covering is thus very important in glare
918 control. As mentioned before, the application of textile floor covering may have
919 consequences to IAQ, cleaning and mobility, as should therefore be applied with
920 caution.

921 Calkins [126] mentions that table lamps should be heavy, and that one should
922 consider cages around the bulbs. This would increase the safety of the lighting and
923 prevent hoarding of the lamps, a behaviour occasionally seen in middle stages of
924 dementia.

925

926 **6.2.2. Space-plan**

927 Building-related solutions on the space-plan level can be found in the field of daylight
928 access and sightlines. Open floor plans allow for increased daylight access.

929 In order to deal with clinging behaviour, both residents (and carers) should have an
930 overview of spaces to keep in contact with one another. Such sightlines can be created
931 with an open floor plan, which is obtained by reducing the number of walls [5]. Some
932 residents with dementia may face difficulty in locating the toilet when needing to visit
933 this facility. It is assumed that toilets are easier found (and thus used) when clearly
934 marked or visible from the living room [5].

935 It is important that older adults frequently go outdoors in order to be exposed to
936 daylight. Special architectural arrangements including a sheltered outdoor terrace and
937 easy outdoor access can be made. In a paper on environmental design for dementia,
938 Brawley [129] asks herself: "*Why are we not focusing on the reasons older adults in
939 nursing homes do not get outside for valuable and much needed sunlight?*" Exposure
940 to daylight can be supplemented by special ceiling-mounted lighting [91].

941

942 **6.2.3. Services**

943 Building-related solutions on the services level can be found in the field of lighting
944 systems and glare control, ballasts of lighting systems, the number and positioning of

945 outlets control systems, and ceiling-mounted luminaires that can be used for light
946 therapy.

947

948 Apart from raising general light levels indoors (Table 3), Mace and Rabins [2], Blom
949 et al. [25], Burton and Torrington [28], Brawley [34,80,127,129], Warner [36], Boyce
950 [50], Cluff [121], Silverstein et al. [130], and Gitlin [131] state that lighting should be
951 consistent and evenly distributed to eliminate areas of shadow and glare. Moreover,
952 glare from lights should be eliminated, and gradual changes in light levels and
953 focused task lighting should be provided. Since many seniors have difficulty
954 identifying the boundaries of objects, lighting should be sufficient to read any visual
955 contrast in the environment [121]. Increased light levels, by up to 3 times, in
956 combination with reduced glare and the use of contrast are means of adapting the
957 environment for age-related changes in vision [35].

958 According to Turner [24], Blom et al. [25], and Brawley [34] consistent and bright
959 light sources may help to eliminate frightening shadows cast by objects in the room,
960 avoid distraction, and lessen the number of hallucinations. Dim shadows and glare can
961 distort images even further, contributing to a resident's hallucination [34]. Of course,
962 glare should not be countered by decreasing the general light levels [23].

963 Turner [24] adds that lighting should not be too bright, since it may hurt the sensitive
964 eyes of older adults and cause tearing. Moreover, the lights may be the reason why
965 someone refuses to look in a specific direction.

966 In kitchens and dining rooms, lighting should increase safety on the work blade. The
967 dining area itself should be well lit in order for people to see and appreciate their food
968 [2,120]. The lighting should not be overpowering or glaring [36]. Extra lighting in the
969 cupboards could help people find food or utensils, and the same strategy could be
970 used in closets to help find clothes. A study by Brush et al. [132] of the effects of
971 modifications to lighting on nutritional intake and behaviour during dinner of two
972 groups of institutionalised older adults with dementia, showed that higher light levels
973 increased caloric intake in one group, and resulted in more conversations during
974 meals. Similar studies need to be repeated in home settings to confirm the positive
975 effects of lighting during mealtime.

976 Increased levels of lighting in bathrooms could help to prevent fall incidents. Since
977 people are (un)dressing and grooming in bathrooms, there should be enough light to
978 facilitate this activity [133]. The latter is also true for bedrooms. When people get out
979 of bed at night to go and visit the bathroom, the path to the bathroom should be well-
980 illuminated [36] to limited to risk of fall incidents. This need for lighting is illustrated
981 by van Berlo [134], who describes the case of a woman, aged 56, who cares for her
982 88-year-old mother-in-law with dementia (pathology not mentioned). *"She can still
983 handle the lighting. At night she leaves a small compact fluorescent lamp on. I once
984 told her: 'Mom, you should leave it on, in case you got to go to the toilet at night'..."*

985 At night, lighting may help to prevent fear. This is illustrated by van Berlo [134] in a
986 case of a 45-year old woman who cares for her 86-year-old mother with probable AD.
987 *"I put her in bed and leave the lights on. I leave more lights on over time. It's a bit
988 like a child's fear that a light needs to be on."*

989

990 Brawley [80] mentions that flickering of old-style magnetic ballasts may cause
991 agitation and headaches and can even trigger seizures, and therefore need to be
992 replaced with electronic ballasts.

993

994 Warner [36] mentions the need for extra outlets for bedside electrical appliances that
995 do not only include a table light, but also communication devices and a clock.

996

997 Brawley [129] calls for the need for daylight and glare control, for instance, through
998 electronic dimmers or step-level switching for lower illumination levels at night. In
999 general, lighting systems should be equipped with dimmers in case people with
1000 dementia experience overstimulation from excess lighting, or in order to create a more
1001 home-like atmosphere. Lighting in the bathroom should provide an enabling and
1002 restful atmosphere, and therefore, lighting should be dimmable [120]. Lighting should
1003 be operable from bed and near the door, and should be equipped with dimmers [36].
1004 Light switches should be of the pressure-plate type instead of handle-type switches
1005 [122].

1006 For institutional two-person rooms, Calkins [135] suggests using separate lamps for
1007 each resident, which he or she can turn on and off. A similar strategy may work for
1008 couples at home as well. Extra night-lights could be a solution to increase safety at
1009 night when going to the bathroom [120].

1010 Van Berlo [134] provides two examples of people with dementia and the challenges
1011 posed in relation to switches. First, there is the case of a 45-year old woman caring for
1012 her 86-year-old mother with probable AD. “[S]he sat in a low chair that was hard to
1013 get out of. [...] We also placed the button of the floor lamp on the armrest, because it
1014 used to be somewhere low and that was somewhat of a burden. So we moved it, so
1015 that she can reach more easily.”

1016 Second, there is a 64-year old woman, who cares for her husband, aged 65, who is
1017 diagnosed with probable AD. “He walks around for six times, before he finds the
1018 switch. I mean, I don’t let him become tired from such things. [...] If I’d say, ‘Please
1019 turn off the lights’, then he has turned to four to five plug sockets, before he reaches
1020 the right light switch. Then I need to direct him: ‘There, forward, to the right’. [...] I
1021 want to let him do it by himself, but I really need to give him directions.”

1022

1023 The increase of the general illuminance level in rooms where people with dementia
1024 spend their days via the installation of ceiling-mounted luminaires is gaining
1025 increased attention [88-92]. More research and modelling are needed in this field, as
1026 current illumination systems are not suitable, or user-friendly, for exposure to the
1027 required high levels of lighting. Carswell et al. [136] suggest that these special
1028 luminaires may not only positively impact people with dementia during the day, but
1029 also have a role to play in nighttime care.

1030

1031 **6.2.4. Skin**

1032 Building-related solutions on the skin level can be found in the field of façade systems
1033 for daylight access and glare control.

1034 Glare from windows should be eliminated, and access to natural daylight should be
1035 provided, for instance as an orientation aid, along with gradual changes in light levels.
1036 Care should be taken to avoid glare from low-elevation sunlight [28]. Proper curtains
1037 and window shades can help to control the visual environment [21,23,25].

1038 In order to provide daylight, as well as cues on the outdoor environment, bathrooms
1039 should preferably be equipped with an outside window [34].

1040 It is important that people get enough rest, which should be the number one priority
1041 when designing and decorating bedrooms [2]. Heavy curtains, as part of the façade
1042 system, can be put in place to keep light out [25]. Blinds and screens could also be
1043 applied.

1044 Tilly and Reed [102] stress the importance of regular sleep-wake cycles and state that
1045 these should be encouraged by ensuring that residents are exposed to sufficient
1046 daylight, apart from keeping bedding dry.

1047

1048 **6.2.5. Structure**

1049 Building-related solutions on the structure level can be found in the field of the design
1050 of the façade and the installation of heavy luminaires. Large windows allow for the
1051 access of daylight and allow people to look outside. Bowlby Sifton [38] states that
1052 windows can help in offering reality reassurance by providing outdoors views that
1053 help with orientation to the season and time of day.

1054 The structure of the ceiling should be sufficiently robust in order to carry the load of
1055 ceiling-mounted luminaires needed for light therapy.

1056

1057 **6.3. The acoustical environment and noise**

1058 The building-related solutions available in relation to the acoustical environment and
1059 noise aim at reducing background noise in the various rooms in the home, and
1060 improving the acoustical environment via the use of specific sound-absorbing
1061 materials. There are no concrete data or design guidelines on optimal sound pressure
1062 levels and reverberation times for home situations yet. Acoustical engineers should be
1063 able to distil relevant design information from the practical situations mentioned in
1064 the following sections.

1065

1066 **6.3.1. Stuff**

1067 Building-related solutions on the stuff level can be found in the field of the
1068 application of sound absorbing materials in the living environment.

1069 A common strategy to limit reverberation times indoors is the placement of sound
1070 absorbing curtains and textile floor covering [127,128,137]. Floor covering should not
1071 only be bought based on the acoustical properties, as it also has an impact on IAQ.

1072 Thick textile floor covering is uneasy for wheelchairs and walkers [36], and should be
1073 resistant against heavy use. When cleaning is required, the sound of hovering can be
1074 frightening. Another issue with textile floor covering is that some people may
1075 experience disorientation or vertigo in response to large, bold geometric patterns [34].

1076 Certain patterns may lead to nausea. Patterns may not be perceived to be level, or
1077 actually seem to move leading to instability [34,100] or stalling. Such covering should
1078 not be used in other to minimise the risk of fall incidents.

1079

1080 **6.3.2. Space-plan**

1081 An open space-plan can improve wayfinding, as people can use auditory cues for
1082 orientation. At the same time, open space-plans have implications to reverberation
1083 times and sound propagation in the dwelling. For instance, open kitchen areas could
1084 also cause overstimulation in the living room due to sounds produced by a kitchen
1085 hood.

1086

1087 **6.3.3. Services**

1088 Building-related solutions on the services level can be found in the field of limiting
1089 background noise and music coming from electronic equipment.

1090 In care settings, people with dementia are exposed to very high levels of intrusive and
1091 disturbing aural stimulation, including intercoms, telephones, paging systems and
1092 alarms [11,21,27,100,122,129], and unfortunately this is often the case at home as
1093 well. Hayen and Gafford [138] mention the importance of a quiet institutional

1094 environment, with tempered loud talking, radios and televisions, and a selection of
1095 background music that soothes the residents rather than entertain carers.
1096 Many studies call for a reduction of excessive noise levels (for instance,
1097 [28,38,129,131]). Moreover, assistive devices as ‘talking’ toilets and mirrors can be a
1098 source of confusion, and should be introduced into the dwelling with great caution.
1099 To many older adults with dementia, the bathroom is a place that can cause great
1100 stress, partly because of sounds and acoustics. According to Warner [36], it is
1101 important to consider problematic sounds that may be confusing or irritating,
1102 including rushing water, the toilet flushing, exhaust fans and HVAC systems, washing
1103 machines, and outside noises, such as traffic or people [34,36,139]. Inside the
1104 bathroom, whirlpools can cause fear and agitation because of the sound they produce
1105 [34]. When using a radio, one should consider the danger of electrocution, as with any
1106 electrical equipment used in bathrooms [120].
1107 During the preparation of meals and dinner, sound can be distracting too, such as
1108 background noise, and sounds from radios, televisions [120] and kitchen hoods. In
1109 dining rooms, excessive background noises from dishwashers and other kitchen
1110 sounds should be limited [36]. If televisions and their sounds cause loss of
1111 concentration, fear, agitation or panic, also due to misinterpretation, they should be
1112 put off, and soft music could be played [23,25]. Larkin [140] states that music also
1113 improves autobiographical recall, and has greater facilitatory effect than either quiet
1114 or background noise. Background noise should be kept to a minimum in order to
1115 assist with concentration. When talking to a person, one should not compete with a
1116 television or a radio [24], since the person with dementia is usually not able to focus
1117 on both voices at the same time. It only adds to the state of confusion. At the same
1118 time, radios may be a source of therapy. Burgio et al. [141] studied an interventions
1119 including listening to white noise; audiotapes of nature. Results indicated a 23%
1120 reduction in verbal agitation in severely demented nursing home residents (n=15),
1121 albeit that the results were obtained despite poor treatment fidelity. Radio-like
1122 interfaces are also used for reminiscence activities and leisure, for instance, by van
1123 Rijn et al. [142].
1124 Finally, fire alarms that are installed for reasons of safety should be loud enough for
1125 older persons to be heard (sound pressure level about 74 dB(A)), even though some
1126 persons may have difficulty recognising the signal [143].

1127

1128 **6.3.4. Skin**

1129 Building-related solutions on the skin level can be found in the field of façade systems
1130 to reduce indoor noise levels.

1131 Reducing background noise starts with the home’s façade. When people live near a
1132 crowded street, traffic noise can be kept out by having windows shut or having
1133 thermally and acoustically insulating panes. At the same time, auditory clues may be
1134 used as orientation aids [121].

1135 The role of sound in bedrooms is evident. A silent bedroom is crucial to good sleep,
1136 which is of great importance to both the person with dementia as the caring partner.
1137 Both Warner [36] and Mace and Rabins [2] stress this need. Apart from the need for a
1138 proper sound-insulation building construction, one could also buy heavy curtains that
1139 not only keep the sun, but also noise, out of the bedroom [25].

1140

1141 **6.3.5. Structure**

1142 Building-related solutions on the structure level can be found in the limitation of
1143 reverberation times through the choice of building materials and finishings.

1144 In case ceilings are dry wall, one can install acoustic panels on walls [127,128,137].
1145 To many healthy people, bathing is an activity of relaxation. Stress and agitation may
1146 be reduced by singing together during bathing [120]. Bathroom acoustics may be
1147 great for singing in the shower, except for those who are irritated or upset by noise
1148 bouncing around in hard, ceramic tile environments [36]. In order to improve the
1149 room acoustics, bathroom finishing materials should be chosen with care in order to
1150 reduce the reverberation time as much as possible, even though out of hygienic
1151 reasons ceramic tiles are the best option.

1152

1153 **7. Conclusions**

1154 Older people with dementia may perceive the indoor environment differently from
1155 counterparts without dementia, which can go together with certain behavioural
1156 symptoms. People with dementia are not just seemingly passive receptors of the
1157 indoor environment, but may actually respond to it in a very outspoken manner, and
1158 that technology installed may actually pose challenges to the provision of care and
1159 well-being.

1160 The design solutions that followed the identification of needs in the domain of the
1161 basic value, may be a first step towards evidence-based and stakeholder-related design
1162 of home environments for people with dementia. Of the three indoor environmental
1163 parameters treated in this paper, light is the best understood. Novel lighting
1164 applications are developed and applied to improve cognition, mood and behaviour,
1165 sleep and vision. Vision can be improved by raising general illuminance levels and
1166 glare control. The economic benefits are thus largely visible for the relevant
1167 stakeholders, although in practice not all older people with dementia have access to
1168 such lighting systems or are sufficiently exposed to daylight. The supply of fresh air,
1169 elimination of bad odours, reduction of background noise and other aspects of the
1170 acoustical environment are recognised as being important to behaviour and well-being
1171 of people with dementia, but are not as well-understood as light and lighting. The
1172 economic benefits of accounting for these parameters are not yet clear. More research
1173 is needed on how and which odours impact well-being and behaviour positively and
1174 negatively, and what the acceptance thresholds are. Also, adequate ventilation systems
1175 should be developed to counter the negative effects of odours without causing distress
1176 by noise. In terms of the acoustical environment, it is not possible to provide specific
1177 data and values of the ideal sound pressure levels and reverberation times for persons
1178 with dementia. The types of noise that may cause distress are not always predictable.
1179 The acoustical environmental is claimed to improve wayfinding, although the
1180 underlying mechanisms are not fully understood. More research is needed in these
1181 fields.

1182 The new framework combining the International Classification of Functioning,
1183 Disability and Health and the Model of Integrated Building Design was a useful tool
1184 for a detailed analysis of various stakeholder-related needs and solutions on a building
1185 system level, bringing together demand and supply and adding a new dimension to the
1186 care of persons with dementia. The synthesis of building-related solutions does not yet
1187 provide an overview based on existing guidelines, but provides directions for home
1188 modifications in relation to the three values considered in this paper. Given the results
1189 of this study, it is worthwhile to investigate and evaluate the impact of the indoor
1190 environmental parameters on older people with dementia further along the lines
1191 indicated. In addition, further research is needed to explore the functional and
1192 economic values of the described environmental parameters as solutions for persons
1193 with dementia and their informal and formal carers.

1194

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1511

1512 Table 1. Cognitive and behavioural problems found among people with dementia
1513 [2,34-37].

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- | | | |
|------------------------------|--------------------|------------------------------|
| • illusions | • agitation | • aggression |
| • hallucinations | • suspicion | • withdrawal |
| • delusions | • loneliness | • declining social skills |
| • impaired wayfinding | • depression | • eating inappropriate items |
| • difficulties understanding | • restlessness | • abnormal sexual behaviour |
| • loss of self-confidence | • misplacing items | • wandering |
| • poor judgment | • hiding things | • repetitive actions |
| • inability to recognise | • hoarding | • sundowning |
| • impaired sense of time | • rummaging | • catastrophic reactions |
| • disorientation | • shadowing | • paranoia |
| • fear of bathing and water | • dependence | |
| • personality changes | • resistance | |
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Table 2. Age-related sensory changes to smell and taste, vision and hearing, and outcomes.

SMELL AND TASTE [1]

- Decreased olfactory cells, may lead to decreased appetite, and decreased protection from noxious odours and tainted food.
- Possible decrease in size and number of taste buds, may lead to poor nutrition.

VISION [1,43]

- Lid elasticity diminished, leading to pouches under the eyes.
- Loss of orbital fat, lead to excessive dryness of eyes.
- (i) Decreased tears, (i) arcus senilis becomes visible, (iii) sclera yellows and becomes less elastic, (iv) yellowing and increased opacity of cornea, may lead to a lack of corneal lustre.
- (i) Increased sclerosis and rigidity of the iris, and (ii) a decrease in convergency ability, lead to presbyopia.
- Decline in light accommodation response leads to lessened acuity.
- Diminished pupillary size leads to a decline in depth perception.
- Atrophy of the ciliary muscles (holding the lens) leads to a diminished recovery from glare.
- Night vision diminishes leading to night blindness.
- Yellowing of the lens may lead to a diminished colour perception (blues and greens).
- Lens opacity may develop leading to cataracts
- Increased ocular pressure may lead to seeing rainbows around lights
- Shrinkage of gelatinous substance in the vitreous, may lead to altered peripheral vision.
- Vitreous floaters appear.
- Ability to gaze upward decreases.
- Thinning and sclerosis of retinal blood vessels.
- Atrophy of photoreceptor cells.
- Degeneration of neurons in visual cortex.

HEARING [1]

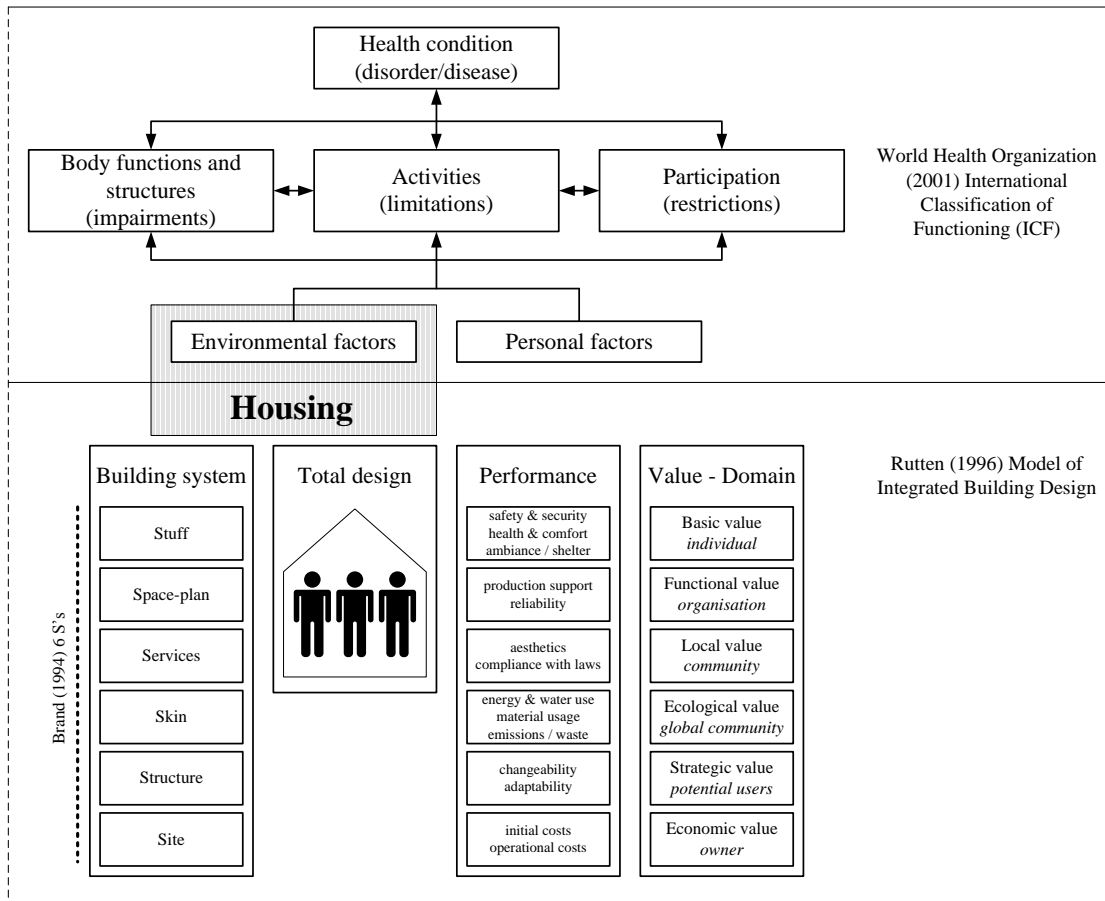
- (i) Thinner, drier skin of the external ear, (ii) longer and thicker hair in the external ear canal, (iii) narrowing of auditory opening, (iv) increased cerumen, (v) thickened and less resilient tympanic membrane, and (vi) a decreased flexibility of the basilar membrane, may result in difficulty hearing high-frequency sounds (presbycusis).
 - (i) Ossilar calcification, and (ii) diminished neuron, endolymph, hair cells and blood supply to inner ear and auditory nerve may lead to a gradual loss of sound.
 - (i) Degeneration of spiral ganglion and arterial blood vessels, and (ii) weakness and stiffness of muscles and ligaments may impair hearing.
-

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1519 Table 3. Illuminance levels per room [104]. Generally, the colour temperature of the
 1520 light sources should be between 2,700 and 3,000 K, in accordance with personal
 1521 preferences. Recommendations by De Lepeleire et al. [105] based on a 55% increase
 1522 of levels stated in the European Standard Lighting of workplaces are included in the
 1523 comments.

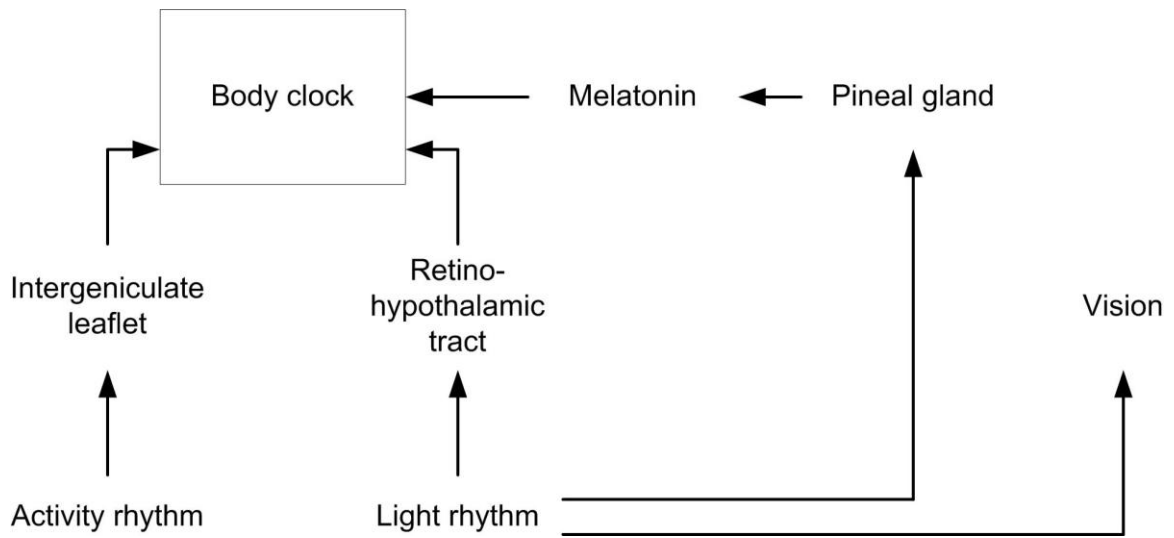
Location	Illuminance [lx]	Comments
Living room	200-300	Install extra light sources to create the desired atmosphere
Living room, near seat	1,000-2,500	At places where a great deal of time is spent, lighting for biological stimulation could be installed. The colour temperature should be between 6,500 and 8,000 K. A chair could be placed near the window.
Dining room (table level)	500-1,000	For eating, reading, leisure
Hobby and work space	500-1,000	De Lepeleire et al. [105] advise about 775 lx
Kitchen	300-500	Task illumination for food preparation, at least 1,000 lx
Bathroom and toilet	> 200	
Bedroom	100-300	Bedside light, about 1,000 lx
Corridors and storage rooms	100-200	Extra night lights (preferably red lights [80,104]). De Lepeleire et al. [105] advise 200 to 300 lx during day, and 50 to 80 during the night.
Stairs	> 200	Optional: install handrails that give off light. De Lepeleire et al. [105] advise 150 to 230 lx for stairs.

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Figure 1. Interactions between the components of ICF by the World Health Organization [19], and the integration of the Model of Integrated Building Design by Rutten [14].



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Figure 2. Simplified scheme of pathways by which light, melatonin, and activity rhythms act as *Zeitgebers*. Taken from Waterhouse et al. [64, p. 110].

1535 Table 4. Basic value needs and their relation to building systems/solutions (economic value). Curtains can be part of stuff and skin, depending on their
 1536 function.

Basic value needs	Building systems										Comments					
	Stuff				Space-plan	Services	Structure	Skin								
	Furniture	Floor covering	Curtains	Other items	Ventilation systems	Lighting	Alarm systems	Controls	Electronic equipment	Sanitary equipment	Other services	Floors	Ventilation systems in façade / operable windows	Curtains, shades and blinds	Windows / glass	
Odours -IAQ																
Need for safety - Impaired odour identification							1									1. Install gas alarms, smoke and fire detectors. Alarms on fridge
Need for safety – Cognitive impairment				1			2									1. Avoid artificial deodorisers / potpourri 2. Install gas alarms, smoke and fire detectors. Alarms on fridge
Incontinence - Impaired odour identification	1	2										3				1. Easy to clean upholstery 2. Easy to clean floor covering 3. Concrete slab or sub-floor may be sealed
Need for ventilation			1	2		3							4			1. Prevent curtains from moving in draught (suspicion) 2. Prevent items as paper from moving in draught (suspicion) 3. Silent automated ventilation systems (low noise) 4. Small openings to prevent people from climbing through. Locks on windows. Easy to reach grids/windows
Olfactory stimulation and way-finding				1		2							3			1. Open kitchen. Stimulation of appetite 2. Prevent 'good' odours to be removed via hood or ventilation system 3. Prevent 'good' odours to be removed via hood or ventilation system
Light(ing)																
Need to avoid glare	1	2	3			4		5				6		7	8	1. Mat upholstery and non-polished furniture 2. Avoid shiny floor covering 3. Type of curtain fabric may influence glare 4. Install consistent lighting. Do not lower light levels 5. Beware of automated glare control (blinds). May cause problem behaviour. 6. Avoid polished floors 7. Install curtains, shades and blinds 8. Special non-glare glazing. May lead to distorted colour perception and dark interiors
Need to avoid excess visual			1			2								3		1. Install curtains. Certain patterns can cause behavioural problems 2. Use electronic ballasts. Install dimmers

<hr/>										
stimulation										
Need for increased light levels	1	2	3		4		5			<ul style="list-style-type: none"> 3. Install curtains, shades and blinds 1. White furniture reflects more light. Risk of glare 2. White floor covering reflects more light. Risk of glare 3. White curtains reflect more light. Risk of glare 4. Increased, consistent, light levels. Provide sufficient lighting at table level. (improve appetite) 5. Install additional outlets near bed 6. Access to windows
Need for access to daylight			1	2				3		<ul style="list-style-type: none"> 1. Choose curtains in order to maximise and minimise daylight entry (when sleeping during day-time). 2. Open floor plan 3. Large windows (avoid over-heating). Windows also provide orientation cues (particularly in bathrooms)
Need for safety					1					<ul style="list-style-type: none"> 1. Extra light in kitchen (near kitchen blade). Put cages around warm bulbs (touch). Heavy table lamps (hoarding)
Need for control over lighting			1		2			3		<ul style="list-style-type: none"> 1. Curtains can help control daylight 2. Dimmers (particularly in bathroom). Lighting operable from bed and near doors. Separate lamps in bedroom. Pressure-plate type light switches. 3. Install curtains, shades and blinds 4. Special non-glare glazing. May lead to distorted colour perception and dark interiors.
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Noise										
Need for low background noise (distraction, hearing impairment)					1	2		3	4	<ul style="list-style-type: none"> 1. Limit amount of alarms when causing overstimulation 2. Limit amount of electronic equipment (tv, radios etc). Also during cooking/dining. Hovering may cause over-stimulation 3. Keep ventilation systems / windows closed to keep traffic noise out. 4. Install acoustically insulating panes
Need for sleep			1			2	3	4	5	<ul style="list-style-type: none"> 1. Install heavy curtains in bedroom to keep (traffic) noise out 2. Structural composition of dwelling can contribute to silent bedroom 3. Keep ventilation systems / windows closed to keep traffic noise out 4. Install heavy curtains or shutters in bedroom to keep (traffic) noise out 5. Install acoustically insulating panes
Limit reverberation times	1	2	3	4	5		6			<ul style="list-style-type: none"> 1. Add furniture 2. Add textile floor covering (impact on hygiene, IAQ, and wheelchair accessibility). Patterns can cause behavioural problems and falls 3. Add curtains. Certain patterns can cause behavioural problems 4. Add other items 5. Lay out of building (size of rooms) impacts reverberation times 6. Bathrooms are often tiled (ceramic tiles for hygiene). Dry-wall ceilings can be equipped acoustics panels
Need to reduce fear and stress (bathroom)					1		2	3		<ul style="list-style-type: none"> 1. Limit noise from ventilation systems in bathrooms 2. Limit noise from washing machines 3. Minimise sounds from sanitary equipment in bathrooms. Avoid whirlpools
Need for safety – Cognitive impairment							1			<ul style="list-style-type: none"> 1. Radio in bathroom may pose danger
<hr/>										

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