Ambient Light Guiding System
for the Mobility Support of Elderly People

Medical, psychological, and technological framework

Deliverable Name:	Medical, psychological, and technological framework
Deliverable Date:	30.11.2012
Classification:	Report
Authors:	Cornelia Schauber, Christoph Nedopil Markus Canazei, Guido Kempter, Markus Laner, Herbert Plischke, Tom Ulmer
Document Version:	2.0
Project Coordinator:	FHV - Fachhochschule Vorarlberg, Austria
Project Partners:	Tridonic GmbH & Co KG, Austria Bartenbach Lichtlabor GmbH, Austria myVitali AG, Switzerland apollis - Institut für Sozialforschung und Demoskopie OHG, Italy YOUSE GmbH, Germany

The project (Guiding Light) no AAL-2011-4-033 is funded under AAL JP

Preface

This document forms part of the Research Project “Ambient Light Guiding System fort he Mobility Support of Elderly People (Guiding Light)” funded by the Ambient Assisted Living Joint Programme (AAL-JP) as project number AAL 2011-4-033. The Guiding Light project will produce the following Deliverables:

D1.1 Medical, psychological, and technological framework

D2.1 Applicable hardware components

D2.2 Applicable software components

D3.1 Solution package description

D3.2 Implementation report

D4.1 Communication strategy

D4.2 Stakeholder management report

D5.1 Field test report

D6.1 Report on market analysis

D6.2 Dissemination plan

D6.3 Final business plan

D7.1 Consortium Agreement

D7.2 Periodic activity and project management report

D7.3 Final report

The Guiding Light project and its objectives are documented at the project website www.guiding-light.labs.fhv.at. More information on Guiding Light and its results can also be obtained from the project consortium:

Prof. Dr. Guido Kempter (project manager), University of Applied Sciences Vorarlberg Vorarlberg (FHV), Phone: + 43 5572 792 7300, Email: guido.kempter@fhv.at

Hermann Atz, Institute for Social Research and Opinion Polling OHG (APOLLIS), Phone: +39 0471 970115, Email: hermann.atz@apollis.it

Dr. Christoph Nedopil, YOUSE GmbH (YOUSE), Phone: +49-89-21556347, Email: christoph.nedopil@youse.de

Mag. Wilfried Pohl, Bartenbach Light Laboratory GmbH (BLL), Phone: +43-512-3338-66, Email: wilfried.pohl@bartenbach.com

Dr. Heinz Seyringer, Tridonic GmbH & Co GK (TKG), Phone: +43-5572-390-26508, Email: heinz.seyringer@zumtobel.com

Mag. Tom Ulmer, myVitali AG (MVA), Phone: +43-5574-90609-0, Email: tom.ulmer@myVitali.com

Contents

1. Introduction

The main aim of this document is to provide an overview of the medical, psychological, and technological framework of Guiding Light. The Deliverable D1.1 is the first outcome of work package (WP) 1, focusing on the consolidation and integration of research findings.

Since the design of the Guiding Light service model depends both on user needs and technical possibilities, this document presents fundamentals of age-specific user conditions and technological developments that have been collected, discussed, and refined within the project consortium. The results will determine the design of Guiding Light and the use cases of field trials planned for the next year (2013). A detailed specification of the target group and the most important stakeholders will be addressed in the upcoming stakeholder management report (D4.2).

This document is structured as followed: After presenting basic statistical facts and models about demographic changes (chapter 1.1), chapter 1.2 presents typical age-related changes of elderly people in order to understand their needs and challenges and to customize the supporting value of Guiding Light accordingly. Chapter 1.3 focuses on typical activities of daily living of seniors, thus providing a basis for assistant use cases. Possible pitfalls and rejections of the elderly towards AAL technology will be considered in chapter 1.4.

The second chapter deals with lighting conditions and requirements in people's homes, and lists standards and concept of the lighting industry. It is followed by an overview of current technological developments of software and sensor components that can be employed for our lighting wayguidance system (chapter 3).

Based on the cited secondary literature, experiences from previous projects (e.g. ALADIN) and expert interviews conducted in Germany, chapter 4 describes the basic aim of Guiding Light (chapter 4.1), and the next steps to be taken (chapter 4.2).

A bibliography has been added to the annex at the end of the document.

2. The lives of elderly people

The project "Guiding Light" aims at the development of a lighting system that enhances the mobility and orientation of elderly people, and to prepare it for market launch. Market success and a high usability of the Guiding Light system will be achieved by taking into account the needs, daily hazzles, and potential objections of the target users in this early project phase already. To this end, study results and statistical facts describing the lives of elderly people have been gathered by the consortium and will be presented in the following chapters. This information forms the basis for the specification of the Guiding Light system, as described in the last chapter of this deliverable.

2.1. Ageing: Statistics and models

Europe becomes older - this is the main trend described by the most recent Demography Report from 2010 by the European Commission and Eurostat[1]. Figure 1 reflects the actualized population pyramid from 1990 and 2010: The “baby boomers” are shifting toward the retirement age, and the oldest age group is composed mostly of females. The population age structure by major age groups from 1990 until 2060 is demonstrated in Figure 2.

Europe has a slight increase in fertility from 1.3 children per woman to approximately 1.7 children per woman with adjustments in postponed births. This is still not the needed rate of 2.1 to keep the demographic structure stable without migration. Due to the “baby boomers” of the 1960s, we will have a large portion of the population in their sixties from now until 2020.

Figure 1: The graph reflects the actualized population pyramid 1990 (blank) and 2010 (solid). The “baby boomers” are shifting toward the retirement age, and the oldest age group is composed mostly of females (EU Demography report 2010).

This is especially true for EU-Member States, such as Germany and Italy, with high-aged populations. According to estimates in 2003, the number of people in Germany who are older than 70 will increase from 10% at present to 18% by the year 2040. About 1.5 million Germans currently spend their life in elderly care homes. This number will double by 2020. Italy presently has the largest proportion of individuals over 65, representing 18% of the population, with the average age of the total population being 40 (Nehmer et al., 2006). Populations of other European states (most of the eastern EU states) will experience this steep ageing increase in approximately 20 years.

1 Demography report 2010 - Older, more numerous and diverse Europeans - European Commission, http://ec.europa.eu/social/

Figure 2: Average EU age structure by major age groups from 1990 until 2060. The younger proportion stabilizes, the working proportion shrinks, the "baby boomers" are in retirement with improving health and increasing lifespan (EU Demography report 2010).

This means a higher need for financial transfer from the younger taxpayers to the retired. If the baby boomers grow older in the 2040´s, our society will face a severe cost increase in caring for this ageing population. If we managed to equip the elderly population with technology or services that allow them to stay at home independently for a longer time, it would help to spare costs and manage the challenges of demographic change a lot better.

On the other hand, "being old" is not a homogeneous state that automatically involves losses and a need for help. According to classical geronotogical theories (e.g. Lalive d'Epinay et al, 1983), the life of an elderly individuum ranges from pre-retirement to pronounced physical and mental dependency and can be classified into four phases (see Table 1):

- **Phase 1:** The last working-phase is characterized by high independence and a lack of impairments regarding daily activities.
- **Phase 2:** During the autonomous retirement age, people can still accomplish basic and complex demands, in spite of first health problems and age-related limitations. It is usually characterized by high personal autonomy.
- **Phase 3:** Due to the increased fragility of this period, doing things and daily activities are still possible but come with many complications. Seniors in this phase tend to dependent on others in doing (complex) everyday tasks.
- **Phase 4:** Elderly people in this phase are often care-dependent, even for basic actitivites due to progressive cognitive and physical limitations.

Table 1: Four stages of old age (Lalive d'Epinay et al., 1983; adapted from Abu-Assab, 2012). Age indications are average means and may differ from person to person.

Phase	Age	Description	Characteristics
1	60-65	Last work phase/ approaching retirement	Economically active Delineation to after-working phase
2	65-75	Autonomous retirement age	Free from work Good economic/social situation High social and personal autonomy Little health problems and limitations
3	75-80	Increased fragility	Hindrances and limitations in functions Complex daily activities pose problems Frequently dependent on others Mentally healthier than physically
4	80+	Dependent retirement age	(Care-)dependent Cognitive limitations (partially dementia) Dependent in even basic daily activities

Especially elderly individuals aged 75 or older often suffer from difficulties regarding basic activities of daily living (ADL) (e.g. shopping, personal hygiene) or instrumental activities of daily living (IADL) (e.g. washing laundry or do communication by telephone). This indicates the need for adaptive living environments for elderly people in order to allow them to live independently at home some time longer. The wayfinding lighting system "Guiding Light" aims at enhancing the autonomy and mobility, and quality of life of elderly people, specifically in phase 3.

2.2. Typical impairments of the elderly

It is a widely held opinion that old age automatically comes with frailness, illness, and care-dependence. This is not necessarily the case: ageing is a normal physiological process, not an illness. However, getting older comes with physiological changes, sometimes starting as early as the mid-thirties (e.g. impairments of sight or cognitive flexibility, see sections below).

In the following sections, typical age-dependent changes or diseases will be presented, as well as studies investigating positive effects of light interventions.

2.2.1. Visual system

The visual system plays a major role in psychomotor and cognitive functions. There are different vision-related physiologic changes occur in the eye during the process of ageing.

Visual acuity. To be able to see details in the central vision (visualizing objects directly in front of the observer with about two degrees visual angle) is the most valid indicator of proper macula function. The macula is the spot of sharpest vision and consists entirely of cones. The macula is responsible for detailed vision (in photopic light situations) and colour vision during the day. Through the cornea and the lens the incoming light focuses on the macula. Visual acuity is therefore also related to refraction of the components of the optical axis, where the light passes. Low light causes the iris to open, and the sharpness of the image decreases. More light leads to a pupil constriction and improves depth of field. On the other hand, in individuals who had cataract surgery light of high intensity can also reduce visual acuity (Berler, 1983).

Visual field. The definition of the visual field is the horizontal and vertical diameter of the space seen binocularly in straight-ahead gaze. The function of the central two degree portion of the visual field is the basic identification of visible objects. In turn, the function of the peripheral part of the retina is motion detection, overview of bigger objects and the vision in dim light. The peripheral visual field has warning functions and functions for spatial orientation. Cones are mainly involved for clear and detailed vision during the day. The peripheral part of the retina contains rods and ipRGCs. As we age the visual field decreases by approx. one to three degrees per decade of life (Johnson, 1983).

Accommodation. Accommodation means the ability to focus on a point in the visual field independent of distance. While the refraction of the cornea is fixed, the lens can adjust viewing distance with the contraction of the ciliar muscle. Then the lens changes its “relaxed” shape from more convex to more flat, to visualize further objects. From around the age of 50, a normal sighted individual has a decrease in the range of accommodation that leads to problems focusing visual acuity. This so-called presbyopia has to be corrected by glasses with positive dioptric values. The lens becomes less clear and begins to scatter more light, resulting in a reduced contrast and more glaring (Glasser, 1998). Due to a progressive yellowing of the lens the older eye has a reduced ability to discriminate blue colors and loses most of its sensitivity to short wavelengths (“blue light”) (van de Kraaz, 2007).

Colour. Colour perception is a function of cones with different opsins. Opsins are receptor proteins which are embedded in special segments of the photoreceptors. The different opsins lead to specific wavelength absorption with the maximum of 430 nm for blue photoreceptive cones, 530 nm for green photoreceptive cones, and 560 nm for red photoreceptive cones. The contribution of the three cone types in combination with “switching cells” transfers the colour signal from the retina to the visual areas of the brain. Macular cone function remains relatively stable throughout life span. With more and more yellowing of the ageing lens, this can lead to a change in colour perception; such as blue appears to become more faded or “washed out” (Stuen, 2003)

Adaptation to light. Adaptation to light and dark is a function of the rods and cones. In healthy individuals adaptation of the rods in the peripheral retina to dark is completed in about 20 min. Adaptation of the cones to bright daylight takes only a few seconds. Older adults have sometimes problems seeing under low illumination. Optical changes like pupillary miosis, increased lens density and neural changes play a role in this age-related impairment. Especially age-related changes in rod-mediated dark adaptation may contribute to problems in night vision (Jackson, 1990).

Contrast sensitivity. Contrast sensitivity is created by a complex retinal process involving signal processing of many cell layers of the retina before transferring the visual signal to further brain regions. The retina extracts differences of shading and colour between objects and backgrounds. Spatial contrast sensivity to photopic levels is reduced in older adults, optic and neural changes in the eye and retina contribute to this impairment (Owsley, 1993). However, the neural changes have a lesser contribution (Burton 1993). It is necessary to pay attention to contrasts in the design of lighting spheres for elder people. Colour and light play an important role for good contrast perception for elder people.

Ocular motility and depth perception. The outer eye muscles move the eyes vertically and horizontally to be able to track and follow visual stimuli. The brain combines the two images from the separate eyes into one image (Faye, 2003). The two images creates a stereoscopic effect by binocular correlation, we call it depth perception or 3D-Vision. Normal ageing leads to a deficit in binocular correlation (Laframboise, 2006). To foster the depth perception, light can be used effectively. How light gets reflected by an object, and how the shadows create a contrast at the edges of an object, can be used to provide an effective cue for the brain. This information can determine the shape of objects and their position in space (Lipton, 1982)

Pathologic illnesses. A pathologic condition of the lens is a cataract. The previously clear lens becomes yellowish, darker and cloudy (opaque) which can lead to almost blindness in advanced state. Another common disease is Glaucoma, often called the “silent thief of sight”. Glaucoma has the origin in too much production of aqueous fluid in the anterior chamber of the eye, or from decreased ability to drain the fluid in the “Schlemm´s canal”. This leads to an increase in intraocular pressure and compression of the retina and especially of the outlet of the optic fibers (blind spot). The age related macular degeneration is a situation where the central view deteriorates due to a lesion around and in the fovea (area of the highest visual resolution). A metabolic retinal disorder is diabetic retinopathy. High blood sugar levels leads to damage in the microvcascular and macrovascular system of the whole body, but also in the retina. In a final state diabetic retinopathy can lead to retinal detachment. Here the sensory retinal layer separates from the underlying vascular layer. This leads to partial blindness in the detached regions (Francois et al. 1991).

In the normal case the eye interacts smoothly with the brain to transmit a clear image. Vision is primarily dependent on the photosensitive cells in the retina. These photoreceptors are named after their appearance in the microscopic view: rods, cones and specialized non-photosensitive switching cells or ganglion cells. In 2001, a new photoreceptor in the eye was discovered, an intrinsically photosensitive Retinal Ganglion Cell (ipRGC) (Brainard 2001, Thapan 2001). These ganglion cells have functions in modulation biological rhythms, spacial vision, and sustained pupil constriction. The pupil size decreases with age and so less light can reach the retina, which decreases other non-visual effects of light (Winn 1994).

Physiological and pathological age related changes of the eye will lead to impaired vision in elder people over time. This can be mitigated i.a. by increasing light in the surrounding of elder people. Given the above mentioned studies, the following recommendations for Guiding Light can be drawn:

- **Increase light levels.** Because less light reaches the retina of the older eye, the light levels in living environments used by older adults should generally be increased by at least two or three times over those values comfortable for younger people.
- **Minimize glare.** Although more light is required for the older eye to see better, glare should be avoided for example by using shades which are put over the light sources.
- **Increase contrast.** As contrast sensitivity decreases with age, the visibility of important objects, such as edges of stairs, ramps, and doorways, should be greatly improved by increasing their contrast with appropriate illumination, paint or similar techniques.
- **Balance light levels.** Because elderly people’s visual system cannot completely adapt to dim conditions, light levels in transitional spaces such as hallways and entrance foyers should be balanced with those of the neighboring spaces.
- **Improve color perception.** As color discrimination is poorer in older adults, high light levels and high-quality LEDs will help older adults to see colors well.

2.2.2. Sleep

Seniors often suffer from chronic sleep disturbances. The overall prevalence lies between 20-70%, as shown in Figure 3 (van Someren, 2000, in Figueiro, 2003). “In general, older adults tend to go to bed earlier and wake up at an earlier time of day than younger adults. Frequent nocturnal awakenings, difficulty falling asleep and increased number of naps taken during the day are also more common in older adults. Sleep disturbances are associated with decreased physical health, including increased cardiovascular problems, disruption of endocrine functions, and decline of immune functions” (Jensen et al., 1998 and van Cauter et al., 1998, in Figueiro, 2003).

The main types of sleeping disorders are sleep onset disorders and sleep maintenance disorders. In addition, there are sleeping disorders that are related to advanced or delayed phase sleeping patterns. In elder people, the former kind is generally predominant, leading to early awakenings. This might not cause any problems as long as the sleep duration is sufficient and the person´s lifestyle can be adapted according to his/her daily routine (Boyce, 2003).

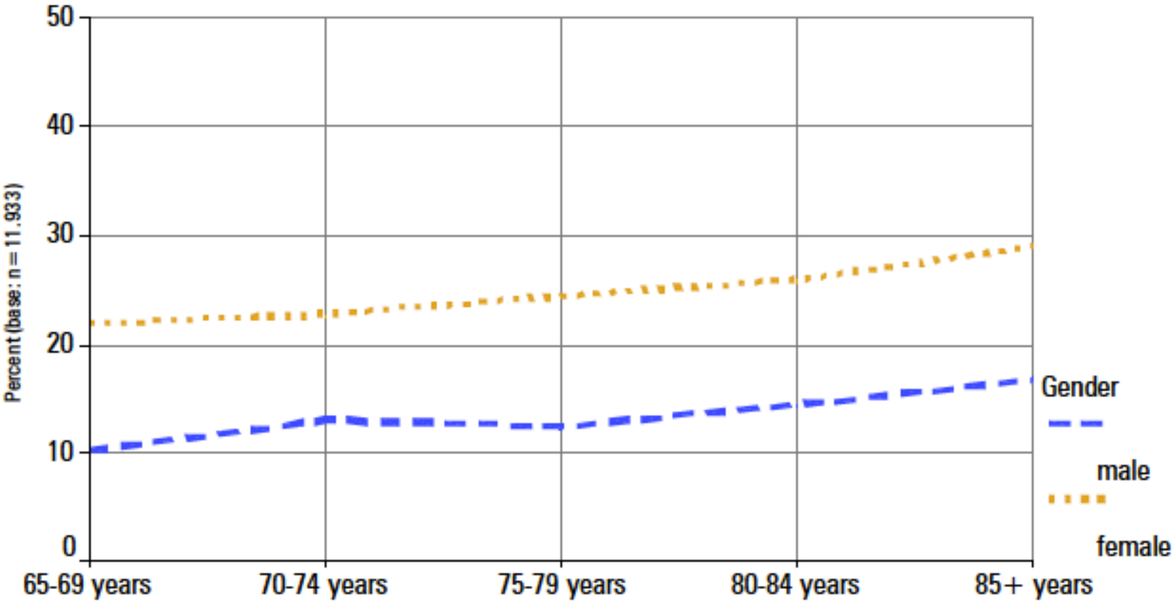


Figure 3: Percentage of individuals with sleeping problems by age group and gender (Becker, 2007)

There is a connection between light and the human rhythms. Early experiments have shown that several bodily functions are oscillating on a daily basis (Pittendrigh, 1960). Among other rhythms, sleep, body temperature, cortisol levels, melatonin and alertness fluctuate throughout the day. Scientific research in this area was boosted since the discovery of the ipRGC in 2001 (Brainard, 2001, Thapan, 2001).

The sequence of sleep and wake phases is steered by inner clocks that have a circadian rhythm which are entrained by external “Zeitgebers”. Bright daylight is the strongest entrainment factor that synchronizes the internal oscillation. The master clock of the system is located in the suprachiasmatic nucleus (SCN) that receives its input from specialized ganglion cells (ipRGC) of the retina. From the retina the light-dark information is transported via the retinohypothalamic tract to the central SCN. Just like the natural pacemaker of the heart, the

SCN has its own rhythm that is overridden by external stimuli (light, social interaction and meals) (Schmidt, 2004).

There are several physiological changes in chronobiology that are commonly seen in ageing people. The overall time of sleep is reduced and the proportion of sws-sleep (deep or slow-wave sleep) is reduced remarkably leading to a reduced ratio of REM- to NREM sleep (Schmidt, 2004).

In general, with increasing age these cycles become more and more desynchronized leading to commonly prevalent sleeping disorders that in turn deteriorate vigilance at daytime. This can be a major predisposing factor for falls (see section 1.2.4).

2.2.3. Mood

Depression is one of the most diagnosed psychiatric disorders in patients visiting general practices. The prevalence of this disorder is about 17 percent, and is the most frequent cause of emotional suffering in later life. Depression significantly decreases quality of life in older adults (Blazer, 1991).

The seasonal affective disorder (SAD) is a seasonal kind of depression that has a regular association between the onset of depression and the time of the year. Although there is also a summer form, the winter form of this disease is much more common. The symptoms of SAD are increased feelings of depression, reduced interest in activities, increased sleep and appetite with consecutive weight gain (Boyce, 2003).

Light treatment. Several causes of SAD have been postulated: disturbance of the circadian system, melatonin concentration, and serotonin regulation. Although none of them have yet been proven, the exposure with bright light (2500 to 10000 lux) has proven to be an effective treatment (Boyce et al, 2003).

2.2.4. Mobility – Falls

Mobility refers to the ability to move in one's environment with ease and without restriction. In the course of ageing, people tend to move less as depicted in Figure 4. Impairments of mobility can occur with normal ageing due to different factors. Physical limitations, for instance, can be caused by neuromuscular or musculoskeletal impairments, as well as fear of discomfort, anxiety or depression. Furthermore, an enforced rest for therapeutic reasons can also lead to mobility impairments, e.g. in the case of immobilization of a fractured bone.

- Impaired bed mobility is defined as the limitation of independent movement from one bed position to another.
- Impaired physical mobility is defined as the state in which an individual has a limitation in independent, purposeful physical movement of the body or of one or more extremities.

Webber (2010) describes the key determinants of mobility in a broader sense as “cognitive, psychosocial, physical, environmental, and financial topics. Cognitive determinants are factors such as mental status, memory, speed of processing, and executive functions. Psychosocial determinants include self-efficacy, coping behaviors, depression, fear, and relationships with others that affect interest and/or motivation to be mobile. Speed of information processing and visual attention are important for safe driving. However, an individual with low self-efficacy beliefs may not even attempt to be mobile beyond the home, despite his or her actual driving or walking capabilities. Older individuals also sometimes self-restrict mobility due to depression or in response to opinions voiced by friends, family, and physicians. Older adults who have had a previous fall, as well as those who have never fallen, may demonstrate fear of falling to the degree that it may interfere with mobility choices. Diagnoses such as mild cognitive impairment and dementia also have the potential to seriously challenge mobility outside the home. Problems related to driving safety, wandering, and getting lost (in vehicle and on foot) are common."

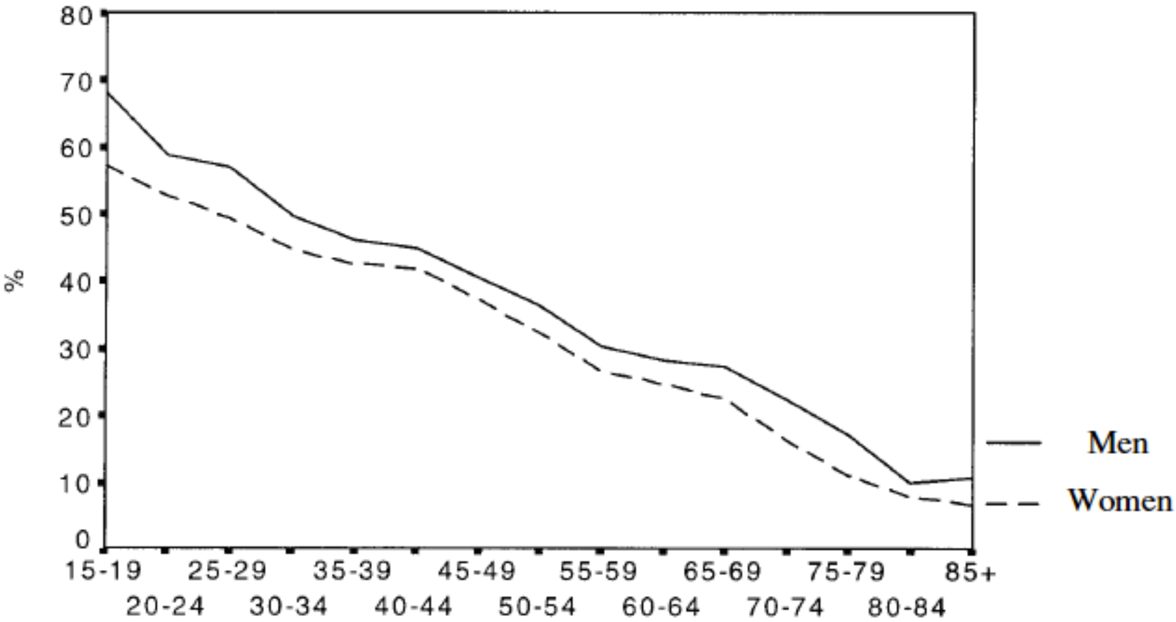


Figure 4: Percentage of participants in sports and physical training activities in Switzerland (1988), by age group and gender (adapted from Lalive d'Epinay et al., 2001)

One of the most important risk factors among elder people for impaired mobility are falls. In general, balance and gait disorders are important risk factors for (injurious) falls in elderly cohorts (Vellas, 1997). Furthermore, vision impairments, symptoms of depression, slower comfortable walking speed, poorer score on the "Timed Up & Go"-test, multimorbidity, poor cognition and hypertension have also been proven to be independent risk factors for indoor falls (Berglang, 2003).

There are several reasons why sleep problems can also contribute to an increased rate of falls among older persons. People with sleep disorders tend to have more opportunities to get out of bed during the day-night cycle because they are more active at night. This is mainly caused by a higher frequency of going to the restroom as the sleep is less deep. What adds to this is that due to sleep problems elder people tend to be more sleepy and less alert during the daytime. This can result in lower cognition, memory disorders, lower concentration and prolonged reaction time, all of which are predisposing factors to cause falls.

These effects can even be aggravated by physicians prescribing hypnotics to elder people suffering from insomnia. Due to the side effects (somnolence, ataxia, slowing of walking speed and diminished stride) this can contribute to a considerable amount of falls with an iatrogenic etiology (Kawamoto, 2002).

Among the worst of the consequences of a fall is the fracture of the neck of the femur, which results in the patient to become bedridden for an extended period of time. This is often associated with serious comorbidities like pneumonia, pulmonary embolism and stroke and can seriously deteriorate the condition of the patient. The incident of this kind of fracture amounts to a number of more than 250.000 per year in the USA. In comparison to that an overall number of 95.000 deaths a year are attributed to falling (Goggin, 1999, in Figueiro, 2006).

Falls have a large socioeconomic impact. This is due to the enormous medical care costs and the need for more extensive care in the wake of such an event. Approximately 10-20 percent of people between 65 and 79 years and 30-40 percent of people over 80 years have at least one fall in a year (Yasumura, 1992, in Kawamoto, 2002).

With assistive systems, e.g. for bright light therapy, sleep disorders especially for demented nursing home patients can be diminished (Fetveit, 2003) and mobility during the day can be improved.

2.2.5. Mental functions – Memory

Ageing is a condition that is inevitable, and the brain starts shrinking already at the age of 25 (Rushton, 2009). But still, there is a chance to keep functions stable, and shrinking does not mean that all functions are necessarily declining. However, at the age of 75, 11-17% of the elderly people suffer from moderate to severe memory impairments (see Figure 5).

If we look at the process of memory decline in more detail, cognition can be divided into two components: a fluid mechanic component and a crystallized pragmatic component (see Catell, 1971; Baltes, 1998). The lifespan trajectories of these components are quite different (see Figure 6):

- The mechanic component represents “fluid intelligence” in terms of basic information processing ability. According to this model, this ability begins to decline at the age of 25.
- However, the pragmatic or “crystallized intelligence” remains the same, or even increases with age. It represents the “cultural knowledge” or “life experience” in an occupational context.

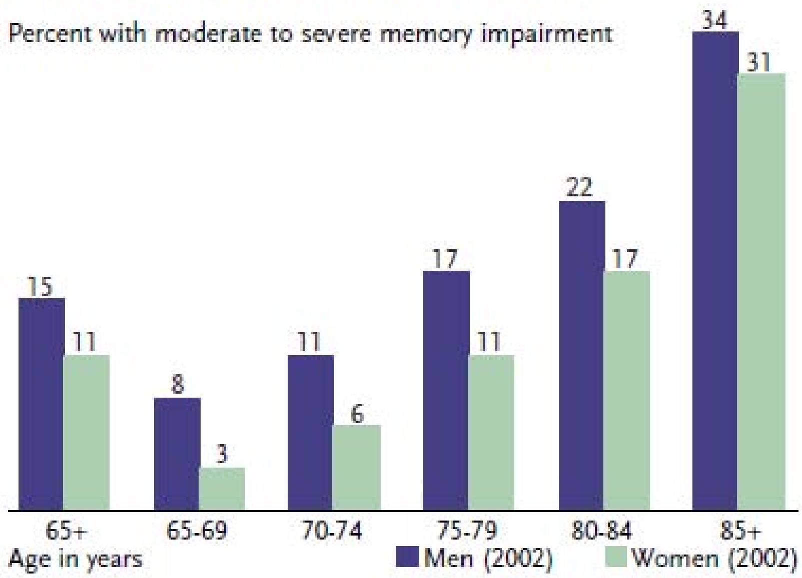


Figure 5: Memory impairment in the age group 65+. Even with the age of 85+, two-thirds of the people suffer from only mild or no memory impairment

Brain jogging and mental activity in general are good preventive agents to slow the decline in "fluidic" brain functions while ageing, and also keeps the "crystalline" information active. Training of cognitive functions has proven to counteract the degree of long-term cognitive decline among older healthy people. The results of a large scale study (2,802 participants aged 65 and older) showed significant improvements in memory, reasoning and information-processing speed after brain-training over five weeks for about 2½ hours per week (Ball, 2002).

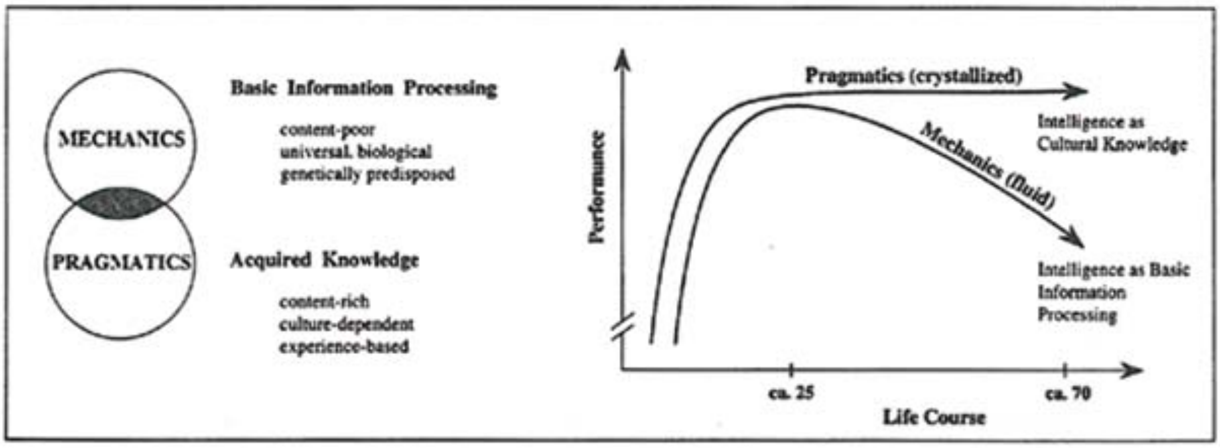


Figure 6: Illustration of the postulated components of cognition. One component is named "Mechanics" which is "fluid" and represents basic information processing, and decreases with age. The other component is named "Pragmatics", which is "crystallized", and represents one`s experience, and stays unchanged or even increases while ageing (Picture from Baltes et al., 1999).

The plasticity of the brain also helps to preserve cognitive functions in older adults. They use much more areas of the brain than younger adults. Thus, an ageing brain can compensate for a possible loss in neuronal function (Dolcos et al., 2002).

Light effects. There has been a lot of research to illuminate the relationship between different lighting conditions on the one hand, and cognitive performance or alertness on the other. Küller and Wetterberg (1996, in: van Bommel, 2003) for example examined the brain-wave patterns (EEG) of people working in office environments with high (1700 lux) and low lighting levels (450 lux). As a result, ECG patterns significantly differed: There were fewer delta waves in higher lighting level environments, indicating less sleepiness of the subjects (van Bommel, 2003).

2.2.6. Dementia and Alzheimer's disease

In healthy elder adults, losing mental functions is not that big of a problem until the age of 85 or above. In contrast, dementia before very old age is a degenerative disease, and Alzheimer's disease is the most common cause of dementia. Other pathologic forms of dementia (e.g. Morbus Pick or frontal lobe dementia) can start even before a person has reached their 40s (Heston, 1982). In the beginning, the patients become more and more oblivious of recent events or familiar tasks. As the disease progresses, the memory loss reaches a more comprehensive extent, associated with changes in personality and deterioration in communication.

Through both, the visual system and the circadian system, lighting can influence the constraints of people with Alzheimer's disease. Due to a cell loss at both retinal and cortical levels, Alzheimer patients show reduced contrast sensitivity. Like in a vicious circle the cognitive losses can then be aggravated by reduced visual capabilities in the long run (Boyce et al., 2003).

Regarding the circadian cycles, patients with Alzheimer's disease have often a very deregulated day-night rhythm. This often poses substantial difficulties to caretakers and will lead to earlier institutionalization. The anatomic evidence of this is to be seen in a degeneration of the suprachiasmatic nucleus (SCN) of such patients. Moreover, they are rarely exposed to bright light outdoors as they often need constant supervision.

Light effects. Research conducted by the Lighting Research Center (LRC) in New York, USA, examined the effect of blue light treatment in persons with Alzheimer's disease in a senior healthcare facility. The question was whether this is feasible to improve sleep efficiency and consolidate sleep at night. The residents were treated with blue light from light emitting diodes (LEDs) with a maximum wavelength of 470nm. The exposition took place in sessions lasting two hours (6-8 pm) before the residents went to their bedrooms. The result of the study showed that the exposure to blue light significantly increased the efficiency of nighttime sleep – a result, that can also be transferred to older adults without Alzheimer's disease (Figueiro, 2005).

It is therefor recommended to expose Alzheimer's patients to bright light during the day and as little light as possible at night. By increasing entrainment with light rest-activity patterns become more stable (Boyce et al, 2003). This is especially relevant to caregivers who have to cope with the burden of Alzheimer patients with very fragmented sleep patterns.

2.3. Daily routines

The idea of Guiding Light is to support elderly people with their everyday activities by an intelligent light system. So, what do seniors typically do during their days – and when do they experience difficulties that could probably be reduced by lighting interventions?

One fundamental factor structuring the day of humans is our biological rhythm orchestrating sleep, activity levels, or body temperature. It is controlled by the suprachiasmatic nucleus (SCN), located in the hypothalamus of the brain and acting as an internal pacemaker. While this biological rhythm follows an approximately 25 hours interval, it is influenced by external "Zeitgeber" like light, social interactions, bodily activity, pharmacological manipulation – and alarm clocks (Aschoff, 1965).

Apart from biological regularities, there are two types of data that give an insight into elderly people's everyday lives: lists with activities of daily living (ADL's) on the one hand, and time use surveys on the other. Findings from these two sources will be presented in the following sections.

2.3.1. Activites of Daily Living

Activities of daily living (ADL's) origin from holistic care models from the 1960s and are based on Maslow's motivation theory (1943). They describe repeating human activities aiming at the fulfilment of a wide range of basic physiological and psychological needs, which might cause difficulties at older age or illness. ADL's are usually acquired as lists of activities (e.g. eating, drinking, dressing/undressing) with grades of autonomy levels for each. ADL lists can be used for diagnosis of care dependency, or for the planning or evaluation of care measures. The Barthel index, as a common example of an ADL-list, is depicted in Table 2. It was originally developed to assess the severity of disability regarding personal care and mobility of stroke patients (Mahoney & Barthel, 1965). Scores are obtained using direct observation, self-report, or responses from family/friends.

Table 2: Criteria list from the Barthel index (Mahoney & Barthel, 1965). Total scores are calculated by summing the individual item scores and range from 0 (dependence) to 100 (independence).

Item	Scoring
Bathing Grooming Feeding	0=dependent 5=independent
Dressing Toilet use Ascend/descend stairs	0=dependent 5=needs help 10=independent
Bowel management Bladder management	0=dependent 5=occasional accident 10=independent
Bed/wheelchair transfer	0=unable 5=major help needed 10= minor help 15=independent
Mobility (level surface)	0=unable 5=wheelchair >50yards 10=walks >50 yards 15=independent

Other screening instruments focus on different types of activities that are necessary for indipendent functioning in the community referred to as instrumental acitivites of daily living (IADL's). They include tasks like meal preparation, cleaning, doing the laundry, shopping, or using the telephone. IADL's can be assessed by the Lawton-Brody scale (Lawton & Brody, 1969), presented in Figure 7. The exact score given for each functioning stage can vary from version to version.

ABILITY TO USE TELEPHONE
3 Operates telephone on own initiative; looks up and dials numbers, etc.
2 Dials a few well known numbers
1 Answers telephone but does not dial
0 Does not use telephone at all

SHOPPING
3 Takes care of all shopping needs independently
2 Shops independently for small purchases
1 Needs to be accompanied on any shopping trip
0 Needs to have meals prepared and served

FOOD PREPARATION
3 Plans, prepares and serves adequate meals independently
2 Prepares adequate meals if supplied with ingredients
1 Heats and serves prepared meals, or prepares meals but does not maintain adequate diet
0 Needs to have meals prepared and served

HOUSEKEEPING
4 Maintains house alone or with occasional assistance (e.g., heavy-work domestic help)
3 Performs light daily tasks such as dish-washing and bed-making
2 Performs light daily tasks but cannot maintain acceptable level of cleanliness
1 Needs help with all home maintenance tasks
0 Does not participate in any housekeeping tasks

LAUNDRY
2 Does personal laundry completely
1 Launders small items; rinses socks, stockings, etc.
0 All laundry must be done by others

MODE OF TRANSPORTATION
4 Travels independently on public transportation or drives own car
3 Arranges own travel via taxi, but does not otherwise use public transportation
2 Travels on public transportation when assisted or accompanied by another
1 Travel limited to taxi or automobile, with assistance of another
0 Does not travel at all

RESPONSIBILITY FOR OWN MEDICATION
2 Is responsible for taking medication in correct dosages at correct time
1 Takes responsibility if medication is prepared in advance in separate dosages
0 Is not capable of dispensing own medication

ABILITY TO HANDLE FINANCES
2 Manages financial matters independently (budgets, write checks, pays rent and bills, goes to Bank) collects and keeps track of income
1 Manages day-to-day purchases, but needs help with banking, major purchases, etc.
0 Incapable of handling money

*Figure 7***:** *Lawton-Brody Instrumental Activities of Daily Living (IADL) Scale. The patient receives a score for each item. The total score may range from 0 – 23. A lower score indicates a higher level of dependence.*

Not only individuals suffering from dementia, but also healthy elderly people usually experience difficulties in coping with these activities, as can be seen in Table 3.

Table 3: Difficulties with IADL's of healthy controls versus patients suffering from different stages of dementia (Study "Möglichkeiten und Grenzen selbstständiger Lebensführung in privaten Haushalten - MUG III, 2005)[2].

IADL difficulties (%)	No dementia	Mild dementia	Medium dementia	Severe dementia
Shopping				
With difficulties	31,0	12,1	5,9	-
impossible	50,3	87,9	94,1	100,0
Housekeeping				
With difficulties	25,3	15,2	2,0	-
impossible	53,2	83,3	98,0	100,0
Finances				
With difficulties	22,1	18,2	-	-
impossible	30,5	77,3	100,0	100,0
Medication				
With difficulties	11,8	9,1	2,0	-
impossible	33,3	74,2	94,1	100,0
Telephone				
With difficulties	10,3	28,8	27,5	15,2
impossible	9,7	21,1	58,8	81,8

2.3.2. Time use surveys

Time Use Surveys are another interesting source to learn about people's common occupations. They gather the amount of time people spend doing various activities, such as paid work, childcare, volunteering, and socializing. As the complete 24-hour day is covered, time use surveys also provide information on a wide variety of other subjects. These may be topics as different as the time use of elderly people, the use of means of transport etc. and mobility or working time arrangements.

For instance, the American Time Use Survey (ATUS) provides nationally representative estimates of how, where, and with whom Americans spend their time. Data files include information collected from over 124,000 interviews conducted from 2003 to 2011. Focussing on elderly people aged 55 or above, it can be seen that there is a constant increase in leisure and sleeping time as people get older (see Figure 8). Interestingly, seniors aged 65 or more living without a spouse usually spent 10 hours per day alone (Figure 9).

2 http://www.bmfsfj.de/doku/Publikationen/mug/abschnitt-1-einfuehrung.html

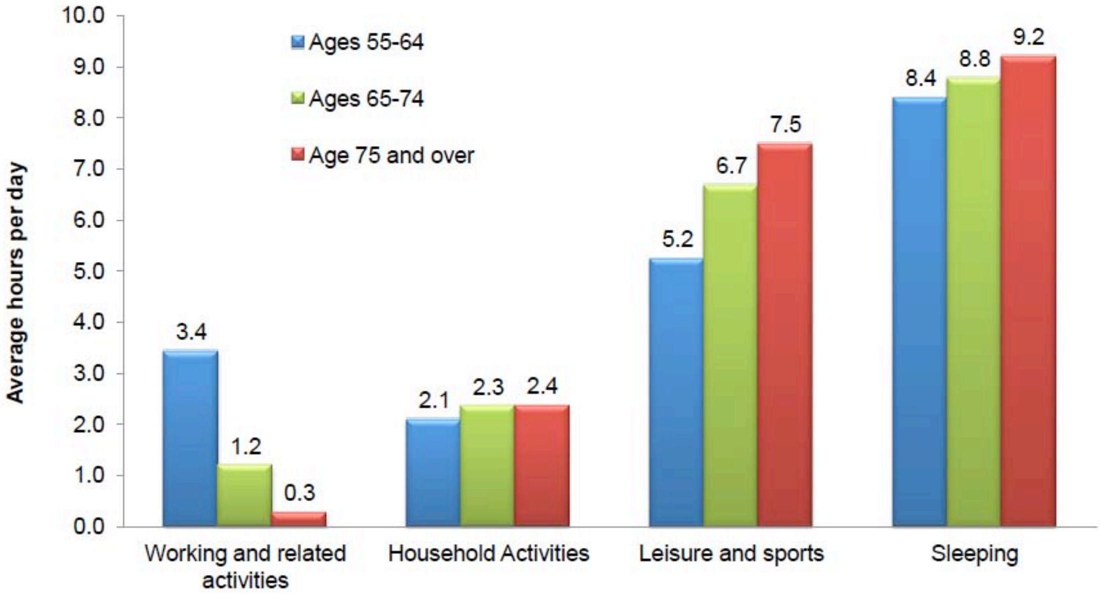


Figure 8: Hours per day that individuals age 55 and over spent doing selected activities (SOURCE: Bureau of Labor Statistics, American Time Use Survey)

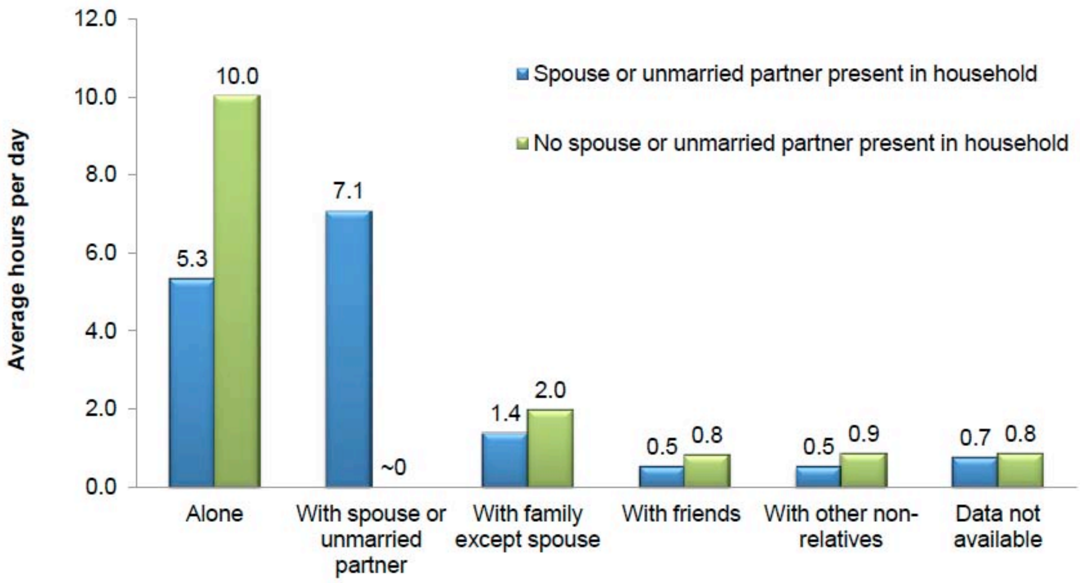


Figure 9: Hours per day of waking, non-work time that individuals age 65 and over spent with others (SOURCE: Bureau of Labor Statistics, American Time Use Survey)

Regarding European data, the German research project „Sentha“ (standing for “Everyday Technology for Senior Households”) can be drawn, funded by the German Research Society (DFG). Its goal was to develop products and services for a continuously ageing society so that older people can maintain their independence in everyday life for as long as possible. The project published studies about selected aspects of old age. Among these are also studies concerning the *popularity* of everyday activities (see Figure 10 and Figure 11). It can be seen that the popularity of activities like computer usage, visiting senior centers, or doing sports considerably differs within the subgroups of seniors.

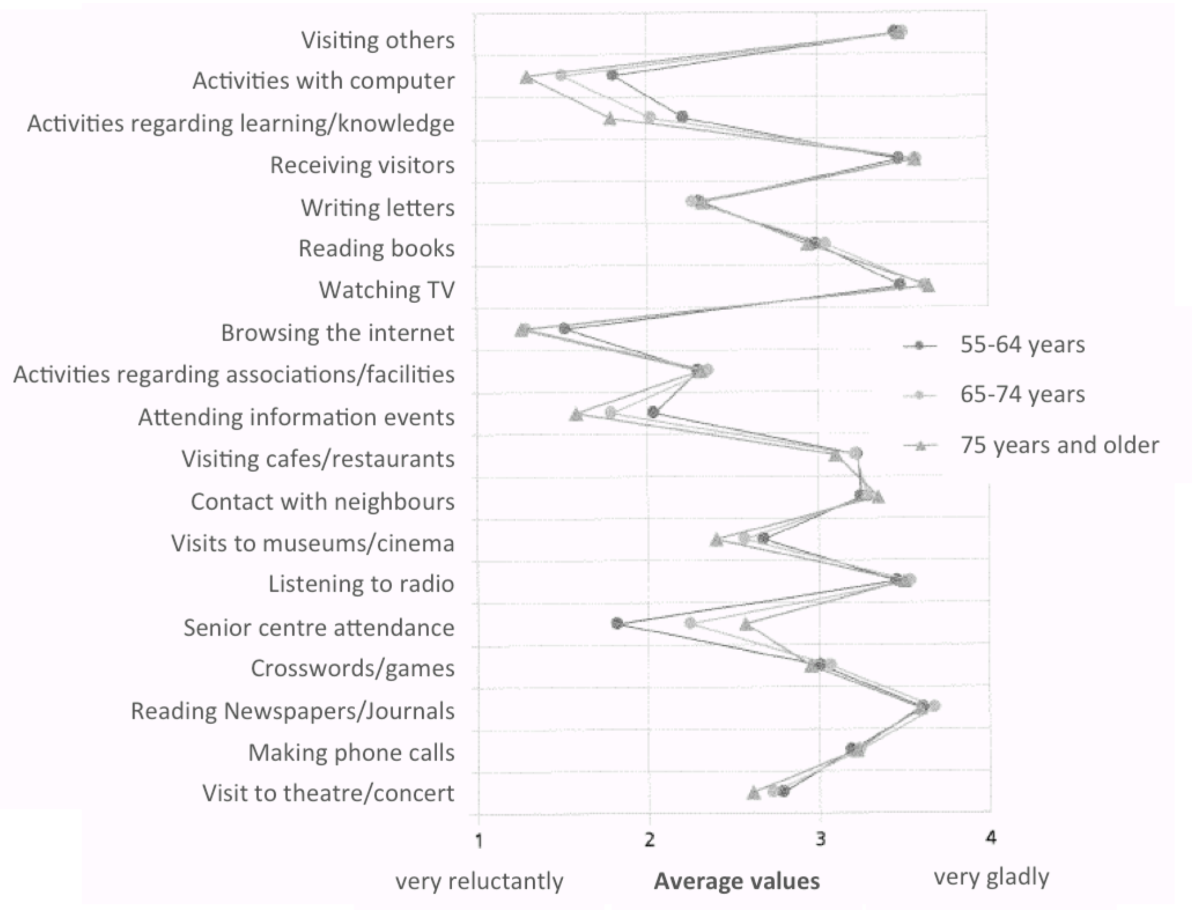


Figure 10: Average popularity values of everyday activities from German seniors aged 55 and more (Sentha study, 2007)

Figure 11: Popularity of health and hygiene related activities from German seniors aged 55 and more (Sentha study, 2007)

All of these activities were taken as a basis to figure out which of them typically lead to difficulties for elderly people regarding their mobility and autonomy at home, and as a starting point for the interventions of the Guiding Light system (see chapter 4.1).

2.4. Attitude towards AAL technology

Ambient assistant living (AAL) systems support handicapped and elderly people to stay independently in their homes, at work, or „on the road" for longer. Developing AAL technology is a corner stone of EU and national funding in order to cope with the demographic changes. However, market success of such system highly depends on the attitude of the users towards AAL systems and should thus be taken into account.

Generally speaking, attitudes towards AAL or technology in general depend on beliefs and values that older people have achieved during their lifetime (Pancer et al., 1992; Gardner et al., 1993). It is often assumed that seniors are rather reluctant to use modern technology – but this is only half the truth. Although elderly users accept new technology less than their younger counterparts (Hertzog & Bleckley, 2001), they are motivated to use it once they are sure that the benefits clearly outweigh the effort of learning or accepting something new (Melenhorst et al., 2006). Furthermore, it has been found that elderly people often lack trust in their own technological capabilities, leading to a rejection of new technology (Lines & Hone, 2004; cited from Holzinger et al, 2007).

Results oft he Garnmarkt study (Fredersdorf & Feuerstein, 2011), based on a survey of 3,606 seniors aged 55 or above, revealed the following preferences regarding living in the old age and technology support:

- 67% prefer to stay in their flat/house and to recieve help from relatives or professional care services.
- 17,6% actually need support with housekeeping by relatives, domestic aid, neigbours, or friends
- 27,3% would use latest technology aids in order to compensate for mobility impariments in older age. Support by relatives ore care service is rated higher, moving to a retirement home rated worse than technical facilities.
- Senior-focused technology aids range at the sixth place of reasons for moving to a board and care home.
- 58% of the respondents would use a system switching the light on when leaving the bed.

Attitudes towards different types of AAL interventions (Figure 12) and sensor usage (Figure 13) are shown below. It can be seen that almost half oft he interviewed seniors agree to have their biodata recorded continuously.

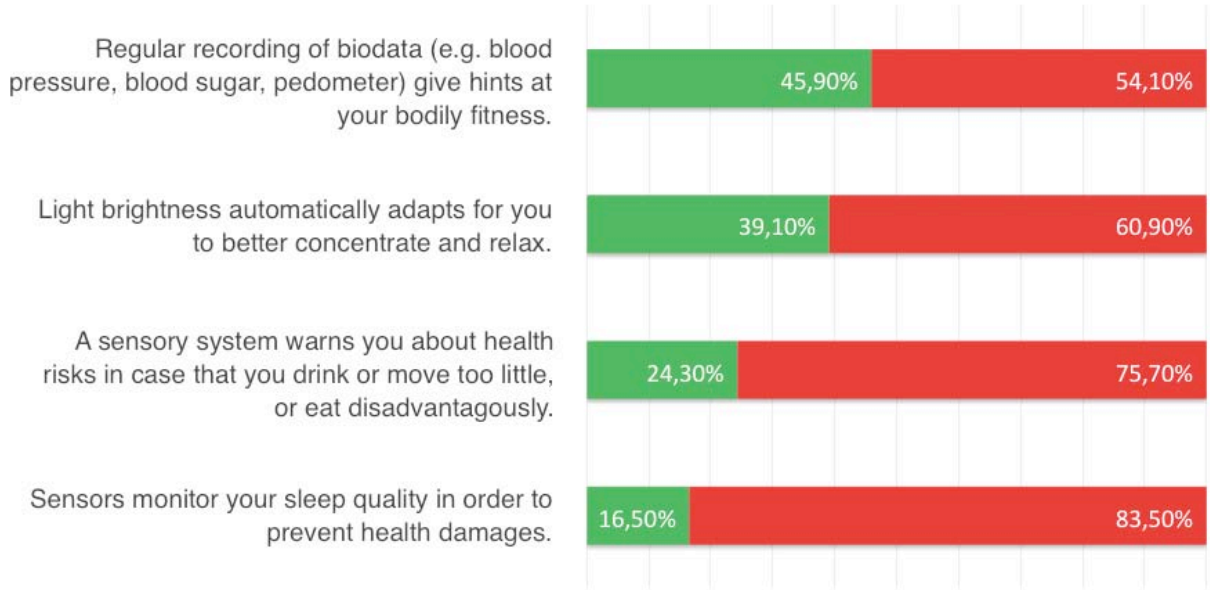


Figure 12: Percentage of Austrian individuals aged 50 and more agreeing (green) and disagreeing (red) with statements regarding the usage of AAL interventions (Fredersdorf & Feuerstein, 2011)

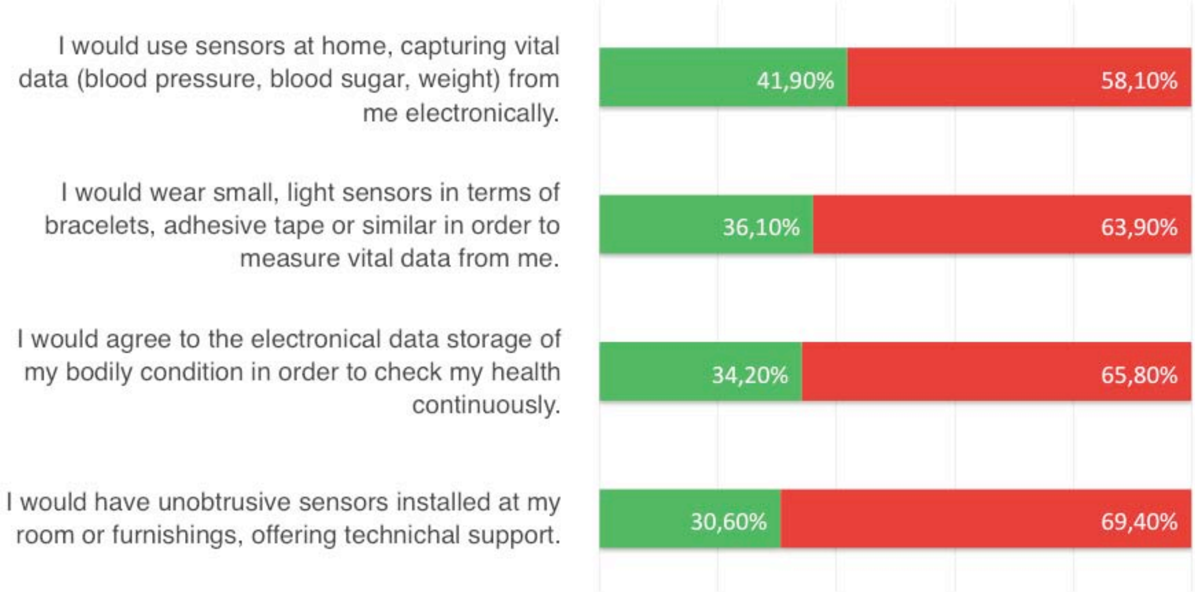


Figure 13: Percentage of Austrian individuals aged 50 and more agreeing (green) and disagreeing (red) with statements regarding the usage of AAL sensor systems (Fredersdorf & Feuerstein, 2011)

In the Guiding Light project, possible fears or objections of senior users will be treated with great care during the development process. In addition, the usability of the system as well as the light interventions will be developed in close cooperation with test persons and important stakeholders.

3. Lighting Requirements

Lighting conditions in private homes

Whether seniors continue living in their own homes, or move to an apartment or retirement community, lighting is going to become an ever more important part of everyday life. It will add to comfort and enjoyment and it will help keep seniors safe and more mobile.

Currently private homes of elderly people…

… are mainly lit by daylight during the day with unevenly distributed light levels indoors (e.g. high light levels near the windows and low light levels in the back).

… are illuminated with artificial lighting systems in areas and rooms with a lack of daylight or for task lighting which often are not used during day- and nighttimes or provide an illumination which doesn't fulfill basic physiological lighting requirement of elderly people (e.g. glare-free higher illuminance levels).

Several studies (Aarts, 2005; Higgins, 2010; Sinoo, 2011) could reveal that **illuminance levels** within working areas in private homes (e.g. bathroom, bedroom and kitchen) are far below 500 lux, which is recommended for younger person at work places. In the course of the EU-funded project "Aladin - ambient lighting assistance for an ageing population" mean horizontal illuminance levels of 113 lux in the working areas were measured (Becker, 2007). These light levels are representative for private homes in general.

In addition, Aarts et al. (2005) assessed light conditions in Dutch care homes and homes for older people. They found that conditions are too poor for proper vision. Similar results have been found and reported in the literature, for instance, in the United States by Hegde et al. (2010) and Bakker et al. (2004), and in Belgium by De Lepeleire et al. (2007).

On the other hand, **transit areas** of private homes of elderly people are illuminated poorly, too. For instance Aarts et al. (2005) reported that mean illuminance levels in transit areas nearby the windows, in the middle of the rooms and in the back did not exceed 28 lux (see Figure 14).

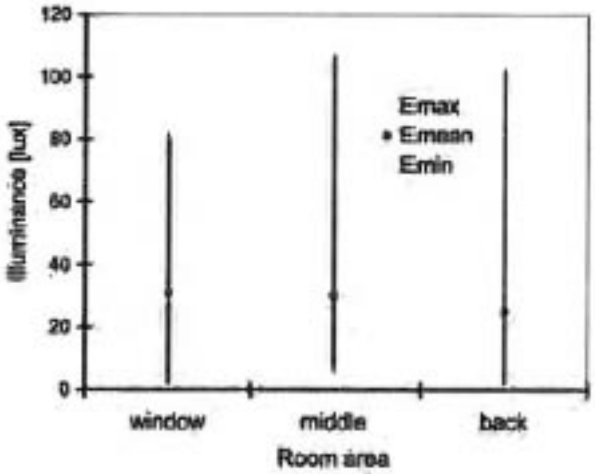


Figure 14: Mean illuminance levels in transit areas (Aarts, 2005)

Again, this light level is far below the recommendations formulated in European lighting standards for the working younger population.

As mention before, during the day **daylight** is the main light source in private homes. Normally, artificial light is used in rooms with a lack of daylight during the day (e.g. toilet, storage room), for task lighting purposes and generally during the night. Due to economic reasons and an increased glare sensitivity, artificial light isn´t used in many cases (e.g. for navigation to the toilet during the night – see Aarts, 2005) although it is needed for proper visual perception and a safe indoor navigation.

As a consequence, great differences in illuminance levels, i.e. **brightness inhomogeneity**, can often be found when travelling through different rooms. Due to impaired lightness adaptation capabilities of elderly people, visual perception while passing through this inhomogeneous lit areas is heavily disturbed. High brightness uniformity (i.e. minor differences in maxima and minima levels of illuminance and luminance) over all indoor areas is necessary to create a safe environment and helps to prevent falling.

The dominant **lamp color temperature** in private homes is warm white with a color temperature between 2700 Kelvin and 3000 Kelvin. Other white light colors (e.g. light sources with a higher amount of short wavelengths) are used seldom. Up to now traditional light sources (incandescent and halogen lamps) and new energy-efficient light technology (compact fluorescent lamps) are widely applied, although the acceptance of compact fluorescent lamps is low due to limited light quality and a noticeable reduced light output when switched on. Measurement of the lighting condition during the day (Sinoo et al. 2011) revealed a color temperature between 3300K and 4500K in seven Dutch nursing homes. These recorded color temperatures (see Figure 15) are a mixture of the prevailing daylight and artificial light and were measured at eye level in areas with different distances to the windows.

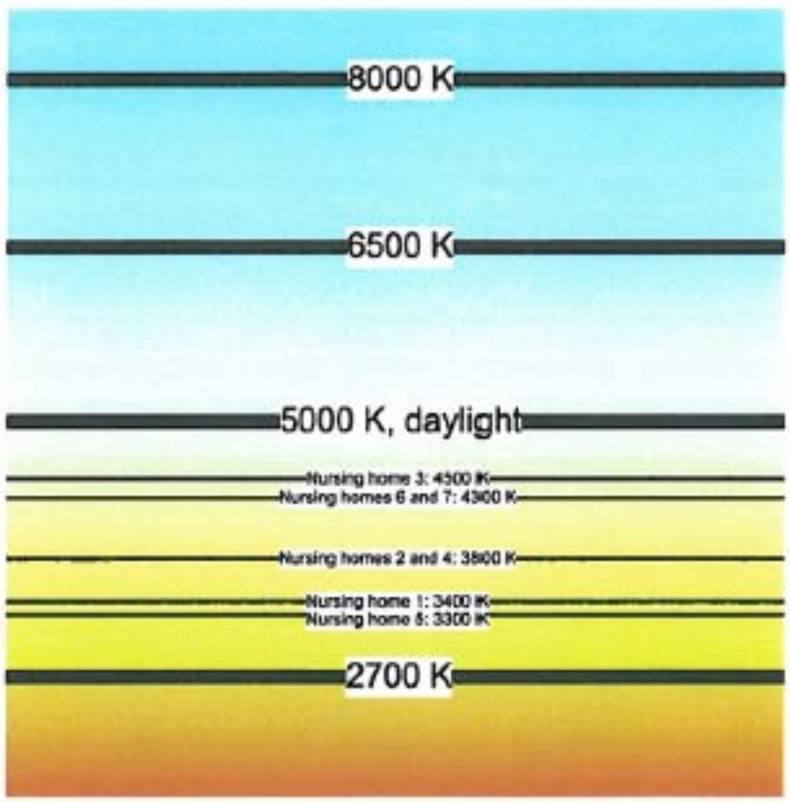


Figure 15: Median of light colors measured in seven nursing homes (Sinoo et al., 2011)

LED technology has not yet entered the private homes in a wider range. But it is foreseeable that this new and highly efficient light technology will strongly enter the market for private lighting within the next years, because of law restrictions[3] and the increasing efforts of the LED lighting industry to reduce prices and offer retrofitting technology.

In private homes, only very simple **lighting control systems** (i.e. dimming light intensity) can be found in rare cases. The main light control devices are on/off switches.

For task lighting purposes (see Fig.3), a lot of elderly people are working under luminaries applied to the ceiling (85%) or under hanging luminaries (49%).

Aarts et al. (2005) reported that hanging lamps or luminaries applied to the ceiling with narrow beam light emission are preferably used for task lighting. However, in average only 60-70% of elderly people living in private homes had one of these luminaries in their household. As a consequence, tasks with higher visual requirements spread over the whole household (e.g. area for meal preparation, for shaving or washing the face or for dressing) are illuminated inadequately.

3 The restrictions of the EU (The European Union's Ecodesign Directive (Directive 2005/32/EG), totally ban of incandescent bulbs by 2016) will push the LEDs also into a wider range of application in private homes.

	Tradi-tional	Hang-ing	Up	Ceiling	Direct	Cove
Average number per household	2.9	0.7	1.0	0.5	0.6	0.2
Use it as task lighting [%]	9	49	29	0	85	23

Figure 16: Light sources present in private homes (Aarts, 2005)

It is very astonishing that elderly all over Europe do not recognize their illumination at home as a great problem (Becker, 2007). For instance, noise from outside, pollution or high indoor temperature in summer are commonly named as more imported problems experienced at home (Figure 17).

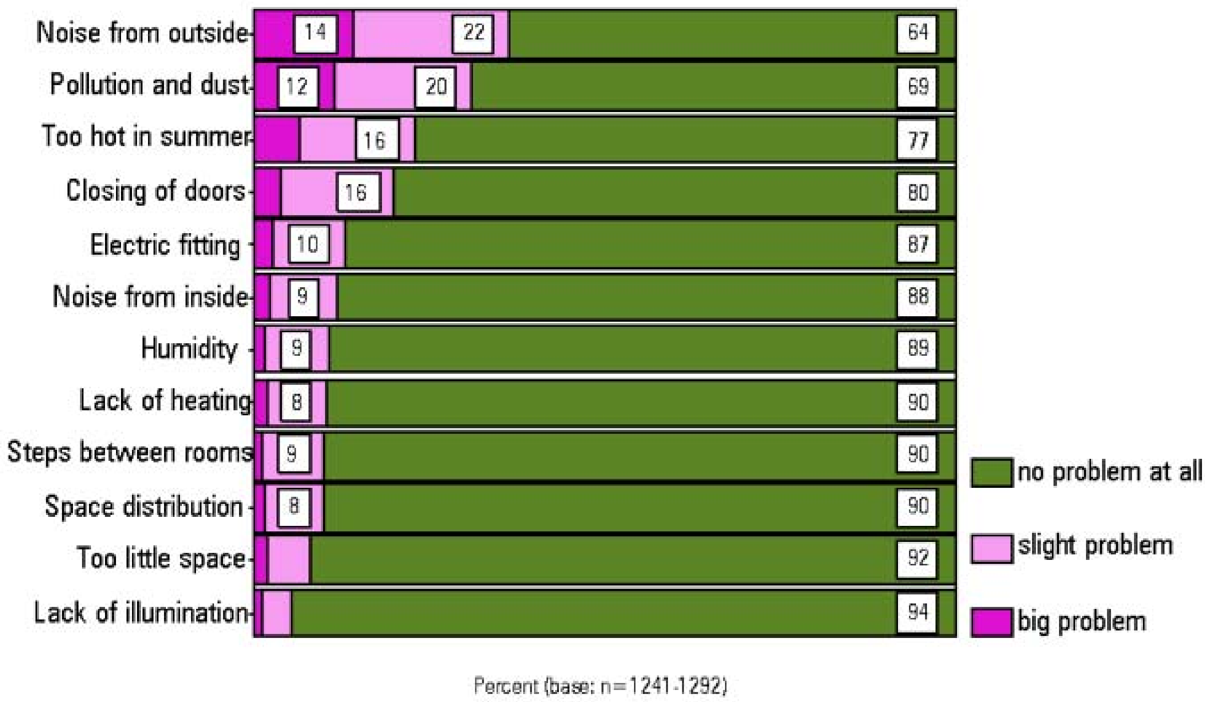


Figure 17: Problems with housing, named by interviewed senior citizens (Becker, 2007)

In addition, within the before mentioned project "Aladin", more than half of the 196 subjects evaluated in the course of a first investigation were convinced that they had enough artificial light, while only seven percent disapproved of their lamps (Becker, 2007).

Finally, field studies clearly demonstrate that exposure to bright light is limited although bright light is needed to synchronize circadian wake-sleep rhythms, improve mood, cognition and sleep quality in the aged. Aarts et al. (2005) reported 19 minutes of light exposure of 1000 lux or more at eye level within a Dutch elderly population living in their private homes.

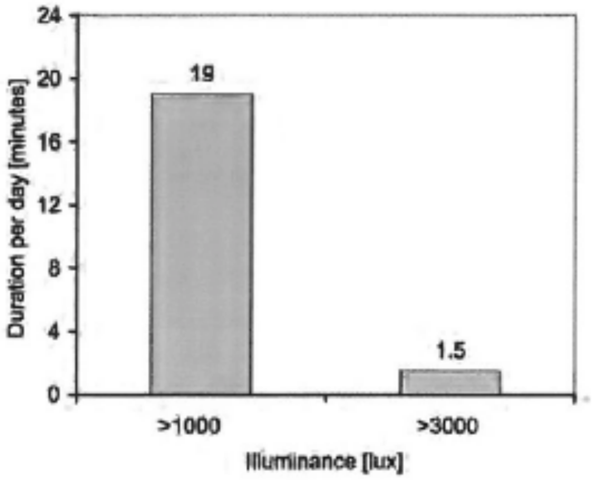


Figure 18: Average daily duration of light exposure of 1000 lux or more (Aarts, 2005)

Field studies in the sunniest part of America reported similar bright light exposure durations. Espiritu et al. (1994) and Savides et al. (1986) measured 59 minutes and 29 minutes of daily light exposure duration over 2000 lux of elderly people between 55 to 81 years and of people with Alzheimer´s dementia living in old people´s home. Campell et al. (1988) recorded daily light exposure duration of 1000 lux or more in old people´s homes of 9 minutes of elderly with beginning Alzheimer´s dementia and of only 1 minute of adult people with severe Alzheimer´s dementia.

Higgins et al. (2010) reported very low levels of light in the home environment of elderly (with light exposure smaller than 20 lux nearly all over the day) considerably less than reported in a study of Martin et al. (2008) with daytime bright light exposure (>1000 lux at eye level) of 48 minutes and 30 minutes, respectively. Finally Mishima et al. (2001) found out that in ten nursing homes, residents received an average of daily 15 minutes of bright light under standard lighting conditions. These low light levels are not able to induce non-visual light impacts.

Summarizing the current lighting condition in private homes, one can state that in general the lighting levels measured in the residences of independently-living elderly people are not adjusted to their reduced retinal levels. Although the daylight conditions are acceptable near the window, it is not enough once you enter further into the room. The artificial light necessary to perform visual tasks is not adjusted to the older eye, either. The fact that most of the interviewed participants did not turn on the light when getting out of bed during the night, in combination with the badly illuminated circulation area in the home, can lead to dangerous situations and shows how unaware elderly people are of the benefit from better illuminance.

The following chapter will try to define what “better immulimance” might mean in concrete terms. To this end, recommendations from standards (2.2) and common procedures (2.3) of the lighting industry will be presented.

3.1. Lighting Standards

Since the 1990, efforts have been carried out to accomplish a joint European illumination standard for functional lighting at work places. With the first release of the **EN 12464-1 "Light and Lighting – Lighting of work places"** a framework for illumination engineers and light planners was given on an European level but depending on the special application and nationality also different national standards have to be taken into account.

Generally spoken, depending on indoor areas, tasks and activities (e.g. general areas inside buildings, industrial activities, educational or health care premises) minimum lighting requirements are given within this lighting standard in the following form:

- minimum level of the **average illuminance** within the work place,
- minimum level of **brightness uniformity** (given by the value g which is the ratio between minimum to average illuminance levels within working areas)
- maximum level of **discomfort glare** (specified with the unified glare rating method) and
- minimum level of **color rendering** (specified with the color rendering index).

Additionally, other lighting aspects like maintenance factor or a minimum indoor daylight level are described for all work places.

Another lighting pre-standard which will become relevant in the near future is **DIN 5031-100 "Optical radiation physics and illuminating engineering - Part 100: Photobiologically effective radiation, quantities, symbols and actions"**. Within this pre-standard so-called melanopic (non-visual, biological or circadian) light effects are described and a calculation procedure of these effects is introduced for the first time.

The **IESNA RP-28-98: *Lighting and the Visual Environment for Senior Living*** was first developed in 1998 by the Lighting for Ageing and Partially Sighted Committee of the IESNA - the Illuminating Engineering Society of North America. IESNA is the recognized authority to set light levels in the United States, Canada and Mexico. The document was adopted in 2001 by the American National Standards Institute (ANSI) making it a national building standard for buildings for older adults. The name was changed to ANSI/IESNA RP-28-2001 and it is included in the American Institute of Architects *Guidelines for Design and Construction of Healthcare Facilities 2006.* The recently updated ANSI/IESNA RP-28-2007 edition is ANSI approved. It has gained broad acceptance and is now the recommended lighting design practice for older adults.

The available illumination guidelines for older people generally do not distinguish between horizontal and vertical illuminances due to visual and biological light effects. Nor do they care about maximal luminance levels within the field of view to avoid discomfort and disability glare. Dutch research teams (Sinoo et al., 2011) recommend that the colour temperature of the light sources should be between 2700K and 3000K in accordance with personal preferences and characterize horizontal illuminance levels (see Table 4).

Table 4: Illuminance Recommendations from Dutch research work (Sinoo et al., 2011)

Location	E_h [lux]	Comments
Living Room	200-300 (ambient lighting) 1000-2500 (task lighting)	Van Hoof et al. (2010)

Dining Room	500-1000 (task lighting)	Van Hoof et al. (2010) and De Lepeleire et al. (2007)
Hobby Space	500-1000 (task lighting)	Van Hoof et al. (2010) and De Lepeleire et al. (2007)
Corridors	200-300 (day) 50-80 (night)	De Lepeleire et al. (2007)

In the following, two recommendations of the Illuminating Engineering Society of North America and the Lighting Research Center in Troy (LRC) and the VDI Directive 6008 are described in more detail.

3.1.1. Illuminating Engineering Society (IES): Lighting your way to better vision (2009)[4]

This brochure describes some of the changes that can be made to a home's existing lighting to make it more comfortable and secure. The following recommendations are given:

- Ambient lighting that is uniform within a room and from one room to another.
- Higher levels of light, because normal age related changes within the eye restrict the light coming in and absorb the light – so more light is needed to compensate.
- Glare-Free light, because light scatters within the eye causing an increased sensitivity to glare and the loss of the ability to see subtle details at lower light levels.
- Light that helps you distinguish colors. The lens of the eye yellows with age, so proper lighting can help compensate.
- Ambient lighting: Look for fixtures that are designed to conceal the light bulb/tube from view or have a diffuser to diminish the brightness of the bulb/tube to control glare.
- Lighting that is directed to the ceiling and walls will provide ambient light. Options include fluorescent fixtures installed out of sight, a light valance, wall wash fixtures, or a torchiere.
- Task Lighting: Installed fixtures or portable table/floor lamps with adjustable lighting levels to provide higher light levels in a specific area.
- Always use electronic ballasts in fluorescent fixtures. These ballasts do not hum or flicker like the older and less efficient magnetic ballasts. Fluorescent sources are available in a range of color temperatures from warm to cool. A warm color similar to an incandescent bulb is described as 3000Kelvin, whereas, a cool color similar to daylight is 5000 Kelvin. 3500 Kelvin offers a good blend between warm and cool. The color rendering index should be 80, or above.
- Windows and skylights: Daylight within a space should be balanced, either by providing it from more than one direction (from opposing walls or skylights) or by increasing the electric lighting. Windows must have woven shades or sheer draperies to filter the

4 http://www.ies.org/PDF/Education/LightingForAgeingEye.pdf

daylight and control glare. Skylights without direct sun exposure and/or with adequate shading may be clear glass or plastic. All others should have diffused glass or plastic to prevent glare and strong shadows in the space.

3.1.2. Lighting Research Center: Lighting the way: a Key to Independence (2001)[5]

The Lighting Research Center (LRC) at Rensselaer Polytechnic Institute developed principles for lighting for older adults and tested those principles in two assisted living facilities. The test results demonstrated that lighting helps older adults maintain their independence and improves their quality of life. The AARP Andrus Foundation awarded the LRC a Dissemination Grant to develop these guidelines for designing lighting for older adults. In addition to this publication, the LRC developed two other guidelines that address the needs of 1) the general public, including older adults and their families and 2) health care professionals.

This publication answers frequently asked questions about how to use lighting to minimize some of the negative changes that occur with age. It also offers practical solutions for the residences of older people:

- *Increase ambient light levels* – Less light reaches the retina of the older eye. The light levels in living environments used by older adults should be increased by at least 50% over those comfortable for younger people. In general, ambient light levels should be at least 300 lux.
- *Increase task area light levels* - At least three times more light will be required in task areas to see fine details (e.g. reading prescriptions) or low contrast objects (e.g. black thread on blue cloth). Light levels on the task should be at least 1000 lux.
- *Minimize glare* – Although more light is required for the older eye to see well, care should be taken to avoid glare. Glare is experienced when light sources or bright reflections in the field of view impair vision, or are simply uncomfortable.
- *Increase contrast* – Because contrast sensitivity is reduced with age, the visibility of important objects, such as stair edges, curbs, ramps, or doorways, can be greatly improved by increasing their contrast with paint or similar techniques.
- *Balance illuminance levels* – Because the older visual system cannot completely adapt to dim conditions, illuminance levels in transitional spaces, such as hallways and entrance foyers, should be balanced with those of the adjacent spaces.
- *Improve color perception* – Color discrimination is poorer for older adults. High illuminance levels and high-quality fluorescent lamps, rather than conventional incandescent lamps, will help older adults to see colors well.

Apply these principles:

- Use light-color finishes on walls, ceilings, and floors to increase diffuse, inter-reflected light in the living environment. This will increase uniformity and reduce glare. Use dark baseboards to help define walls and floors.

5 http://www.lrc.rpi.edu/programs/lightHealth/AARP/pdf/AARPbook2.pdf

- Keep room finishes simple, and avoid complex decorative patterns to minimize confusion with objects on floors and furnishings.
- Identify where visual tasks will be performed, and put extra light at those places. More light is needed to see details, such as reading or sewing. Use adjustable light fixtures (luminaires) to increase light levels in these areas.
- Use switches and dimmers to help people adjust the light level for their task needs.
- Shield direct views of light bulbs (lamps) by using architectural features, such as valances, soffits, and coves, or by choosing luminaires that use baffles, lenses, or louvers.
- Avoid clear-glass luminaries.
- Avoid reflections of light sources from shiny surfaces, such as floors and countertops, by changing the position of the light source relative to the usual line of sight or by using matte finishes.
- Daylight through windows and skylights will increase light levels in the space and improve color discrimination. Use blinds, shades, or curtains to minimize glare from windows.
- Create intermediate illuminance levels in transitional spaces that lead from bright, outdoor areas, to dim, indoor spaces. At night, transition spaces between the relatively bright indoor spaces to the dark night enable older adults to adapt more completely as they move around the different spaces.

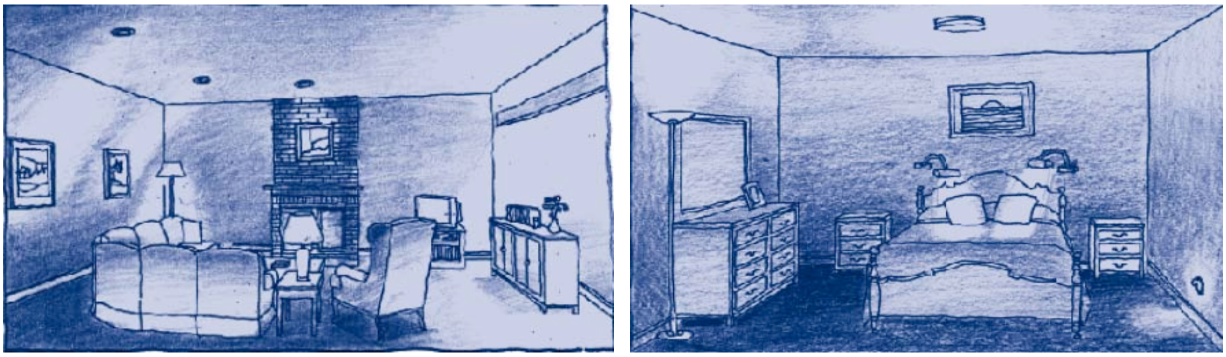


Figure 19: Intermediate illuminance levels in transitional spaces

3.1.3. VDI Directive 6008: Barrier Free Buildings for Living – Recommended Practice for Lighting and the Visual Environment for Senior Living[6]

This VDI standard gives recommendations regarding illumination level, light colour, and types of light and light effects for different rooms (see

6 http://www.derungslicht.com/derungs/file/katalogbestellung/seniorenpflege_en_2.pdf

Table 5). Foir instance, night light should be indirect, warm-white and 50-100 lux, while reading light should be direct, warm-white or neutral-white with up to 1000 lux.

Table 5: VDI Directive 6008

Area	Light effect	Illumination level E[lx]	Color of light	Type of lighting
Corridors	day lighting close to floor (10 cm above floor) eye level (140-160 cm above floor)	200-300 lux 300-500 lux (cylindrical)	warm-white/neutral-white warm-white/neutral-white	direct / indirect direct / indirect
	night lighting, close to floor	50-100 lux	warm-white/neutral-white	direct / indirect
Recreation areas	day lighting, close to floor	200-500 lux	warm-white/neutral-white	direct / indirect
Residents' rooms	care light bed level (85 cm above floor)	300-500 lux	warm-white/neutral-white	direct / indirect, twin-component lighting, depending on type of care
	reading light, work light bed level / eye level (separate auxiliary lighting, if needed)	300-1000 lux	warm-white/neutral-white	direct / twin-component lighting
	living room light, close to floor	100-500 lux	warm-white	direct / indirect
	night light, close to floor monitoring lights for staff at night, close to floor	50-100 lux approx. 5 lux	warm-white warm-white	indirect indirect
Restrooms	For patients: basic lighting close to the floor; accent lighting at face level	200-500 lux	warm-white/neutral-white	direct / indirect

3.2. Lighting concepts of the leading European lighting industry

Main components of lighting concepts for the aged population:

- **ambient lighting:** general lighting in a room for walking around, conversation and identifying objects.
- **task lighting:** provides higher light levels in a specific area for performing visual tasks, such as reading sewing, and cutting.
- **accent light:** is used to highlight artwork or special architectural features.
- **daylight from windows and skylights:** provide ambient lighting and due to the high light levels, some people also use daylight or direct sunlight for visual tasks such as mending or working on puzzles.
- **interior surfaces:** contribute to good lighting in the sense that lighter colours on ceiling and walls will reflect more light within a space. Dark colours absorb the light and should only be used on moldings or small areas. To better control glare, ceilings and walls should also have flat finish paint or general areas and a matte finish for kitchens and bathrooms.

What constitutes a good illumination for supporting visual perception of the elderly?

- **Ambient lighting that is uniform** within a room and from one room to another because older eyes take longer to adjust to changes in light levels.
- **Higher levels of light** because normal age-related changes within the eye restrict the light coming in and absorb the light. Thus more light is needed to compensate this process.
- **Glare-free light** because light scatters within the eye causing an increased sensitivity to glare and the loss of the ability to see subtle details at lower light levels.

What constitutes a good illumination for supporting non-visual lighting effects?

- **Varying light colours and intensities** during the day constitute a clear visual signal of the time of the day.
- **Higher vertical illuminances at eye level**, especially in the early morning or early evening hours according to the subjective biological needs (e.g. to phase advance or phase delay circadian rhythms, to enhance mood, to shorten sleep latency, to increase sleep duration, etc.)
- **Maximal outdoor daylight exposure** facilitates exposure to UV-radiation and significantly increases the daily light dose.

In the following sections, lighting concepts of Zumtobel, Derungs Medical Lighting, Osram and Trilux are introduced. All descriptions literally reproduce the concepts of these companies.

3.2.1. ZUMTOBEL: Light for care (2009)[7]

Zumtobel compares lighting standards for the working population with their recommendations for elderly people (see Fig. 7). An example of day room´s illumination according to these recommendations is given in Figure 21.

Lighting recommendations for resident`s room are as follows:

- Lighting scenes that are as varied as possible for different activities such as needle-work, reading and watching TV deliver an agreeable living concept
- Diffuse luminaires or luminaires that have a relatively large indirect component, and light colors that are as warm as possible from 2700 to 3500 K accentuate a feel-good atmosphere
- A minimum lighting level ensures night-time orientation; slow dimming and sensors built into beds have proved to be especially useful
- Provide a dedicated reading light near the bed or elsewhere for reading
- Ease of operation is paramount for the elderly

7 http://www.zumtobel.com/PDB/teaser/CS/AWB_Care.pdf

	EN 12464	Zumtobel's recommendations
Reception/entrance	– 300 lx	– 300 lx
Corridor areas	– In the daytime 200 lx – At night-time 50 lx	– During the day: at least 60% of the illuminance level prevailing in the lounge area – At night: 50 lx, adjustable up to 100 lx
Communal space, recreation room	– 200 lx	– In the morning: 300 to 500 lx with a colour temperature from 4500 to 6500 K – In the day time: up to 1500 lx throughout the day with a colour temperature from 4500 to 6500 K – In the evening: 300 to 500 lx with a colour temperature from 2700 to 3500 K
Resident's room and bathroom	– 100 lx for bedrooms – 200 lx for bathrooms	– Residents' rooms: at least 300 lx, colour temperature from 2700 to 3500 K. Additional reading light with luminance of 1000 lx in reading area and/or additional bedside reading and examination light. Night-time orientation light. – Bathroom: 300 lx, 2700 to 3500 K; separate mirror lighting
Administrative and task areas	– 500 lx for offices	– 500 lx with variable lighting situations, especially for night-time working
		– Another recommendation: adequate transitional zones between brighter and darker areas and between outdoor and indoor areas give older eyes sufficient time to adapt to different lighting conditions.

Figure 20: Recommendations of Zumtobel regarding different living areas

Figure 21: Lighting Concepts of day rooms according to Zumtobel´s recommendations, realized in a care retirement home

3.2.2. Derungs Medical Lighting: Senior care – good lighting enriches senior living[8]

Patients with dementia have difficulties with spatiotemporal orientation. This leads to implications of inactivity, confusion and depression. “Visual Timing Light”, the innovative light management system from DerungsLicht AG uses artificial light to simulate the twenty-four hour cycle, from sunrise to sundown and night-time.

A twenty-four hour cycle of light to organize daily course of activity…

8 http://www.derungslicht.com/derungs/file/katalogbestellung/seniorenpflege_en_2.pdf

- positively affects the day / night cycle
- helps balance hormone production
- regular sleeping and eating habits
- positively affects mood and sense of well-being; invigorates the senses
- compensates for mood fluctuations and depressions
- enhances overall performance
- significantly improves articulation of patients with dementia

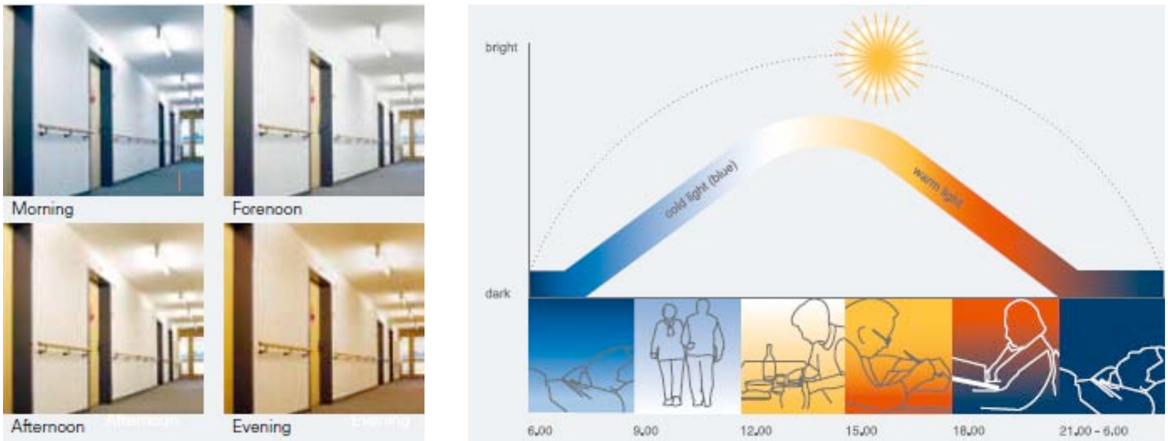


Figure 22: Visual Timing Light (Derungs Licht AG)

A sophisticated light control system is used to define the different light effects from morning until night. As the time of the day progresses, this lighting system features a different illumination level and light temperature (see Figure 23).

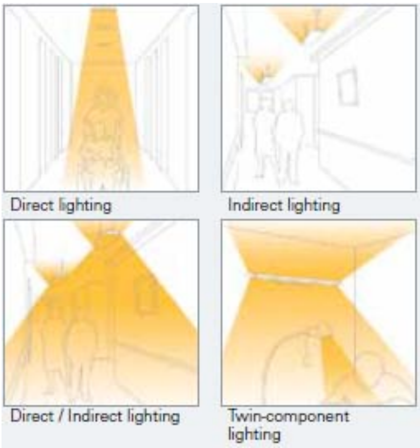
Glare, reflections and shadows should be controlled and light should be evenly distributed within the rooms in the following way:

Glare control. The eyes of the elderly are more sensitive to glare than the eyes of younger adults. Light is diffused differently in older eyes. Derungs Licht AG products come equipped with diffusers with each clear glass incandescent or halogen lamp to help control glare.

Light distribution. By using light to brighten walls, corridors appear wider. Indirect ceiling light fixtures make rooms seem more inviting and open. Derungs Licht AG can precisely define the emitted light by using specially designed, light directing elements. The light is directed into the room in an optimal fashion. The room is illuminated uniformly. This creates illumination that is comfortable and low in glare, reflections and shadows.

Reflection control. Derungs light solutions keep reflections to a minimum by using diffusers with both direct or indirect lighting. Derungs' luminaires control the light through sophisticated light directing prisms. In this way, shiny surfaces are not spot-lit and reflections are minimized.

Shadow control. The interplay of light and shadow is indispensable in safely finding one's way around a room and in recognizing objects. Concentrated light sources and bundled light create lighting that promotes the formation of sharp and deep shadows. This produces sharp contrasts that may conceal objects or obstacles with dark shadows. Using light sources that cover an extensive area and radially diffuse the light, as is done, for instance, with ceilings illuminated by indirect lighting, creates illumination that casts few shadows. Shadows necessary for orientation, however, are missing. The shapes are no longer recognized and obstacles may not be perceived as such. The objective consequently has to be to provide illumination that produces an average degree of shadiness. Derungs Licht AG customizes lighting systems to meet the unique needs of the customer and to produce just the right degree of shadiness by utilizing the benefits of top-quality indirect/ direct lighting and twin-component lighting systems.



Features of poor light diffusion

Direct lighting
+ very good to average energy efficiency
- discomforting glare for patients confined to bedrest
- reflective glare on equipment
- dark shadow on facial features and objects
- faces not bright enough for visual communication
- reflections on the floor
- room appears to be dark

Indirect lighting
+ excellent glare control
+ minimum reflections
+ room appears to be bright
+ hardly any shadows
- average to poor energy efficiency
- ceilings are too bright for patients confined to bedrest
- diffuse lighting atmosphere (hardly any contrasts)

Features of good light diffusion

Direct / Indirect lighting
+ good energy efficiency
+ hardly any shadows
+ hardly any reflections
+ good glare control
+ room appears to be bright
+ homogeneous, soft transitions due to multiple reflectance

Twin-component lighting
+ like direct / indirect lighting
+ partial amplification of lighting due to task / reading lights

Derungs Licht AG understands the significance of direct / indirect lighting and twin component lighting. The light fixture product range focuses on providing lighting solutions in these areas. Our priority is to provide excellent lighting solutions that use a basic principle: provide indirect lighting while diffusing direct light to properly balance the atmosphere safely and effectively.

Figure 23: Lighting concepts for the aged (Derungs Licht AG)

3.2.3. Osram: Improved quality of life for dementia patients – St. Katharina research project in Vienna (2012)[9]

In cooperation with the Lighting Competence Centre and other partners, Osram conducted a trial intended to examine precisely this question in the dementia care ward of the St. Katharina residential care home in Vienna over a period of 15 months.

In various old-age homes where experiments have been carried out with “luminous ceilings” (for instance “Haus im Park” in Bremerhaven, “Haus Ruhrgarten” in Mulheim), positive effects on the well-being and social behaviour of residents were observed. In spite of the initial scarcity of available data, there was sufficient evidence to suggest that a positive development might be initiated by using adequate lighting: increasing social activities during the day result in greater fatigue in the evening, providing in turn for more restorative sleep at night and accordingly favourable effects on the residents’ mental and emotional state.

9 http://www.zumtobel.com/PDB/teaser/EN/Study_Health_and_Care_StKatharina.pdf

In a residential ward for dementia patients in the St. Katharina old age home in Vienna, controllable lighting was installed in the course of refurbishment, allowing for different lighting intensity levels and light colors to be implemented and their effects on the well-being of residents to be examined systematically.

The biological effect of bright light on people causes an increase of their activity during the day and stabilization of the circadian rhythm. In order to guarantee the biological effects of light also indoors, it is necessary for artificial lighting to be similar to daylight. At present, this is not possible using conventional lighting. In the case of warm or intermediate light sources – which are usually used indoors – biological efficacy could only be achieved at dramatically increased levels of illuminance and thus considerably higher energy costs.

The biological effects of the SKYWHITE fluorescent lamp with a color temperature of 8000K, an increased blue component, and a light color that is more similar to daylight at comparable illuminance and comparable energy efficiency, are 2 to 2.5 times higher than those of conventional fluorescent lamps.

It must be taken into account that the perception of light and colors by the geriatric resident is different from that of the nursing staff or generally younger persons. This is due to the age-related cataract of the eye. The yellowish discoloration of the lens leads to a wavelength-related reduction of transmission, the short-wave blue components are thus reduced more strongly.

Apart from the light color, also illuminance influences the biological effect of light. To achieve an illuminance level of 1000 lx, a wide-area source of light emanating diffuse light is required. This corresponds to the bright sky outdoors. The illuminance of this source of lightshould be able to produce some 3000 lx on a horizontal surface. The corresponding lighting system allowing for adjustment of the color temperature between 3000 K and 8000 K and of illuminance up to approx. 3000 lx was provided for the St. Katharina old-age home.

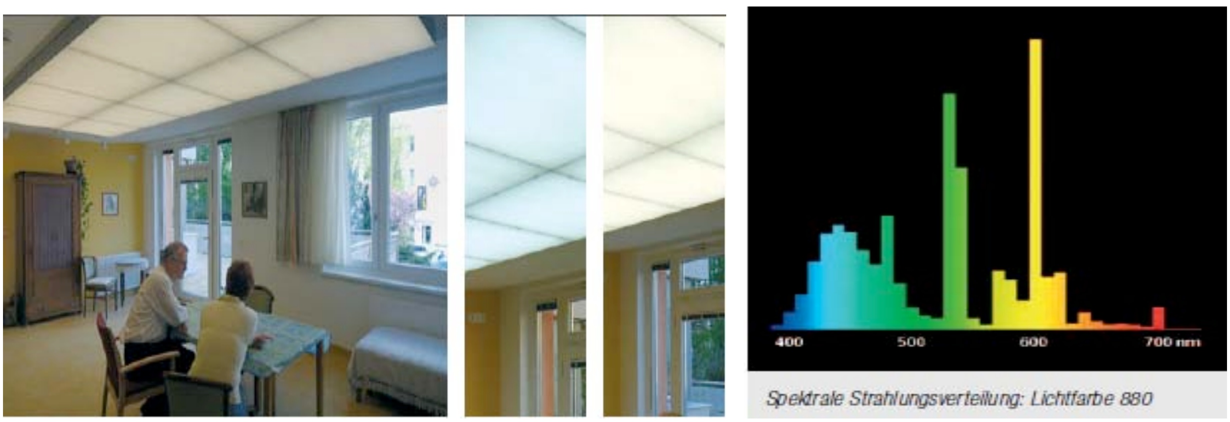


Figure 24: St. Katharina research project: light system and lamp emission spectrum (Osram)

3.2.4. TRILUX: New Light (2012)[10]

If rooms have low quantities of daylight or even none at all, patients and residents often lose their sense of time. TRILUX lighting solutions specifically support the biological rhythm of patients and care personnel. Acuro Active simulates the course of natural light during the day: the specially developed controller mixes the light of warm white (3000 K) and daylight white (6500 K) LEDs according to the time of day. With their finely structured, opal diffuser and homogeneous light emission surface without dark spots, both luminaires ensure harmonious, glare-free light in sanitary areas, corridors and traffic zones. Safety is of course of prime importance in the health sector, and the optional emergency switching enables immediate, full illuminance at night as well.

TRILUX offers a variety of lighting solutions that enhance the well-being of seniors.

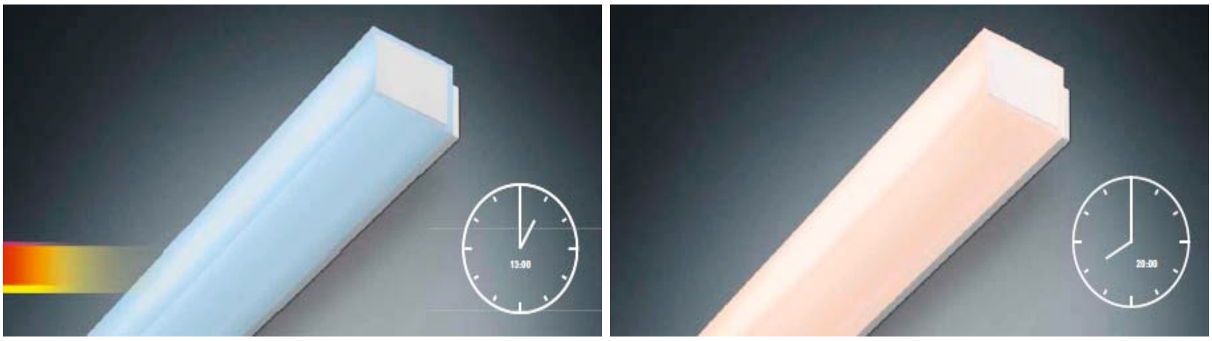


Figure 25: Lamp emission spectra during the day and night (Trilux)

4. Technical Framework

The implementation of the Guiding Light system implies the usage of different components, regulating the lighting conditions in the homes of elderly people according to given sitations, or rather accumulated empirical values over a period of time. Thus, a flexible software aggregating and analysing the input from various sensors has to be chosen for the system. In the following chapters, available software (chapter 3.1) and sensors (3.2) will be presented.

4.1. Software

4.1.1. System Requirements

The focus of the project is to develop a lighting solution with product character which combines hardware and software in a manner that can be easily be finalized from prototype into a market-ready solution. Therefore some major requirements are defined for software development in general:

Integration of existing technologies where possible. We expect to use and integrate available and proofed hardware as far as possible and useful. If standard solutions which fulfill

---

10 http://www.trilux.com/fileadmin/redaktion/pdf/DE/Kompetenz/Anwendungsbereiche/Gesundheit/Neues-Licht-in-der-Pflege-TRILUX-2012.pdf

the requirements cannot be found or are not suitabe a customized solution has then to be developed. The emphasis of the project should be to create an intelligent solution on basis of available technologies, standards, hardware and software, rather than to develop hardware from the scratch.

Create a system that fits the requirements of the user with little or no manual configuration. It is intended to develop a solution which doesn't have to be tailor-made for every single user. The solution has to fit the requirements of the users defined in the definition of target groups. However has to be considered to equip the system with functionality for configuring the system within defined parameters and/or develop algorithms which make the system automatically adapt to user specific situations. The lighting algorithm itself is planned to have a self-learning behaviour which is based upon parameters that are measured within the user residence or directly from the vital signs of the user.

4.1.2. Initial situation

To meet the requirements mentioned above, we will use an existing software („myVitali") as basis for collecting and visualizing sensor data as well as for connecting users with expert.

The health management system myVitali (http://www.myvitali.com, MVA) brings in the possibility of starting with an easily extendable and scalable modular system in terms of home automation, health monitoring and shared distribution of sensor data to different user groups. The philosophy, architecture and features of that system are described in the following:

Main goals and purpose. myVitali has its focus in improving the health and quality of life of its main users. This can be achieved by analysing the situation of the main user via sensor data, that is being collected automatically by myVitali or manually by the user. Based on that analysis and interpretation of the collected data the system gives feedback to the health situation of the user and also gives suggestions how to improve that situation. The system is objectifying the situation to have the basis for support and advice.

User groups. Different user groups are working together using myVitali. The systems allows the main user to connect to other user groups in terms of sharing his data to get assistance, support or therapy from the others. Other user groups are typically experts like doctors, coaches and similar as well as contact persons like relatives, neighbours, friends who will support the main user in critical situations or who are in any other way interested in his health status.

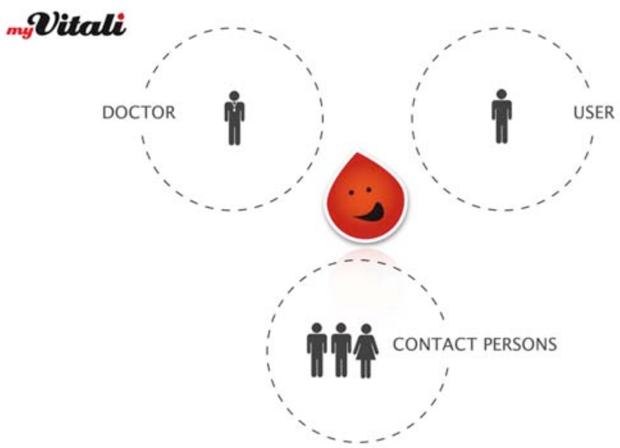


Figure 26: myVitali user groups

Architecture. myVitali is a webbased software with service oriented architecture (SOA). The backend provides a set of services which can be used by a variety of clients. Clients are user devices (tablets, smartphones, PCs, TVs with webacces touchscreen-terminals), which are visualizing collected data in a manner that fits the needs and requirements of the specific user group. Business logic is based on the backend and delivered to the clients by services.

The system is designed to be easily scalable and configurable to fit different user needs and match the requirements of a wide variety of target groups. This is provided by a system based on easily combineable modules within specific user groups and above (see Figure 27).

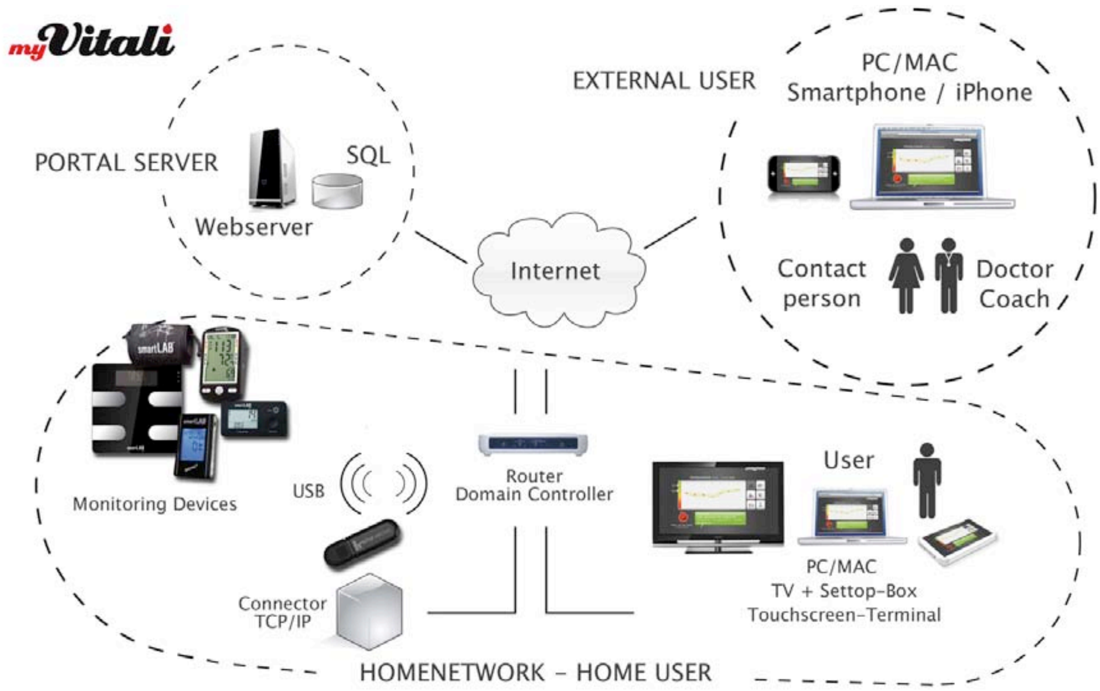


Figure 27: myVitali technical overview

Visualiziation. One of the main goals of myVitali is to transpose user‘s sensor data to an easily understandable message, and to let the user know what to do to improve his or her health situation. The sensor data are therefore analysed and interpreted based upon a complex policy framework and thereafter merged into a combination of charts, colored codes and messages delivered to the user by the virtual coach of the system, named „Vitali“. The visualization of the variety of sensor data in a comprehensible and well designed form is one of the major strengths of that system. The complexity of the visualization is based on the type of the user: i.e. a patient will get a far more simplified view of his data than the doctor will.

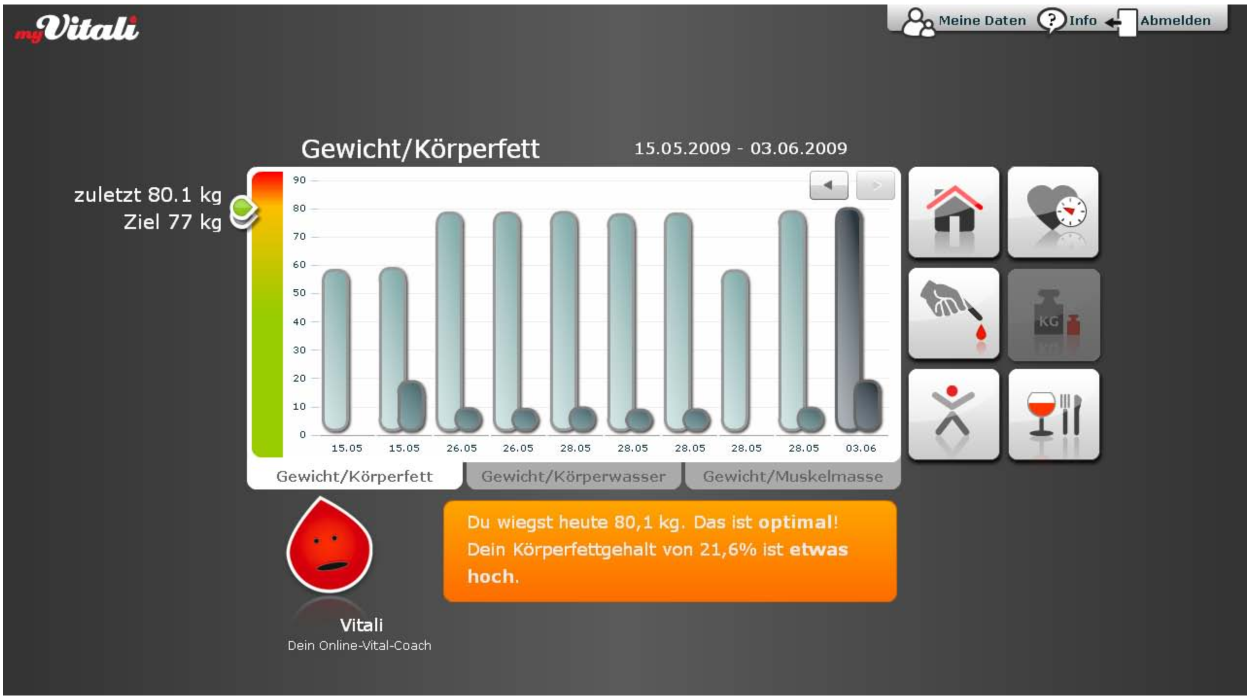


Figure 28: Sample of myVitali visualization (weight management)

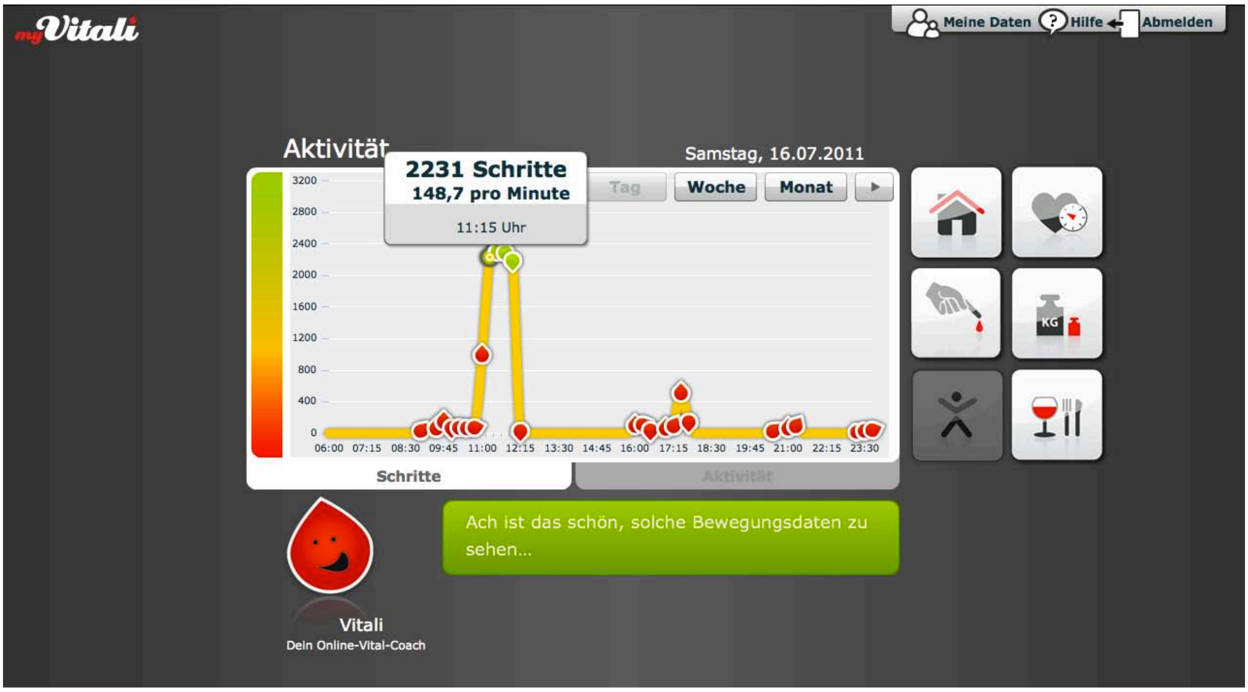


Figure 29: Sample of myVitali visualization (activity management)

Business model. myVitali with its core module (health management) is targetting the consumer mass market. To reach a big share of the market, the business model is based on monthly fees of micro payments (e.g. 1,99 EUR for one module per month and user). This approach has already been partly transferred to a fitting model for Guiding Light during a workshop with initiative from the AAL Association. The transnational AAL2Business Workshop (1st of June, 2012 in Vienna) was a platform to present the business plan of myVitali as a working example. The feedback from the moderators about the business model was very positive and promising. They predicted a high chance of success for the project in general and the business model in special. The details about the Guiding Light business model will be described in Deliverable 6.3 at a future time.

4.1.3. Development

An extension of the given functionalities and features of myVitali will be done by adding new modules to the framework. It has not been defined yet where exactly the components of the lighting software (including light spectrum curves, genetic algorithm for light adaption, evaluation components etc.) will be placed. Since the approach of myVitali is a webbased one, it may be necessary to have one or more appliances running within the user residence as well.

To keep the installation cost as low as possible, it is recommended to use the backend resources for as many computing tasks as possible. Especially for the outlook to the market it will be an advantage if not a requirement to follow the principle of myVitali, to keep the house installation lightweight and easy to install and maintain and shift all possible intelligence to the backend system. Nevertheless should the system within the residence keep its main functionality in case of a internet failure which means that the controlling of the lighting has to keep its functionality independently of internet access.

4.2. Sensors

4.2.1. Requirements

In order to obtain detailed information about the influence and effects of the lighting system, we need to measure several parameters from the main user. It has not been defined yet which parameters are absolutely necessary and which ones are optional. Below are some examples of potentially useful aspects:

- Lighting exposure
- position inside the residence
- position inside every single room
- position outside the residence (route, distance traveled)
- body position
- current activity of user (is moving or not)
- level of activity (quantity, intensity, frequency, continuity, duration)
- mood
- stimulus/impulse
- sleep (duration, quality, sleep cycles, interruptions, start-/ending time)
- vital parameters (heart rate, blood pressure, weight, body fat, blood glucose etc.)
- food and fluid intake

In addition, we also need to analyse some parameters from the environment of the user, e.g.

- lighting situation (brightness, light color, intensity, etc.)
- temperature

- humidity
- carbon dioxid saturation
- energy and sources consumption (water, gas, heating, power etc.)
- weather situation (cloudiness, sunshine)

In some areas of measuring data, we might expect difficulties of different nature, like technological challanges, challanges in complexity or effort of the recommended solution (since the installations has to be made in residences where people are already living), or ethical aspects which prevent to use certain approaches or just limitations of budget. All those aspects have to be considered, together with the benefit and results of the demanded feature. The project consortium then has to decide whether the approach has to be followed, or whether it is implemented in a reduced variant or eventually even canceled.

The following section gives an overview about possible approaches to acquire specific parameters for the Guiding Light system in more detail.

Position tracking

Since we need to know if the lighting solution is inducing a different behaviour of the user, we have to track certain aspects which will point out the activities of daily living and the movement patterns of the person within his residence and outside. Especially the tracking of the location over time can help to determine the direct and indirect influence Guiding Light actually has on the user.

Tracking of activity through PIR sensors (passive infrared). This approach is not tracking the exact position but given activities at a certain time within a specific area of the residence. It includes sensors (see Figure 30) covering different zones with one single device (normally 4 quadrants). By combining several of these devices, it is possible to create a grid of zones inside a room and to have an accurate enough tracking of the position. It can then be differentiated for example whether the resident is standing or moving in the kitchen unit, sitting at the table or on the sofa, and so forth.

Figure 30: Example for PIR sensor (here: EnOcean model)

Visual tracking. Based on some kind of camera system, the room is recorded and some image recognition algorithm detects the position of one or more persons within the observed area. For an exact position, the camera system would use a stereoscopic technology (like the Kinect system oft he XBox, see Figure 31). The problem with this approach is the acceptance of the user to have cameras installed in his home, even though the image recognition is just for parameter extraction and the images are then deleted.

Figure 31: Example of stereoscopic camera (here: Microsoft Kinect)

GPS Tracking. Normally, GPS tracking inside of rooms are made for big buildings and not appropriate nor affordable for private households. Still, we found some companies that are offering specific indoor and outdoor solutions (e.g. GeoCare, see Figure 32). However, most of these systems require the user to wear technical badges or markers (besides the equipment for the rooms), which is a disqualifier since that would surely pose acceptance and complience problems especially for our target group.

Figure 32: Example of GPS-tracking device (here: Geocare)

Other approaches. We were in touch with several experts with experience regarding other technical approaches, for instance transit time based approaches via ultrasonic, approaches with RIFD and tagging, or bearing approaches using radio frequency. All of them were either far too expensive, too complex and time-consuming in installation, or not accurate enough.

Some examples for companies which are offering solutions for location tracking and which we have been in contact with:

- Fidelak GmbH, http://www.fidelak.com
- Beckhoff Automation GmbH, http://www.beckhoff.at
- Geodog GmbH, http://www.geo-care.de
- automationNEXT GmbH, http://www.automationnext.com
- Intenta GmbH, http://www.intenta.com

Tracking of vital signs

If we want to measure the system's influence on vital parameters of the user, we have to measure vital data either selectively (i.e. the user has to do a measurement with a device) or permanently (the user is wearing a device or a sensor can measure vital signs from the distance or by indirect parameters, e.g. carbon dioxide saturation in the air). Wearing sensors is eventually involved with problems of compliance or difficulties in handling (e.g. when dressing). Doing specific measurements once or more often a day can be also a stress factor. On the other hand, most of the older people are used to measure their vital signs since they have to due to some chronical diseases (e.g. high blood pressure, diabetes, obesity etc.).

The core system of myVitali includes measurement devices and clients for visualization of vital data. Those parameters can support the feedback of the main systems and eventually proof some positive effects of Guiding Light on those parameters as well.

In the following lists, we marked values which we can measure using a device for a single measurement with 1) and the need to wear a sensor for accurate measurement with 2). If a sensor is to be worn somewhere at the body, a convenient position should be preferred if possible. Activity sensors for example can be found with different recommended or possible body positions (wrist - mostly preferred position, ankle, chest via necklace, hip/belt, trouser pocket, handbag).

Available devices and parameters (transmitting data wireless to the system):

- activity (number of steps in time, freuquency of steps, estimated calories burnt by activity, estimated distance walked) 2)
- blood pressure and pulse 1)
- blood glucose level 1)
- body weight, body fat, body water, muscle mass, BMI 1)

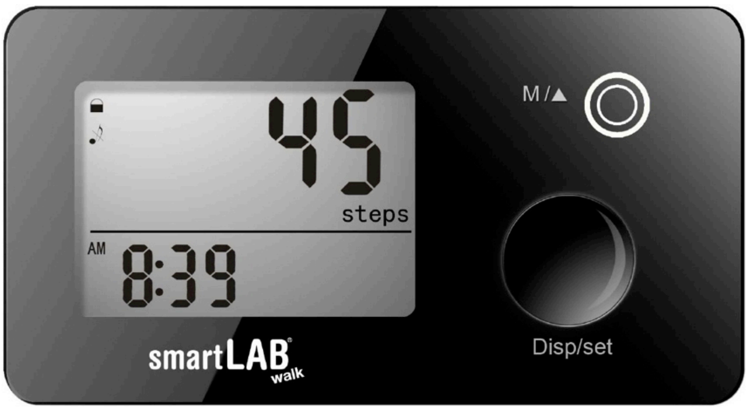


Figure 33: Example for a wireless tracking device (here: smartLAB walk+ wireless activity sensor)

Additional parameters, that could be taken into consideration:

- heart rate 1) for punctual measurement, 2) for a long term measurement
- heart rate variability 2)
- ECG 2)
- body position 2)
- breathing 2)
- altitude difference 2)

Examples for vendors of devices which we were or are in contact with:

- ActiGraph Inc., http://www.actigraph.com
- Fitbit Inc., http://www.fitbit.com
- Movisens GmbH, http://www.movisens.com
- HMM GmbH, http://www.hmm.info
- Zephyr Technology ltd., http://www.zephyr-technology.com
- Polar Electro Oy, http://www.polar.com
- Affectiva Inc., http://www.affectiva.com
- Mitac Europe Ltd., http://eu.mio.com

Light exposure measurement

The amount of light that a person is exposed to (specifically the face) is an important factor in order to analyse possible correlations with vital data, activity parameters, or other aspects of the resident's behaviour. One example of such a sensor is „Dimesimeter", an optical sensor combined with an accelerometer (see Figure 34). However, the measurement of the exposed light to the face remains a challenge, since it is difficult to place sensors around the face which are small enough and easy in handling to be accepted and convenient.

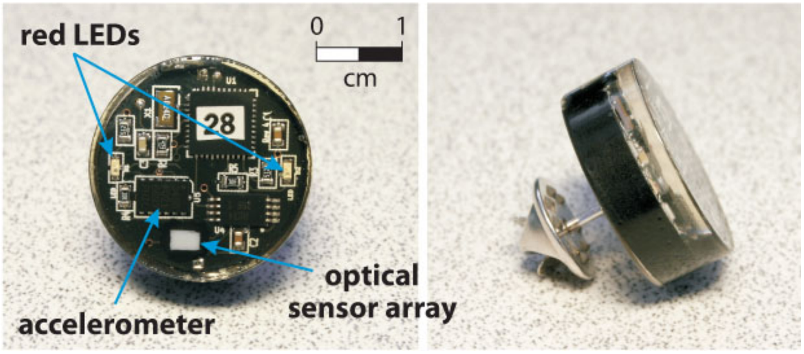


Figure 34: The Dimesimeter (developed by the Lighting Research Center - LRC) has approximately 2 centimeters in diameter and is battery-powered. Due tot he pin, it can be attached to a shirt collar, lapel, or hat.

4.2.2. Starting situation

myVitali is providing a framework which can easily integrate various sensors. Those sensors can monitor the vital signs of the user itself, as well as the environment the user is living in by means of different technologies.

Examples of wireless technologies:

- EnOcean (energy harvesting wireless sensor technology; http://www.enocean.com/en/home/)
- Wifi
- ANT+
- Zigbee (IEEE 802.15.4)
- Bluetooth

The advantage of EnOcean is its wireless approach and the reduction of maintenance due to energy harvesting. However, since the energy used for sending wireless telegrams is created by either piezo-electric mechanisms or by solar panels, the sensor itself must not exceed a certain limit of power consumption. For specific situations (e.g. sending data with high frequency) it may be necessary to use wired sensors alternatively.

The myVitali framework is providing a number of different interfaces and APIs to let the devices and gateways communicate (REST, SOAP, XML-RPC, HTTP-Request, AMF, Java RPC). The devices send data through different kinds of gateways or interfaces. Depending on the use case, one or more of those gateways will be used.

Mobile Gateways

The gateway will collect data based on one or more wireless technologies (e.g. ANT+) and will then forward the data to the backend over a mobile network (GPRS). The gateway uses an M2M-card (SIM) which means that the ongoing transmission is based on some contract with a cellphone company. Example: HMM hFon Collect.

Software Gateway

Using a USB-dongle (e.g. a Garmin ANT2USB dongle) and a software gateway running on a PC, Plug-PC or embedded PC, this solution does not need some kind of a mobile contract. The PC although has to be running as long as data should be transmitted.

Figure 35: Mobile gateway HMM hFon Collect (left) and software gateway ANT+ dongle (right)

Controller/home gateway

A controller unit implemented in the electric cabinet connected to a bus terminal or a bidirectional gateway which receives data via external antenna. The controller will communicate with the backend via defined API (e.g. XML-RPC or TCP/IP). Example: Thermokon STC-Ethernet.

Figure 36: Thermokon EnOcean gateway

Smartphone or tablet as gateway

A smartphone can communicate with devices based on built-in chips or connected dongles with wireless protocol (e.g. Bluetooth 4.0). The communication with the backend over services is done by a native application running on the smartphone.

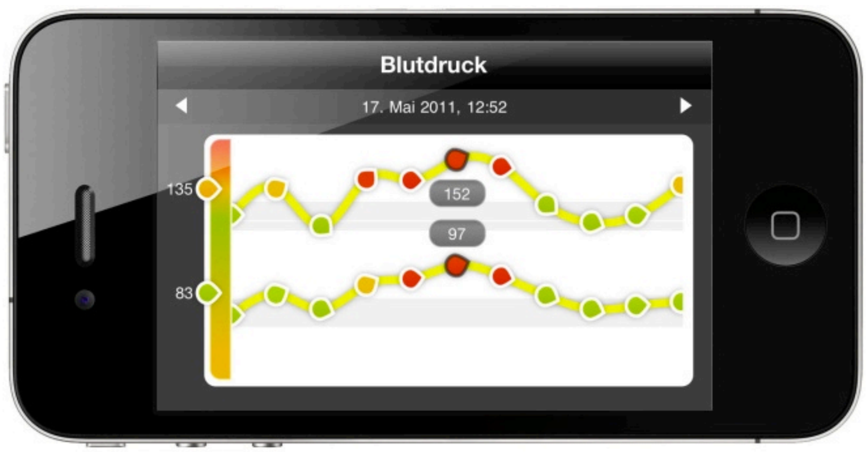


Figure 37: Results of vital data analysis of the myVitali system on an Apple iPhone 4

Based on the framework myVitali is providing, it is easily possible to extend the system by sensors, actuators, gateways, protocols and technologies as needed. The modular approach makes it easy to attach new modules loosely and integrate date to already existing services and visualizations.

5. Conclusions for Guiding Light

In the previous chapters, we have shown that the percentage of elderly people within our societies will increase over the next decades. We have also illustrated age-related limitations (or even diseases) that endanger an independent, mobile life in higher age.

On the other hand, several studies have been cited, proving the benefit of light interventions on many of these age-related challenges: Light is not only crucial for perception and spatial orientation, it can also improve temporal orientation and circadian rhythm, guide attention, and – taken together – enhance the mobility and indepence of the elderly.

The basic idea of Guiding Light is to specify when, how much and for how long light can be applied for a positive effect on the lives of elderly people, as demanded by Figuero (2003).

5.1. Light interventions of Guiding Light

Within this project, we aim at influencing mobility parameters quantified by selected activities of daily living and fundamental circadian activity rhythms (e.g. sleep parameters, room zone usage duration) by the aid of improved **spatiotemporal orientation**. This goal will be reached primarily by applying individually specified ambient lighting interventions at private homes. As a consequence, we intend to vary ambient and task light intensities and light colours over time to support spatial orientation, visual performance and to improve sleep-wake rhythms.

In the past, interventions focused on light signals generated by bright, highly saturated light colours (e.g. green backlight of a drug locker to remember medication intake or self-luminous amber door frame to increase postural control and stability after leaving bed during the night - Brooke-Wavell, 2002). As mentioned before, we intend to improve spatial and temporal orientation by means of ambient lighting. In the following, these interventions will be described in more detail.

5.1.1. Ambient lighting intervention for spatial orientation purposes

Field studies (Tranah, 2011) with elderly living at home or in care facilities have already shown that disorders of spatiotemporal orientation are increasing with age and can be considered as an early symptom of Dementia. It is a matter of fact that visuospatial deficits often precede typical memory losses in early stages of Alzheimer´s Dementia.

Elderly people, who live in a home that features a high proportion of open spaces such as circulation areas and interconnected rooms, and fewer enclosed rooms with a clearly legible meaning and function, are more dependent on others with regard to their activities of daily living such as eating, dressing, or using the bathroom (Marquardt, 2010). It can be hypothesized that homes, consisting of mainly enclosed rooms with a clearly legible meaning and function, form a spatial system that can better be memorized, resulting in more successful navigation of the place. Also, rooms associated with distinct purposes may support individuals with their activities of daily living. Adapting the home to the needs of people with dementia would then encompass decreasing the home's convexity, for example by concentrating spaces and giving them an assigned meaning.

Conventional environmental interventions, which intend to support spatial orientation, mainly consist of colour coding measures (e.g. changing wall or floor colours) or the presentation of familiar symbols to improve room identification.

The use of colour and colour contrasts specifically, was found to be effective (see Fig.1) not only for improving vision and clarity of the environment, but also in promoting better orientation, preventing sensory deprivation, enhancing memory, and creating a sense of safety and independence (Gohar, 2008).

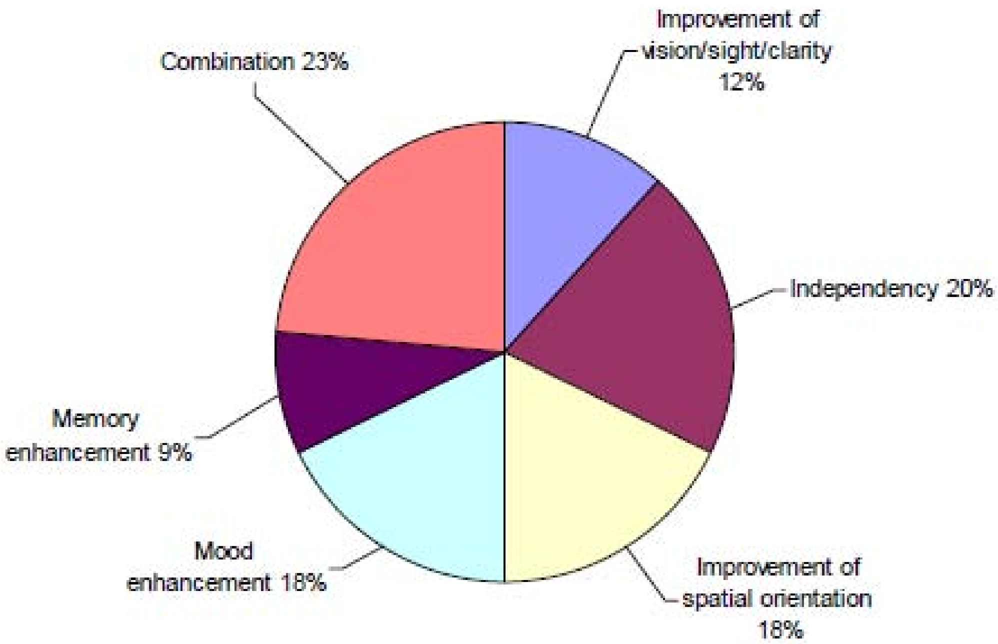


Figure 38: Reported effects of colour and colour contrasts (Gohar, 2008)

Furthermore, the application of bright colours is associated with positive emotions and often applied (Hemphill, 1996; Hupka et al., 1997; Valdez & Mehrabian, 1994). Astonishingly, brightness is usually generated by painting walls in specified colours instead of using light interventions.

Recently, Figueiro and colleagues (2009, 2011) reported significant effects of a self-luminous door frame and self-luminous navigation lines (integrated in the floor), on essential gait parameters of elderly people during night-time navigation tasks in a poorly lit environment. These lighting interventions have nothing in common with ambient lighting interventions because they are applied for signalling purposes and do not suffice for room illumination.

Generally speaking, different room zones can be related to specific tasks at a specific time of day: cooking, sleeping, reading, eating, and personal hygiene all take place at different places at different times. It is the genuine idea of this project to direct attention of the elderly to certain room zones to maintain or encourage time-of-day related activities by means of ambient lighting interventions which should enhance spatial orientation and capture attention to specific room zones and tasks.

To our knowledge, we are the first to implement such a spotlight concept, which clearly differentiates the central task area from the peripheral room environment by the usage of different luminance levels and light colours.

In general, a spotlight is able to visually differentiate activity-related areas from their surroundings and thus supports maintenance of attention and reduction of distraction. Furthermore, it allows energy-efficient optimal illumination while performing daily activities. It has to be mentioned that zonal lighting concepts are based on balanced ambient and task lighting components which recognize age-related visual impairments (e.g. limits environmental brightness level to reduce discomfort and disability glare, increases illuminance level to improve contrast sensitivity and spatial orientation and visual search). The spotlighting can either be triggered automatically after recognition of an activity in a specified room zone by means of motion sensors. Thus, the distinct activity or the movement of an elderly person at a special moment determines the start of the zonal lighting. On the other hand, spotlighting can be triggered automatically by a pre-programmed lighting control system, which has been defined in advance on the basis of individual daily routines. On the basis of such a prototypical activity rhythm, an elderly person could be softly reminded to start a certain activity at a certain time of the day (if necessary) by zonal lighting interventions prior to the actual start of the activity.

Furthermore, data from motion sensors can be utilized to quantify an individual's typical rhythm of daily activities over a certain observational period (e.g. several days or weeks). This includes the influence of light to mobility parameters quantified by selected activities of daily living (e.g. room zone usage duration), fundamental circadian activity rhythms (e.g. sleep parameters) as well as overall motility of person (e.g. complexity of body movement). The results from analysing motion sensor data might be used for programming the lighting control prior to automatic lighting, to detect deviations from prototypical activity rhythm, subsequently, for re-programming automatic lighting control after a specific time period as well as, finally, for evaluation purposes within an effect study.

To sum up, our spotlight concept aims at

- improving visual perception (e.g. visual acuity, contrast sensitivity, colour perception)
- reducing visual fatigue
- facilitating spatial exploration
- supporting visual search and spatial attention
- supporting room zone semantics and thus creating a distinction between spatial information and object information in terms of "where" and "what"
- providing environmental cues and identity (i.e. distinctiveness)

5.1.2. Ambient lighting intervention for temporal orientation purposes

Circadian rhythms are critically involved in control of sleep-wake cycles and numerous physiological processes. In addition, they may also play an important role in rhythms associated with cognitive processing including alertness, learning, and memory.

Ageing is associated with altered circadian activity rhythms including decreased amplitude (peak activity), fragmentation or loss of rhythms, alterations in entrainment, and decreased sensitivity to phase resetting signals (Kripke, 2005; Buysee, 2005; Czeisler, 1992; Duffy, 2002; Weitzmann, 1982; Yonn, 2003; Sakurai, 1998). The timing of activity also advances with age, resulting in an earlier onset of sleepiness in the evening, and an earlier morning waking time. These age-related changes may be the result of degeneration or decreased neuronal activity of suprachiasmatic nucleus neurons, decreased responsiveness of the circadian clock to entraining agents such as light, and decreased exposure to bright light and structured social and physical activity during the day.

Disturbances of the sleep-wake cycle, which are reflected in poor activity rhythms, are particularly pronounced in Alzheimer's disease, and are hypothesized to be one of the primary causes of institutionalization. Furthermore, it was reported previously that older community-dwelling women and men with weak circadian activity rhythms have a higher mortality risk (Paudel, 2010).

Studies have demonstrated that normal aging is accompanied by a 40% decrease in endogenous circadian amplitude and a 50% reduction in amplitude in the Alzheimer´s disease group, compared with normal young subjects (Weldemichael, 2010).

Possible interventions to strengthen circadian rhythms in elderly people may include physical activity and light exposure, which have both been demonstrated to influence cognitive functioning and affective state (Ancoli-Israel, 1997; Campell, 1995), to strengthen circadian activity rhythms, to increase circadian amplitude, shift circadian phase, and to improve sleep synchronization in older adults (Ancoli-Israel, 2002; Ancoli-Israel, 2003; Baehr, 2003; Reid, 2010).

A chronobiological and non-pharmacological treatment of irregular sleep-wake rhythms is to consolidate sleep during the night and wakefulness during the day. Thus elderly should be exposed to bright light during the day, and bright light should be avoided in the evening and at night. Daytime physical and social activities also should be strongly encouraged (Naylor, 2000; Benloucif, 2004; Niggemyer, 2004; Vitiello, 1994).

For instance, several illumination related studies focused on the positive effects of artificial bright light, as well as of outdoor natural light on people with dementia, both increasing sleep duration and causing less aggressive and agitated behaviour (Calkins, Szmerekovsky, & Biddle, 2007; Riemersma-van der Lek et al., 2008; Sloane et al., 2005; Sloane et al., 2007).

To sum up research reports on positive lighting effects on elderly, the following lighting parameters will be utilized as Guiding Light interventions:

- time-of-day dependent variation of light colour and light intensity
- bright light in the morning shortly after awakening or during evening hours when it is dark outside (applied by means of a conventional bright white light therapy device)
- increased ambient light / light dose during the day (artificial light inside or daylight outside) which causes an increase in circadian amplitude of hormonal and cardiovascular circadian rhythms

5.2. Next steps

“A new generation of lighting specifiers will have to come to grips with the timing of light and its duration as well as its quantity, spectrum and spatial distribution spectrum and spatial distribution to ensure a high quality luminous environment for older adults” (Figueiro, June 2003). The goal of this project is to generate positive impact to the mobility of older people by means of room lighting. Generally, mobility refers to the ability to move to a particular place at a certain time with ease and without restriction. This ability is necessary to perform activities of daily living independently. Loss in mobility is either caused by reduced psycho-motoric ability or relevant cognitive deficits or both together. We will focus on improvements of cognitive abilities such as spatio-temporal orientation, which can be influenced by room lighting. We will implement a new zonal lighting concept for living rooms of older people, which is based on balanced ambient and task lighting components.

The next step concerns to the operationalization of mobility by means of real-time data collection with sensor technologies as well as ex-post data collection with questionnaire tools and to prepare these data collecting instruments. Another task is to develop a setup for the room lighting installation in order to pursue considered zonal lighting concept. Furthermore, we have to define the interfaces and ways of interaction between mobility monitoring and lighting control, i.e., we will determine how to use monitoring data for (re-) programming automatic light control for ambient and task lighting components.

6. References

Abu-Assab, S. (2012). Integration of Preference Analysis Methods into Quality Function Deployment. Wiesbaden: Gabler Verlag / Springer Fachmedien. DOI 10.1007/978-3-8349-7075-6_2.

Aldwin, C.M., and Levenson, M.R. (1994). Ageing and personality assessment. In M.P. Lawton & J. Teresi (Eds.), Annual review of gerontology/geriatrics (Vol 14, pp. 182-209). New York: Springer.

Ancoli-Israel, S., Poceta, J.S., Stepnowsky, C., Martin, J., and Gehrman, P. (1997). Identification and treatment of sleep problems in the elderly. Sleep Medicine Reviews 1, 3–17.

ANSI/IESNA Recommended Practice-28-2007 (2007). Lighting and the Visual Environment for Senior Living. New York: Illuminating Engineering Society of North America.

Aarts, M., and Westerlaken, A.C. (2005). Field study of visual and biological light conditions of independently-living elderly people. Gerontechnology 4(3), 141-152.

Ancoli-Israel, S., Klauber, M.R., and Jones, D.W. (1997). Variations in circadian rhythms of activity, sleep, and light exposure related to dementia in nursing-home patients. Sleep 20, 18–23.

Ancoli-Israel, S., Martin, J.L., and Kripke, D.F. (2002). Effect of light treatment on sleep and circadian rhythms in demented nursing home patients. J Am Geriatr Soc 50, 282–289.

Ancoli-Israel, S., Gehrman, P., and Martin, J.L. (2003). Increased light exposure consolidates sleep and strengthens circadian rhythms in severe Alzheimer's disease patients. Behav Sleep Med 1, 22–36.

Aschoff, J. (1965). The phase-angle difference in circadian periodicity. In J. Aschoff: "Circadian Clocks" (pp. 262-278). Amsterdam: North Holland Press.

Baehr, E.K., Eastman, C.I., Revelle, W., (2003). Circadian phase-shifting effects of nocturnal exercise in older compared with young adults. Am J Physiol Regul Integr Comp Physiol 284, R1542–R1550.

Bakker, R., Iofel, Y., and Lachs, M.S. (2004). Lighting levels in the dwellings of homebound older adults. Journal of Housing for the Elderly 18(2), 17-27.

Ball, K., Berch, D.B., and Helmers, K.F. (2002). "Effects of cognitive training interventions with older adults: a randomized controlled trial". JAMA 288(18), 2271–2281.

Baltes, P.B., Staudinger, U.M., and Lindenberger, U. (1999). Lifespan psychology: Theory and application to intellectual functioning. Annual Review of Psychology 50, 471–507.

Becker, U. (2007). Deliverable 1.1: Specification of the criteria to be used, the sample of users involved and the description of tests to be performed. EU-funded project Aladin IST-045148, pp.14-16.

Benloucif, S., Orbeta, L., and Ortiz, R., (2004). Morning or evening activity improves neuropsychological performance and subjective sleep quality in older adults. Sleep 27(8), 1542–1551.

Bergland, A., Jarnlo, G.B., and Laake, K. (2003). Predictors of falls in the elderly by location. Aging Clinical and Experimental Research 15, 43.

Berler, D.K., and Peyser, R. (1983). Light intensity and visual acuity following cataract surgery. Ophthalmology 90, 933.

Blazer D, Burchett B, Service C, George L. (1991). The association of age and depression among the elderly: an epidemiologic exploration. J Gerontol Med Sci 46, M210-M215.

Boyce, P., Hunter, C., Howlett (2003). The Benefits of Daylight through Windows. – Literature review report. Lighting Research Institute, Rensselaer Polytechnic Institute, New York.

Brainard, G.C., Hanifin, J.P., Greeson, J.M., Byrne, B., Glickman, G., Gerner, E., and Rollag, M.D. (2001). Action spectrum for melatonin regulation in humans: evidence for a novel circadian photoreceptor. The Journal of Neuroscience 21, 6405–6412.

Brooke-Wavell K, Perrett L, Howarth P, and Haslam R. (2002). Influence of the visual environment on the postural stability in healthy older women. Gerontology 48(5), 293–297.

Burton, K.B., Owsley, C., and Sloane, M.E. (1993). Ageing and neural spatial contrast sensitivity: photopic vision. Vision Research 33, 939–946.

Buysse, D.J., Monk, T.H., Carrier, J., and Begley, A. (2005). Circadian patterns of sleep, sleepiness, and performance in older and younger adults. Sleep 28, 1365–1376.

Calkins, M., Szmerekovsky, J.G., and Biddle, S. (2007). Effect of increased time spent outdoors on individuals with dementia residing in nursing homes. Journal of Housing for the Elderly 21(3-4), 211–228.

Campbell, S.S., Kripke, D.F., Gillin, J.C., and Hrubovcak J.C. (1988). Exposure to light in healthy elderly subjects and Alzheimer's patients. Physiol. Behav. 42, 141–144.

Campbell, S.S., Terman, M., and Lewy, A.J. (1995). Light treatment for sleep disorders: consensus report. V. Age-related disturbances. J Biol Rhythms 10, 151–154.

Czeisler, C.A., Dumont, M., and Duffy, J.F. (1992). Association of sleep-wake habits in older people with changes in output of circadian pacemaker. Lancet 340, 933–936.

De Lepeleire, J., Bouwen, A., De Coninck, L., and Buntinx, F. (2007). Insufficient lighting in nursing homes. Journal of the American Medical Directors Association 8(5), 314-317.

DIN EN 12464-1 (2011). Light and lighting - Lighting of work places - Part 1: Indoor work places.

DIN SPEC 5031-100 (2012). Strahlungsphysik im optischen Bereich und Lichttechnik - Teil 100: Über das Auge vermittelte, nichtvisuelle Wirkung des Lichts auf den Menschen - Größen, Formelzeichen und Wirkungsspektren.

Dolcos, F., Rice, H. J., & Cabeza, R. (2002). Hemispheric asymmetry and ageing: right hemisphere decline or asymmetry reduction. Neuroscience and biobehavioral reviews 26(7), 819–826.

Duffy, J.F., Zeitzer, J.M., and Rimmer, D.W. (2002). Peak of circadian melatonin rhythm occurs later within the sleep of older subjects. Am J Physiol Endocrinol Metab 282, E297–E303.

Espiritu, R.C., Kripke, D.F., Ancoli-Israel, S., Mowen, M.A., Mason, W.J., Fel, R.L. Klauber, M.R., and Kaplan, O.J. (1994). Low illumination by San Diego adults: association with atypical depressive symptoms. Biol. Psychiatry 35, 403–407.

Faye, E. (2003). Poor vision. In J. Grimley Evans, T. Franklin Williams, B. Lynn Beattie, J.-P. Michel and G. K. Wilcock: The Oxford Textbook of Geriatric Medicine – 2nd Edition (pp. 881-882). Oxford: Oxford University Press.

Fetveit, A., Skjerve, A., and Bjorvatn, B. (2003). Bright light treatment improves sleep in institutionalised elderly—an open trial. International Journal of Geriatric Psychiatry 18, 520–526.

Figueiro, M.G. (2005). Bright side of blue light. Lighting Design + Application (LD+A), 16-18.

Figueiro, M.G. (Feb. 2003). Research Recap: Circadian Rhythm. Lighting Design + Application (LD+A) 33.2, 17-18.

Figueiro, M.G. (June 2003). Research Recap: Light, Ageing & the Circadian System - Reviving 'All That Jazz?'. Lighting Design + Application (LD+A) 33.6, 8-11.

Figueiro, M.G., Rea, M.S. (2006). Light, sleep quality and falls: is there a relationship, in: International Conference on Ageing, Disability and Independence, February 1-5, St. Petersburg, USA.

Francois, J., and Hollwich, F. (1991). Augenheilkunde in Klinik und Praxis: In vier Bänden. Georg Thieme.

Fredersdorf, F., and Feuerstein, G. (2011). Bevölkerungsumfrage 2010 in der Markgemeinde Götzis zum Thema „Wohnen im Alter".

Gardner, D.G., Dukes, R.L., & Discenza, R. (1993). Computer Use, Self-Confidence and Attitudes: A Causal Analysis. Computers in Human Behavior 9 (3), 427-440.

Glasser, A., and Campbell, M.C. (1998). Presbyopia and the optical changes in the human crystalline lens with age. Vision Research 38, 209.

Gohar, N. (2008). Evidence Based Research: The application of colour contrasts in the home environment of the elderly and visually impaired individuals. Sydney. Home Modification Information Clearinghouse, University of New South Wales.

Hegde, A.L. (2010). Assessment of lighting in independent living facilities and residents' perceptions. Journal of Applied Gerontology 29(3), 381-390.

Hemphill, M. (1996). A note on adults' color-emotion associations. Journal of Genetic Psychology, 157, 275-281.

Hertzog, C., and Bleckley, M.K. (2001). Age differences in the structure of intelligence: Influences of information processing speed. Intelligence 29(3), 191–217.

Heston, L.L., and Mastri, A.R. (1982). Age at onset of Pick's and Alzheimer's dementia: Implications for diagnosis and research. Journal of Gerontology 37, 422–424.

Higgins, P., Hornick, R., and Figueiro, M.G. (2010). Older adults' rest-activity and light exposure patterns in the home setting: a methodological case study. In: Am J Alzheimers Dis Other Demen 25 (4), 353–361.

Holzinger, A., Searle, G., and Nischelwitzer, A. (2007). On Some Aspects of Improving Mobile Applications for the Elderly. In C. Stephanidis (Ed.): Universal Access in HCI, Part I, HCII 2007, LNCS 4554 (pp. 923–932). Heidelberg: Springer Verlag.

Hupka, R.B., Zaleski, Z., Otto, J., Reidl, L., and Tarabrina, N.V. (1997). The colors of anger, envy, fear, and jealousy: A Cross-cultural study. Journal of Cross-Cultural Psychology 28(2), 156-171.

Jackson, G.R., Owsley, C., and McGwin Jr, G. (1999). Ageing and dark adaptation. Vision Research 39, 3975–3982.

Johnson, C.A., Keltner, J.L. (1983). Incidence of Visual Field Loss in 20,000 Eyes and Its Relationship to Driving Performance. Arch Ophthalmol 101(3), 371-375.

Kawamoto, R. (2002). Sleep problems as a risk factor for fall in community-dwelling older persons. Geriatrics & Gerontology International 2, 16–22.

Kripke, D.F., Youngstedt, S.D., and Elliott, J.A. (2005). Circadian phase in adults of contrasting ages. Chronobiol Int 22, 695–709.

Laframboise, S., De Guise, D., and Faubert, J. (2006). Effect of ageing on stereoscopic interocular correlation. Optometry & Vision Science 83, 589–593.

Lines, L., and Hone, K.S. (2004). Eliciting user requirements with older adults: lessons from the design of an interactive domestic alarm system. Universal Access in the Information Society 3(2), 141–148.

Lipton, L. (1982). Foundations of the stereoscopic cinema: a study in depth (Van Nostrand Reinhold), 56.

Lalive d'Epinay, J.L., Maystre, C., and Bickel, J.-F. (2001). Aging and Cohort Changes in Sports and Physical Training from the Golden Decades Onward: A Cohort Study in Switzerland. Society and Leisure 24(2), 453-481.

Lalive d'Epinay, C., Christe, E., Coenen-Huther, J., Hagmann, H.-M., Jeanneret, O., Junod, J.-P., Kellerhals, J., Raymond, L., Shellhorn, J.-P., Wirth, G. and De Wurstenberger, B. (1983) *Vieillesses. Situations, Itinéraires Et Modes De Vie Des Personnes Âgées Aujourd'hui*, Saint-Saphorin, Georgi.

Lawton, M.P., and Brody, E.M. (1969). Assessment of older people: self-maintaining and instrumental activities of daily living. Gerontologist 9(3), 179-186.

Mahoney, F.I., and Barthel, D (1965). Functional evaluation: the Barthel Index. Maryland State Med Journal 14, 56-61.

Marquardt, G., Johnston, D., Black, B., Morrison, A., Rosenblatt, A., Lyketsos, C., and Samus, Q. (2010). Association of the Spatial Layout of the Home and ADL Abilities Among Older Adults With Dementia. American Journal of Alzheimer's Disease & Other Dementias.

Martin, J.L., Alam, T., Harker, J.O., Josephson, K., and Alessi C.A. (2008). Sleep in assisted living facility residents versus home-dwelling older adults. J Gerontol A Biol Sci Med Sci 63(12), 1407–1409.

Maslow, A.H. (1943). A theory of human motivation. Psychological Review 50(4), 370–396.

Melenhorst, A.S., Rogers, W.A., and Bouwhuis, D.G. (2006). Older adults' motivated choice for technological innovation: Evidence for benefit-driven selectivity. Psychology and Aging 21(1), 190–195.

Mishima, K.M, Okawa, M., Shimizu, T., and Hishikawa, Y. (2001). Diminished melatonin secretion in the elderly caused by insufficient environmental illumination. J Clin Endocrinol Metab 86(1), 129– 34.

Naylor, E., Penev, P.D., and Orbeta, L. (2000). Daily social and physical activity increases slow-wave sleep and daytime neuropsychological performance in the elderly. Sleep 23(1), 87–95.

Niggemyer, K.A., Begley, A., and Monk, T. (2004). Circadian and homeostatic modulation of sleep in older adults during a 90-minute day study. Sleep 27(8), 1535–1541.

Owsley, C., Sekuler, R., and Siemsen, D. (1983). Contrast sensitivity throughout adulthood. Vision Research 23, 689–699.

Pancer, S., Margo, M.G., & Gebotys, R.J. (1992). Understanding and Predicting Attitudes Towards Computers. Computers in Human Behavior 8 (2), 211-222.

Paudel, M.L., Taylor, B.C., and Ancoli-Israel, S. (2010). Rest/activity rhythms and mortality rates in older men: MrOS Sleep Study. Chronobiol Int 27, 363–377.

Pittendrigh, C.S. (1960). Circadian rhythms and the circadian organization of living systems. In Cold Spring Harbor Symposia on Quantitative Biology, pp. 159–184.

Reid, K.J., Baron, K.G., and Lu, B. (2010). Aerobic exercise improves selfreported sleep and quality of life in older adults with insomnia. Sleep Med 11, 934–940.

Riemersma-van der Lek, R.F., Swaab, D.F., Twisk, J., Hol, E.M., Hoogendijk, W.J.G., and Van Someren, E.J.W. (2008). Effect of bright light and melatonin on cognitive and noncognitive function in elderly residents of group care facilities. Journal of the American Medical Association 299(22), 2642–2655.

Rushton, J.P., and Ankney, C.D. (2009). Whole brain size and general mental ability: A review, Int J Neurosci. 119(5), 691-731.

Sakurai, N., Sasaki, M. (1998). An activity monitor study on the sleep-wake rhythm of healthy aged people residing in their homes. Psychiatry Clin Neurosci 52, 253–255.

Savidesa, T.J., Messina, S., Sengera, C., and Kripke, D.F. (1986). Natural light exposure of young adults. Physiol. Behav. 38, 571–574.

Schmidt, R., Lang, F., Thews, G. (2004). Physiologie des Menschen, Heidelberg: Springer Verlag.

Sinoo, M.M, van Hoof, J., and Kort, H.S.M. (2011). Lighting conditions for older adults in the nursing home: Assessment of environmental illuminances and colour temperature. Building and Environment 46 (10), 1917-1927.

Sloane, P.D., Noell-Waggoner, E., Hickman, S., Mitchell, C.M., Williams, C.S., Preisser, J.S., Brawley, E. (2005). Implementing a lighting intervention in public areas of long-term care facilities: Lessons learned. Alzheimer's Care Quarterly 6(4), 280–293.

Sloane, P.D., Williams, C.S., Mitchell, C.M., Preisser, J.S., Wood, W., Barrick, A.L., and Zimmerman, S. (2007). High-intensity environmental light in dementia: Effect on sleep and activity. Journal of the American Geriatrics Society 55(10), 1524–1533.

Stuen, C., and Faye, E.E. (2003). Vision loss: Normal and not normal changes among older adults. Generations 27, 8–14.

Thapan, K., Arendt, J., and Skene, D.J. (2001). An action spectrum for melatonin suppression: evidence for a novel non-rod, non-cone photoreceptor system in humans. The Journal of Physiology 535, 261–267.

Tranah, G.J., Blackwell, T., Stone, K., Ancoli-Israel, S., Paudel, M., Ensrud, K., Cauley, J., Redline, S., Hilier, T., Cummings, S., and Yaffe, K. (2011). Circadian Activity Rhythms and Risk of Incident Dementia and Mild Cognitive Impairment in Older Women. Ann Neurol 70, 722-732.

Valdez, P., and Mehrabian, A. (1994). Effects of color on emotions. Journal of Experimental Psychology 123(4), 394-409.

Van Bommel, van den Beld (2003). Lighting for work: visual and biological effects. Philips Lighting.

Van de Kraats J., van Norren D. (2007). Optical density of the ageing human ocular media in the visible and the UV. J. Opt. Soc. Am. A. V24 N7, P1842–1857.

Van Hoof, J. Kort, H., Duijnstee, M.S., Tutten, P., and Hensen, J. (2010). The indoor environment and the integrated building design of homes for older people with dementia. Building and Environment 45(5), 1244-61.

Van Someren, E.J.W. (2000). Circadian and sleep disturbances in the elderly. Exp. Gerontol. 35, 1229-1237.

Vellas, B.J., Wayne, S.J., Romero, L.J., Baumgartner, R.N., and Garry, P.J. (1997). Fear of falling and restriction of mobility in elderly fallers. Age and Ageing 26, 189–193.

Vitiello, M.V., Prinz, P.N., and Schwartz, R.S. (1994). Slow wave sleep but not overall sleep quality of healthy older men and women is improved by increased aerobic fitness. Sleep Res 23, 149.

Webber, S.C., Porter, M.M., and Menec, V.H. (2010). Mobility in older adults: A comprehensive framework. Gerontologist 50, 443–450.

Weitzman, E.D., Moline, M.L., Czeisler, C.A., and Zimmerman, J.C. (1982). Chronobiology of aging: temperature, sleep-wake rhythms and entrainment. Neurobiol Aging 3, 299–309.

Weldemichael, D., and Grossberg, G. (2010). Circadian Rhythm Disturbances in Patients with Alzheimer´s Disease: a Review. International Journal of Alzheimer´s Disease. Article ID 716453, 9 pages, 2010. doi:10.4061/2010/716453.

Winn, B., Whitaker, D., Elliott, D.B., and Phillip, N.J. (1994). Factors affecting light-adapted pupil size in normal human subjects. Invest Ophthalmol Vis Sci. V35, P1132-1137.

Yoon, I.Y., Kripke, D.F., and Elliott, J.A. (2003). Age-related changes of circadian rhythms and sleep-wake cycles. J Am Geriatr Soc 51, 1085–1091.

7. Annex: Bibliography

7.1. Light

7.1.1. Lighting Standards

Alzheimer Knowledge Exchange (2010). Lighting Considerations.

Brawley, E. (2006). Lighting: Partner in quality care environments.

Cook, G.. Lighting the homes of people with visual impairment.

Figueiro, M.G. 24 hour lighting scheme for older adults.

Figueiro, M.G. (2008): A proposed 24 h lighting scheme for older adults. In: *Lighting Research and Technology* 40 (2), 153–160.

Figueiro, M.G. (2011). Developing architectural lighting designs to improve the health and well-being of older adults.

IES CG 1-09 (2009): Lighting For the Aging Eye.

Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (2010): Blendung - Theoretischer Hintergrund.

Mighton, J.: Lighting Environments for senior Living.

Noell-Waggoner, E.: Lighting in Nursing Homes - the unmet need.

Ruijs, L.: Light Design to Reduce Stress in Mental Health Care.

Murray Alzheimer Research and Eductation Program: Why is Lighting Important to Older Adults?

Lewis, A., and Torrington, J. (2012). Extra-care housing for people with sight loss: Lighting and design. In: *Lighting Research and Technology*.

7.1.2. Visual Impairment

Blackmore-Wright, S. (2012): Blue-light Filtering Intraocular Lenses. In: *Touch Briefings*.

Bonnie An Henderson MD; Kelly Jun Grimes MS (2009): Blue-Blocking IOLs: A Complete Review of the Literature. In: *Survey of Ophthalmology*.

Brabyn, J. (2001): The Smith Kettlewell Institute (SKI) Longitudinal study of vision function and its impact among the elderly. In: *Optometry and Vision Sciences* 78 (5), 264–269.

Clear, R. (2012): Discomfort Glare: What Do We Actually Know?

Davis, R. (2002): Task lighting for the Elderly. In: *Journal of the illuminating Engineering Society,* 31 (1), 20–32.

Davison, J. (2011): Recent studies provide an updated clinical perspective on blue light-filtering IOLs. In: *Graefes Arch Clin Exp Ophthalmol* 249, 957–968.

Del Viva, M. M.; Agostini, R. (2007): Visual Spatial Integration in the Elderly. In: *Investigative Ophthalmology & Visual Science* 48 (6), 2940–2946.

Elliot, D. (1993): Assessing the Reliability, Discriminative Ability, and Validity of Disability Glare Tests. *Investigative Ophthalmology & Visual Science* 34 (1).

Else Vengnes Grue {et al.} (2010): Recent Visual Decline—A Health Hazard with Consequences for Social Life: A Study ofHome Care Clients in 12 Countries. In: *Current Gerontology and Geriatrics Research*.

Eperjedi, F. (2002): Do tinted lenses or filters improve visual performance in low vision? A review of the literature. In: *Ophthal. Physiol Opt* 22, S. 68–77.

Gibbons, R. (2012): Glare Modeling Formulae.

Haegerstrom-Portnoy, G. (1999): Seeing into old age: Vision function beyond acuity. *Optometry and Vision Sciences* 76 (3), 143–158.

Haegerstrom-Portnoy, G. (2005): The Glenn A. Fry Award Lecture 2003: Vision in Elders—Summary of Findings of the SKI Study. *Optometry and Vision Sciences* 82 (2), 87–93.

Hammond, B. (2012): The visual effects of intraocular filters. In: *Scientifica*.

Haymes, S. (2006): The Letter Contrast Sensitivity Test: Clinical Evaluation of a New Design. In: *Investigative Ophthalmology & Visual Science* 47 (6).

Kline, D.W. (1987): Ageing and the spatiotemporal discrimination performance of the visual system. In: *Eye* 1, S. 323–329.

Knoblauch, K. (1987): Age and illuminance effects in the Farnsworth-Munsell 100-hue test. In: *Applied Optics* 26 (8).

Loughman, J. (2010): Macular pigment and its contribution to visual performance and experience. *Journal of Optometry* 3(2), 74–90.

Owsley, C. (2003): Contrast sensitivity. *Ophthalmology Clinics of North America*, 171–177.

Park, N. (1999): Impact of different fluorescent light color temperatures and color rendering indices on lighting preference, visual comfort, value discrimination and color descorptiors for elderly consumers.

Pokorny, J. (1997): How much light reaches the retina. In: *Colour Vision Deficiencies XIII*, 491–511.

Ross, J. (1985): Effect of age on contrast sensitivity function: uniocular and binocular findings uniocular and binocular findings Effect of age on contrast sensitivity function: uniocular and binocular findings. *Br J Opthalmol* 69, 51–56.

Schäfer, S. (2012): Rezeptororientierte Charakterisierung breitbandiger Spektren als Basis einer mesopischen Hellempfindung.

Salvi, S. (2006): Ageing changes in the eye. In: *Postgrad Med* 82, 581–587.

Schieber, F.: Age and Glare Recovery Time for Low-Contrast Stimuli.

Sekuler, A. (2000): Effects of Aging on the Useful Field of View. In: *Experimental Aging Research* 26, 103–120.

Sekuler, R. (2000): Age-Related Changes, Optical Factors, and Neural Processes. In: *Encyclopedia of Psychology, Oxford University Press*.

Shinomori, K. (2005): Ageing effects on colour vision - changed and unchanged perceptions. In: *AIC Colour*.

Smith, G. (2002): Disability glare and its clinical significance. *Optometry*.

van de Pol, M. (1999): Visual Performance on the Small Letter Contrast Test: Effects of Aging, Low Luminance and Refractive Err or.

Van der Berg, T. (2010): Ocular Media Clarity and Straylight. In: *Encyclopedia of the EYE*.

Vos, J. (2003): Reflections on glare. In: *Lighting Research and Technology* 35 (163).

Watson, A. (2012): A unified formula for light-adapted pupil size. *Journal of Vision* 12 (10), 1–16.

Werner, A. (1995): Ageing and chromatic contrast sensitivity.

Werner, J. (2005): Night vision in the elderly: consequences for seeing through a "blue filtering" intraocular lens. *Br J Opthalmol* 89, 1518–1521.

Whiteside, M. (2006): SENSORY IMPAIRMENT in Older Adults. PART 2: VISION LOSS. In: *AJN* 106 (11).

Withouck, M. (2012): Age related colour appearance differences for unrelated self-luminous colours.

Wu, Ch (2012): Evaluation of Visual Performance Using LED Signboards under Different Ambient Conditions. In: *Procedia Engineering* 29, 975–980.

Yamagishi, M. (2012): Effects of LED lighting characteristcs on visual performance of elderly people.

Zigman, S. (1992): Light filters to improve vision. In: *Optometry and Vision Sciences* 69 (4), 325–328.

Navarro, R. (2009): The Optical Design of the Human Eye: a Critical Review. In: *J Optom* 2, S. 3–18.

Predicting Perceptions: Proceedings of the 3rd International Confernce on Appearance.: Effects of Appearance in Visual Palatability of Dishes for the Elderly under Several Lighting Conditions.

Polat, U.; Schor, C.; Tong, J.-L.; Zomet, A.; Lev, M.; Yehezkel, O. et al. (2012): Training the brain to overcome the effect of aging on the human eye. *Sci. Rep* 2.

van den Berg, T., van Rijn, L.J. (René), Kaper-Bongers, R., Vonhoff, D.J., Völker-Dieben, H.J., Grabner, G. et al. (2009): Disability Glare in the Aging Eye. Assessment and Impact on Driving. *J Optom* 2, 112–118.

7.1.3. (Chrono-)biological Impairment

ASHLEY MAE STRIPLING (2008): Ambient light and sleep in community dwelling older adults. PhD Thesis.

Bernhofer, E. (2012): Light exposure, sleep-wake patterns, mood, and pain in hospitalized adult medical patients.

Cherepanova, V. (2000): The effects of phototherapy on diurnal rhythms of physiological parameters and melatonin excretion in subjects with SAD.

Doherty, A. (2010): Effects of environmental colour on mood: a wearable LifeColour capture device. In: *Proceedings of the international conference on Multimedia*.

Eindhoven, University of Technology: Light & Care 2010: Symposium Proceedings 2010.

Figueiro, M. (2008): A proposed 24 h lighting scheme for older adults. In: *Lighting Research and Technology* 40 (2), S. 153–160.

Figueiro, M. (2008): Developing Architectural Lighting Designs to Improve Sleep in Older Adults. *The open sleep journal* (1), 40–51.

Figueiro, M. (2010): Lighting the Way: A key to independence in age.

Figueiro, M.G., and Rea, M.S: (2012): Short-Wavelength Light Enhances Cortisol Awakening Response in Sleep-Restricted Adolescents. *International Journal of Endocrinology*.

Fetveit, A. (2004): The effects of bright-light therapy on actigraphical measured sleep last for several weeks post-treatment. A study in a nursing home population. *J Sleep REs.* (13), 153–158.

Gasio, P. (2003): Dawn–dusk simulation light therapy of disturbed circadian rest–activity cycles in demented elderly. *Experimental Gerontology* (38), 207–216.

Giménez, Marina C.; Hessels, Martijn; van de Werken, Maan; Vries, Bonnie de; Beersma, Domien G. M.; Gordijn, Marijke C. M. (2010): Effects of artificial dawn on subjective ratings of sleep inertia and dim light melatonin onset. *Chronobiol Int* 27(6), 1219–1241.

Grandner, M. (2006): Light exposure is related to social and emotional functioning and to quality of life in older women. *Psychiatry Research*, 35–42.

Herbst, K. (2012): Intrinsically photosensitive retinal ganglion cell function in relation to age: A pupillometric study in humans with special reference to the age-related optic properties of the lens. *BMC Ophthalmology* 12 (4).

Kantermann, T., Forstner, S., Halle, M., Schlangen, L., Roenneberg, T., Schmidt-Trucksäss, A., and Lucia, A. (2012): The Stimulating Effect of Bright Light on Physical Performance Depends on Internal Time. *PLoS ONE* 7 (7), e40655.

Kent, Shia T.; McClure, Leslie A.; Crosson, William L.; Arnett, Donna K.; Wadley, Virginia G.; Sathiakumar, Nalini (2009): Effect of sunlight exposure on cognitive function among depressed and non-depressed participants: a REGARDS cross-sectional study. In: *Environ Health* 8 (1), 34.

Kripke, D. (2007): Circadian phase response curves to light in older and young women and men. In: *Journal of Circadian Rhythms*.

Radzey, B.; Kreutzner, G. (2010): Licht und Demenz. In: *Proceedings*.

Rautkyla, E.; Puolakka, M.; Halonen, L. (2012): Alerting effects of daytime light exposure - a proposed link between light exposure and brain mechanisms. *Lighting Research and Technology* 44 (2), 238–252.

Shikder, S. (2012): A systematic review on the therapeutic lighting design for the elderly.

Tsai, Y.-F., Wong, T.K.S., Juang, Y.-Y., and Tsai, H.-H. (2004): The effects of light therapy on depressed elders. *Int. J. Geriat. Psychiatry* 19 (6), 545–548.

Turner, P.L. (2008): Circadian photoreception: ageing and the eye's important role in systemic health. *Br J Opthalmol* 92, 1439–1444.

Turner, P.L., Van Someren, E.J.W., and Mainster, M.A. (2009): The role of environmental light in sleep and health: Effects of ocular aging and cataract surgery. *Sleep Medicine Reviews*, 1–12.

University of Nebraska Medical Center (2012): Light Therapy Literature.

van Hoof, J. (2008): Ambient bright light in dementia: Effects on behaviour and circadian rhythmicity. In: *Building and Environment*.

van Hoof, J., Schoutens, A.M.C., Aarts, M.P.J. (2009): High colour temperature lighting for institutionalised older people with dementia. In: *Building and Environment*, 1–11.

van Someren, Eus J.W; Riemersma-Van Der Lek, Rixt F. (2007): Live to the rhythm, slave to the rhythm. In: *Sleep Medicine Reviews* 11 (6), 465–484.

Zeitzer, J. (2011): Effectiveness of evening phototherapy for insomnia is reduced by bright daytime light exposure. In: *Sleep Medicine Reviews* 12 (8), S. 805–807.

7.1.4. Illumination in situ

Aarts, M. (2005): Field study of visual and biological light conditions of independently-living elderly people.

Higgins, P. (2010): Older adults' rest-activity and light exposure patterns in the home setting: a methodological case study. In: *Am J Alzheimers Dis Other Demen* 25 (4), S. 353–361.

Miller, D. (2010): Ecological measurements of light exposure, activity and circadian disruption. In: *Lighting Research and Technology* 42, S. 271–284.

7.1.5. Lighting Control Strategies

Aldrich, M. (2010): Dynamic Solid State Lighting. PhD Thesis.

Aldrich, M., Zhao, N., and Paradiso, J. (2010): Energy efficient control of polychromatic solid state lighting using a sensor network: SPIE.

El-Nasr, M.: Dynamic Intelligent Lighting for Directing Visual Attention in Interactive 3D Scenes.

Greenspan, J. (2012): Adaptive lighting. In: *Final Report for ECE 445, Senior Design*.

Zhao, Nan (2010): Smart Solid-State Lighting Control - Steuerung eines Intelligenten Belichtungssystems mit LED Lichtquellen, RWTH Aachen.

Hakulinen, J.: Light Control Architecture for Multimodal Interaction in Physical and Augmented Environments.

van Essen, H.: Exploring the Role of Autonomous System Behavior in Lighting Control.

TU Eindhoven (2009): Adaptive Lighting Environments.

Offermans, S.: Breakout 404: A Smart Space Implementation for Lighting Services in the Office Domain.

7.1.6. Light and Mobility

Figueiro, M., Gras, L., Qi, R., Rizzo, P., and Rea, M. (2008): A novel night lighting system for postural control and stability in seniors. In: *Lighting Research and Technology* 40 (2), 111–126.

Figueiro, Mariana G.; Plitnick, Barbara; Rea, Mary S.; Gras, Laura Z.; Rea, Mark S. (2011): Lighting and perceptual cues: Effects on gait measures of older adults at high and low risk for falls. In: *BMC Geriatr* 11 (1), 49.

Harwood, R. (2001): Visual problems and falls. In: *Age and Aging* 30, S. 13–18.

Lighting Research Center: Innovative Lighting technique reduces risk for falls in older adults.

Lighting Research Center: Lighting for better postural stability and control in older adults.

McCurry, S. (2011): Increasing Walking and Bright Light Exposure to Improve Sleep in Community-Dwelling Persons with Alzheimer's Disease: Results of a Randomized, Controlled Trial. In: *J Am Geriart Soc* 59 (8), S. 1393–1402.

Shakespeare, R.: Designing visually accessible spaces : The role of radiance.

Shakespeare, R.: DEVA Update.

7.1.7. Further Topics

Bajaj, A. (2011): Validation of a light questionnaire with real-life photopic illuminance measruements: The Harvard light exposure assessment questionnaire. In: *Cancer Epidemiol Biomarkers Prev* 20 (7), S. 1341–1349.

Newsome, P.: The Effects of Ultraviolet and Visible Light on the Eye.

Philips (2012): Licht bewegt: Erleben sie, was Licht in Seniorenzentren bewirken kann.

Plischke, H., and Lang, D. (2010): "Light and the Ageing Society" – Bedeutung für AAL Systeme zuhause und unterwegs. In: *3.AAL Kongress*.

Schierz, C.: Mehr Licht im Alter 2008.

Schierz, C. (2008): Licht für die ältere Bevölkerung – physiologische Grundlagen und ihre Konsequenzen. In: *Licht*.

Welten, S.: Sundroid: Solar Radiation Awareness with Smartphones.

Scientific Committee on Emerging and Newly Identified Health Risks (2012): Health Effects of Artificial Light.

7.2. Mobility

Personal Motion Technologies for Healthy Independent Living (2010). In: *National Institute on Aging* Workshop Summary.

Allen, H. (2010): The role of contrast sensitivity in global motion processing deficits in the elderly. In: *Journal of Vision* 10 (10), S. 1–10.

Benbow, B. (2012): Annotated bibliography dementia design: Wayfinding and layout.

Benninghouse, T. (2008): Age and Gender Differences in Some Components of Spatial Cognition. In: *Women and Aging: New REsearch* (Chapter 16).

Bosco, A. (2003): Assessing age differences in spatial orientation tasks following map study. In: *Imagination, Cognition and Personality*.

Bridge, Catherine (2009): The application of colour and colour contrast in the home environment of the elderly and visually impaired individuals. Evidence based research.

Buchman, A. (2009): Association between Late-Life Social Activity and Motor Decline in Older Adults. In: *Arch Intern Med.* (169(12)), S. 1139–1146.

Carvalho-Bos, S. (2007): Strong Association of the Rest–Activity Rhythm With Well-Being in Demented Elderly Women. In: *Am J Geriatr Psychiatry* (15(2)).

Cerny, M. (2008): The Circadian Cycle Monitoring. In: *Proceedings of the 5th International Workshop on Wearable and Implantable Body Sensor Networks, The 5th International Summer School and Symposium on Medical Devices and Biosensors*.

Crespo, C. (2010): Algorithm for Sleep/Wake Identification From Actigraphy. In: *Biosignal*.

Ding, J. (2012): Powerful Actigraphy Data Through Functional Representation.

Frei, Anja; Williams, Kate; Vetsch, Anders; Dobbels, Fabienne; Jacobs, Laura; Rüdell, Katja; Puhan, Milo A. (2011): A comprehensive systematic review of the development process of 104 patient-reported outcomes (PROs) for physical activity in chronically ill and elderly people. In: *Health Qual Life Outcomes* 9 (1), S. 116.

Hort, J.: Spatial navigation in Alzheimer disease and amnestic mild cognitive impairment.

Iachini, Tina; Ruggiero, Gennaro; Ruotolo, Francesco (2009): The effect of age on egocentric and allocentric spatial frames of reference. In: *Cogn Process* 10 (S2), S. 222–224.

Marquardt, G. (2011): Wayfinding for People With Dementia: A Review of the Role of Architectural Design. In: Health Enviroments Research & Design Journal 4(2).

Marquardt, G.; Johnston, D.; Black, B. S.; Morrison, A.; Rosenblatt, A.; Lyketsos, C. G.; Samus, Q. M. (2011): Association of the Spatial Layout of the Home and ADL Abilities Among Older Adults With Dementia. In: *American Journal of Alzheimer's Disease and Other Dementias* 26 (1), S. 51–57.

Marquardt, G.; Schmieg, P. (2009): Dementia-Friendly Architecture: Environments That Facilitate Wayfinding in Nursing Homes. In: *American Journal of Alzheimer's Disease and Other Dementias* 24 (4), S. 333–340.

Marquardt, G.; Schmieg, P. (2009): Demenzfreundliche Architektur. In: *Z Gerontol Geriat* 42 (5), S. 402–407.

Morganti, Francesca; Gaggioli, Andrea; Strambi, Lorenzo; Rusconi, Maria; Riva, Giuseppe (2007): A virtual reality extended neuropsychological assessment for topographical disorientation: a feasibility study. In: *J NeuroEngineering Rehabil* 4 (1), S. 26.

Neumeyer, R. (2009): Effects of Interior Spatial Features on Use and Perception of Space: An Exploratory Study in Two Assisted Living Facilities in Oregon.

Pantzar, M.: Future Shock – Discussing the Changing Temporal Architecture of Daily Life.

Schweizer, Ch (2007): Indoor time–microenvironment–activity patterns in seven regions of Europe. In: *Juornal of Exposure Science and Environmental Epidemiology* 17, S. 170–181.

Teresi, J. (2000): The Therapeutic Design of Environments for People With Dementia: Further Reflections and Recent Findings From the National Institute on Aging Collaborative Studies of Dementia Special Care Units. In: *The Gerontolist* (40(4)), S. 417–421.

Willis, S. (1986): Training the elderly on the ability factors of spatial orientation and inductive reasoning. In: *Psychology and Aging* (1(3)).

Kaye, J. (2012): Home-Based Activity Changes Associated with MCI.

Lymberopoulos, D. (2012): Extracting Spatiotemporal Human Activity Patterns in Assisted Living using a Home Sensor Network.

Paterson, Donald H.; Warburton, Darren E. R. (2010): Physical activity and functional limitations in older adults: a systematic review related to Canada's Physical Activity Guidelines. In: *International Journal of Behavioral Nutrition and Physical Activity* 7 (1), S. 38.

Rand, Debbie; Eng, Janice J.; Tang, Pei-Fang; Hung, Chihya; Jeng, Jiann-Shing (2010): Daily physical activity and its contribution to the health-related quality of life of ambulatory individuals with chronic stroke. In: *Health Qual Life Outcomes* 8 (1), S. 80.

van der Voordt, T.: Lost in a Nursing Home.

7.3. Methodology

Albert Ali Salah (2010): T-Patterns Revisited: Mining for Temporal Patterns in Sensor Data. In: *Sensors* 10, S. 7496–7513.

Ancoli-Israel, S. (2003): The Role of Actigraphy in the Study of Sleep and Circadian Rhythms. In: *Sleep Medicine Reviews* 26 (3), S. 342–392.

Brankovic, S. (2010): Interlinked positive and negative feedback loops design emotional sweating.

Cardinaux, F. (2012): Modelling of behavioural patterns for abnormality detection in the context of lifestyle reassurance.

Chang Yang, C. (2011): Monitoring and assessment of activities of daily living in the home environment.

Fang, J. (2012): Discovering Routine Events and their Periods in Sensor Time Series Data.

Farias, Sarah Tomaszewski; Mungas, Dan; Reed, Bruce R.; Cahn-Weiner, Deborah; Jagust, William; Baynes, Kathleen; DeCarli, Charles (2008): The measurement of everyday cognition (ECog): Scale development and psychometric properties. In: *Neuropsychology* 22 (4), S. 531–544.

Gaddam, A. (2011): Trial & Experimentation Of A Smart Home Monitoring System For Elderly. In: *IEEE Transactions on Information Technology in Biomedicine*.

Gallacher, J. (2011): Generating Large-Scale Longitudinal Data Resources for Aging Research. In: *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences,*

Gimeno-Santos, Elena; Frei, Anja; Dobbels, Fabienne; Rüdell, Katja; Puhan, Milo A.; Garcia-Aymerich, Judith (2011): Validity of instruments to measure physical activity may be questionable due to a lack of conceptual frameworks: a systematic review. In: *Health Qual Life Outcomes* 9 (1), S. 86.

Gordon, A. (2012): A systematic mapping review of Randomized Controlled Trials (RCTs) in care homes. In: *BMC Geriatr* 12 (31).

Grandin, Louisa D.; Alloy, Lauren B.; Abramson, Lyn Y. (2006): The social zeitgeber theory, circadian rhythms, and mood disorders: Review and evaluation. In: *Clinical Psychology Review* 26 (6), S. 679–694.

Hoque, E. (2012): AALO: Activity recognition in smart homes using Active Learning in the presence of Overlapped activities. In: *Pervasive Health*.

Kahnemann, D. (306): A Survey Method for Characterizing Daily Life Experience: The Day Reconstruction Method. In: *Science* 2004.

Lymberopoulos, D. (2012): A methodology for extracting temporal properties from sensor network data streams.

Magnusson, M. (2000): Discovering hidden time patterns in behavior: T-patterns and their detection. In: *Behavior Research Methods, Instrmuents & Computers* 32 (1), S. 93–110.

Mahmoud, S. (2012): User Activities Outlier Detection System Using Principal Component Analysis and Fuzzy Rule-Based System. In: *PETRA*.

Marjorie Skubic, Rainer Dane Guevara and Marilyn Rantz (2012): Testing Classifiers for Embedded Health Assessment. In: *ICOST*, S. 198–205.

Mautz, R. (2012): Indoor Positioning Technologies.

Monk, T. (2002): A simple way to measure daily lifestyle regularity. In: *J Sleep REs.* (11), S. 183–190.

Monk, T. (2010): Enhancing circadian Zeitgebers.

Monk, T. (2010): Enhancing Circadian Zeitgebers. In: *Sleep Medicine Reviews* (33(4)).

Munoz, Andres (2012): An Approach for Representing Sensor Data to Validate Alerts in Ambient Assisted Living. In: *Sensors* 12, S. 6282–6306.

Nansen, B.; Arnold, M.; Gibbs, M. R.; Davis, H. (2009): Domestic orchestration: Rhythms in the mediated home. In: *Time & Society* 18 (2-3), S. 181–207.

Raftery, A. (2012): Bayesian probabilistic population projections for all countries. In: *PNAS*.

Reeves, Martin: Measuring Psychosocial Treatment outcomes with older people.

Reeves, Martin (2004): Measuring Outcomes in Routine Clinical Practice: Paper 3.

Rohan; S. (2012): Chronotherapeutical approach: Circadian rhythm in human and its role in occurrence and severity of diseases. In: *International Journal of PharmTech Research* (4(2)), S. 765–777.

Stone, A. (2006): A Population Approach to the Study of Emotion: Diurnal Rhythms of a Working Day Examined With the Day Reconstruction Method. In: *Emotion* 6 (1), S. 139–149.

Symanzik, J. (2008): Exploratory Graphics for Functional Actigraphy Data. In: *WNAR - JSM*.

Tacken, M.: Temporal aspects fo the out-of-home activities of elderly people.

Teixeira, T.: A survey of human sensing: Methods for detecting presence, count, location, track and identity.

Universität Witten: Assessments in der Versorgung von Personen mit Demenz.

Valdez, P.: Rhythms of Mental Performance.

Virone, G.: Activity prediction for in-home activity monitoring.

Virone, G. (2008): Assessing Behavioral Rhythms for the benefit of the older Generation. In: *Oregon Center for Aging and Technology* Präsentation.

Virone, G. (2008): Behavioral patterns of older adults in assisted living. In: *IEEE Transactions on Information Technology in Biomedicine* (12(3)).

Virone, G. (2008): Toward Information Systems for Ambient Assisted-Living.

Werner, H. (2008): Agreement Rates Between Actigraphy, Diary, and Questionnaire for Children's Sleep Patterns. In: *Arch Pediatr Adolesc* (162(4)), S. 350–358.

Zisberg, A.: Influence of Routine on Functional Status in Elderly: Development and Validation of an Instrmuent to measure Routine.

Zisberg, A. (2010): Contribution of Routine to Sleep Quality in Community Elderly. In: *Sleep Medicine Reviews* (33(4)).

Morgenthaler, T. (2007): Practice Parameters for the Use of Actigraphy in the Assessment of Sleep and Sleep Disorders: An Update for 2007 Practice Parameters for the Use of Actigraphy in the Assessment of sleep and Sleep Disorders: An Update for 2007. In: *Sleep Medicine Reviews* (30(4)).

Morton, N. de (2008): A systematic review of mobility instruments and their measurement properties for older acute medical patients. In: *Health and Quality of Life Outcomes* 6 (44).

Sadeh, Avi (2011): The role and validity of actigraphy in sleep medicine: An update. In: *Sleep Medicine Reviews* 15 (4), S. 259–267.

Sanchez-Ortuno, M. (2010): Home Is Where Sleep Is: An Ecological Approach to Test the Validity of Actigraphy for the Assessment of Insomnia. In: *Journal of Clinical Sleep Medicine* (6(1)).

Sant Anna, A. (2008): Gait Unsteadiness Analysis from Motion Primitives. In: *Gerontology* 7 (2), S. 204.

Scanaill, Cliodhna Ní (2006): A Review of Approaches to Mobility Telemonitoring of the Elderly in Their Living Environment. In: *Annals of Biomedical Engineering* 34 (4), S. 547–563.

Tamura, Y. (2012): Home geriatric physiological measurements. In: *Physiol Meas* 33, S. 47–65.

7.4. Sensors

Austin, D. (2011): On the Disambiguation of Passively Measured In-home Gait Velocities from Multi-person Smart Homes. In: *J Ambient Intell Smart Environ* 3 (2), S. 165–174.

Austin, D. (2011): Unobtrusive Monitoring of the Longitudinal Evolution of In-Home Gait Velocity Data with Applications to Elder Care. In: *Conf Proc IEEE Eng Med Biol Soc*, S. 6495–6498.

Avci, A. (2012): Activity Recognition Using Inertial Sensing for Healthcare, Wellbeing and Sports Applications: A Survey Activity Recognition Using Inertial Sensing fo Wellbeing and Sports Applications: A Survey.

Bamis, A. (2012): The BehaviorScope Framework for Enabling Ambient Assisted Living. In: *Microsoft Research*.

Brownsell, S. (2012): Developing a Systems and Informatics based approach to Lifestyle Monitoring within eHealth: Part II - Analysis & Interpretation.

Che-Chang Yang; Yeh-Liang Hsu (2012): Remote monitoring and assessment of daily activities in the home environment. In: *Journal of Clinical Gerontology & Geriatrics*, S. 1–8.

Chen, K. (2012): Re-defining the roles of sensors in objective physical activitity monitoring. In: *Med Sci Sports Exerc* 44 (1), S. 13–23.

Chen, L. (2012): Sensor-based Activity Recognition. In: *IEEE SMCC*.

Chien-Chang Hsu * (2011): A Novel Sensor-Assisted RFID-Based Indoor Tracking System for the Elderly Living Alone. In: *Sensors* 11 (10094-10113).

Chiriac, S. (2012): An ambient assisted living monitoring system for Activity Recognition - Results from the first evaluation stages. In: *5.AAL-Kongreß, Berlin*.

Conaire, C. (2012): SenseCam Image Localisation using hierarchical SURF trees.

Crispim, C. (2012): A Multi-Sensor Approach for Activity Recognition in Older Patients.

Ferdous, S. (2012): Multi Person Identification and Localization in Pervasive Assistive Environments. In: *International Journal of Computer Science and Management Research* 1 (4).

Fleury, Anthony et al (2009): Supervised Classification of Activities of Daily Living in Health Smart Homes using SVM. In: *IEEE EMBC*.

Fouquet, Y.: Telemonitoring of the elderly at home: real-time pervasive follow-up of daily routine, automatic detection of outliers and drifts. In: *Smart Home Systems*.

Fouquet, Y. (2012): Behavioral telemonitoring of the elderly at home: Persistent Actimetric Information from location data in Health Smart Homes.

Fouquet, Y. (2012): Telemonitoring of the elderly at home: Real-time pervasive follow-up of daily routine, automatic detection of outliers and drifts.

Gabel, M. (2012): Full Body Gait Analysis with Kinect. In: *Microsoft Research*.

Guyon, Dennis: The Dimesimeter: a user friendly circadian light meter.

Guyon, Dennis (2011): Dimesimeter - Light and activity measurement system description and calibration.

Guyon, Dennis (2012): New tools to measure light exposure, activity, and circadian disruption in older adults.

Guyon, Dennis (2012): The Dimesimeter: a user friendly circadian light and activity sensor.

Hagler, S. (2010): Unobtrusive and Ubiquitous In-Home Monitoring: A Methodology for Continuous Assessment of Gait Velocity in Elders. In: *IEEE Transactions on Information Technology in Biomedicine* 57 (4), S. 813–820.

Han, Yongkoo (2012): A Framework for Supervising Lifestyle Diseases Using Long-Term Activity Monitoring. In: *Sensors* 12, S. 5363–5379.

Han, Yongkoo; Han, Manhyung; Lee, Sungyoung; Sarkar, A. M. Jehad; Lee, Young-Koo (2012): A Framework for Supervising Lifestyle Diseases Using Long-Term Activity Monitoring. In: *Sensors* 12 (5), S. 5363–5379.

Hayes, T.: An approach for deriving continuous health assessment indicators from in-home sensor data.

Hayes, T. (2004): An Unobtrusive In-home Monitoring System for Detection of Key Motor Changes Preceding Cognitive Decline. In: *Proccedings of the 26th Annual International Conference of the IEEE EMBS*.

Hayes, T. (2008): Unobtrusive assessment of activity patterns associated with mild cognitive impairment. In: *Alzheimers Dement* 4 (6), S. 395–405.

Hazem Wannous, Vladislavs Dovgalecs Rémi Mégret and Mohamed Daoudi (2012): Place Recognition via 3D Modeling for Personal Activity Lifelog Using Wearable Camera. In: *MMM*.

Hnat, T. (2012): Doorjamb: Unobtrusive Room-level Tracking of People in Homes using Doorway Sensors. In: *SenSys*.

Ince, N. (2012): Integration of Wearable Wireless Sensors and Non-Intrusive Wireless in-Home Monitoring System to Collect and Label the Data from Activities of Daily Living.

Jaeyong Sung, Colin Ponce Bart Selman Ashutosh Saxena (2012): Unstructured Human Activity Detection from RGBD Images. In: *IEEE International Conference on Robotics and Automation*.

Juan J. Villacorta *, María I. Jiménez Lara del Val Alberto Izquierdo (2011): A Configurable Sensor Network Applied to Ambient Assisted Living. In: *Sensors* 11, S. 10724–10737.

Kempter, G. (2012): Mobiles Messgerät für die Untersuchtung des Lichteinflusses auf zirkadiane Rhythmen. In: *Proceedings of the EHealth*.

Kourosh Khoshelham (2012): Accuracy and Resolution of Kinect Depth Data for Indoor Mapping Applications. In: *Sensors* 12, S. 1437–1454.

Kropf, J. (2012): A modular and flexible system for activity recognition and smart home control based on nonobtrusive sensors. In: *Pervasive Health*.

Lauterbach, Ch (2012): SensFloor Matte.

Lei, J. (2012): Fine-Grained Kitchen Activity Recognition using RGB-D. In: *UbiComp*.

Martin, J. L.; Hakim, A. D. (2011): Wrist Actigraphy. In: *Chest* 139 (6), S. 1514–1527.

Murrill, B. (2012): Smart Meter Data: Privacy and Cybersecurity. In: *Congressional Research Service*.

Nirjon, S. (2012): Kinsight: Localizing and Tracking Household Objects using Depth-Camera Sensors.

Patel, P. (2012): A Passive Monitoring System in Assisted Living Facilities: 12-Month Comparative Study. In: *physical & Occupational Therapy in Geriatrics* 30 (1), S. 45–52.

Patel, S. (2012): A review of wearable sensors and systems with application in rehabilitation. In: *Journal of NeuroEngineering and Rehabilitation* 9 (21).

Pavel, M. (2007): Continuous, unobtrusive monitoring for the assessment of cognitive function.

Pulli, M. (2010): A system for monitoring people's home activities.

Schindhelm, C. (2012): Evaluating SLAM Approaches for Microsoft Kinect. In: *The Eighth International Conference on Wireless and Mobile Communications*.

Stone, E. (2012): Capturing Habitual, In-Home Gait Parameter Trends Using an Inexpensive Depth Camera.

Stone, E. (2012): Passive, In-Home Gait Measurement Using an Inexpensive Depth Camera: Initial Results. In: *6th International Conference on Pervasive Computing Technologies for Healthcare*.

Tamura, Y. (2012): Localization System using Microsoft Kinect for Indoor Structures. In: *The Japan Society of Plasma Science and Nuclear Fusion Research* 7.

Tapia, E.: Activity Recognition in the Home Using Simple and Ubiquitous Sensors.

Tapia, E. (2003): Activity Recognition in the Home Setting Using Simple and Ubiquitous Sensors.

Weiss, M. (2012): Leveraging smart meter data to recognize home appliances.

Wu, H. (2012): Development and evaluation of a blackberry-based wearable mobility monitoring system.

Xia, L. (2012): Human Detection Using Depth Information by Kinect.

Zapata, J. (2012): Wireless Sensor Network for Ambient Assisted Living.

Zhang; Ch. (2012): RGB-D Camera-based Daily Living Activity Recognition.

Zhang, Sen; Ang, Marcelo H.; Xiao, Wendong; Tham, Chen Khong (2009): Detection of Activities by Wireless Sensors for Daily Life Surveillance: Eating and Drinking. In: *Sensors* 9 (3), S. 1499–1517.

Zouba, N. (2012): An Activity Monitoring System for Real Elderly at Home: Validation Study.

SeongHo Song (2011): A Monitoring System for Assessing Life Pattern of the Elderly Living Alone. In: *AISS* 3 (7), S. 311–323.

Virone, G. (2002): A System for Automatic Measurement of Circadian Activity Deviations in Telemedicine. In: *IEEE Transactions on Information Technology in Biomedicine* 49 (2).

Vitaliy Kolodyazhniy, Jakub Späti Sylvia Frey Thomas Götz Anna Wirz-Justice Kurt Kräuchi Christian CajochenFrank H. Wilhelm (2012): An Improved Method for Estimating Human Circadian Phase Derived From Multichannel Ambulatory Monitoring and Artificial Neural Networks. In: *Chronobiol Int*, S. 1–20.

7.5. User-centric stuff / Usability

Andreas Holzinger, Gig Searle and Alexander Nischelwitzer (2007): On Some Aspects of Improving Mobile Applications for the Elderly.

Aliakseyeu, D. (2011): Proceedings of the workshop on User Interaction Techniques for Future Lighting Systems. In: *URL: http://interactingwithlight.id.tue.nl/*.

Barry, J. (2008): Everyday habits and routines: Design strategies to individualize home modifications for older people.

Eurostat (2004): How Europeans spend their time everyday life of women and men.

Gauthier, Anne H. (2000): Time use in retirement: What do social policy regimes purchase.

Hoube, M. (2003): Time use and Leisure of Flemish elderly.

IBES - Institute for a Broadband-Enabled Society (2012): Smart technologies for older people: a systematic literature review of smart technologies that promote health and wellbeing of older people living at home.

Jimison, H. (2008): Barriers and Drivers of Health Information Technology Use for the Elderly, Chronically Ill, and Underserved: Evidence Report/Technology Assessment, No. 175. In: *Evidence Report/Technology Assessment No. 175*.

Krantz-Kent, R. (2007): How do older Americans spend their time? In: *Monthly Labor Review*.

McKinnon, A. (1992): Time use for self care, productivity, and leisure among elderly Canadians.

Robinson, J. (2009): Senioritis in repose. In: *International Juornal of Time Use Research* 6 (2), S. 306–313.

Salmi, P.: Wayfinding Design: Hidden Barriers to Universal Access Wayfinding Design: Hidden Barriers to Universal Access.

Shen, Gail H. C.; Sylvia, Louisa G.; Alloy, Lauren B.; Barrett, Fred; Kohner, Melissa; Iacoviello, Brian; Mills, Ana (2008): Lifestyle regularity and cyclothymic symptomatology. In: *J. Clin. Psychol* 64 (4), S. 482–500.

Srinivasan, S. (2007): Fractional-Split Models of the Time-Use Patterns of Elderly Americans.

Tuomi-Gröhn, T.: Studying daily life through rhythms: rhythms and practices in everyday life of families in transition. In: *Präsentation* 2010.

van Hoof, J.: Designing a supportive living environment for older people with dementia.

Marquardt, G. (2011): A Descriptive Study of Home Modifications for People with Dementia and Barriers to Implementation. In: *J Hous Elderly* (25(3)).

Parsons, K. (2000): Environmental ergonomics: a review of principles, methods and models. In: *Applied Ergonomics* 31, S. 581–594.

Stewart, N. (2010): An Exploration of Home-care Technology to Enhance the Dialogue of Care between Older People and Carers.

7.6. Product specifications

Lighting, Philips: MASTER LEDlamps DimTone: Product Familiy Leaflet.

Lighting, Philips: Product Leaflet: 8-40W E27.

Lumitech (2012): PI-LED Technologie.

OSRAM: Ambient light sensor SFH 3410 and SFH 3710.

Schneider, Justine (2010): Nottinghamshire Evaluation of Just Checking Telecare System.

Srirama, S. (2012): Zompopo: Mobile Calendar Prediction based on Human Activities Recognition using the Accelerometer and Cloud Services.

VMSens (2012): Foot Tracker Pure Inertial Pedestrian Dead Reckoning.

7.7. Diseases of Elderly

Ahn, I. (2009): Impairment of Instrumental Activities of Daily Living in Patients with Mild Cognitive Impairment. In: *Psychiatry Invest* 6, S. 180–184.

Antigoni F (2009): Depression in the Elderly: Limits and Challenges - a Nursing Perspective. In: *International Journal of Caring Scienes* 2 (3).

Bakotic, M. (2012): Regulation of sleepiness: The role of the arousal system.

Behan, J. (2008): Determining the Relationship between Sleep and Social Activity in Community Dwelling Older Individuals.

Brandenberger, G. (2005): Sleep Stage 2: An Electroencephalographic, Autonomic, and Hormonal Duality Gabrielle Brandenberger, PhD; Jean Ehrhart; Martin Buchheit, PhD. In: *Sleep Medicine Reviews* (28(12)).

Brown, J. (2004): Models of Quality of Life: A Taxonomy, Overview and Systematic Review of the Literature. In: *European Forum on Population Ageing*.

Buysse, D. (2010): Night-to-Night Sleep Variability in Older Adults with and Without Chronic Insomnia. In: *Sleep Medicine Reviews* (11(1)).

Cappuccio, F. P.; Cooper, D.; D'Elia, L.; Strazzullo, P.; Miller, M. A. (2011): Sleep duration predicts cardiovascular outcomes: a systematic review and meta-analysis of prospective studies. In: *European Heart Journal* 32 (12), S. 1484–1492.

Cooke, J. (2011): Normal and Abnormal Sleep in the Elderly. In: *Handb Clin Neurol* (98), S. 653–665.

Cornelissen, G. (2012): When You Eat Matters: 60 Years of Franz Halberg's Nutrition Chronomics. In: *The Open Nutraceuticals Journal* (5), S. 16–44.

David, R. (2010): Non-pharmacologic management of sleep disturbance in Alzheimers disease. In: *The Journal of Nutrition, Health and Aging* (14(3)).

EU Project CHANGE: Some aspects to improve interpersonal Communication with elderly patients.

Garcia, A. (2010): Circadian variations in the capacity to adjust behavior to environmental changes. In: *Sleep Science*.

Gordon, A.: Sleep in Care Homes.

Grandner, M. (2012): Age and Sleep Disturbances Among American Men And Women: Data From the U.S. Behavioral Risk Factor Surveillance System Age and Sleep Disturbances Among American Men. In: *Sleep Medicine Reviews* 35 (3).

Gustavsson (2011): Cost of Disorders of the Brain in Europe 2010.

Hu, K. (2009): Reduction of scale invariance of activity fluctuations with aging and Alzheimer's disease: Involvement of the circadian pacemaker. In: *PNAS*.

Kello, Christopher T.; Beltz, Brandon C.; Holden, John G.; van Orden, Guy C. (2007): The emergent coordination of cognitive function. In: *Journal of Experimental Psychology: General* 136 (4), S. 551–568.

Monk, T. (2006): Sleep in healthy seniors: a diary study of the relation between bedtime and the amount of sleep obtained. In: *J Sleep REs.* (15), S. 256–260.

Monk, T. (2009): Effects of a two-hour change in bedtime on the sleep of healthy seniors. In: *Chronobiol Int* (26(3)), S. 526–543.

Monk, T. (2011): Circadian Type and Bed-Timing Regularity in 654 Retired Seniors: Correlations with Subjective Sleep Measures Circadian Type and Bed-Timing with Subjective Sleep Measures. In: *Sleep Medicine Reviews* (34(2)).

Nebes, R. (2009): Self-Reported Sleep Quality Predicts Poor Cognitive Performance in Healthy Older Adults. In: *Journal of Gerontology* (64(2)).

Nilesh N. Kate, M. Chandrasekhar Ambareesha Kondam E. Kayalvizhi M.Suresh U. Kavitha: A study on effect of altered circadian rhythm in the development of obesity.

Paavilainen, P. (2005): Circadian activity rhythm in demented and non-demented nursing-home residents measured by telemetric actigraphy. In: *J Sleep REs.* (14), S. 61–68.

Peigneux, Philippe (2012): Age-related changes in sleep and circadian rhythms: impact on cognitive performance and underlying neuroanatomical networks. In: *Frontiers in Neurology*.

Rawashdeh, Oliver; Maronde, Erik (2012): The hormonal Zeitgeber melatonin: role as a circadian modulator in memory processing. In: *Front. Mol. Neurosci* 5.

Roepke, S. (2010): Sleep disorders in the elderly. In: *Indian J Med Res* 131.

Ruesten, Anne von; Weikert, Cornelia; Fietze, Ingo; Boeing, Heiner; Bayer, Antony (2012): Association of Sleep Duration with Chronic Diseases in the European Prospective Investigation into Cancer and Nutrition (EPIC)-Potsdam Study. In: *PLoS ONE* 7 (1), S. e30972.

Sorensen, L. (2007): Everyday life and social relations in home-living patiens with mild Alzheimer disease and their caregivers: Quantitative and qualitative analyses.

Tikotzky, L. (2012): Sleep problems during adolescence: Links with daytime functioning.

Traido, C. (2009): Daily Activity and Life Satisfaction in Older People Living in Rural Contexts. In: *The Spanish Journal of Psychology* 12 (1), S. 236–245.

Volicer, L. (2001): Sundowning and Circadian Rhythms in Alzheimer's Disease. In: *Am J Psycvhiatry* 158, S. 704–711.

Welsh, D.: Circadian rhythm dysregulation in the eldlery: advanced sleep phaser syndrome.

Wirz-Justice A, Cajochen C. (2011): Zirkadiane Rhythmen und Depression: Chronobiologische Behandlungsmöglichkeiten.

Yamamoto, M. (2012): Relationship between Cognition and Activities of Daily Living in Elderly Women with Mild Cognitive Impairment in Japan. In: *International Journal of Clinical Medicine*.

Zulley, J. (1992): Chronobiologie des Alterns. In: *Wiss. Zeitschrift der Humboldt-Universität zu Berlin* (41).

Lee, I-Min; Shiroma, Eric J.; Lobelo, Felipe; Puska, Pekka; Blair, Steven N.; Katzmarzyk, Peter T. (2012): Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. In: *The Lancet* 380 (9838), S. 219–229.

7.8. Further research topics

Light and Seniors. In: IES Research Symposium 2012: Programme 2012.

Society for Research on biological Rhythms (2012): Proceedings.

Ward, S. (2004): Assessment of Heart Rate and Electrodermal Activity during Sustained Attention to Response Tests. In: Computers in Cardiology (31), S. 473–476.

Michel Maurício Mendes Cânovas: HRV in Smartphone for Biofeedback