Get Ready for Activity – Ambient Day Scheduling with Dementia

Applicable hardware components

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Preface

This document forms part of the Research Project "Get Ready for Activity – Ambient Day Scheduling with Dementia (GREAT)" funded by the AAL 2016 "Living well with dementia" funding program as project number AAL-2016-023. The GREAT project will produce the following Deliverables:

D1.1 Medical, psychological, and technological framework

D2.1 Applicable hardware components

D2.2 Applicable software components

D2.3 Field tested hardware components

D2.4 Field tested software components

D3.1 Implementation report

D3.2 Field test report

D4.1 Communication strategy

D4.2 Stakeholder management report

D5.1 Report on market analysis

D5.2 Dissemination plan

D5.3 Final business plan

The GREAT project and its objectives are documented at the project website http://uct-web.labs.fhv.at. More information on GREAT and its results can also be obtained from the project consortium:

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Content

1 GREAT Concept

1.1 Overview

The GREAT system should be usable in widely varying environments. Therefore, a highly modular approach has been chosen. Individual components like light, sound, and scent modules can be used individually or in combination. The system also gathers data from motion detectors and physiology sensors to detect potential activity and stress levels of persons in a room (see Figure 1 for an overview).

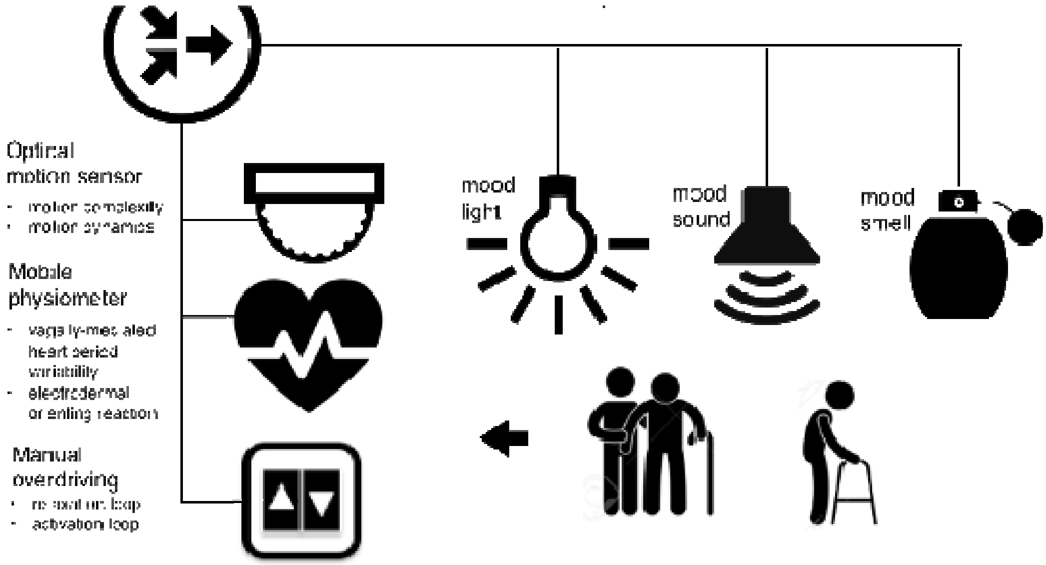


Figure 1: GREAT Components Overview, Source: GREAT consortium

The system is able to perform activation and relaxation for each module according to manual control via app.

Beside manual control, an automation of activation/relaxation at specific times is possible to support caregivers in facilities with a daily routine e.g. activation scenes before breakfast or relaxation scenes before going to bed.

2 Light Module

2.1 Basic Considerations

The GREAT lighting system was designed to fulfil visual and biological lighting needs of elderly people with dementia and furthermore to stimulate the affective state of these persons by activating or relaxing light scenes. Visual improvement and biological light effects should improve the subject's health on the long run by e.g. enhancing mobility due to better lighting conditions and the regulation of activity-rest patterns.

Elderly in general and therefore also elderly with cognitive disorders are commonly faced with restrictions in vision due to the aging eye. Limited vision may lead to uncertainty in moving around indoors and therefore may restrict mobility of elderly. The less active people are during the daytime the more sleep problems they usually have. Sleep is one of the most important mechanisms of the body to clear the brain from metabolic waste products. There are some hints in the literature that accumulation of these waste products in cerebral structures may lead to a faster degradation and aggravate symptoms of dementia [2, 3]. Light therapy is the most successful non-pharmacological intervention against sleep disorders, that commonly arise in people with dementia and often lead to high care expenses. The GREAT lighting solution should improve circadian rhythms and sleep on the long run.

Beside the long-term effects the GREAT lighting system can perform acute interventions in terms of lighting scenes that lead to an activation or relaxation. They were used for e.g. preparing and activating patients for upcoming activities like therapy sessions or to calm them down before going to bed. The preparation for these activities should improve the commitment and may also improve the effectiveness of therapy sessions or other activities.

The idea of a health provoking light incorporating a light therapy approach into an ambiance room lighting was implemented in a mobile version as free-standing luminaire and in a wall-mounted version. With these two versions of the luminaire the lighting module fits to different use cases, namely clinical wards, nursing homes and private settings. Especially for clinical settings specific safety regulations were considered for the market ready end-product. They will be described in detail below.

Changes in the lighting system from the first prototype developed at the beginning of the GREAT project mainly concern the hardware of the luminaire to improve output, performance and design.

The luminaire was redesigned and improved by EMT and Bartenbach for the upcoming field trials regarding

- the quality of light
- the application in care facilities and hospitals
- the production and transportability for the field trials
- the operation stability

The lighting concept and underlying control algorithm were kept as described in “deliverable 2.1 Applicable hardware components”.

2.2 Lighting concept and control algorithm

The lighting concept contains a fixed biodynamic lighting curve, regulating activity-rest-patterns on the long run, and dynamically applicable light interventions leading to acute activation or relaxation. As the lighting concept and control algorithm were kept as described in “deliverable 2.1 Applicable hardware components”, they will be described only shortly within this deliverable.

Visual requirements are considered at any time and in any lighting scene. Therefore, the light intensity at the task area shows a ratio of $0.3 < E_{cylindric}/E_{horizontal} < 0.6$ at eye level and at height of desk. The maximal luminance level is restricted to 1000 cd/m² to avoid glare. Horizontal illuminances of 1000 Lux during the day and 300 Lux during the night will be delivered in the task area to provide optimal visual conditions. The spectral quality of our used LEDs will provide a colour rendering index of at least 90 and multiple shadows will be avoided. A PWM-dimming frequency of >1,25Hz will be used to ensure that even very sensitive persons will not be harmed.

The biodynamic lighting curve integrates a light dose approach dawn-dusk simulation (variations in light levels and additionally coupled with variations in colour temperature) and a variation of the lighting environment during the siesta. Beside the two light interventions, activation and relaxation, a TV scene can be provided to create a cosy and relaxing lighting ambience while watching TV. The lighting system will be controlled via App and if necessary, a switcher for turning on and off the light. Figure 2: Schematic representation of the lighting solution in GREAT. The biodynamic curve is running automatically, light interventions (activation, relaxation, TV scene) are adjustable manually or automatically. Figure 2 shows a scheme of the biodynamic lighting curve in a 24-hours cycle.

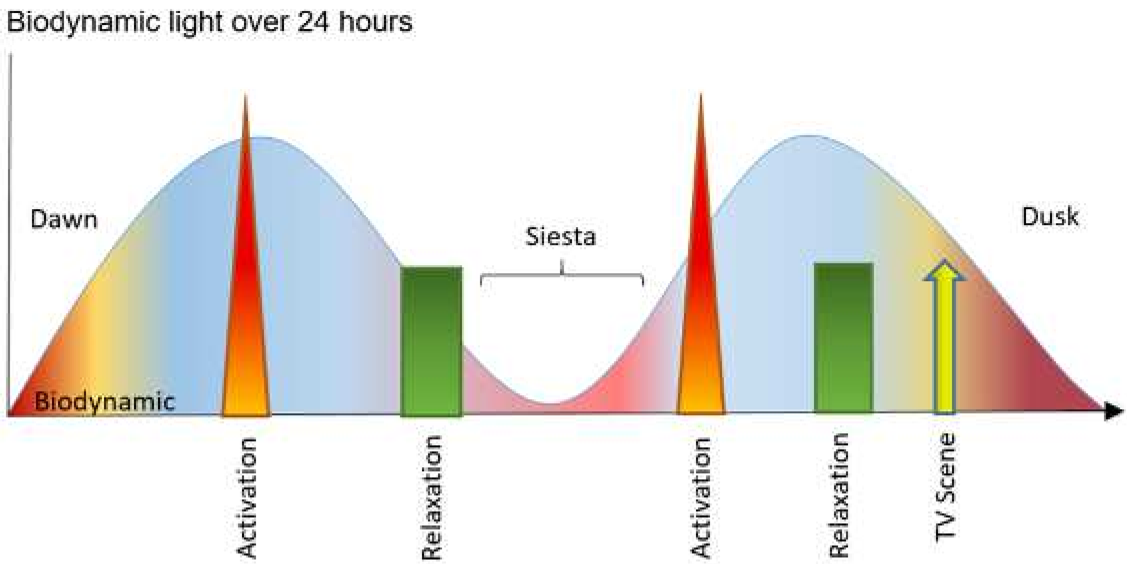


Figure 2: Schematic representation of the lighting solution in GREAT. The biodynamic curve is running automatically, light interventions (activation, relaxation, TV scene) are adjustable manually or automatically

The biodynamic curve considers different colour temperatures and light levels at different times of the day. During the day high light levels and a high colour temperature simulating a bright day are applicated to reach immediately higher activity levels and long-term health effects on sleep. During the night low light levels and a low colour temperature are provided to enhance a normal melatonin cycle that is important for the circadian rhythm and therefore on the long run for health. Between day and night, a dusk-dawn simulation will be performed, that supports a soft switch between day and night. In the morning this will enable persons to wake up softly without symptoms of sleep inertia, in the evening it calms down and prepares for going to sleep. The light curve is shown in Figure 3. Figure 4 shows the whole GREAT lighting concept.

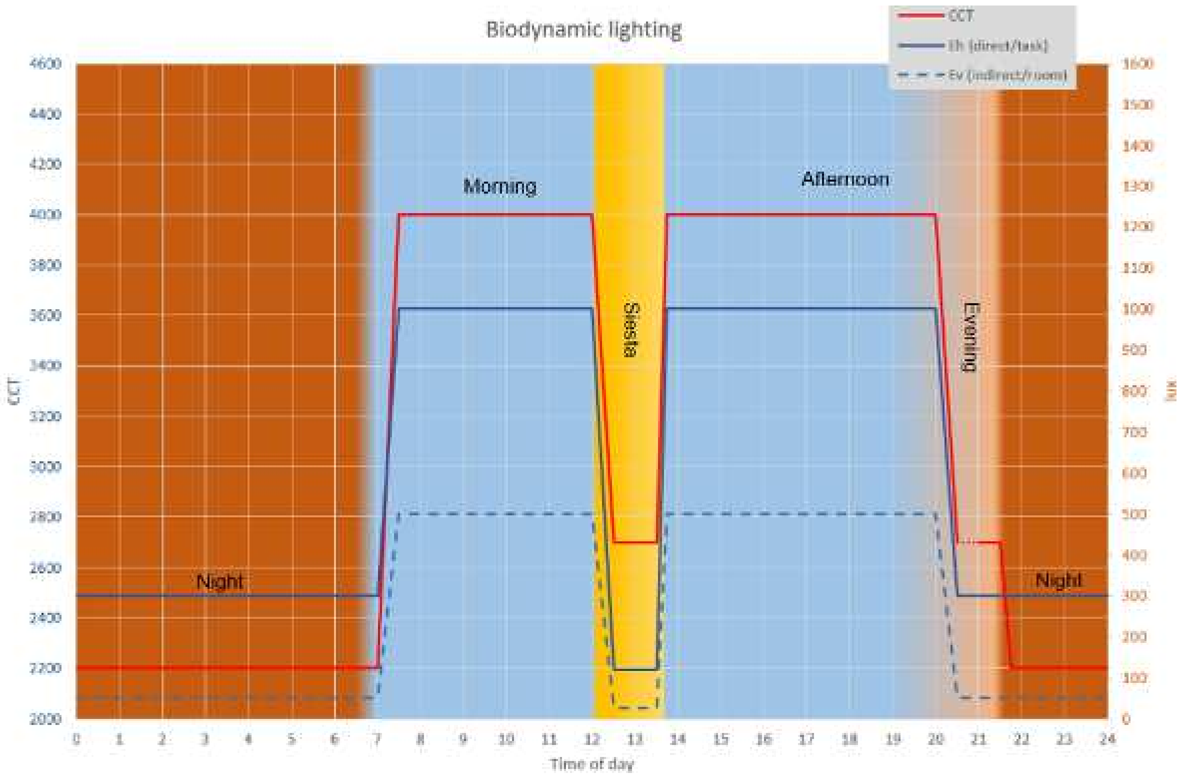


Figure 3: Biodynamic lighting concept. CCT…colour temperature in Kelvin, Eh…horizontal illuminances of the task light, Eh_{Room}…horizontal illuminance of ambient room light (resulting from Ev + Eh Task, for clarity reasons Eh_{Room} is not shown), Ev…vertical illuminance at the eye level

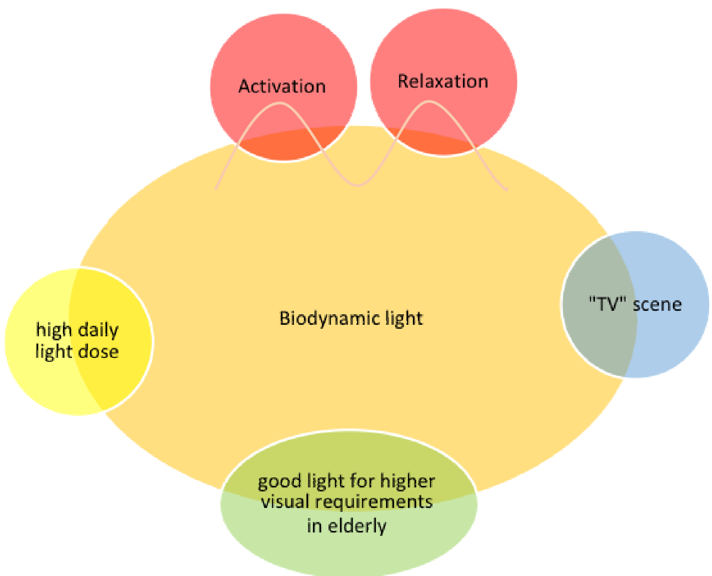


Figure 4: GREAT lighting concept

2.2.1 Light scenes

There are four light scenes that can overwrite the biodynamic curve:

- Activating light cue: sudden increase in illuminance after a short reduction leads to cognitive stimulation that activates observers
- Relaxing light cue: reduction in illuminance and colour temperature to stimulate relaxation in observers
- TV scene: specific ambient lighting to provide a cosy ambience during watching TV
- Norm light: light setting of constant light level without light therapy approach and dynamics. The colour temperature will be adapted either to day- or night-time.

Activation via light cue

An activating light cue starts with an unrecognisable reduction in vertical illuminance of 50% relative to the original value of the light curve. This reduction needs 5 min. After that a recognisable increase in vertical illuminance up to 600 lux (120%) will appear. Directly after reaching the peak a slow linear reduction back to the original value will be performed over 15 min. Activating cues can be used between 8 a.m. and 7 p.m. The usage is limited for reasons of wrong usage too late at the day (e.g. activating shortly before going to bed).

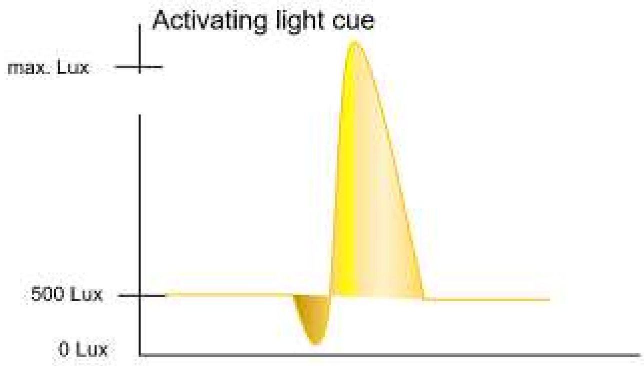


Figure 5: Activating light cue

Relaxation via light cue

For relaxation, a reduction in illuminances and colour temperature will be performed. In detail, horizontal illuminance will be reduced to 120 lux, vertical illuminance to 20-30 lux (~25%) and colour temperature to 2700 K within 10 min. These light settings stay constant for 40 min. Afterwards light settings will increase back to origin light levels.

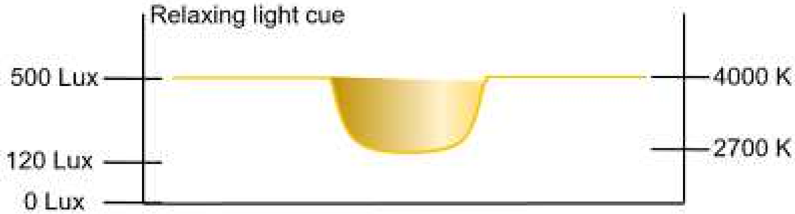


Figure 6: Relaxing light cue

TV scene

Watching TV is beside reading and social activities also an activity that takes place in the every-day life of elderly people in care-facilities, hospitals and private homes. Therefore, our lighting system will provide a cosy ambience for this situation. Light levels will be reduced but will be enough for identifying the buttons of the controller and the surrounding.

Norm light

There is the possibility to activate a norm light, if biodynamic lighting is not desired of any reason or if there is an emergency (e.g. in siesta time, when light is dimmed) or any other reason when light is needed immediately. It will provide a good but not bright light for visual efforts fulfilling current standards. Colour temperature varies between day- and night-time.

For all light scenes transition curves were described to provide smooth changes between different light curves (for detailed description of light levels and colour temperature values see D2.1 Applicable hardware components).

The different scenes are provided in the GREAT-control-app. Basically activation and relaxation are provided as control options. If desired also the TV scene and the norm light will be provided (see Figure 7).

Figure 7: Different control options for the GREAT luminaire: basic functions (left), advanced functions (right)

2.3 Hardware: The GREAT Luminaire

2.3.1 Optical Concept

The GREAT luminaire uses an indirect approach for the illumination where the light is directed upward and the ceiling acts as a reflector (see Figure 8). In that way, the luminous area is greatly enlarged and much larger luminous fluxes can be used without glaring. Therefore, it is possible for the GREAT luminaire to reach a vertical illuminance E_v of 200 lx by the use of the indirect light.

By combining this indirect "Uplight" with a smaller diffuse panel ("Downlight") and an additional flexible spot for task lighting the target E_v of 500 lx can be reached as well as a task illuminance (horizontal) of 1000 lx as shown in Figure 8.

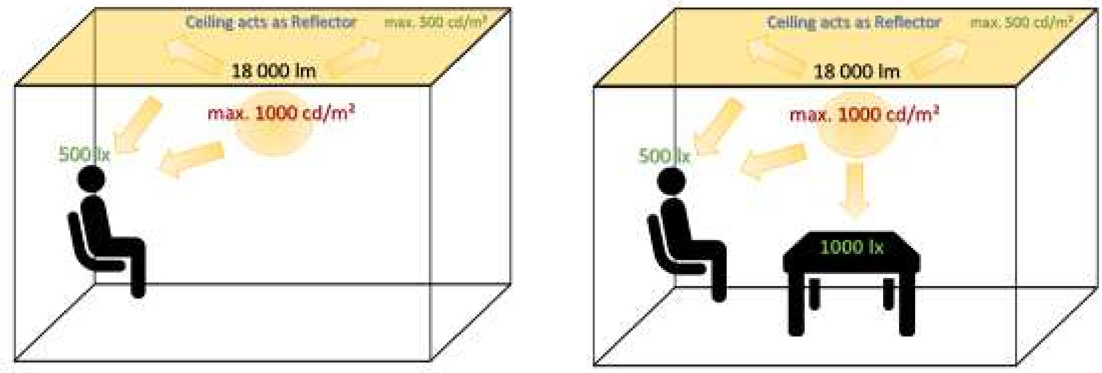


Figure 8: Increasing the vertical illuminance by adding a diffuse panel to the luminaire (left) and reaching high horizontal illuminances by adding task lighting by spots (right)

Table 1 shows the advantages and disadvantages of diffuse and direct task lighting. By combining the two approaches we can not only combine the positive properties of each lighting concept, but also reduce the disadvantages such as light pressure. This knowledge was generated in the research project "CommONEnergy" by Bartenbach (Figure 9).

Table 1: Advantages and disadvantages of diffuse and task lighting

Downlight: Diffuse Panel	Spot: Task lighting
+ no radiation "pressure" + flexible usage (e.g. dining table, bedroom) + increases vertical illuminance	+ excellent task lighting
- no significantly increased task illuminance - limitation of the light flux by luminous density	- radiation pressure - risk of glare

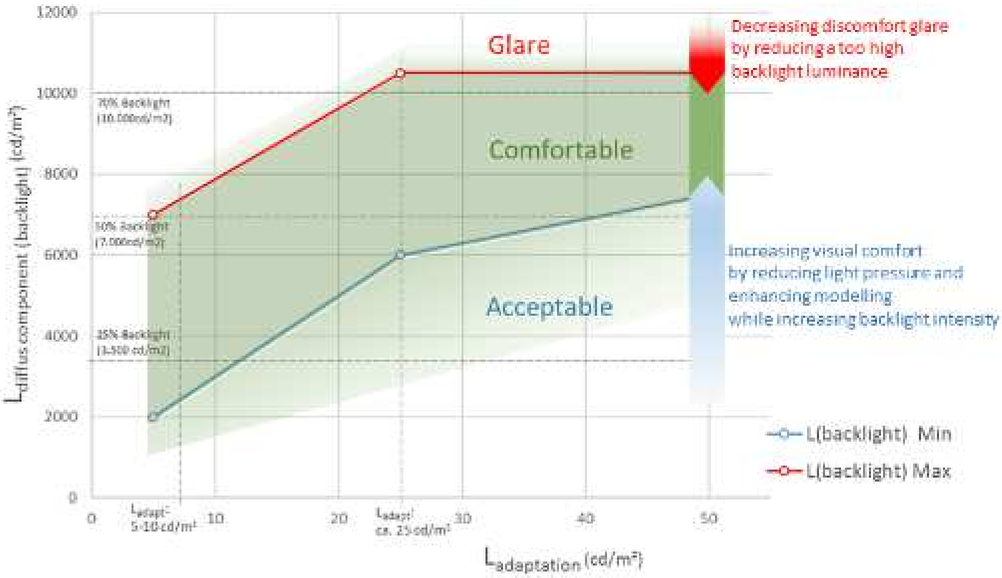


Figure 9: Results of light pressure study

2.3.2 Uplight Concept

The final solution uses an uplight for the GREAT luminaire which was developed by Bartenbach as a low budget solution. Since no high-quality reflectors are needed for this solution but only standard materials and a small amount of a scatter gloss material the production costs can be kept low.

The optical concept is shown in Figure 10. A printed circuit board (PCB) with LEDs is placed on a scatter gloss material (MIRO-SILVER 20|2000 AG). Light emitted from the LEDs will be reflected diffusely from the scatter gloss material and a broad light distribution in the forward direction is reached.

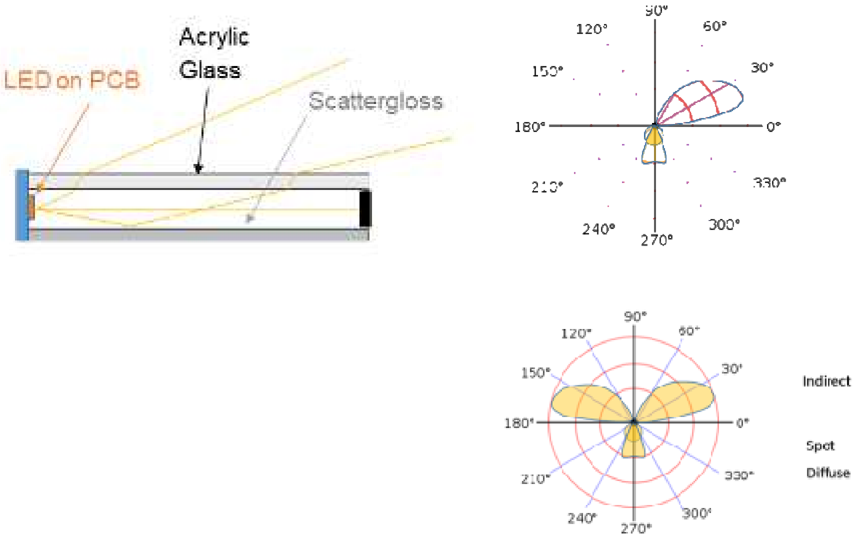


Figure 10: Optical concept for the GREAT Uplight (left) and the 2 possible Luminous Intensity Distribution curves LID (right): The Indirect light is available as an asymmetric solution for the wall mounted luminaire and as a symmetrical light distribution for example for the free-standing luminaire situated in the middle of the room

The light sources of the uplight and the downlight are:
75 NICHIA E17 CRI90 LEDs with 2200K (100 lm@350mA) and 75 NICHIA E17 CRI90 LEDs with 5000K (150l m@350mA) alternately are placed every 3 mm onto the PCB (see Figure 12). The efficiency of this uplight is 67% according to the measurements of the mock-up. So, the luminaire output luminous flux is 5000 lm@2200K and 7500 lm@5000K.

Figure 11: Picture of the Uplight of the GREAT luminaire

Figure 12: The LEDs are placed on the edge for lateral input of light in the light guiding plate

The warm white LEDs with 2200K and the cold white LEDs with 5000K can be controlled separately. Furthermore, a temperature measurement was integrated to guarantee a stable thermal environment for the LEDs. The maximum power for the uplight module is 75W.

In Figure 13 the Dialux simulation for the GREAT uplight can be seen. The uplight generates a soft indirect light and approximately 300 lx horizontally on the task area.

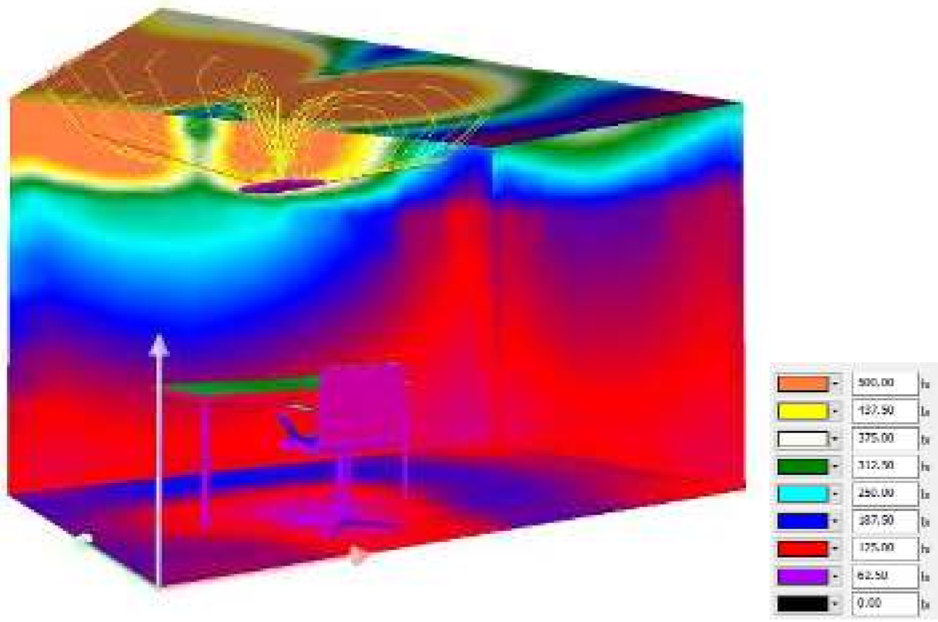


Figure 13: Dialux simulation of the GREAT Uplight

2.3.3 Downlight Concept

The light quality of the direct light was not satisfactory. Therefore, a glare-free downlight with an edge-lit "Light Guiding Plate" was developed and implemented (see Figure 14). This "Light Guiding Plate" (LGP: thickness 8mm) from Jungbecker (manufacturer) contributes to a glare-free illumination of the task area. This component also adds vertical illuminance to the expected illuminance levels that are needed to provide health effects.

Figure 14: Downlight of the GREAT luminaire and LPG

In the Dialux simulation of the uplight and the downlight the illuminances and the uniform light distribution on the working plane can be seen (Figure 15).

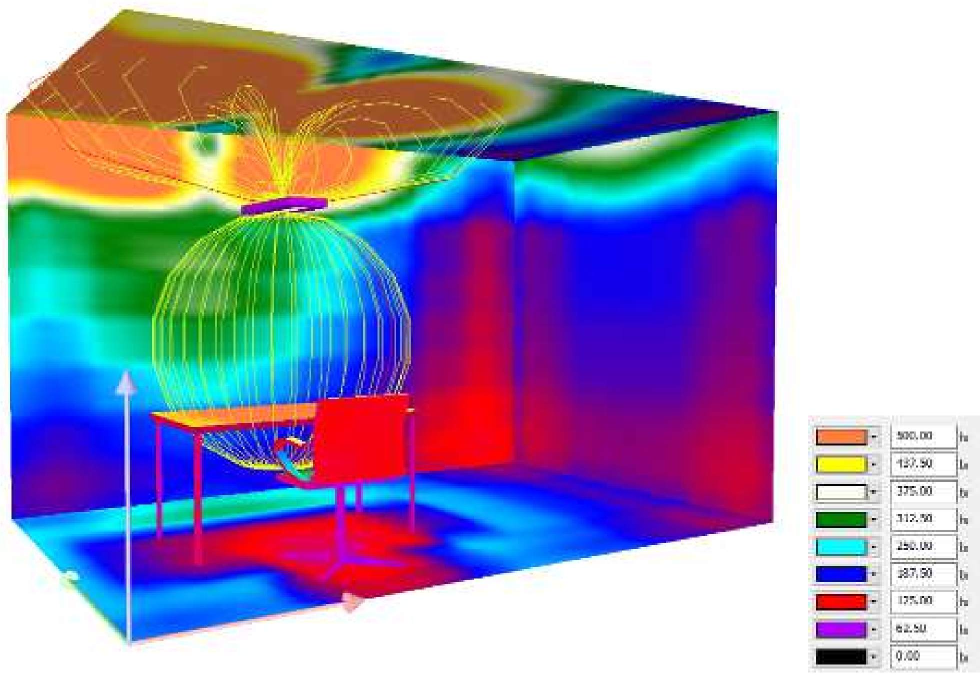


Figure 15: Dialux simulation of the GREAT Uplight and Downlight

2.3.4 Spot Concept

The addable spot is flexible and easy adjustable at the front of the cooling part of the luminaire. It provides a specific task light with more than 1000 lx horizontal illuminance at the desk (see Figure 17). It consists of a precise facetted reflector-system (see Figure 16) and will be miniaturised for design reasons.

The light sources are 8 NICHIA E17 CRI90 LEDs with 2200K (150 lm@500mA) and 8 NICHIA E17 CRI90 LEDs with 5000K (225 lm@500mA) alternately placed onto the PCB. The efficiency of this Downlight is 83% according to measurements of a sample. So, the luminaire output luminous flux is 1000 lm@2200K and 1500 lm@5000K. The additional illumination of the task area via spot can be seen in Figure 17.

Figure 16: Spot of the GREAT luminaire

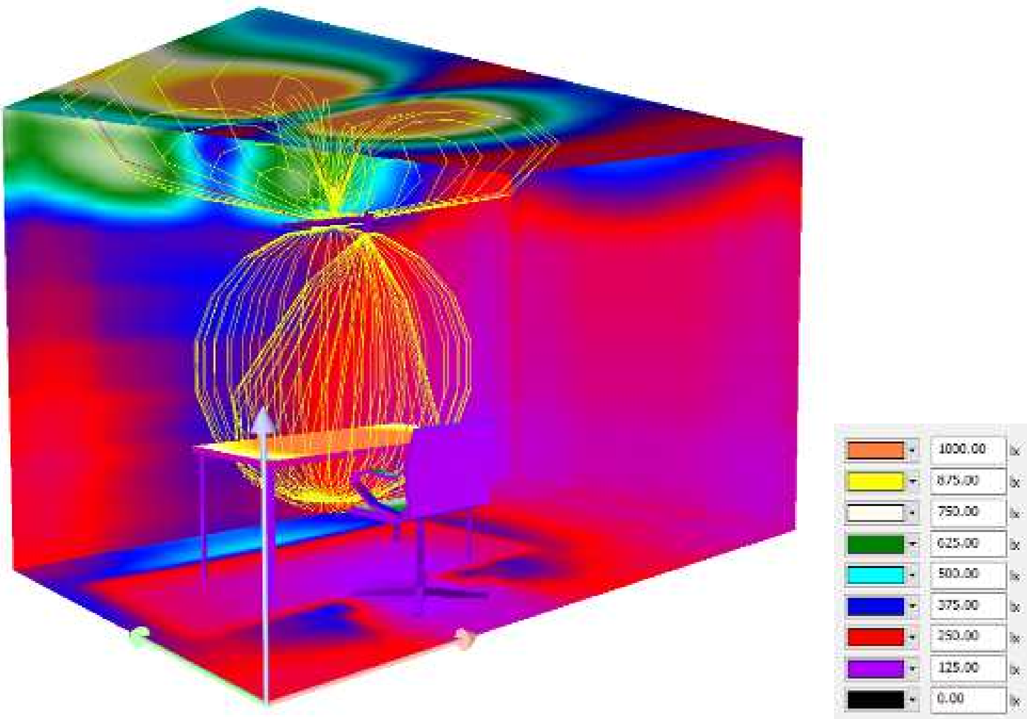


Figure 17: Dialux simulation of the GREAT Uplight, Downlight and Spot

The finalized lighting concept as developed by Bartenbach now combines 3 components: an indirect component, the uplight, where most of the luminous flux is emitted and that contributes to the vertical illuminance E_v needed to invoke the biological effects. This uplight is combined with the downlight that uses a luminous panel for additional vertical illuminance E_v and a flexible spot that can be added for task illumination (increased horizontal illuminance). The Luminous Intensity Distribution (LID) for the GREAT luminaire can be seen in Figure 10.

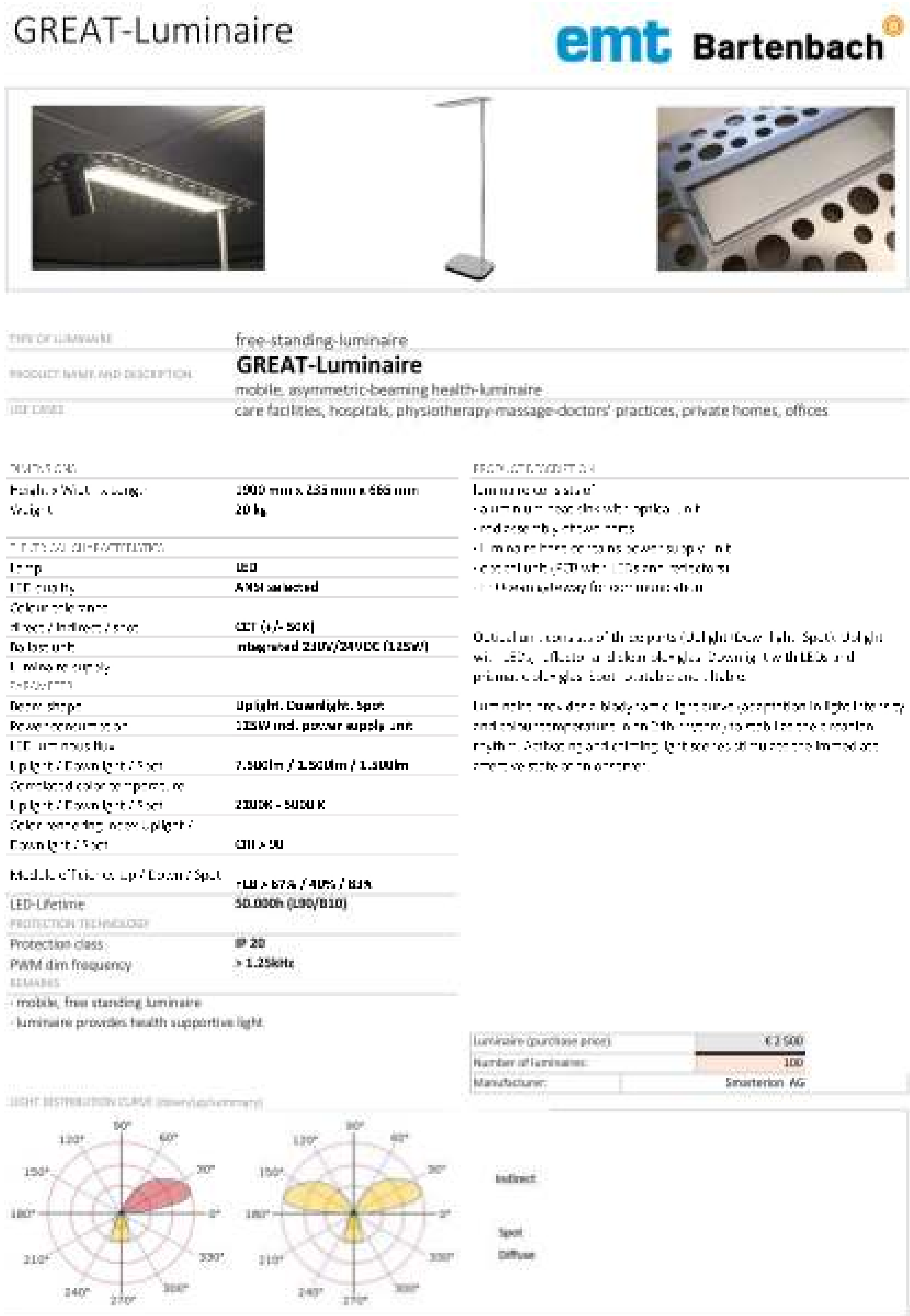
The luminaire meets the lighting requirements for elderly people and moreover the requirements for office lighting according to DIN EN 12464-1 (calculated with Dialux, light calculation software):

	Indirect (100%)	Direct+Spot (100%)	Total (100%)
Horizontal illuminance Eh (table)	305 lx	735 lx	1.040 lx
Vertical illuminance Ev (eye)	195 lx	645 lx	840 lx
Luminance L (ceiling) maximum	415 cd/m²	20 cd/m²	435 cd/m²
Unified glare rating according to DIN EN 12464-1 UGR (gesamt)	< 10	19	12

Figure 18: Dialux simulation of the GREAT Uplight, Downlight and Spot, results
The values listed in the table are already achieved with warm white LEDs (2200K). With cold white LEDs (5000K) higher illuminances can be achieved.

2.3.5 Technical specification sheet

Bartenbach designed a technical specification sheet for sales and marketing of the freestanding GREAT luminaire, where all important technical details are described (see Figure 19).



GREAT-Luminaire

emt Bartenbach

TYPE OF LUMINAIRE	free-standing-luminaire
PRODUCT NAME AND DESCRIPTION	**GREAT-Luminaire** mobile, asymmetric-beaming health-luminaire
USE CASES	care facilities, hospitals, physiotherapy-massage-doctors' practices, private homes, offices

DIMENSIONS	
Height x Width x Length	1900 mm x 235 mm x 665 mm
Weight	20 kg
TECHNICAL CHARACTERISTICS	
Lamp	LED
LED quality	ANSI selected
Colour tolerance direct / indirect / spot	CCT (+/- 50K)
Ballast unit	integrated 230V/24VDC (125W)
Luminaire supply	
PARAMETER	
Beam shape	Uplight, Downlight, Spot
Power consumption	125W incl. power supply unit
LED luminous flux Uplight / Downlight / Spot	7.500lm / 1.500lm / 1.500lm
Correlated color temperature Uplight / Downlight / Spot	2700K - 5000 K
Color rendering index Uplight / Downlight / Spot	CRI > 90
Module efficiency Up / Down / Spot	ηLB > 67% / 40% / 83%
LED-Lifetime	50.000h (L90/B10)
PROTECTION TECHNOLOGY	
Protection class	IP 20
PWM dim frequency	> 1.25kHz
REMARKS	

- mobile, free standing luminaire
- luminaire provides health supportive light

Luminaire (purchase price):	€ 2 500
Number of luminaires:	100
Manufacturer:	Sinnterion AG

LIGHT DISTRIBUTION CURVE

Figure 19: Technical specification sheet GREAT luminaire

2.3.6 Total luminaire and practical approach

In Figure 20Figure 20 and Figure 21 the light distribution of the GREAT luminaire is shown as well as the isolines for the horizontal illuminance at the working plane. One can see that a large part of the room (25 m^2) is illuminated very well with the targeted horizontal illuminance. The luminances in the room are visualised in Figure 22.

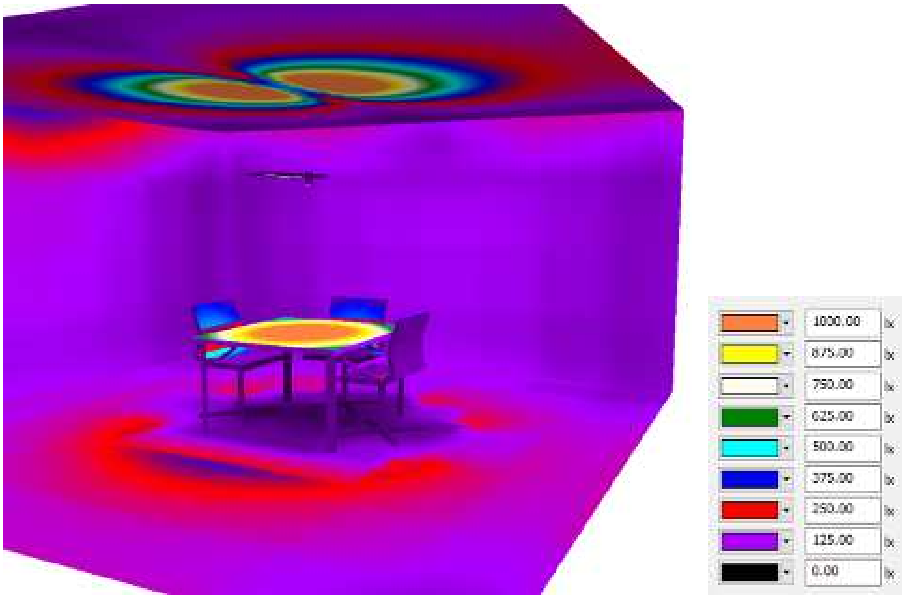


Figure 20: Dialux simulation of the GREAT luminaire showing the illuminances in a 25 m² room.

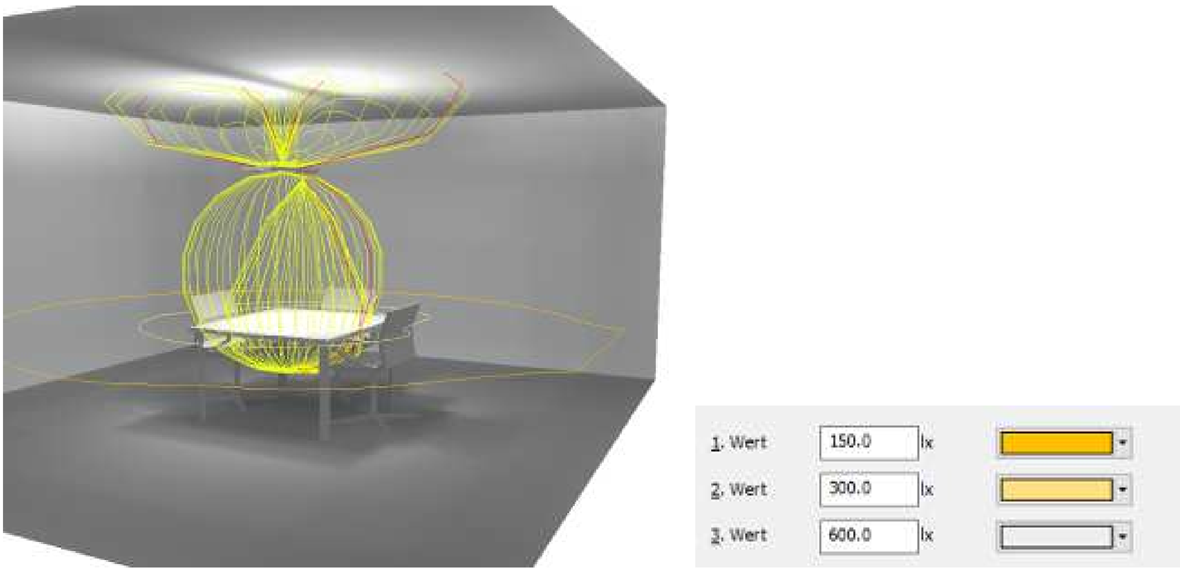


Figure 21: Dialux simulation of the light distribution of the GREAT luminaire. Also shown are the isolines for 150 lx (orange), 300 lx (yellow) and 600 lx (grey) horizontal illuminance.

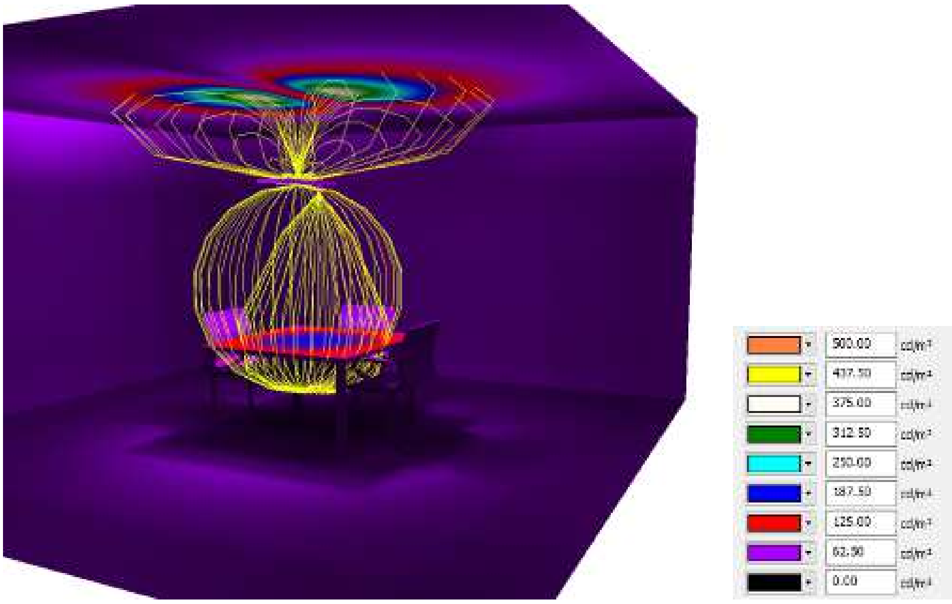


Figure 22: Dialux simulation of the GREAT luminaire showing the luminances in a 25 m² room.

As described above Bartenbach and EMT realized different versions of the GREAT-luminaire: a mobile free-standing luminaire and a wall-mounted luminaire. Both contain the same luminaire's head but with different bases as seen in Figure 23 and Figure 24.

Figure 23: Free-standing, mobile GREAT luminaire

Figure 24: Wall-mounted GREAT luminaire in a patient's room in the hospital in Hall (Austria)

Moreover, for both versions specific safety features were implemented. The free-standing luminaire consists of a buckling mechanism (see Figure 25) and the wall-mounted luminaire has a breaking point (see Figure 26) that leads to a controlled fall of the luminaire's head and opens the mounting base. The mechanisms avoid that persons can be hurt when hanging on the luminaire's head or the mounting base and therefore fulfils the safety regulations in psychiatric wards.

Figure 27 and Figure 28 show the practical implementation of both versions during the field trials. One can see that both versions fit very well in already consisting clinical furniture and the installation effort is very low.

Figure 25 : The buckling mechanism of the free-standing luminaire

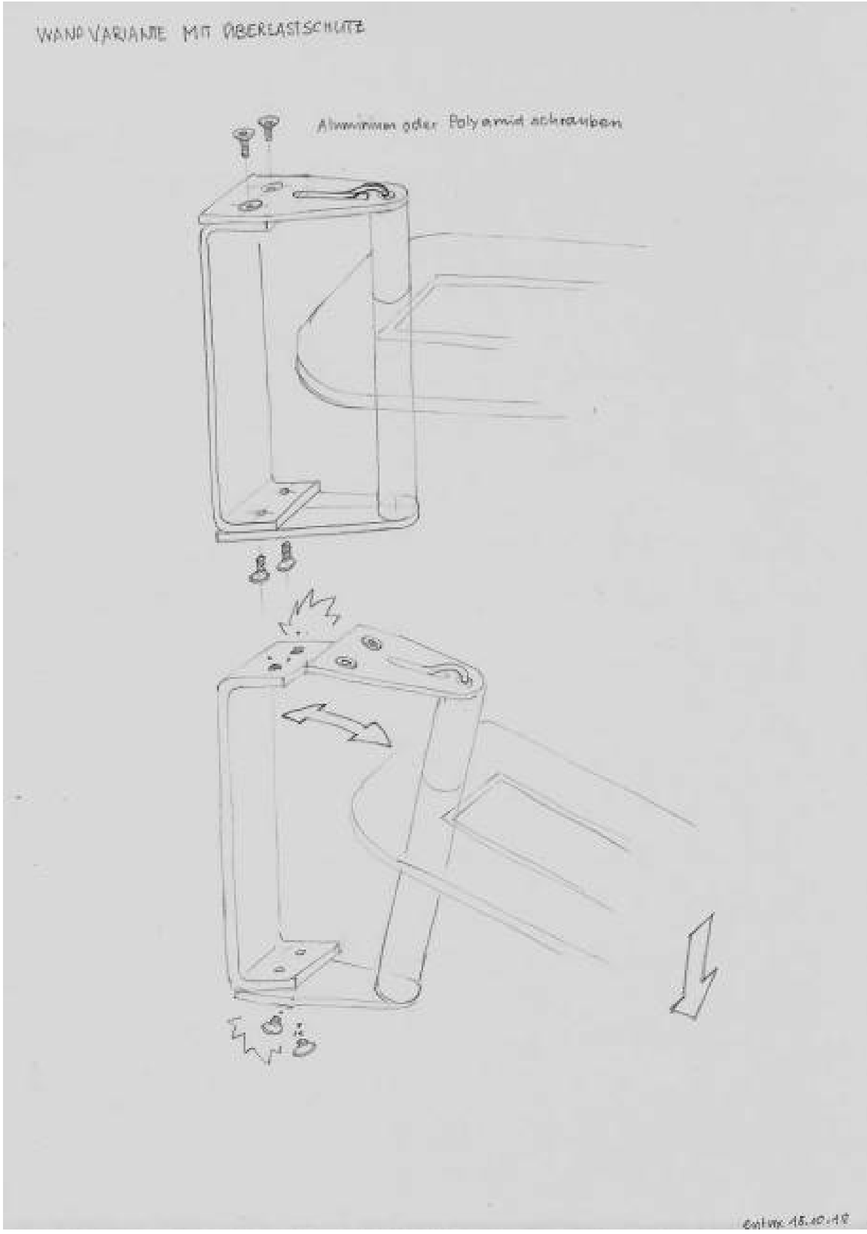


Figure 26: Special adjustment for psychiatric institutions: breaking point for protection against suicide

Figure 27: GREAT system implemented in a patient's room in the hospital in Hall (Austria)

Figure 28: GREAT standing luminaire in the common area in the hospital in Hall (Austria)

2.4 Electronic Engineering and Mechanical Design

2.4.1 Adjustments of mechanical and electronic design for use in care facilities

Tests with the functional sample luminaire showed that the weight of the luminaire body must be reduced for several reasons:

- The heavy body of the luminaire loads the linkage and the base very much
- The high quantity of material increases the price of the aluminium body
- The signal reception of the radio module is reduced by the surrounding aluminium

For these reasons, the electronic engineering and the mechanical design were completely readapted.

The body of the luminaire has been reduced by 5mm in height. This resulted in a weight reduction of 35%. In order that the electronics still fits, it was also completely redesigned (see Figure 29).

Figure 29: New, optimized luminaire head with EnOcean board and driving board

The controller communicates with the luminaire via radio signals. An EnOcean transceiver based on 868 MHz with adapted profile is used. In the field tests, communication problems of the luminaire with the controller arose. These problems increased when several luminaires in different rooms were operated by one controller.

Tests in the laboratory and on site were necessary to be able to assign the problem.
With various software optimizations on the controller and on the luminaire, a reliable operation could be realized.

From the feedback after the first test runs, it became clear that a switch (see Figure 30) for the operation of the luminaire is additionally desired. The switch has been assessed and tested by emt and the software in the luminaire has been correspondingly adapted.

Figure 30: EnOcean switch

As an additional option, the luminaire can be controlled via Casambi control system when used as a stand-alone a plug & play product.

2.4.2 Production and application

Since the luminaire is used in hospitals, it should comply with the standards concerning product safety:

- For the CE conformity with the newly created electronics and mechanics, the required measurements were carried out in a certified laboratory.
- All production documents have been created. The luminaire was then produced by a professional OEM lighting manufacturer and tested for safety.

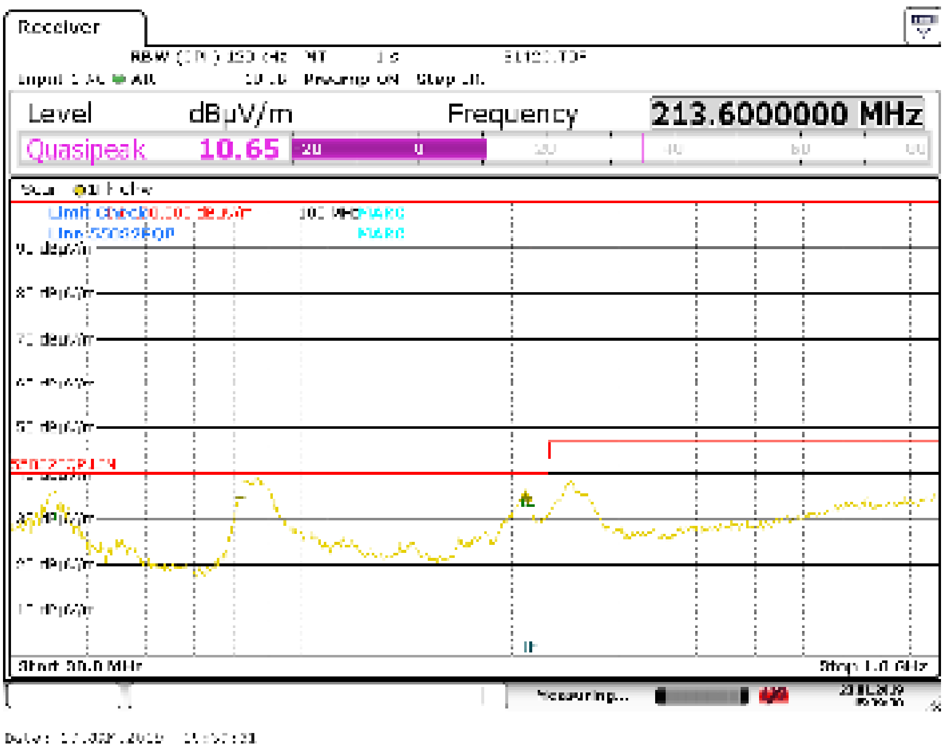


Figure 31: EMV measurement of the GREAT luminaire for CE conformity

2.4.3 Transportability of the luminaire

For the simplified transport of the luminaire for the field tests, we took the following steps:

- Adapt the base of the luminaire so that the power supply is placed safely and protected (see Figure 34)
- Make the 2-part linkage easy separable (see Figure 33)
- Design a suitable package for shipment to the test locations

Especially the downlight and the heavy cooling sink was totally reconfigured from the prototype state which led to a lighter and modern appearance. In addition, these changes result in a great reduction in the weight of the whole luminaire, which was a very important necessity. For a more comfortable packaging and transportation the linkage was divided into two parts that will be plugged together reversible (see Figure 33). The luminaire therefore fits into a 1 x 0.5m package that can be sent by a usual transportation service.

Figure 32: Transportable GREAT Luminaire

Figure 33: Easy adjustment of GREAT luminaire

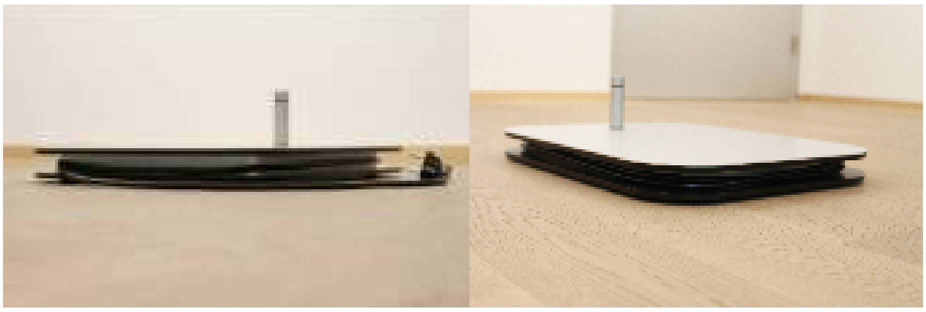


Figure 34: Cable storage feature

Table 2: GREAT Light Module hardware component list

1	Uplight: light guiding reflector, scatter gloss material (MIRO-SILVER 20 | 2000 AG), cover: acrylic glass
1	PCB with 25 NICHIA E17 CRI90 LEDs with 2200K + 25 NICHIA E17 CRI90 LEDs with 5000K
1	Downlight with light guiding plate (Jungbecker)
1	Adjustable spot with precise facetted reflector
1	Aluminium heat sink
1	Rod assembly of two parts
1	Luminaire base with power supply unit
1	EnOcean transceiver based on 868 MHz
1	EnOcean switch

3 Sound Module

The core hardware of the sound module remains unchanged from the original prototype. The only changes made were to use longer power cables to allow for easier placements in the field test settings, as well as loudspeaker control covers to prevent accidental adjustments of volume. A more detailed description of the hardware selection process and audio tests of the speakers can be found in D2.1.

3.1 Basic Considerations

The sound module of the GREAT System is based on music player hardware to play individualized sound files. To also allow for playback of ultra-sonic components of sounds, the sound module uses a 384 kHz digital analog converter.

3.2 Module Implementation

The sound module is based on a Raspberry Pi Zero W single board computer that provides WLAN connectivity. For audio output an IQaudIO Raspberry Pi DACZero module is used, that is attached to the GPIO header of the Raspberry. The module offers 192kHz/24bit playback (using a TI PCM5122 DAC offering 32-bit/384kHz). It features a112dB SNR and -93db THD. The DAC is connected via an I2S Interface to the Raspberry Pi.

As sound output device, the commercially available Logitech Z150 active loudspeakers are used. They are small enough to integrate into a typical GREAT setting, while still allowing for acceptable ultrasonic capability in this price range (limiting the range to about 1m). They operate on the same 5V level as the Raspberry PI. Therefore, the sound module only requires one common power supply.

Figure 35: GREAT sound module based on Logitech Z150 active speaker

The Raspberry Pi control board is built into the casing of the Logitech Z150 speakers, resulting in a very compact sound module setup (see Figure 35).

To place the Raspberry Pi Zero and the Pi-DAC Zero safely inside the Logitech Z150 speaker, a holder has been constructed and 3D printed (see Figure 36 for the internals of the sound module and Figure 37 for a 3D model of the module holder).

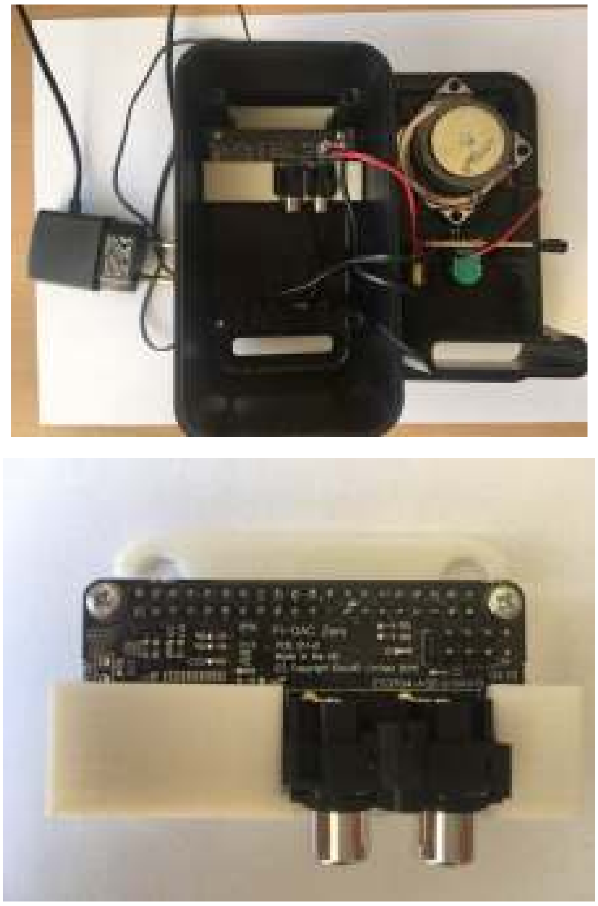


Figure 36: Raspberry PI and Pi-DAC Zero integrated into the Z150 active speaker.