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 ... 6

1.1 Overview ... 6

2 Light Module ... 6

2.1 Basic Considerations ... 6

2.2 Lighting concept and control algorithm ... 7

2.2.1 Light scenes ... 10

2.3 Hardware: The GREAT Luminaire ... 12

2.3.1 Optical Concept ... 12

2.3.2 Uplight Concept ... 13

2.3.3 Downlight Concept ... 16

2.3.4 Spot Concept ... 17

2.3.5 Technical specification sheet ... 18

2.3.6 Total luminaire and practical approach ... 20

2.4 Electronic Engineering and Mechanical Design ... 25

2.4.1 Adjustments of mechanical and electronic design for use in care facilities ... 25

2.4.2 Production and application ... 26

2.4.3 Transportability of the luminaire ... 27

3 Sound Module ... 29

3.1 Basic Considerations ... 29

3.2 Module Implementation ... 29

3.3 Speaker Covers ... 33

4 Scent Module ... 34

4.1 Basic Considerations ... 34

4.2 Mechanical Design ... 34

4.3 Casing ... 38

4.3.1 Front Casing ... 38

4.3.2 Rear Casing ... 39

4.3.3 Raspberry Pi Casing ... 39

4.3.4 Droplet shield ... 40

4.4 Electrical Design 40
4.4.1 Environmental sensor 43
4.5 Functional Tests 44
5 Repeater 44
6 Sensor Technology 46
6.1 Sensors for acquiring activation and relaxation status 46
6.1.1 PIR Sensor 47
6.1.2 Body worn sensor 49
6.2 Environmental Sensor 54
7 Controller 56
8 References 58
9 List of figures 59
10 List of tables 62

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).

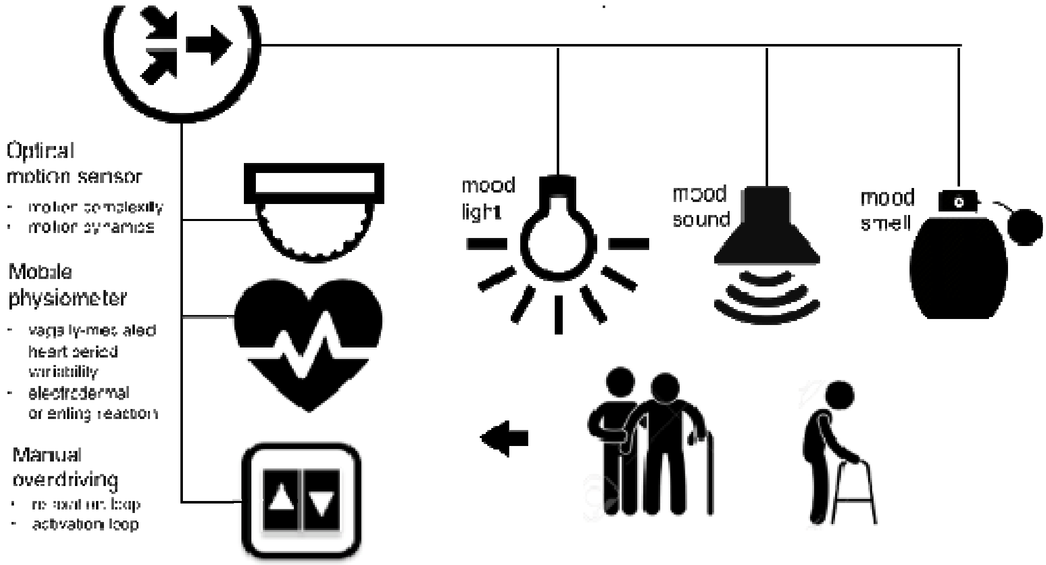


Figure 1: GREAT Components Overview, Source: GREAT consortium

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.

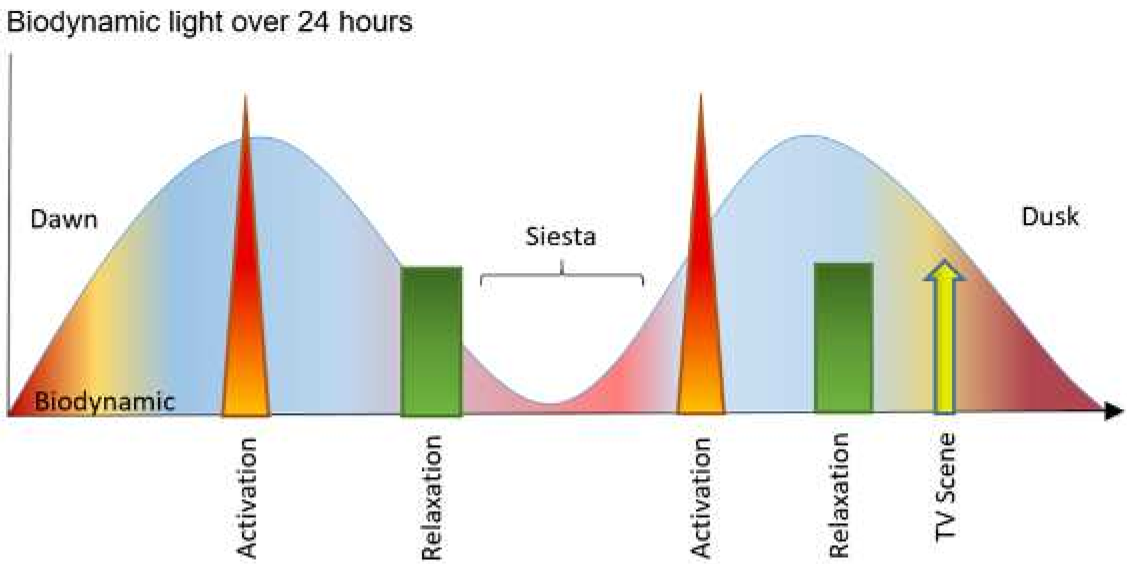


Figure 2: Schematic representation of the lighting solution in GREAT. The biodynamic curve is running automatically, light interventions (activation, relaxation, TV scene) are adjustable manually or automatically

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.

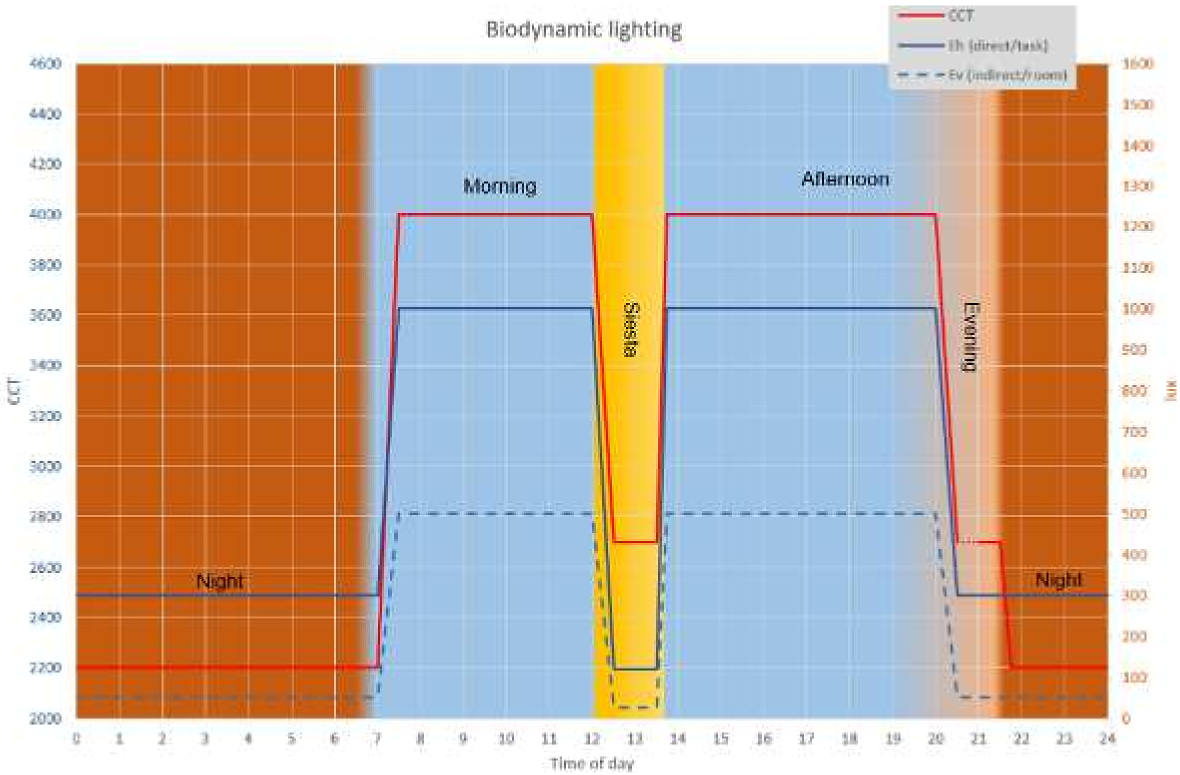


Figure 3: Biodynamic lighting concept. CCT…colour temperature in Kelvin, Eh…horizontal illuminances of the task light, Eh_{Room}…horizontal illuminance of ambient room light (resulting from Ev + Eh Task, for clarity reasons Eh_{Room} is not shown), Ev…vertical illuminance at the eye level

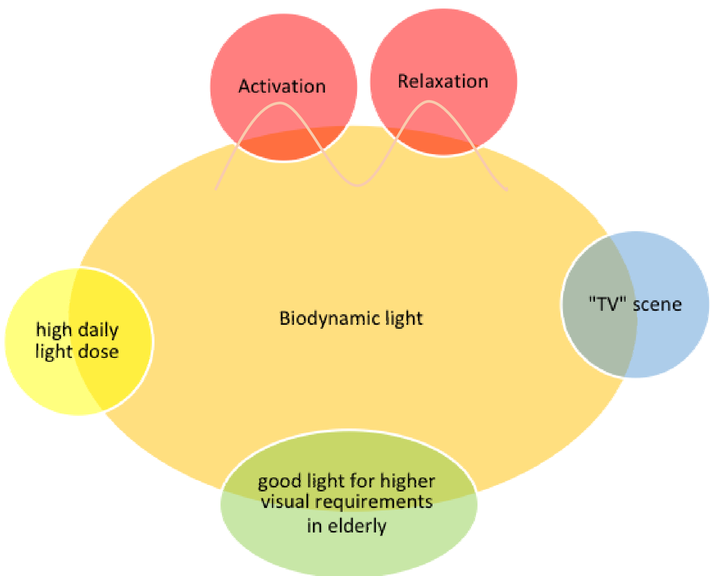


Figure 4: GREAT lighting concept

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).

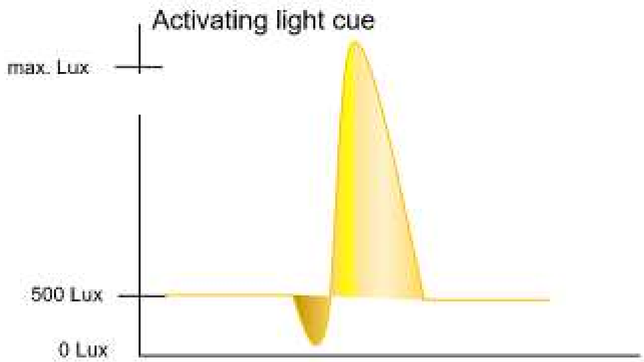


Figure 5: Activating light cue

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.

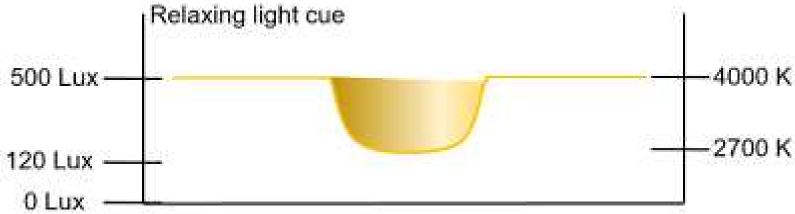


Figure 6: Relaxing light cue

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.

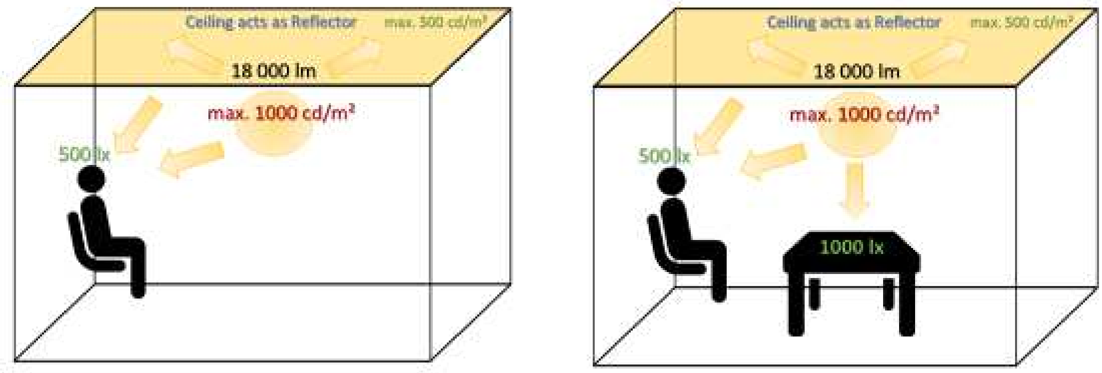


Figure 8: Increasing the vertical illuminance by adding a diffuse panel to the luminaire (left) and reaching high horizontal illuminances by adding task lighting by spots (right)

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

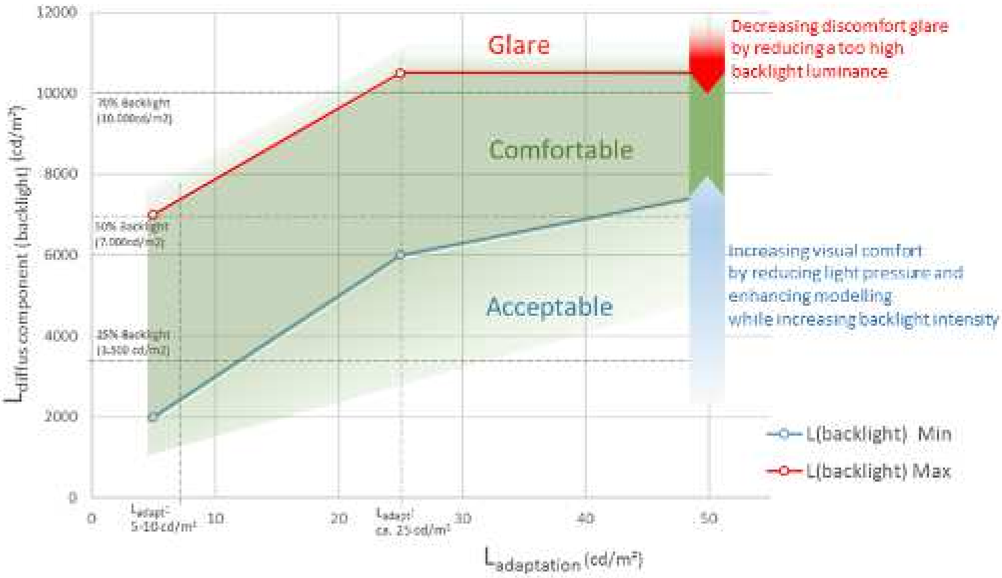


Figure 9: Results of light pressure study

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.

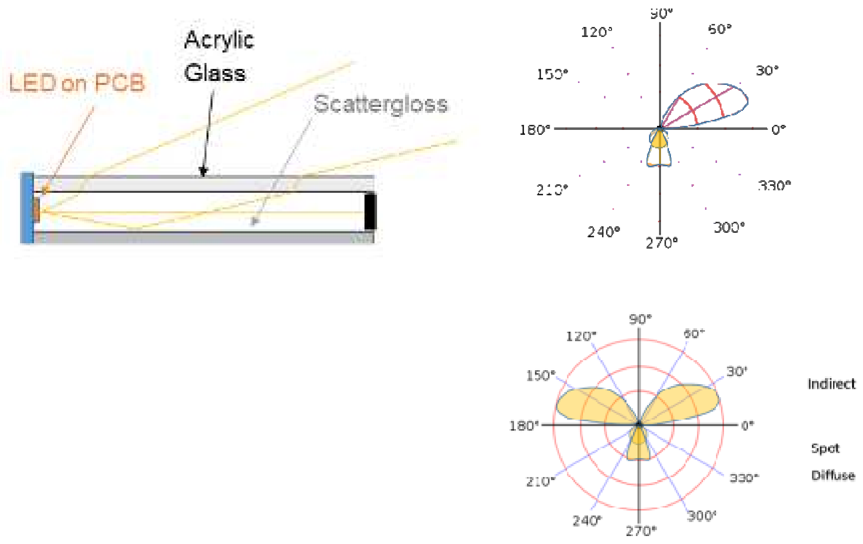


Figure 10: Optical concept for the GREAT Uplight (left) and the 2 possible Luminous Intensity Distribution curves LID (right): The Indirect light is available as an asymmetric solution for the wall mounted luminaire and as a symmetrical light distribution for example for the free-standing luminaire situated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

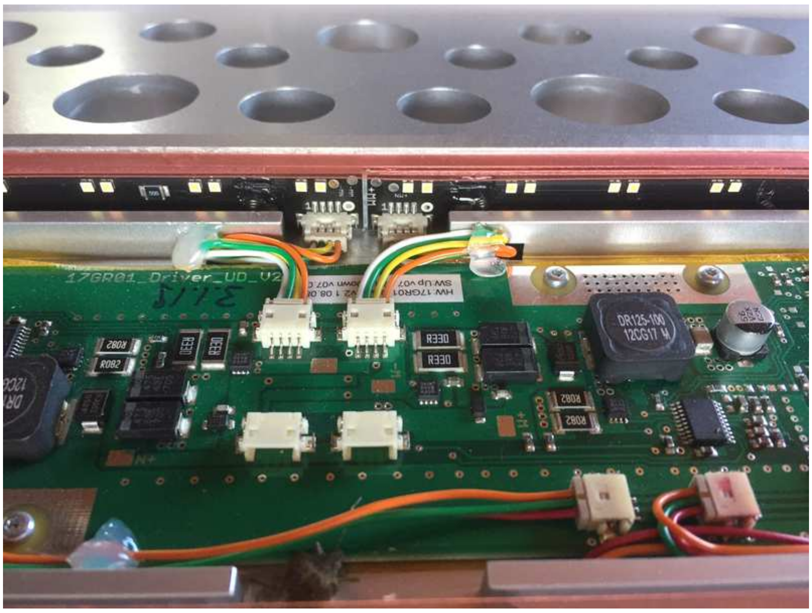


Figure 12: The LEDs are placed on the edge for lateral input of light in the light guiding plate

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.

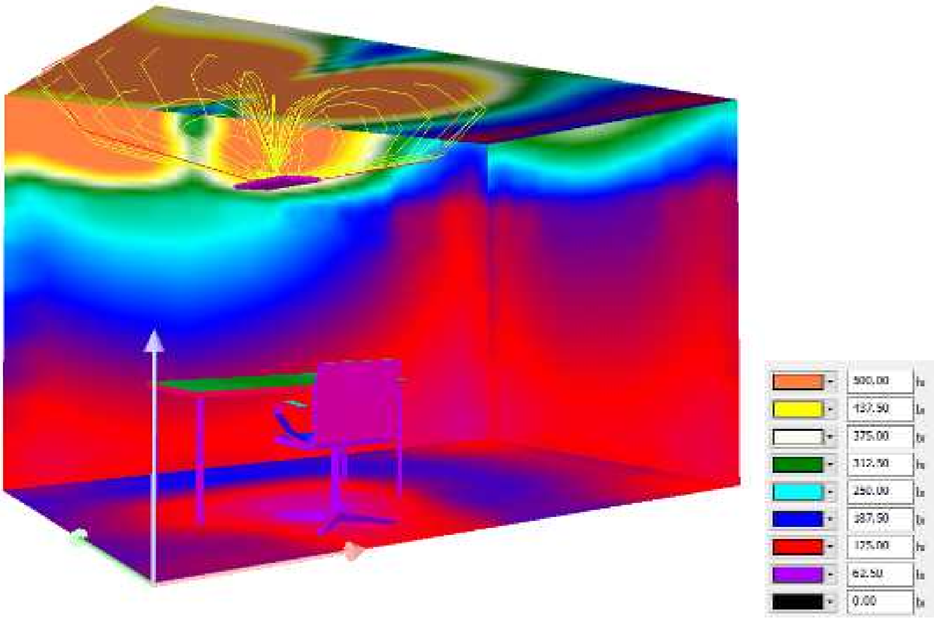


Figure 13: Dialux simulation of the GREAT Uplight

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).

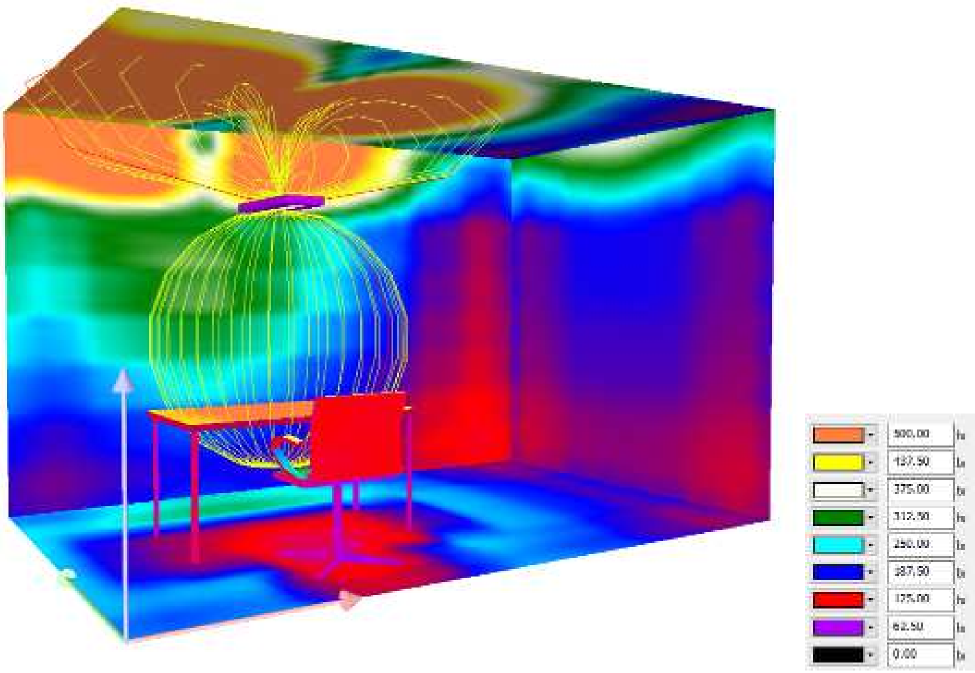


Figure 15: Dialux simulation of the GREAT Uplight and Downlight

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

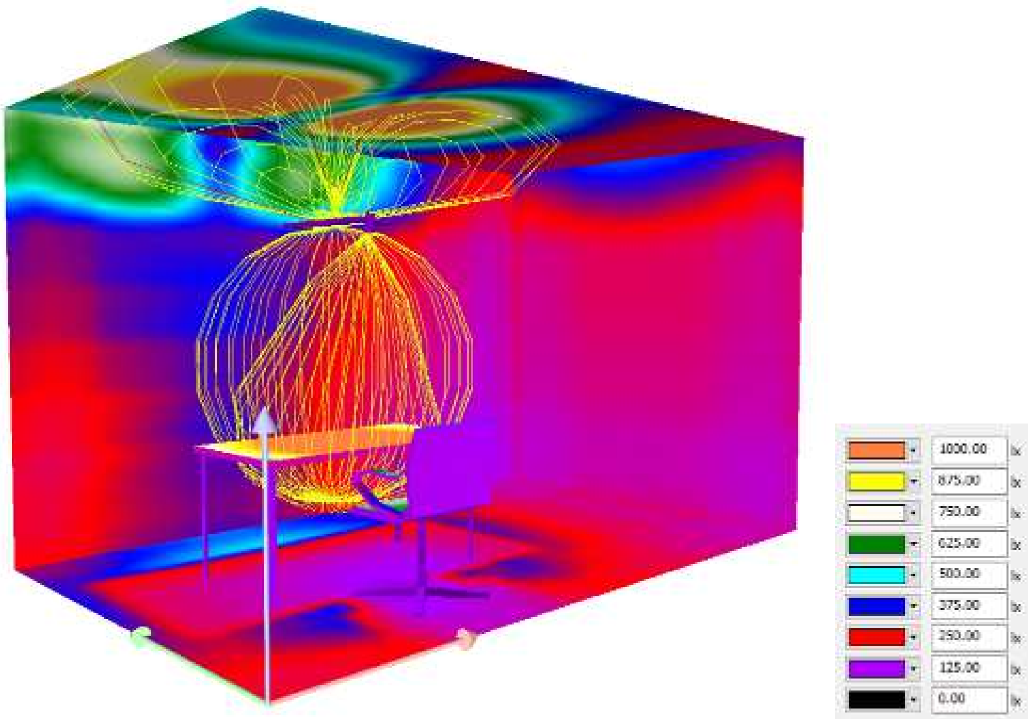


Figure 17: Dialux simulation of the GREAT Uplight, Downlight and Spot

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**
ELEKTRICAL 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	**2200K - 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

PRODUCT DESCRIPTION

luminaire consists of
· aluminium heat sink with optical unit
· rod assembly of two parts
· luminaire base contains power supply unit
· optical unit (PCB with LEDs and reflectors)
· EnOcean gateway for communication

Optical unit consists of three parts (Uplight+Downlight+Spot). Uplight with LEDs, reflector and clear plexiglas. Downlight with LEDs and prismatic plexiglas. Spot rotatable and tiltable.

Luminaire provides a biodynamic light curve (adaptation in light intensity and colour temperature in an 24h-rhythm) to stabilize the circadian rhythm. Activating and calming light scenes stimulate the immediate affective state of an observer.

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

LIGHT DISTRIBUTION CURVE (down/up/summary)

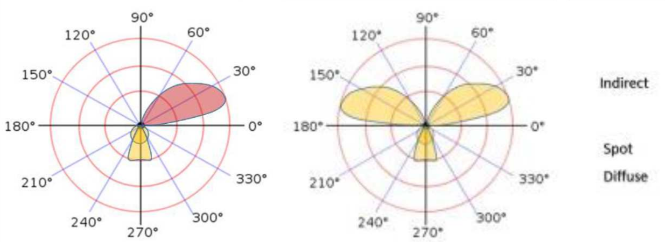


Figure 19: Technical specification sheet GREAT luminaire

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.

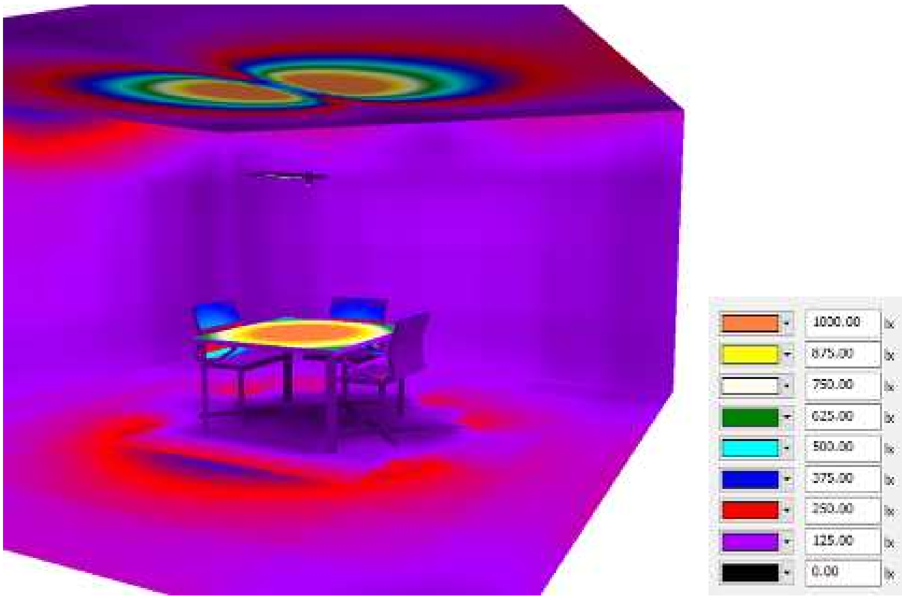


Figure 20: Dialux simulation of the GREAT luminaire showing the illuminances in a 25 m² room.

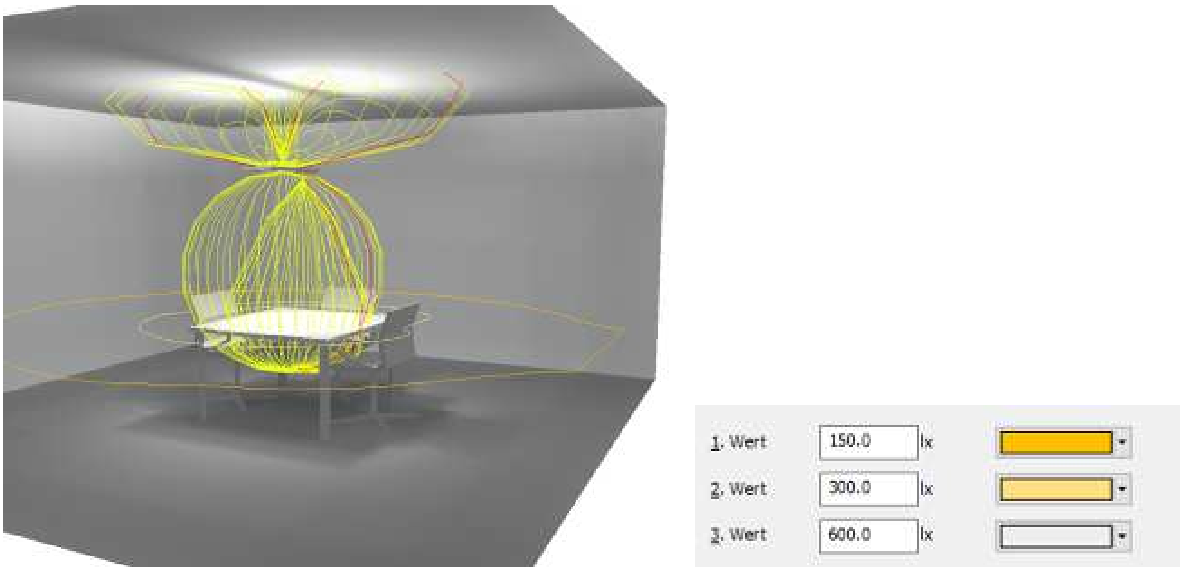


Figure 21: Dialux simulation of the light distribution of the GREAT luminaire. Also shown are the isolines for 150 lx (orange), 300 lx (yellow) and 600 lx (grey) horizontal illuminance.

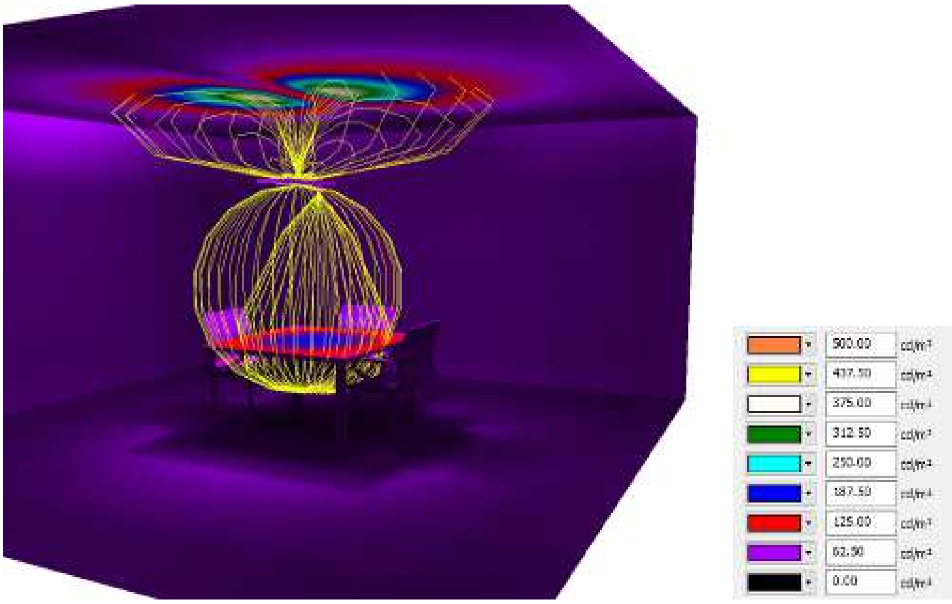


Figure 22: Dialux simulation of the GREAT luminaire showing the luminances in a 25 m² room.

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

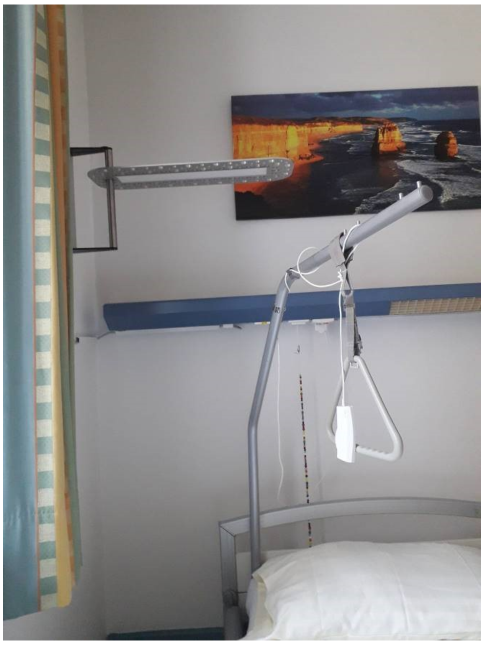


Figure 24: Wall-mounted GREAT luminaire in a patient's room in the hospital in Hall (Austria)

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

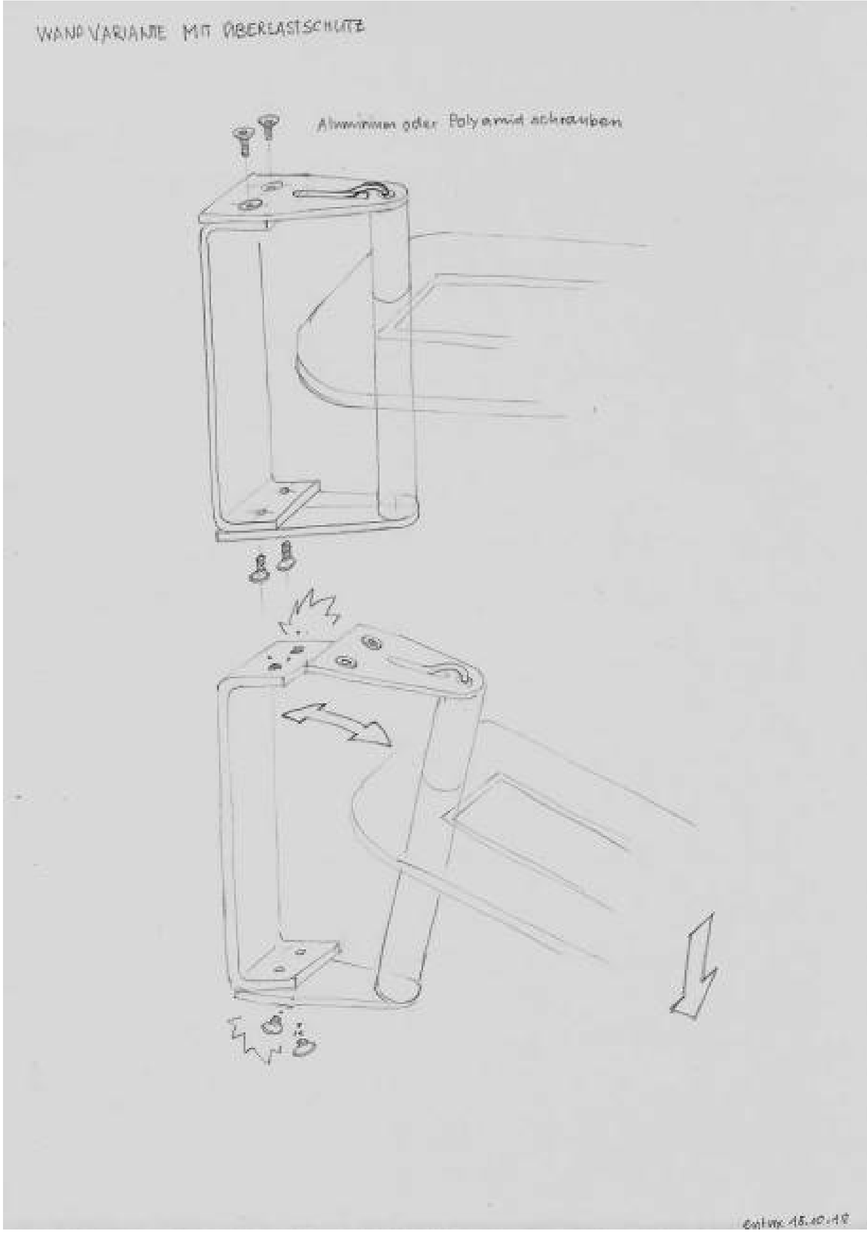


Figure 26: Special adjustment for psychiatric institutions: breaking point for protection against suicide

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).

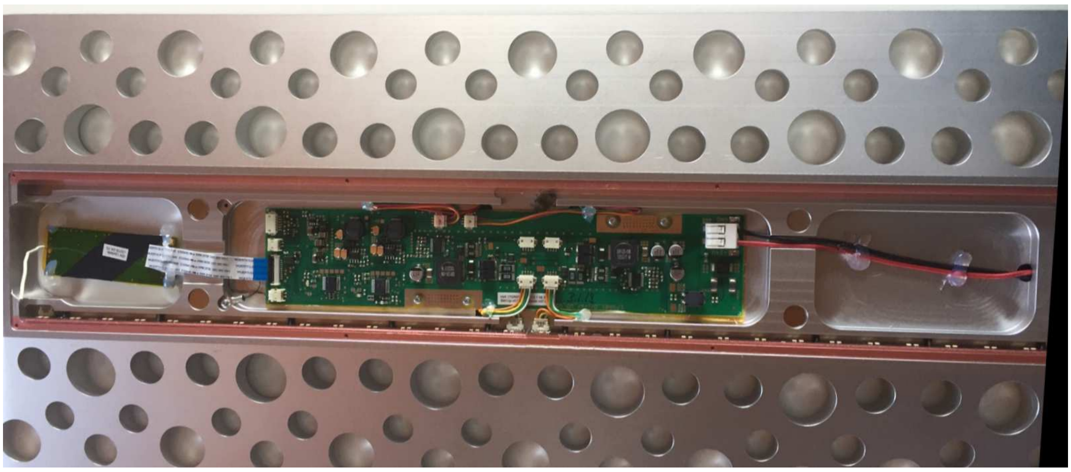


Figure 29: New, optimized luminaire head with EnOcean board and driving board

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.

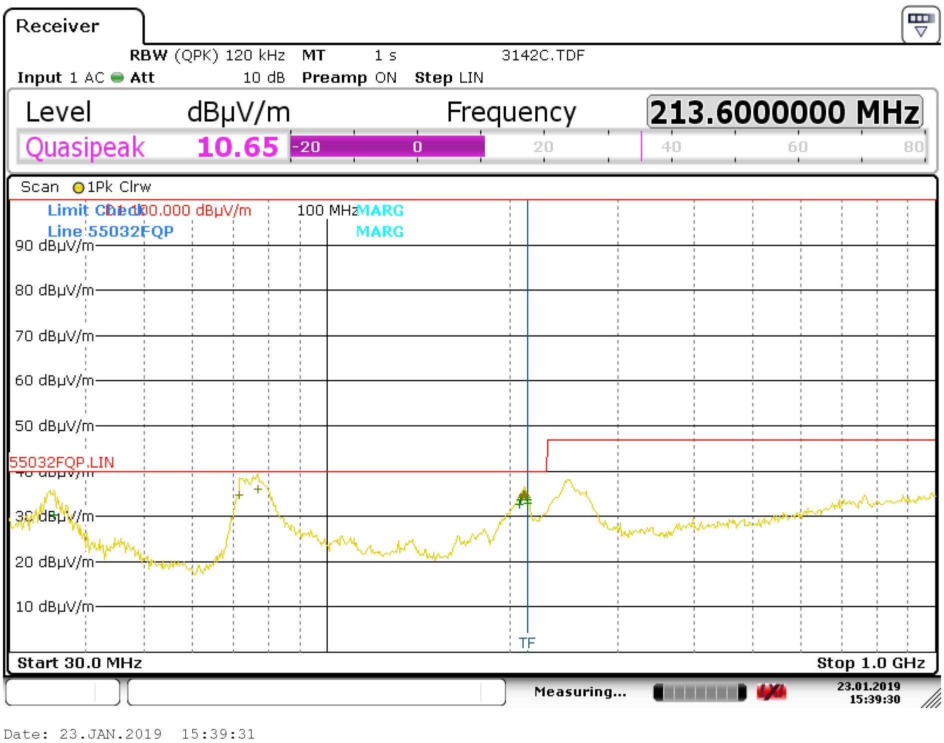


Figure 31: EMV measurement of the GREAT luminaire for CE conformity

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

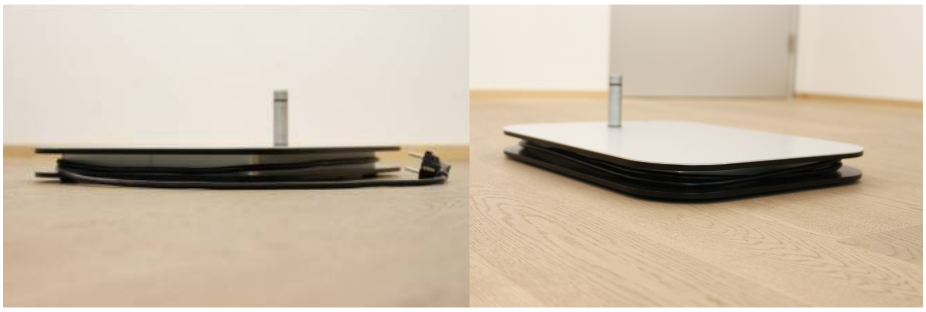


Figure 34: Cable storage feature

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).

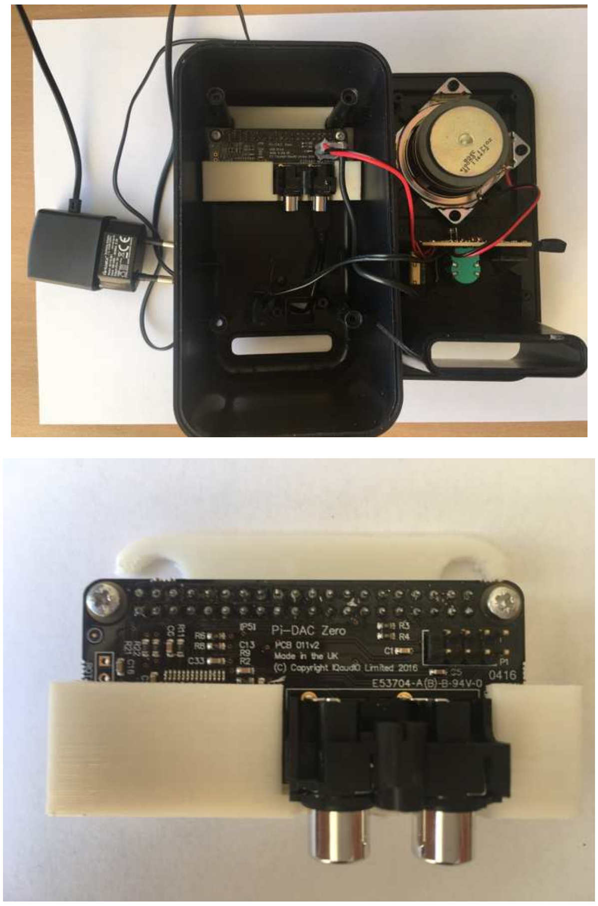
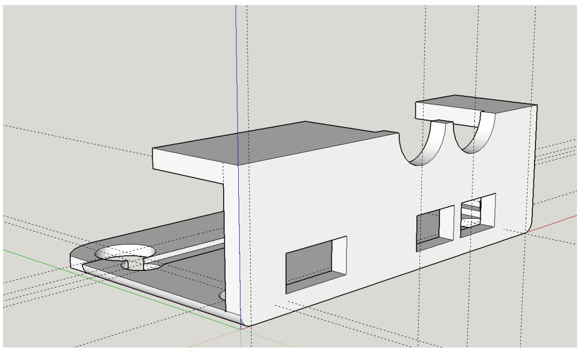


Figure 36: Raspberry PI and Pi-DAC Zero integrated into the Z150 active speaker.



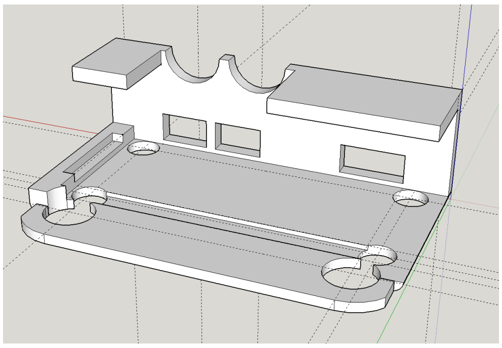


Figure 37: 3D model of Raspberry PI + Pi-DAC Zero holder for mounting inside Z150 speaker

The Logitech amplifier board is connected to the Pi-DAC Zero via the 2x4 header on the Pi-DAC Zero, which provides line-out left/right, as well as GND and a 5V power supply (see Figure 38 for details of the wiring). Note that the original power supply connection is unmounted from the speaker system.

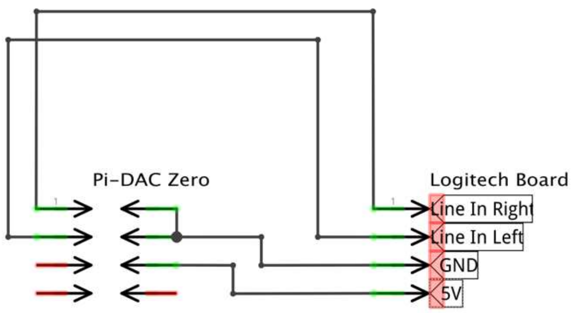


Figure 38: Wiring of the Pi-DAC 2x4 header to the Logitech board inside the speaker

As an alternative to building the sound module hardware into the Z150 speakers, a separate housing has been designed, in case the Raspberry Pi and Pi-DAC Zero should be connected to an existing sound system or alternative speakers. Figure 39 shows the 3D model of the case divided into two parts.

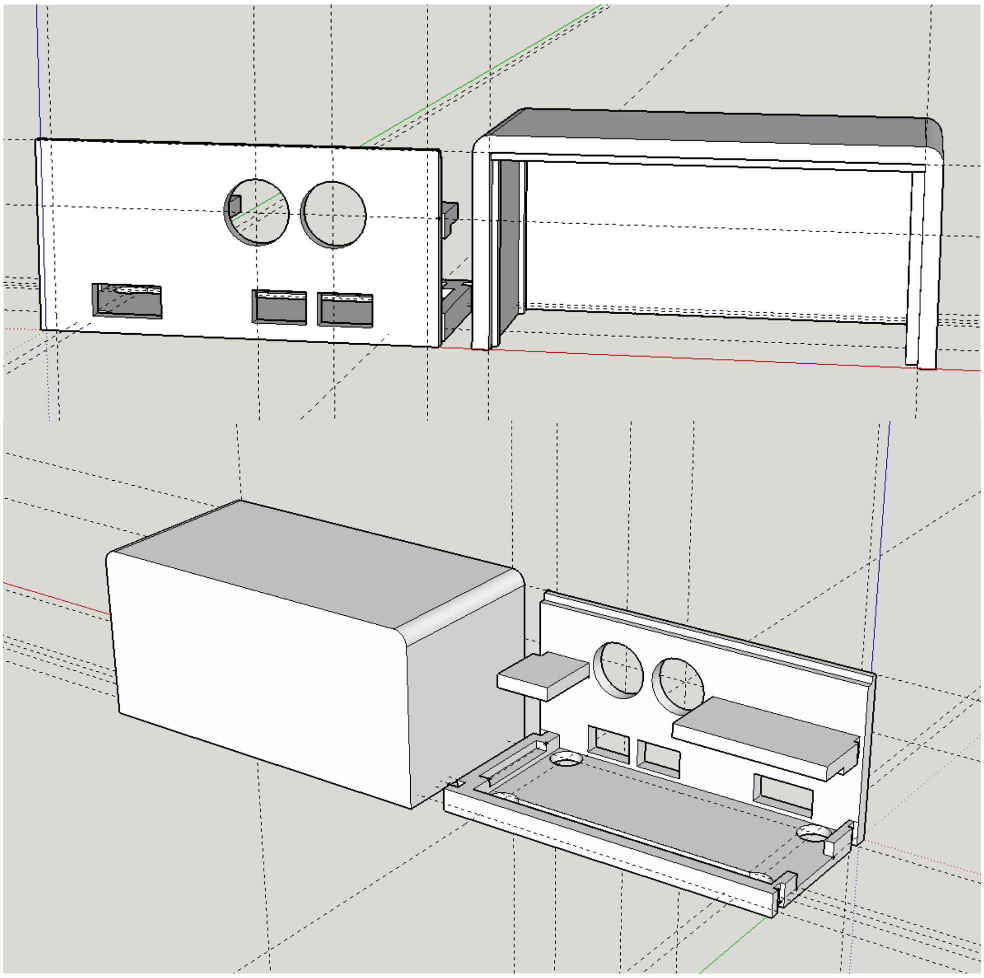


Figure 39: 3D model of separate housing for sound module logics

During the field test, the Logitech speakers with the built-in sound module have been used (see Table 3 for a list of required components).

Table 3: GREAT Sound Module hardware component list

1	Raspberry Pi Zero W board
1	IQaudIO PiZero DAC
1	Micro USB Power Supply, 1A
1	microSDHC card, 16GB, Class 10 (industrial)
1	Logitech Z150 Speaker Pair

The external sound module has been used in combination with a high-quality active speaker (Pioneer RM05) for testing inside the GREAT cabin. This speaker has an advertised frequency range of 40-50.000 Hz, and therefore a significantly better reproduction of ultra-sonic sound range.

Figure 40: External sound module with a Pioneer RM05 Speaker featuring a frequency range of 40-50.000Hz

3.3 Speaker Covers

To prevent accidental adjustment of the speaker volume by the built-in volume adjustment knobs, a selection of speaker covers has been designed. For the field tests, the minimalist grey cover has been preferred (see Figure 41).

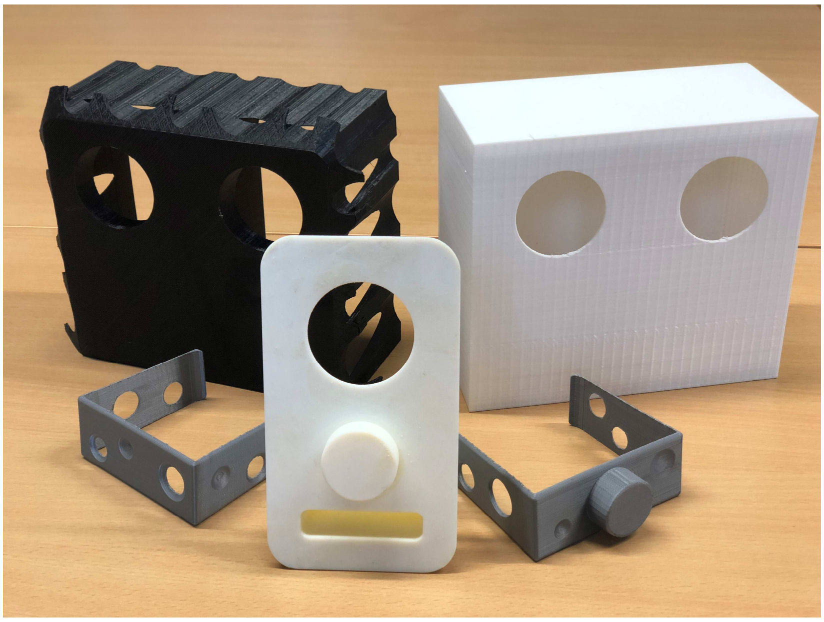


Figure 41: Speaker covers to prevent accidental adjustment of volume level

4 Scent Module

Compared to the field trial phase the scent module was reworked significantly: the casing presented in D2.1 as an outlook was further adapted, one-part 3D-printed and the other vacuum-formed. The pumping mechanism was changed from piston-based to spring-loaded. Further smaller changes will be presented in the sub-chapters below.

4.1 Basic Considerations

The GREAT-system requires a scent-module, which can adequately enhance the room atmosphere by dispersing respective odors. This basic requirement has not changed since the beginning of the project and we continue using spray-based dispersion for our field-test phase. Due to feedback from the tests so far hardware upgrades on the in- and outside of the device were necessary. The scent module should look more appealing and be able to resist harsher external influences (the previously used acrylic glass could shatter and did not look professional enough).

As stated further below, the pump mechanism from the functional test phase was not satisfying (a small portion of the droplets were too big and left stains on surrounding furniture), therefore the activation mechanism of the scent module was also improved. Changing the method of dispersion completely was considered (to either ultrasonic or heat vaporization), but next to the downsides already mentioned in D2.1 – involuntary vaporization, ultrasonic noise (which conflicts with the sound module) and alteration of the scent molecules (due to heat) – financially it was not an option to develop a completely new scent module.

4.2 Mechanical Design

Feedback during the early field-test-phase stated that the piston-based pumping mechanism created droplets of an undesirable size (too big). These droplets did not vaporize on their way from the bottle to the ground but left visible drops on the furniture or floor below. After the final vaporization there, a dry stain could still be seen.

We identified the sinusoidal stroke of the piston as the main problem: for a pump-action-based disperser, the last part of the compression is the most significant one, as the pump-head is fully loaded with liquid and when pressed appropriately quickly, it will create the desired scent-cloud. Unfortunately, the sinusoidal stroke does not allow for this, as the speed of the piston decelerates. Figure 42 shows a sinusoidal stroke, data used for linearization and a linear approximation, which would continue with constant speed until the maximum stroke.

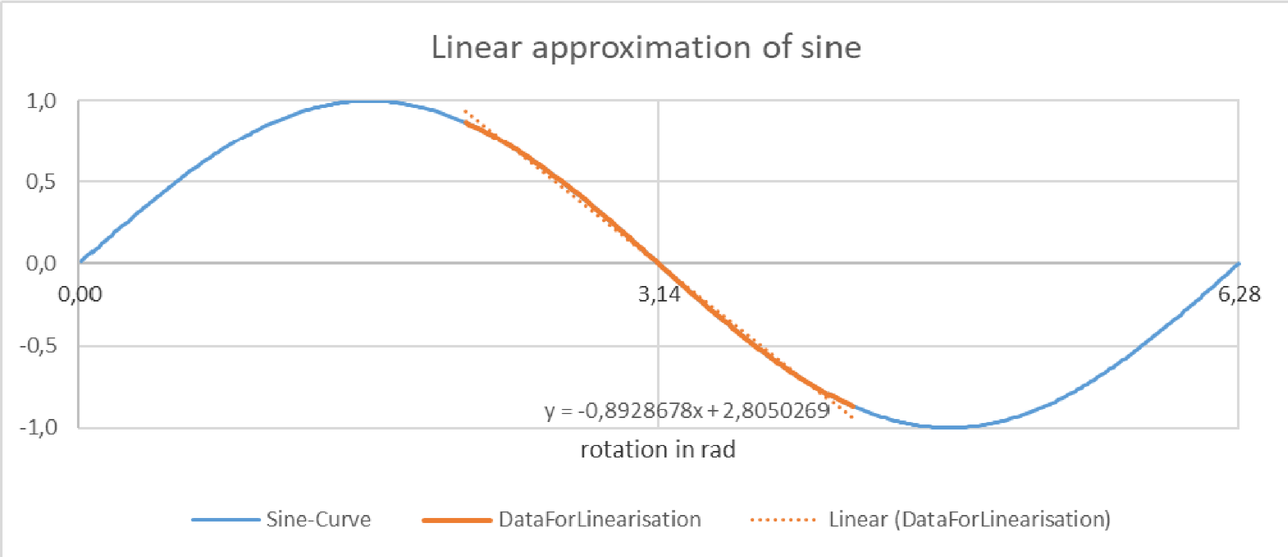


Figure 42: Sine, linearization and database for linearization and formula for the linear approximation

The error between that approximation and the sine curve can be seen in Figure 43. After 226 degrees, the sine starts to decelerate more and more, which means that during the last quarter of a stroke, the scent module would dispense at decreasing velocity, which lead to the undesired droplet size. In figures x and y, a stroke starts at 90 degrees and ends at 270 degrees. This means, one stroke lasts for 180 degrees (half of a rotation). The difference between 226 and 270 is 44, which makes up a quarter of one stroke.

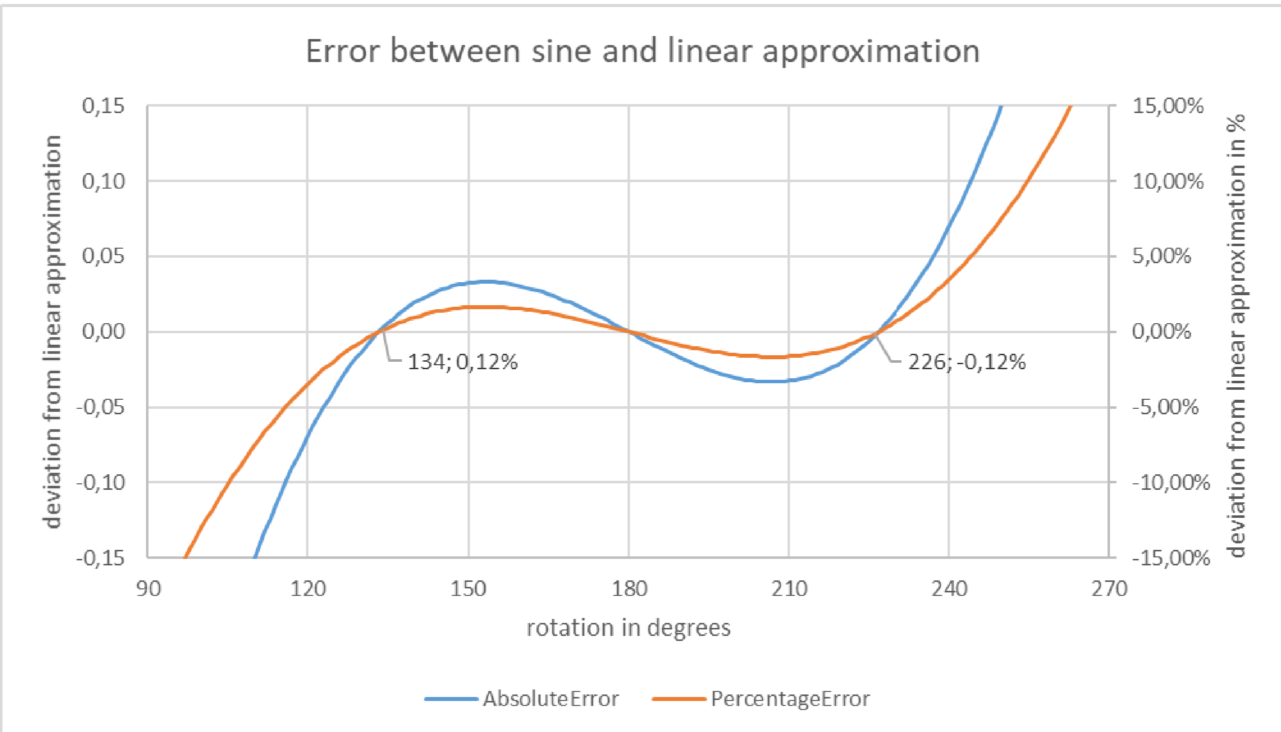


Figure 43: Error between sine and linear approximation, absolute [-1, 1] and percentage

To avoid this problem, we remodeled the interior parts of the casing, with the major change being the removal of the piston and the addition of a spring as seen in Figure 44. The moving parts of the mechanism were previously milled at the FH Vorarlberg. During the redesign, an iterative design process was used, where each step of the evolution was 3D-printed. Figure 44 shows the four new parts responsible for releasing the scent. The part seen on top fixes the motor, prevents the gears from slipping away, attaches to one end of the spring and the lever. As it is the only non-moving part, it will be referenced as "mount". The redesigned piston (as seen in the left half of the center row in Figure 44) now is disconnected from the other parts and only attaches to the linear guide. The final iterations also contain a screw to stop the piston from falling off the linear guide when changing the bottles. The eccentric (as seen in the right half of the center row in Figure 44) is held in place within a gear by a perpendicular screw and catches the lever on each rotation. The lever (as seen in the bottom row of in Figure 44) is attached to the mount at two points: a screw at the bottom, allowing it to pivot and with the spring at the top.

Figure 44: Evolution of mount (top), piston (center left), eccentric (center right) and lever (bottom)

The motor and the gears remain, but now they spin an eccentric which in the one half of a rotation simultaneously stretches a spring and moves the lever away from the bottle, allowing the pump head to rise to its normal level (seen on the right side of Figure 45). At the maximum stroke, it moves away from the lever, which is then pulled onto the piston by the spring, which leads the force to the pump head (seen on the left side of Figure 45). The motor then continues to spin without load until the eccentric catches the lever again.

Figure 46 shows the mechanic as installed in the field-test prototypes. It was replaced in all field-test-modules between March and May 2019. For a video of the new functionality, please visit our twitter page: https://twitter.com/GREAT_AAL/status/1111238884720033792.

The total amount of parts required was reduced and assembling the module is now faster than before. Replacement parts can be printed at the FH Vorarlberg should any damages occur. Using our own 3D-printers instead of purchased parts presents a valuable reduction in costs for our field test prototypes.

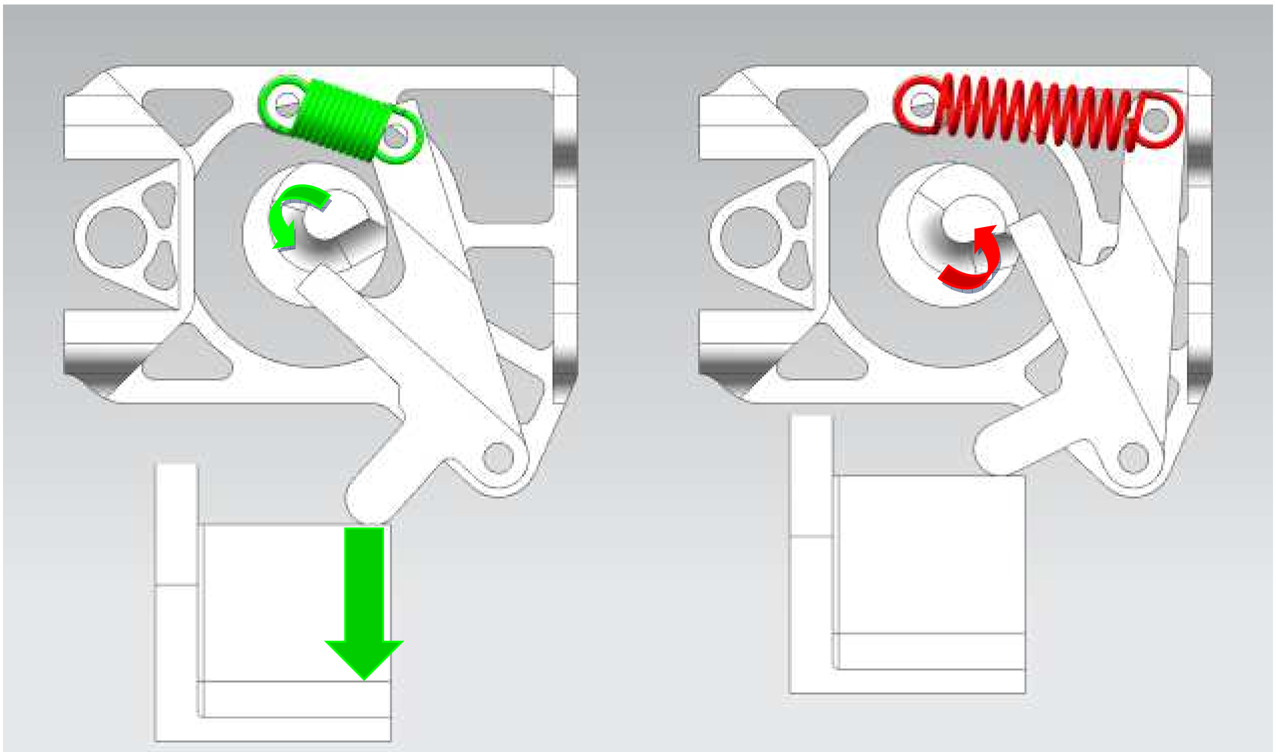


Figure 45: Left shows the no-load-phase of the motor, right shows the spring-tensioning-phase of the motor

For the new mechanism we need two additional screws (the ones preventing the piston from sliding off the linear guide) but less nuts as all but two screws (they can be seen in Figure 46 on the right, being screwed from the outside into the mount) directly screw into the 3D-printed material.

Figure 46: Reworked mechanic installed in the rear casing

4.3 Casing

The casing consists of two main parts: a front part (evolution as seen in Figure 47), a rear part, and a small inner casing to protect the microcontroller. In 2018 we also used optional shields (also seen in Figure 47) to prevent bigger droplets from hitting furniture. However, these shields have been retired, as the reworked mechanism vaporizes the scent liquid sufficiently.

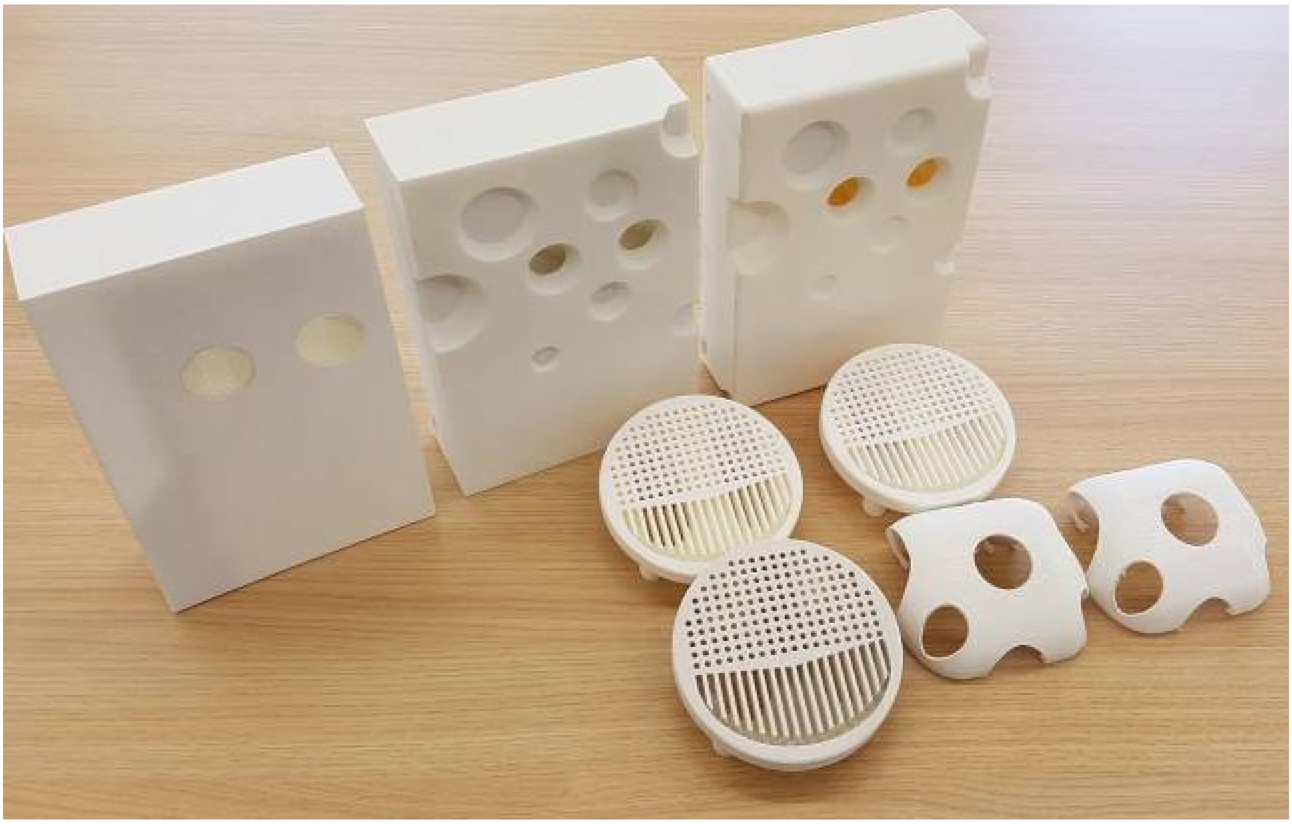


Figure 47: Evolution of the 3D-printed front casing (top) and the two variants of shields (bottom)

4.3.1 Front Casing

To create an appealing look, which visually connects light, and scent module, the previous casing (left casing in Figure 47) was reworked with an external designer (center casing in Figure 47) who also helped creating the cooling body for the lamp. The final design (right casing in Figure 47) has rounded edges and (not visible in this picture) increased space for the motors inside.

The production of the resulting 3D-model was outsourced to a local company, specializing in small series production. The actual manufacturing-process is vacuum forming, as it creates a nice-looking finish and has appropriate mechanical durability.

When the Raspberry Pi is connected to its power source, the front casing cannot be removed, as the plug locks it in place. This was introduced to prevent modules from spraying at users servicing them. The front casing can also be seen in Figure 48 on the right side.

Figure 48: Left shows the completely mounted rear casing, right shows the front casing

4.3.2 Rear Casing

As before, the rear casing holds all mechanical and electrical parts as well as the bottled scents (see Figure 48, left side). Previously, it consisted of two identical aluminium bodies and a separate plate, where the microcontroller could be mounted.

During the redesign, all parts were fused together and then were 3D-printed at the local company, which vacuum-formed the front casing. Apart from mounting-holes for the screws, which were adopted from the aluminium cases, cable guides, pockets for the VOC-sensor and a possible sound level meter (not integrated) and louvers were implemented.

4.3.3 Raspberry Pi Casing

We also decided to encase the microcontroller (see chapter 4.4) for the scent module in a 3D-printed box (see Figure 49). The three reasons for this were:

- Protection (ESD problematic or purely mechanical damages)
- Preventing mishandling the 2nd USB-connector
- Easier fitting to the rear casing: instead of 4 screws, 4 nuts, 4 plastic spacers and 12 isolation rings, only the Raspberry PI casing, 2 screws and 2 nuts are required. Mounting all pieces is now much easier, as no parts can come loose at any time (the isolation rings and spacers tended to slip away when a screw was removed).

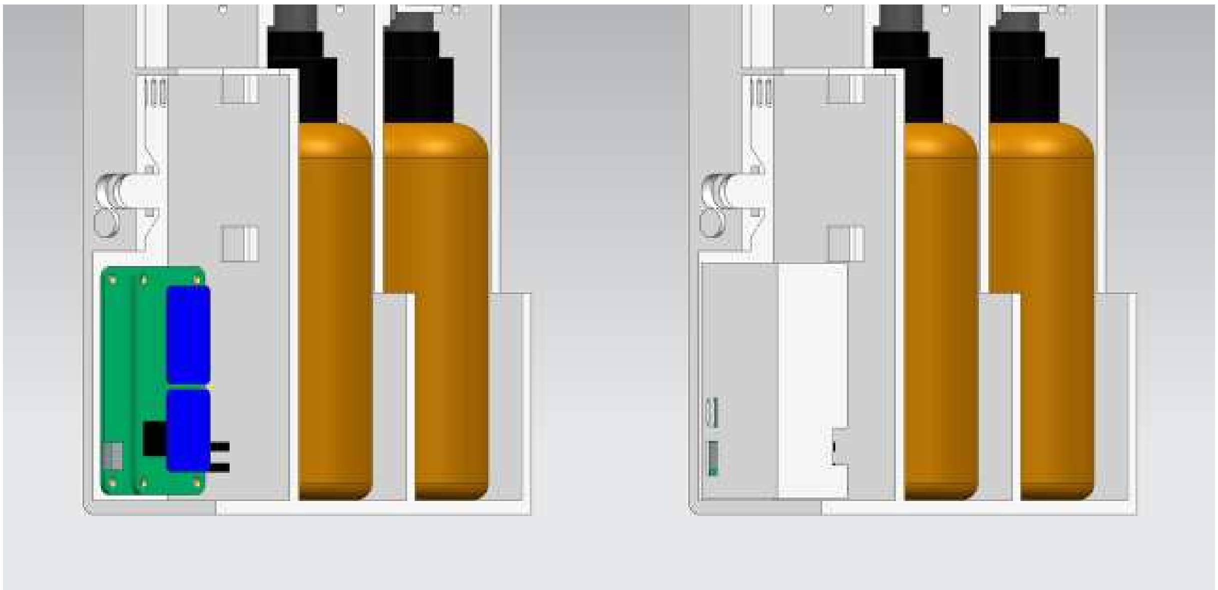


Figure 49: Microcontroller; left unprotected; right covered

4.3.4 Droplet shield

Before reworking the piston-mechanism, we reduced the amount of visible droplets by creating removable shields. They were clipped onto the front casing and prevented droplets from leaving the scent module and therefore also from creating stains on furniture. The first design (reminiscent of a smiley-face) successfully caught most of the droplets in a small integrated basin but was too airtight for adequate vaporization of the scents.

The second design (which included bigger holes, projected from the front casing) was designed to allow improved airflow past the caught scent, but the vaporization still was not enough. The shields can be seen in Figure 47.

4.4 Electrical Design

The scent module is powered by a USB power supply rated at 5V/1A. The main electrical components of the scent module are a controller board, a motor driver unit for the motors and an analog digital converter (ADC) for system feedback. The actuators of the scent module are controlled by a Raspberry PI Zero W board (see Figure 50), that allows for connection to a building automation system over WLAN and handles the logics of dispensing.

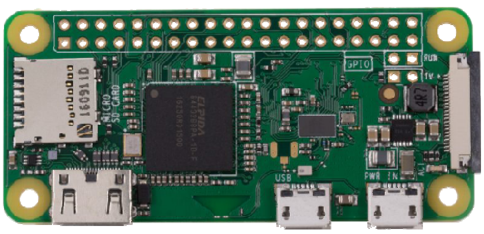


Figure 50: Raspberry Pi Zero W board computer

The motors of the scent module are connected to the Raspberry Pi Zero board via an Adafruit DRV8833 motor driver board that features current limiting (both, for protecting the power supply against overload in case the motor is locked, and against injuries) as well as reverse voltage protection for the controller board. One DRV8833 board allows for the connection of up to two motors (see Figure 51). The DRV8833 board is controlled over digital outputs of the GPIO header of the Raspberry board and provides fault input via a digital input.

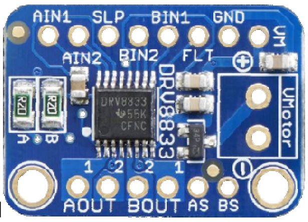
a


Figure 51: Adafruit DRV8833 motor driver breakout board.

An Adafruit ADS1015 ADC module (featuring 12-bit resolution) is used to measure the current flowing to the motors via a shunt resistor (see Figure 52). The ADC module is connected via an I2C interface to the main controller board.

Figure 52: Adafruit 12bit ADC converter ADS1015 breakout board

By measuring the current flowing to the motors, the software can detect peaks and values, which relate to the inverse current position of the pump spray. This allows for automatic turn off at the upper position, which allows for easy removal and insertion of scent bottles. Also, the exact number of actuations of the pump spray can be detected in this way (see Figure 53 for typical current flow of the prototype loaded with bottles and without bottles).

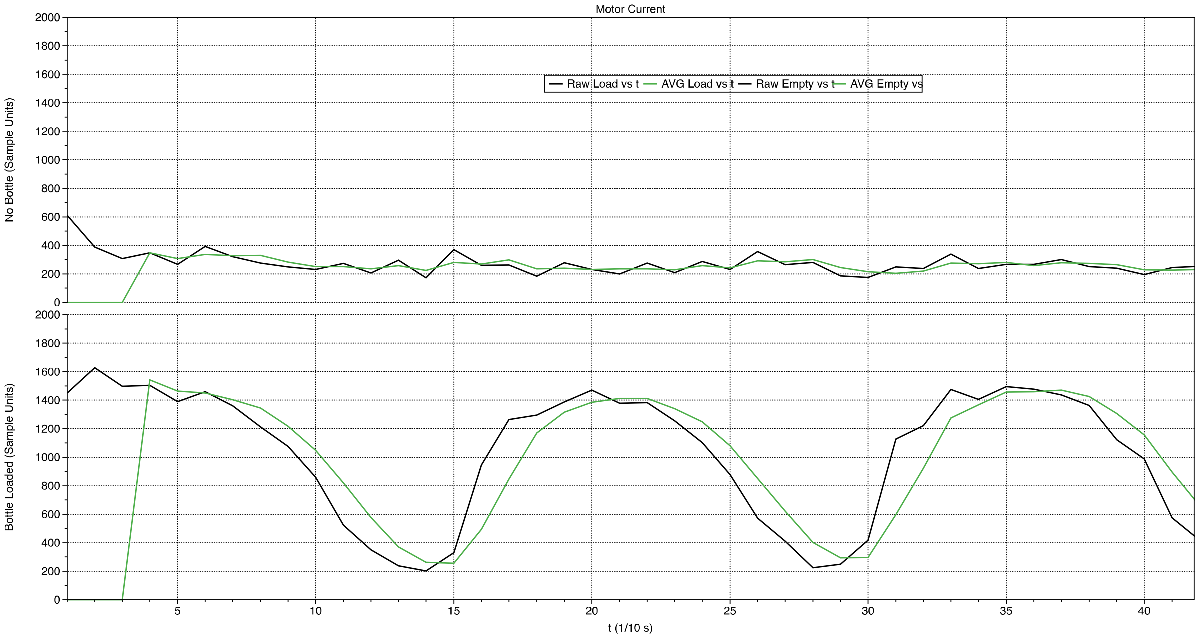


Figure 53: Current flow to motor during pump cycles with no bottle inserted (top), and bottle inserted bottom) as raw signal and smoothed signal.

Figure 54 shows the detailed wiring of the DRV8833 and ADS1015 modules to the Raspberry board.

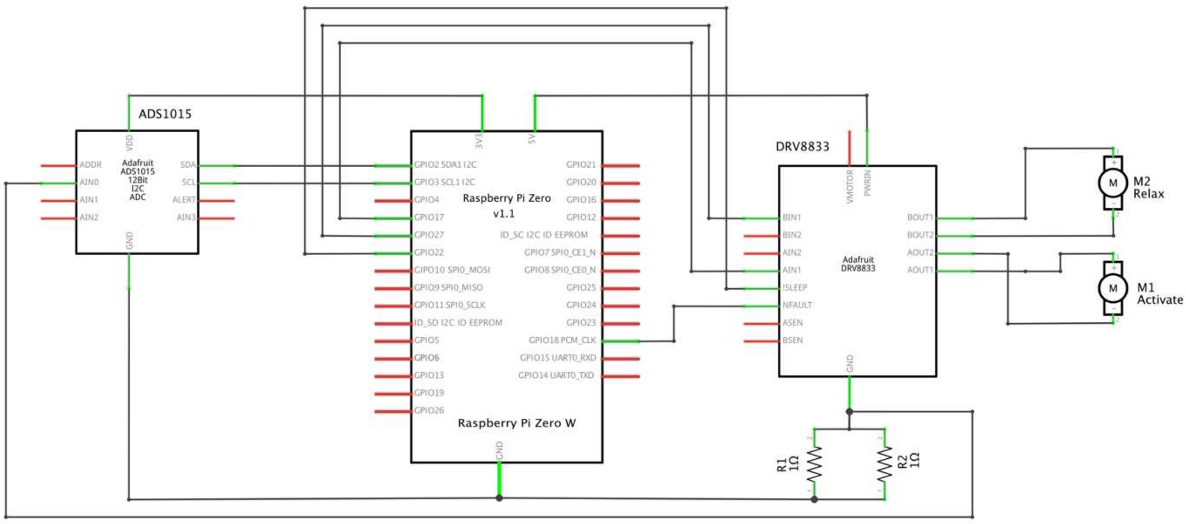


Figure 54: Schematics for the electrical components of the scent module.

While the first prototypes built for functional testing were wired manually, a printed circuit board (PCB) has been designed to make the assembly easier for the field test prototypes. Figure 55 shows the circuit board layout, providing headers to directly plug the individual boards together.

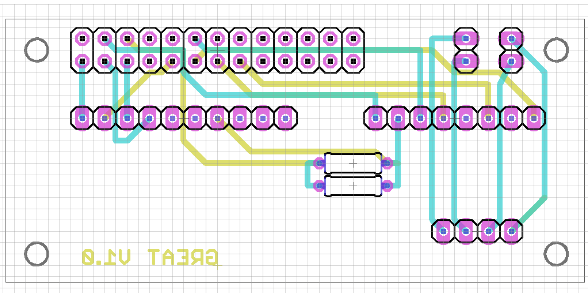


Figure 55: Printed circuit board design for the scent module electronics.

4.4.1 Environmental sensor

For the final field test design, we decided to put an environmental sensor into each scent module, since it became clear, that variations in test settings required continuous monitoring of air quality. The respective data is used to measure the effect dispensing scent and to prevent oversaturation.

The environmental sensor module is mounted on the left top corner of the scent module housing, pointing to the side, as seen in Figure 56 and in Figure 49. This position was chosen, to prevent actual droplets from hitting the sensor and actually measure the contents of the air without direct exposure to the spray channel.

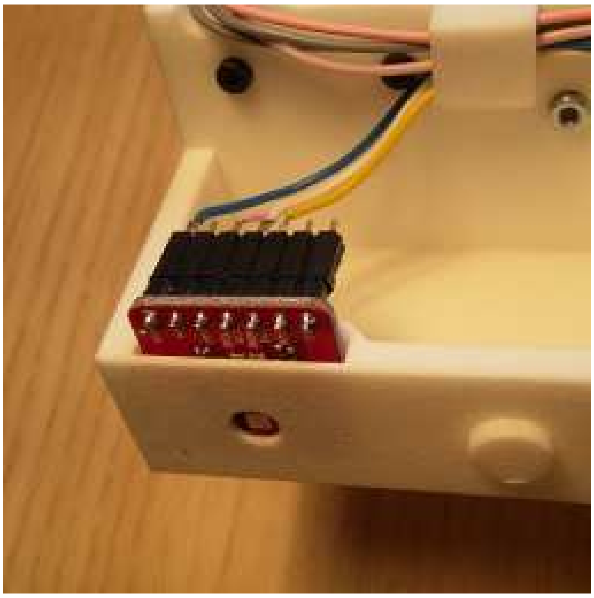


Figure 56: VOC sensor mounting

Table 4 shows the hardware component list for the electrical parts of the scent module.

Table 4: GREAT Scent Module hardware component list

1	Raspberry Pi Zero W board
1	Adafruit DRV8833 motor driver breakout board
1	Adafruit ADS1015 ADC breakout board
1	Micro USB Power Supply, 1A
1	microSDHC card, 16GB, Class 10 (industrial)
2	Resistors 1Ohm ¼ Watt
2	Pololu Micro Metal Gear Motor 6V 30:1
1	Watterott Bosch BME680 breakout board

4.5 Functional Tests

Concerning electronics, the functional and field tests were successful for the scent module, no malfunctions, errors or weaknesses occurred.

5 Repeater

During adaptations to the field test setups at the testing places in Hall and Neumarkt, reception issues of EnOcean telegrams between the controller and the luminaires have been discovered. Due to the metal casing of the luminaire, and the unavoidable electromagnetic noise produced by LED drivers, the EnOcean performance is significantly reduced compared to e.g. PIR sensors which only have a plastic housing.

To work around this limited range of EnOcean telegrams, a special purpose repeater was developed, that besides the standard EnOcean repeating functionality also offered a logging functionality of received telegrams and their signal strength, to assist in finding the best placements of the repeaters and reconstruct what was going on, if a luminaire did not handle a switching command.

The GREAT Repeater is based on a Raspberry PI Zero with an EnOcean TCM310 transceiver module (see Figure 57). The transceiver board is directly attached to the GPIO Header of the Raspberry Pi Zero. The transceiver module can be configured to run as a level 1 (only one step forwarding) or a level 2 (multistep forwarding) repeater and also allows for setting filters (e.g. depending on the signal level) for which telegrams should be repeated. This way EnOcean traffic caused by repeating signals can be reduced to a minimum. The Raspberry Pi and the EnOcean module are placed inside a 3D printed housing (see Figure 58).

The software running on the Raspberry Pi reads received telegrams from the transceiver module over the UART port and forwards them via a WLAN connection to a configurable receiver.

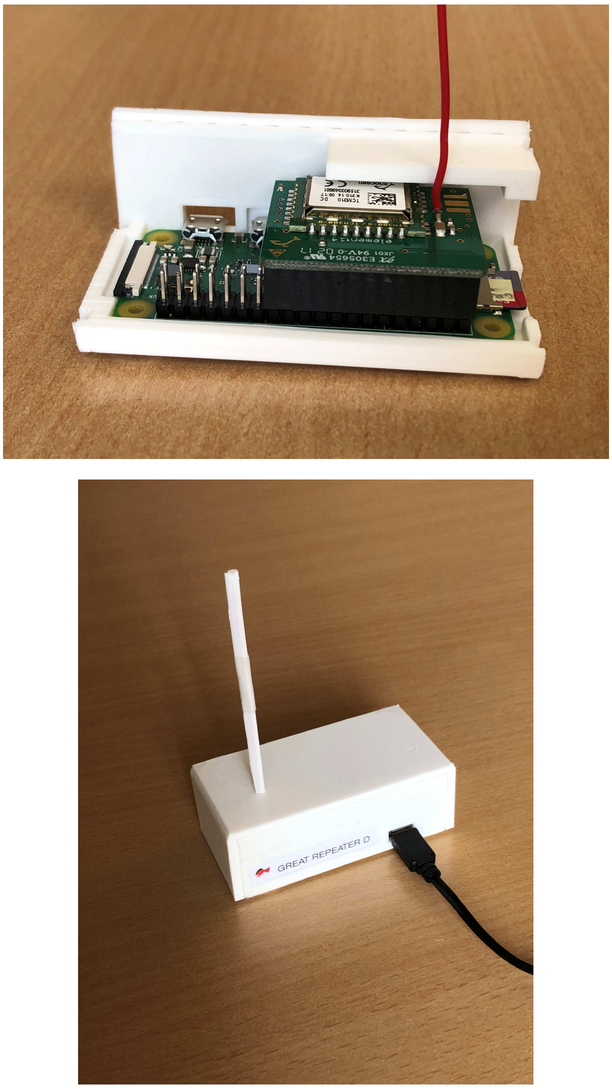


Figure 57: EnOcean Repeater based on Raspberry Pi Zero and TCM310

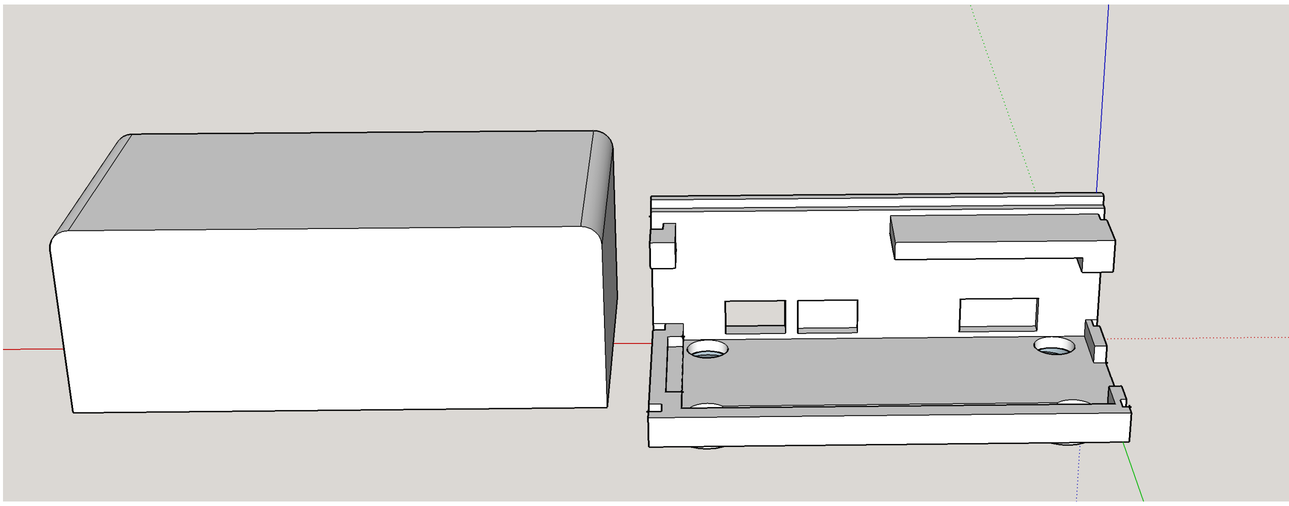


Figure 58: 3D printed housing for the repeater

Table 5 shows the component list required for the GREAT Repeater.

Table 5: GREAT Repeater component list

1	Raspberry Pi Zero W board
1	EnOcean Pi Module with TCM310
1	3D Printed Housing
1	Micro USB Power Supply, 1A
1	microSDHC card, 16GB, Class 10 (industrial)

6 Sensor Technology

6.1 Sensors for acquiring activation and relaxation status

The sensors used to detect changes in the activation and relaxation level of the group follow two approaches. Ambient PIR (passive infrared) sensors measure group activity based on frequency of motion detection. As soon as at least one person is in the room, the system uses the PIR sensors to continuously determine the relative activity level in the room (estimated number of entries/exits per time unit, estimated number of persons, total movement per area and person). The PIR data cannot be assigned to any person.

Body worn sensors are in use for caregivers to measure activity level and stress level. Wearables and smart textile for the patients are not in use due to the vulnerability of the target group and expected difficulties with acceptance and adherence.

6.1.1 PIR Sensor

The standard use case for PIR sensors is triggering lighting on basis of detected movement or presence. Part of further investigation is the detection of inactivity. Can the presence of inactive presence be recognized by history knowledge about the number of persons entered the room? For GREAT the main aspect is monitoring of activity and detection of group activity levels.

For the activation of lighting the sensor is typically triggered once by motion or presence and switches the light. For a period of 60-90 seconds or more the light is activated and the sensor falls into a sleep mode to conserve energy. After that sleep period the sensor starts to detect activity again. If no activity is detected, the light is switched off otherwise the light stays on and another sleep period starts.

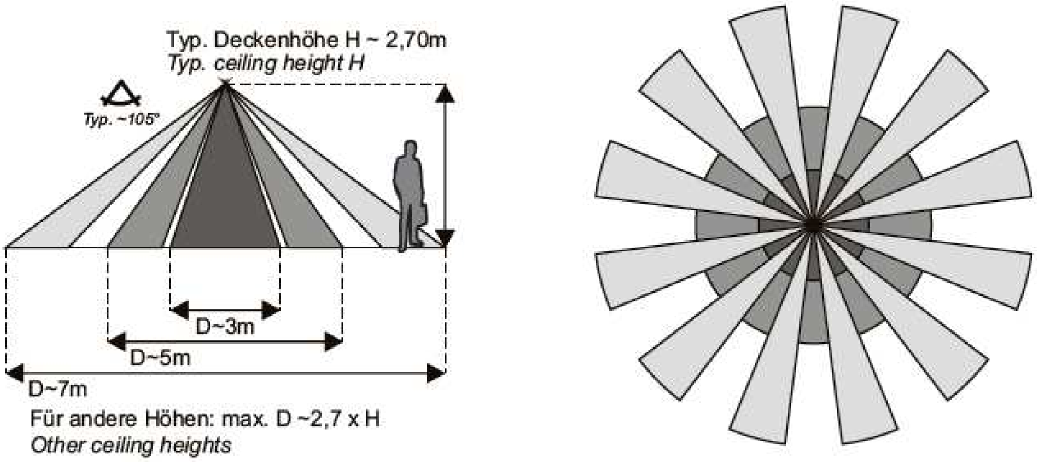


Figure 59: Detection range

The requirement for GREAT is to continuously detect activity. Therefore, the sleep period has to be as short as possible. To support convenient and modular installation the second requirement is wireless technology. Since there is a conflict between a wireless and energy-saving architecture and high frequency detection the chosen product has to be modified. The minimum sleep period was reduced to about 1 second. An additional modification is made due to the fact, that the sensor is placed on top of the ceiling and not as concealed installation (see Figure 60). If the human heat source moves through the individual zones, different charge differences are generated on the associated sensor elements and a movement can be detected over a large. The main issue would be to recognize not only movements and classify a single person's activities as shown in (Nef et al. 2015; Luo et al. 2017), but also how group activities can be classified and what this means related to a stressful or too calm situation. The sensor uses an optical shell combined with a magnetic cap to provide easy access in case of battery change without the necessity to completely removing the sensor. For GREAT the Thermokon "EasySens" SR-MDS BAT will be used (for technical specifications see Table 6, picture see Figure 60).

Table 6: Technical specification for Thermokon SR-MDS BAT

Vendor	Thermokon Sensortechnik GmbH (Germany)
Series	EasySense
Type	SR-MDS BAT
Retail price	250,00 EUR
Technical design	Wireless
Wireless technology	EnOcean ISO/IEC 14543-3-10
Radio frequency	868,3 MHz
Functions	Motion detection and brightness measurement
Motion detection	Passive infrared
Detection area	360°; 105° conical (ceiling installation)
Detection radius (2,5 m room height)	3,25 m
Power source	3 x Battery 3,6V 1/2 AA LS14250
Brightness (Accuracy)	0-510 Lux (+/- 30 Lux)
Sleep time interval (modified)	1s – 1000s

Figure 60: Thermokon SR-MDS BAT with extra light 3D printed cover

6.1.2 Body worn sensor

Changes in activity and stress or relaxation level can be measured by body worn sensors, which measure corresponding physiological parameters like heart rate, skin conductance or motion patterns via accelerometers. The Everion sensor from the company Biovotion (Zurich, Switzerland) makes use of various sensing techniques which can all be applied on the upper arm. There are several optical channels based on different colours to detect changes in subcutaneous tissue and a galvanic skin response sensor (GSR). Based on this raw data the human understandable vital parameters are calculated. The vitals available are listed in Table 7. The most interesting and most often used parameter for stress recognition is the heart rate variability (HRV). It is calculated based on the beat to beat (R-R interval) as illustrated in Figure 63. The HRV of a well-conditioned heart is typically large at rest. It might decrease in case of activity or interesting for us in case of mental stress. Biovotion applies to root mean squared of successive differences (RMSSD) to calculate the HRV. For our algorithm to recognize stress phases as shown in Figure 63, we apply three functions on the R-R intervals (according to Ulrich Reimer et al., 2017):

- SDNN: standard deviation of RR intervals (i.e., intervals between two heart beats)
- RMSSD: root mean square difference of successive RR intervals in the time frame
- PNN50: percentage of pairs of adjacent RR intervals differing by more than 50 ms.

Figure 61: Biovotion Everion upper arm sensor

Figure 62: Everion back with light and galvanic skin sensors

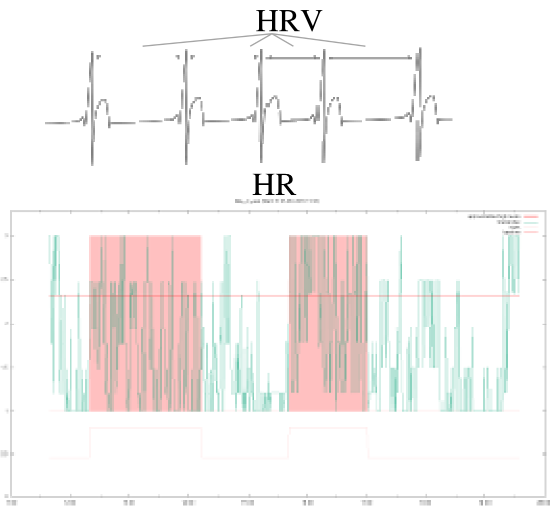


Figure 63: HRV signal and marked high stress segments

Therefore, we need the R-R values in milliseconds which are provided every second (1Hz). Together with the main vitals, a quality value in the range of 0-100 is provided. Values with a quality below 50 are ignored.

The algorithm applied in detail to derive the stress segments with the result shown in Figure 63 is described in detail in (Ulrich Reimer et al. 2017).

Another interesting testing parameter for our application might be the GSR, also referred to as Electrodermal Activity (EDA), which measures changes when starting to sweat. This is commonly used as a sensitive measure for emotional arousal. The GSR provided every second is expressed in a value between 0 – 65535 and has a conversion factor of 1/3000.

The advantage of the Everion in comparison to other sensors is its approval in Europe as a medical device for heart rate (HR) and blood oxygenation or oxygen saturation (SpO2) and its ISO certifications (ISO 1345). An approval by the FDA in the USA is currently ongoing. Also, the higher level of acceptance is an advantage which has been shown in our tests at the sleep laboratory where the devise has been applied by over 40 healthy test persons and over 30 unhealthy persons in parallel to ECG with electrodes attached and wrist worn devices (Reimer et al. 2017). The sensor is lightweight and convenient to wear, can store data locally, transmit data in real-time or whenever in range of a gateway and can be recharged easily by placing the sensor onto a conductive charging cradle. The comfortable wearing is supported by an elastic textile band available in different sizes as shown in Figure 64.

Figure 64: Different sizes of bands for an optimal fit

Table 7: Technical specification for Biovotion Everion

Vendor	Biovotion AG (Switzerland)
Type	Everion
Price (project)	550,00 EUR
Technical design	Wireless with rechargeable battery
Wireless technology	Bluetooth 4.0 + LE (IEEE 802.15.1)
Transmission range	<10 m
Radio frequency	2,4 GHz
Parameters	Heart rate Blood oxygenation Skin temperature Skin blood perfusion Steps / Motion

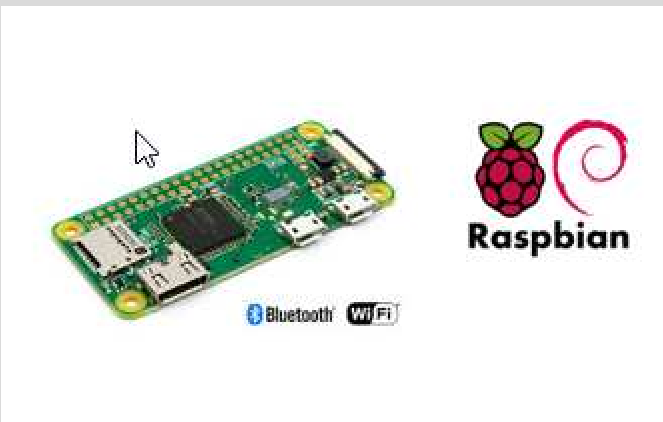
Experimental parameters (project)	Respiratory rate Heart rate variability Energy expenditure Blood pulse wave Skin conductance
Data modes	Vital sign parameters, raw data, mixed mode
Battery life	24 h
Power source	Embedded Li-Ion battery rechargeable

The sensor can transmit pre-calculated vital sign data or raw data from every parameter channel in real-time or buffer it to the internal memory. The memory can hold several days of vital sign data or 4 hours of raw data. The sampling rate of raw data at 53 Hz with 12 different channels causes a heavy data volume which leads to asynchronous data transmission over time (transmission is slower than recording of raw data).

In GREAT the vital sign mode is the preferred mode since the basic vital parameters are calculated in real-time for detection of changes in activation/relaxation and physical activity levels. For receiving data, a gateway has to be installed. Different variations are currently evaluated and considered for use. The preferred gateway is a Raspberry Pi 3 board controller which is also in use as the main controller of the GREAT system. Alternatives can be smartphones with an Android operating system or a Raspberry Pi Zero, which is the cheapest of all variations. The vendor currently only supports Windows and Android operating systems. Those variations rely on more expensive hardware like Stick-PCs based on Intel architecture, which is in conflict with a cheap end user price. To provide maximum compatibility and avoid problems with different Bluetooth stacks of different hardware components the vendor developed his own BT-Dongle. This dongle is also expensive (120 CHF). Different alternatives including advantages and disadvantages as well as the price tag are listed below (Figure 65).

For the functional tests, we started with the PC-Stick version and transfer the collected vitals every evening to our Cloud Server where also the logs from all devices are stored.

Originally, for the field tests, we planned for the cheaper variant with a Raspberry Pi 3 running Android. However, while porting the software, unexpected driver issues occurred. Therefore, we kept the working solution from the functional tests for the field test prototypes.

Variation	Pro/Cons	Price (CHF)
Intel Stick-PC with Windows 10 and BT-Stick		
	Pro: Use of existing software Cons: Expensive Stability issues	250
Raspberry Pi 3 with Windows		
	Pro: Cheap Cons: Porting of software	170
Raspberry Pi Zero with onboard BT		
	Pro: Cheap Board in use in other modules Cons: Porting of software	30

Raspberry Pi 3 with Android		
	Pro: Cheap Software under development by vendor Cons: Stability issues	60
Raspberry Pi 3 with Wine Emulation		

Figure 65: Possible hardware combinations incl. price tags

6.2 Environmental Sensor

In order to get more information about the environment where the GREAT system is being used and integrated, environmental sensor unit (BOSCH BME 680) has been incorporated into the scent module using a ready-made breakout board for easier placement and connection (see Figure 66).

The environmental sensor unit is connected to the controller of the Scent module via an I2C interface. It allows for measurements of air quality (VOC - Volatile Organic Compounds), temperature, pressure and relative humidity (see Table 8).

Figure 66: Watterott Bosch BME 680 breakout board

Table 8: Bosch BME 680 Environmental Units Specification

Interface	I²C and SPI
Gas sensor Response time (τ 33-63%) Sensor-to-sensor deviation Power consumption Output data processing	< 1 s (for new sensors) +/- 15% +/- 15 < 0.1 mA in ultra-low power mode direct output of IAQ: Index for Air Quality
Humidity sensor Response time (τ0-63%) Accuracy tolerance Hysteresis	8 s ± 3 % relative humidity ≤ 1.5 % relative humidity
Pressure sensor RMS Noise Sensitivity Error Temperature coefficient offset	0.12 Pa (equiv. to 1.7 cm) ± 0.25 % (equiv. to 1 m at 400 m height change) ±1.3 Pa/K (equiv. to ±10.9 cm at 1°C temperature change)

7 Controller

The main controller is based on a Raspberry Pi 3 single board-computer (Figure 67). It features a Broadcom BCM2837 system on a chip with four ARM Cortex-A53 cores clocked at 1.2 GHz. It includes 1 GB of LPDDR2 RAM and features a 10/100 Ethernet port, a 2.4 GHz 802.11n wireless module and a Bluetooth 4.1 LE module. For extension, it offers 4 USB2 ports and a 40-pin GPIO header (e.g. providing support for I2C, I2S, SPI, UART interfaces).

To integrate EnOcean components, a Raspberry Pi EnOcean module based on the TCM310 EnOcean transceiver module is connected to the built in UART via the GPIO header of the Raspberry. For better signal performance of the EnOcean modules, an external 868 MHz antenna was originally connected to the EnOcean module, however, tests during the field trials have shown that the integrated antenna of the EnOcean module would be sufficient, if it's straightened. Table 9 lists the hardware components required for the GREAT controller.

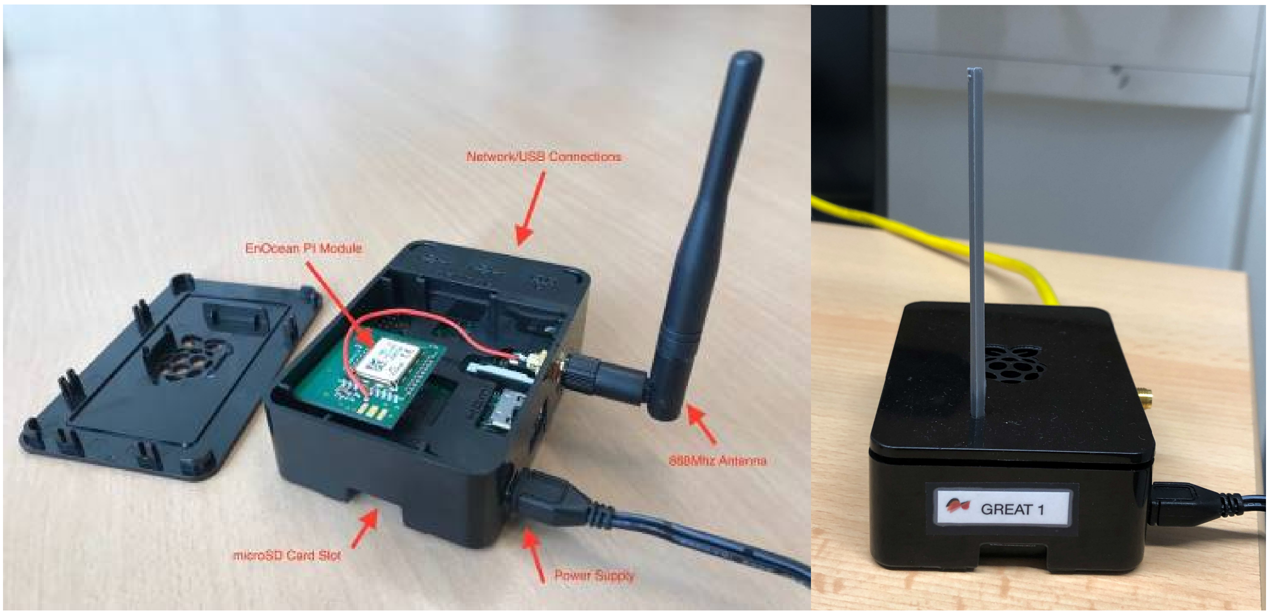


Figure 67: Controller setup based on Raspberry PI 3 and EnOcean PI 868 MHz module with external antenna on the left, and wire-antenna on the right.

Table 9: GREAT Controller hardware component list

1	Raspberry Pi 3 board
1	Casing for Raspberry Pi 3
1	Micro USB Power Supply, 2.5A
1	microSDHC card, 16GB, Class 10 (industrial)
1	EnOcean PI 868 module for Raspberry
1	868MHz Antenna H-Tronic 1618110
1	SMA-Connector Socket

The reasons for choosing the Raspberry Pi 3 board as basis for the controller instead of other single board computers (e.g. like the Beagle Bone boards) were price, strong community support including a wide range of extensions, and most importantly built-in wireless support.

For a documentation of the software architecture and features of the field test prototype see Deliverable 2.4.

8 References

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9 List of figures

Figure 1: GREAT Components Overview, Source: GREAT consortium......6

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......8

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......9

Figure 4: GREAT lighting concept......9

Figure 5: Activating light cue......10

Figure 6: Relaxing light cue......11

Figure 7: Different control options for the GREAT luminaire: basic functions (left), advanced functions (right)......11

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)....12

Figure 9: Results of light pressure study......13

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......14

Figure 11: Picture of the Uplight of the GREAT luminaire......14

Figure 12: The LEDs are placed on the edge for lateral input of light in the light guiding plate......15

Figure 13: Dialux simulation of the GREAT Uplight......15

Figure 14: Downlight of the GREAT luminaire and LPG......16

Figure 15: Dialux simulation of the GREAT Uplight and Downlight......16

Figure 16: Spot of the GREAT luminaire......17

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

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.......18

Figure 19: Technical specification sheet GREAT luminaire......19

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

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. 20

Figure 22: Dialux simulation of the GREAT luminaire showing the luminances in a 25 m² room. 21

Figure 23: Free-standing, mobile GREAT luminaire 21

Figure 24: Wall-mounted GREAT luminaire in a patient's room in the hospital in Hall (Austria) 22

Figure 25 : The buckling mechanism of the free-standing luminaire 22

Figure 26: Special adjustment for psychiatric institutions: breaking point for protection against suicide 23

Figure 27: GREAT system implemented in a patient's room in the hospital in Hall (Austria) . 24

Figure 28: GREAT standing luminaire in the common area in the hospital in Hall (Austria) .. 24

Figure 29: New, optimized luminaire head with EnOcean board and driving board 25

Figure 30: EnOcean switch 26

Figure 31: EMV measurement of the GREAT luminaire for CE conformity 26

Figure 32: Transportable GREAT Luminaire 27

Figure 33: Easy adjustment of GREAT luminaire 28

Figure 34: Cable storage feature 28

Figure 35: GREAT sound module based on Logitech Z150 active speaker 29

Figure 36: Raspberry PI and Pi-DAC Zero integrated into the Z150 active speaker. 30

Figure 37: 3D model of Raspberry PI + Pi-DAC Zero holder for mounting inside Z150 speaker 31

Figure 38: Wiring of the Pi-DAC 2x4 header to the Logitech board inside the speaker 31

Figure 39: 3D model of separate housing for sound module logics 32

Figure 40: External sound module with a Pioneer RM05 Speaker featuring a frequency range of 40-50.000Hz 33

Figure 41: Speaker covers to prevent accidental adjustment of volume level 33

Figure 42: Sine, linearization and database for linearization and formula for the linear approximation 35

Figure 43: Error between sine and linear approximation, absolute [-1, 1] and percentage 35

Figure 44: Evolution of mount (top), piston (center left), eccentric (center right) and lever (bottom) 36

Figure 45: Left shows the no-load-phase of the motor, right shows the spring-tensioning-phase of the motor 37

Figure 46: Reworked mechanic installed in the rear casing 37

Figure 47: Evolution of the 3D-printed front casing (top) and the two variants of shields (bottom) 38
Figure 48: Left shows the completely mounted rear casing, right shows the front casing ... 39
Figure 49: Microcontroller; left unprotected; right covered 40
Figure 50: Raspberry Pi Zero W board computer 40
Figure 51: Adafruit DRV8833 motor driver breakout board. 41
Figure 52: Adafruit 12bit ADC converter ADS1015 breakout board 41
Figure 53: Current flow to motor during pump cycles with no bottle inserted (top), and bottle inserted bottom) as raw signal and smoothed signal. 42
Figure 54: Schematics for the electrical components of the scent module. 42
Figure 55: Printed circuit board design for the scent module electronics. 43
Figure 56: VOC sensor mounting 43
Figure 57: EnOcean Repeater based on Raspberry Pi Zero and TCM310 45
Figure 58: 3D printed housing for the repeater 46
Figure 59: Detection range 47
Figure 60: Thermokon SR-MDS BAT with extra light 3D printed cover 49
Figure 61: Biovotion Everion upper arm sensor 50
Figure 62: Everion back with light and galvanic skin sensors 50
Figure 63: HRV signal and marked high stress segments 50
Figure 64: Different sizes of bands for an optimal fit 51
Figure 65: Possible hardware combinations incl. price tags 54
Figure 66: Watterott Bosch BME 680 breakout board 54
Figure 67: Controller setup based on Raspberry PI 3 and EnOcean PI 868 MHz module with external antenna on the left, and wire-antenna on the right. 56

10 List of tables

Table 1: Advantages and disadvantages of diffuse and task lighting 12
Table 2: GREAT Light Module hardware component list 28
Table 3: GREAT Sound Module hardware component list 32
Table 4: GREAT Scent Module hardware component list 44
Table 5: GREAT Repeater component list 46
Table 6: Technical specification for Thermokon SR-MDS BAT 48
Table 7: Technical specification for Biovotion Everion 51
Table 8: Bosch BME 680 Environmental Units Specification 55
Table 9: GREAT Controller hardware component list 57