Guiding Light

Ambient Light Guiding System for the Mobility Support of Elderly People

Final report

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Preface

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

D1.1 Medical, psychological, and technological framework

D2.1 Applicable hardware components

D2.2 Applicable software components

D3.1 Solution package description

D3.2 Implementation report

D4.1 Communication strategy

D4.2 Stakeholder management report

D5.1 Field test report

D6.1 Report on market analysis

D6.2 Dissemination plan

D6.3 Final business plan

D7.1 Consortium Agreement

D7.2 Periodic activity and project management report

D7.3 Final report

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

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1. Introduction

Light isn´t just a requirement for visual performance. Several studies proof that light also has an influence on many other psycho-physiological parameters of human beings, e.g. on cognitive performance, immune- and drive system and the activity regulatory system in accordance with circadian rhythm (Boyce, 2014; Veitch & Galasiu, 2012). A comparison of LED-lamps with fluorescent lamps and incandescent lamps shows that the effect of lighting technologies is definitely comparable with appropriate specification (Kempter et al., 2012; Plischke et al., 2013). Differences in the effect of artificial lighting on people is mainly achieved with elaborated control (Kempter, 2012a) whereas LED-lamps show clear advantages compared to other lighting technologies in the implementation of control signals (Khanh et al., 2015).

Due to the dynamic controllability and the light bundling charactreistics of LED-lamps the question arises, if a locally and timely diversifying illumination of interior spaces increases the tendency of people to stay at defined times at particular places, without having any other symbolic information. This question is not only interesting for people in public spaces but also for individual persons and their private spaces. Usually people follow an individual daily structure, which in fact can differ according to weekdays or holidays, but follows a recurrent pattern over a longer period (cf. Eurostat, 2009). Bedtimes e.g. show a big regularity, the time spent in kitchen, living space and bathroom are repeated within a certain fluctuation range and time spent outdoors often follows a pattern (Kempter et al., 2014).

However, under certain circumstances, for example in the course of the aging process, the hitherto habitual daily structure can undergo an unintentional change (Lotfi et al., 2012). In this case, a light guiding system, which enhances not only the day-/night rhythm but also a more differentiated daily structure rhythm through room lighting, could provide a remedy. The influence on the day-/night rhythm of temporal variation of light intensity and light colour has already been proven several times (Kahn et al., 2015; Veitch & Galasiu, 2012). Whereas findings are rare, how the spatiotemporal variation of light intensity and light colour affects where a person stays at particular daytimes preferably (Kempter et al., 2014). Guiding the places of stay in the flat, which can be influenced by room lighting, over the whole day and influence the time spent outdoors is almost impossible.

Just a few studies indicate that this is possible. Wardorno et al. (2012) point out that people stay longer and preferred in room areas with warm-white light especially in the evening. The study of Frölich (2012) shows that light intensity and light colour variations can be used to guide people´s attention. Furthermore people rate their spatial orientation skills in corridors with light intensity of 500 lux and colour temperature of 2700 kelvin higher than in corridors with lower intensity and higher temperature (Hidayetoglu et al., 2012). However, those studies were all carried out in virtual realities. Just one field study of Bieske and Dierbach (2006), which was performed in the real world, showed that spatial and temporal orientation of elderly people increased after the implementation of circadian illumination.

Another project that dealt with spatiotemporal orientation is “Guiding Light”, an intelligent light guiding system developed by a project consortium. This system should lead older people at determined times to predefined locations in the house and outdoor stays, without any other external influence. One precondition is the assumption that room lighting increases not only the motility in terms of more physical activity but also the mobility in terms of effortless change in indoor and outdoor stays. Those effects shouldn´t lead to undesirable actions, for example the “restless-leg-syndrome” or the “restless wandering” of people with dementia. The aim of Guiding Light is to fit increasing motility and mobility with a desired daily structure – to have ”the right amount of activity at the right time at the right place”.

The aim of our lighting intervention is to support the desired daily structure by providing ideal lighting conditions to the senior residents, thus improving for instance sleep quality, or enhancing the drive to go for a walk. Furthermore, everyday activities like reading or cooking are also supported by optimal lighting, taking into account the higher need for light of elderly people.

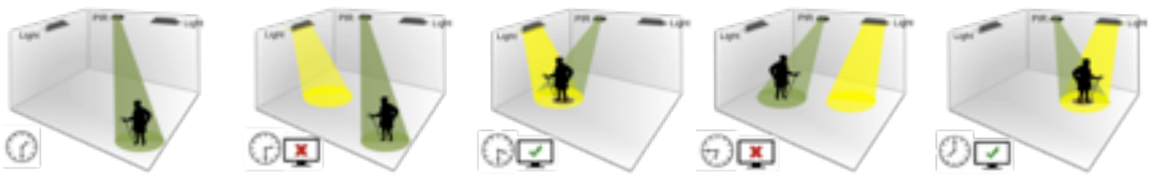

Figure 1. Basic idea of Guiding Light is zonal lighting at predefined daytimes.

The figure above illustrates an example: At half past one, the presence of a senior inhabitant is detected within his or her apartment. At half past two, Guiding Light starts the task light of a predefined room zone, where the inhabitant typically stays during this time until half past three (e.g. in the reading chair). If the inhabitant is not in this zone at half past two, the system recognizes an exception from the typical daily structure. In case of repeatedly exceptions for several days, Guiding Light will change lighting parameters such as switch on time, light intensity and light color. On the other hand, if the senior resident is in this area until half past three, the system recognizes the repetition of the daily structure. At a quarter to seven, the Guiding Light task light illuminates a new room zone according to the typical daily structure of the senior (e.g. in the kitchen). Again, if the inhabitant is not in the assumed room zone at this moment, the system recognizes another exception from the typical daily structure. which is not the case at eight o'clock, when inhabitant stays in the room zone according to his typical daily structure.

2. Specifics of Guiding Light

For Guiding Light specially produced LEDs of the type Cree XT-E were used. Depending on the specification they can be used for homogeneous illumination of a room as well as for focused illumination of particular room zones. Ambient room lighting was realized by indirect lighting with pendant luminaires (50 LEDs 2200 kelvin and 50 LEDs 5700 kelvin; luminous flux F = 12078 lumen) and uplights with 9 LEDs 2200k and 9 LEDs 5700k (F = 1685 lumen). With these lights an average horizontal illumination level of up to E_h = 300 lux with a range of colour temperature from 2200 to 4000 kelvin should be achieved. Room zone lighting was realized by direct illumination with pendant luminaires (12 LEDs 2200k and 12 LEDs 5700k; F = 2825 lm), uplights with 9 LEDs 2200k and 9 LEDs 5700k (F = 2125 lm), reading- and mirror lamps with 6 LEDs 2200k and 6 LEDs 5700k (F = 1590 lm) and floor unit luminaires with 3 LEDs 2200k and 3 LEDs 5700k (F = 731 lm). With these lights an average horizontal illumination level of up to E_h = 2000 lux with a range of colour temperature from 2200 to 4000 kelvin without any glare should be achieved.

For the light programming was also distinguished between ambient room lighting or homogeneous illumination of a room and focused illumination of particular room zones. Ambient room lighting is switched on and off presence controlled through the application of PIR-sensors (Passive-Infrared-Sensors). Just in the bedroom the light has to be switched on and off manually. The automatic registration of a persons attendance in the other rooms is not only based on a locally recognition of movement but also through an analysis of the suite of releases of all PIR-sensors in the household and a thereof deduced conclusion where a person is located. If there is more than one person in a room, the light turns off within a predefined follow-up time after the last person left the room. Unlike the room lighting, the room zone illumination has to be switched on and off manually.

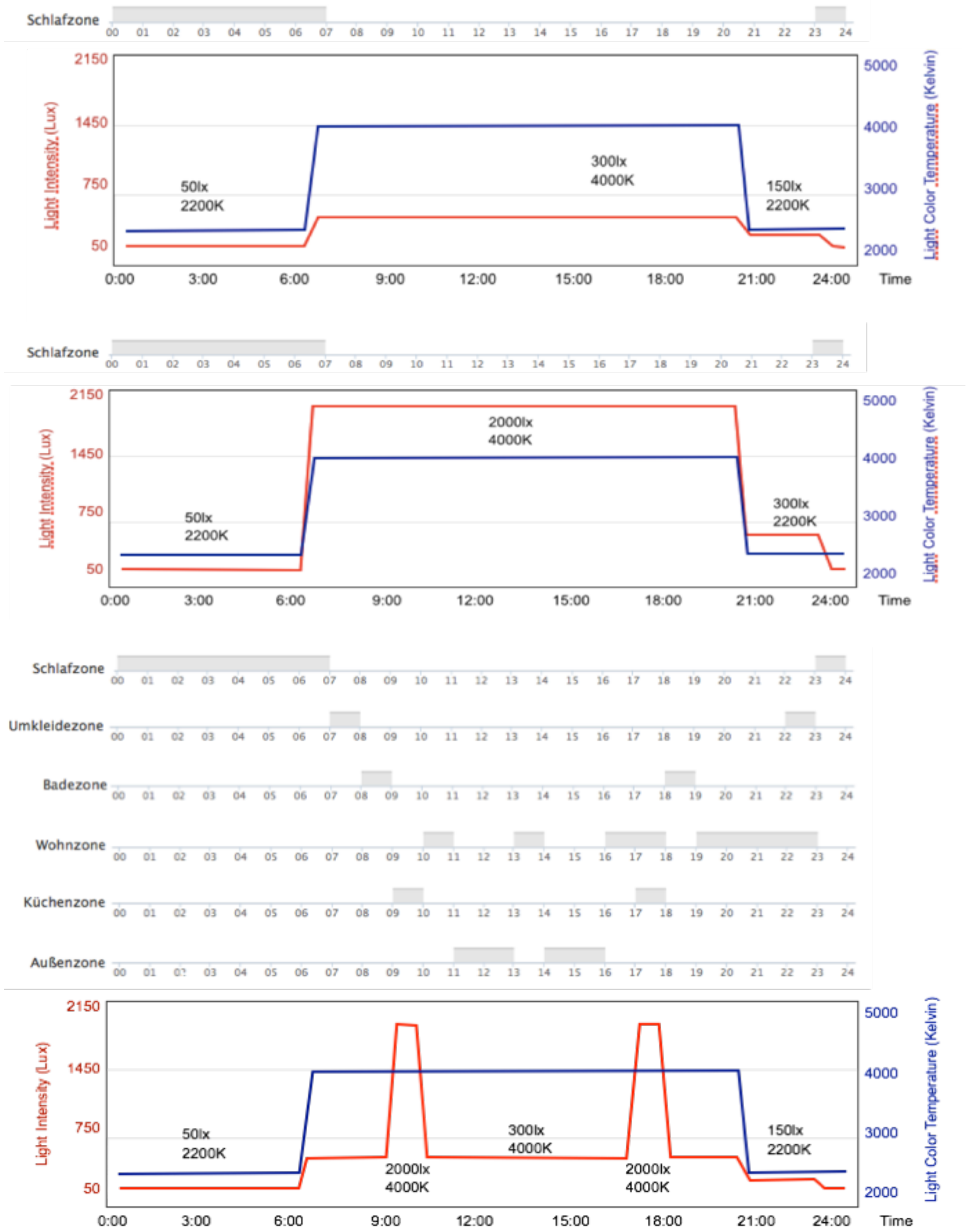

Figure 2. Exemplary light control curve with daily structure light intervention (basic configuration). Top: ambient lighting for all rooms. Middle: day/night light intervention for all room zones. Bottom: daily structure light intervention for kitchen zone.

The basic setting of light intensity and light colour of the ambient room lighting are defined as follows (see figure 2 top): The light is constantly at 300 lux and 400 kelvin from the individually planned get up time till two hours before bed time. Two hours before the planned bedtime until the actual bedtime the settings are at constant light at 150 lux and 2200 kelvin – this corresponds with the evening illumination. The time between bedtime and the planned get up time the illumination is at 50 lux and 2200 kelvin – this corresponds with the night illumination. The brightness levels are applied for ground level. The transition between the different ambient lighting moods takes place within half an hour by linear interpolation.

The basic setting of light intensity and light colour of the room zone lighting is determined by two selectable control logics. The logic for the illumination with day-/night rhythm is as follows (see figure 2 middle): The light colour is the same as for the ambient room lighting. The maximum brightness is the result of a contrast sensitivity test, which determines the maximum brightness at any loss of visual performance (up to 2000 lux). From the planned get up time till two hours before bedtime the zonal illumination is at constant light and the determined maximum brightness. Two hours before the planned bedtime until the actual bedtime the zonal illumination is at constant light and at one third of the maximum brightness. The time between bedtime and the planned get up time the zonal illumination is at constant light and at one sixth of the maximum brightness. The second control logic is for the illumination according to the daily structure rhythm. The basic setting for this logic initially follows the first logic.

Additionally this logic is combined with the individual daily structure (see figure 2 below). When the light sensor is actuated, the luminaires of a room zone are only activated with the maximum brightness, if a person should stay in this particular room zone according to her individual daily structure. Otherwise, the room zone lighting uses the adjustments of the ambient room lighting. The transition between the different zonal lighting moods in both cases takes place within half an hour by linear interpolation. The light control of the illumination with daily structure rhythm shows a linear interpolation course – from the brightness value of the ambient room lighting to the brightness value of the intended active room zone lighting.

Because findings concerning the effect of single light attributes are divergent, two attempts were carried out to optimize attributes of residential lighting within the framework of Guiding Light. The first approach is based on the simulation of a sunset by means of room lighting, because this should have a positive impact on sleep quality and cognitive performance by day (cf. Rea & Figueiro, 2014; Tonetti et al., 2014). This illumination complies with the day-/night rhythm. For the subjects under this condition every 14 days (+/- four days) the timeframe of the evening illumination was varied between two and four hours or directly switched between day and night illumination for reasons of control. The second approach gradually adapts the light attributes based on continuous feedback of the light effects on human beings. In this case, the light control is considered as an evolutionary system. During a continuous, but barely perceptible, change of the light attributes, only those attributes are continued which achieved the desired effects (Kempter, 2012a). This illumination complies with the daily structure rhythm. For the subjects under this condition every 14 days (+/- four days) all luminaires were automatically reprogrammed by means of a rule based system based on an analysis of continuous measured PIR-sensor data.

The aim of the on going optimization process of the daily structure rhythm was, based on the above described basic setting, to modify the maximum brightness of the ambient room lighting, the maximum brightness of the active room zone lighting, the division factor of the evening ambient room lighting, the division factor of the nocturnal ambient room lighting, the division factor of the evening active room zone lighting and the division factor of the nocturnal active room zone lighting, if necessary. Following alteration constants were used for the adjustment vector: for the maximum brightness a 5% alteration constant, for the division factors of the evening and nocturnal room zone lighting a 20% alteration constant and for the division factor of the evening and nocturnal room lighting a 10% alteration constant. The brightness of the inactive room zone lighting followed the brightness of the ambient room lighting.

The analyses of the PIR-sensor data of the households, taking place every 14 days, comprised the evaluation of the activity during the day (amount of stays, degree of movement during the day, time spent outdoors), the daily structure (deviation of nominal stays), deviation from the beginning of the nominal stay, deviation from the end of the nominal stay) and the sleep quality (degree of movement during night, sleep duration during night, time spent awake during night).

The deduction of a changing vector for the new light programming was based on the comparison of the last two every 14 days measuring periods. If the new programming lead to an optimization of the parameters the pursuant control variables weren´t changed. If deterioration occurred, the system repeated the last change of the control variables, which achieved an improvement. If that change also didn´t show an improvement, the opposite change of the last control variables was performed. If there wasn´t any improvement yet, the system cancelled the last change (just in the amount of the changing constant). In the case the new programming lead to a brighter light during the night than in the evening, the brightness of the evening light was chosen for the light during the night.

For the daily structure rhythm intervention the relationship between the light control values and the valuation parameters was determined in an effect matrix. The rule-bound system accessed this matrix. If the daily activity decreased, the brightness of the ambient room lighting during the day and in the evening was changed. The brightness of the active room zone lighting by day and in the evening was changed, if the daily structure got worse. If the sleep quality decreased the brightness of the ambient room lighting during the night and the active room zone lighting during the night were changed in accordance with the optimization algorithm.

3. Evaluation of Guiding Light

To measure the effect of Guiding Light, the LED-lamps with the day-/night rhythm control and the daily structure rhythm control were tested over a period of half a year, from summer 2014 until Spring 2015, in a few private households. Four households were equipped with the daily structure rhythm control and seven households with the day-/night rhythm control. For reasons of control and to measure the extent of possible light effects, eight test households without a Guiding Light system were included in the study.

Over the period of at minimum one month the individual daily structure of all participants was appraised before Guiding Light was activated. This was done with the help of continuously gathered data through PIR-sensors (Passive-Infrared-Sensors), which were installed in all test households. How the PIR-data were analysed and the daily structure determined, is described in the following chapter.

During the entire study the motility and mobility of the participants as well as the fitting of both attributes with the individual daily structure was examined successively by means of the PIR-sensors. How the complying indicators were calculated is described in the next chapter. Additionally to the data collection via PIR-sensors, the participants had to complete an online questionnaire every two weeks, rating their physical and mental fitness, the extent of social contacts as well as their quality of sleep and life. Data collection started at different times in the participating households, but at least one month before the light installation and the activation of Guiding Light.

The subjects were living alone men and women in the age of 63 to 89. At the beginning of the study they didn´t differ substantially regarding their physical fitness (e.g. fear to fall), their mental fitness (e.g. spatiotemporal orientation), their extent of social contacts and their quality of sleep and life. The original average illumination of the 19 test households was E_h = 30 – 1500 lux in the living space and the kitchen, E_h = 70- 250 lux in the bathroom and E_h = 40 – 150 lux in the bedroom.

In addition to the field tests, there were several final end-users and end-user organizations who participated in our user-centered design process of Guiding Light. For the purpose of context analysis and investigating end-user requirements, we interviewed caregivers, gerontologists, physiologists, and physiotherapists from end-user organizations at the very beginning of our project. We are always in close contact with end-user organizations who are participating in field tests.

During initial contact with our test subjects, we also investigated their requirements for structuring the daily live and the use of lighting within their accommodation. In the course of software development, we conducted paper prototype evaluation together with several seniors and care personnel. We compared expert user interfaces on how easy it is for care experts to accomplish tasks with the application by using cognitive walkthrough methods. We iteratively redesigned older person's user interfaces on the basis of usability testing with seniors.

4. Observed light effects

Within the framework of Guiding Light motion detection and presence detection were carried out by PIR-sensors. Motion detection takes place through temperature change on the surface of the sensors. Temperature change can be caused through persons or other creatures which radiate warmth that come across the sensors, particular extensive body movements and other phenomena like warm drafts. The detection behaviour of the PIR-sensors is configurable. Independent of the brightness in the room the PIR-sensor instantly sends the raw value "true" or "1" if there is any movement. If the sensor doesn´t register any movement for one second, he sends the raw value "false" or "0".

In one room zone there can be one or more PIR-sensors. As soon as at least one sensor of a room zone registers a movement within one minute the minute meter is set to "true" or "1". The minute meter for the time spent outdoors is set to "true" or "1" if for this minute the absence from home of the person is registered (see location determination). The degree of movement is calculated by the sum of the minute meters, e.g. for five room zones the maximum of movement in one minute can be five minutes, in case a person comes across all room zones in one minute. If the degree of movement of several days should be observed, the arithmetic mean of all minute meters of the same time of day is calculated.

For all participants of the control group (CG), the day-/night rhythm illumination group (DN) and the daily structure rhythm illumination group (DS) the average degree of movement per day was calculated. Then each group mean of the period before the first light intervention was compared with the group mean of the period after the first intervention. The two periods were depending on the implementation of Guiding Light and thus not the same for all participants. For the CG the process data were divided in two comparable time periods.

Univariate ANOVA showed significant differences for the comparison of the degree of movement of different periods ($p < .001$). The degree of movement in the DS group increases from $M_{DS1} = 683$ minutes of movement to $M_{DS2} = 789$ minutes of movement whereas the other groups don´t show a significant increase (from $M_{CG1} = 352$ to $M_{CG2} = 368$ and from $M_{TN1} = 252$ to $M_{TN2} = 253$ minute of movement).

Figure 3 shows the daily degree of movement of each group for comparable measurement periods. In the process data, a baseline around 250 to 350 minutes of movement can be recognized, around which the data of the CG group ($\tan \alpha = 0.026$) and the data of the DN group ($\tan \alpha = -0.046$) are moving. The light intervention doesn´t seem to have any impact in the DN group. Whereas in the DS group the baseline is just recognizable when a new participant joined the sample (for participant number 5 the first light intervention started before the displayed time frame). After the light intervention the degree of movement increases ($\tan \alpha = 0.859$) and reaches twice the extent of the baseline.

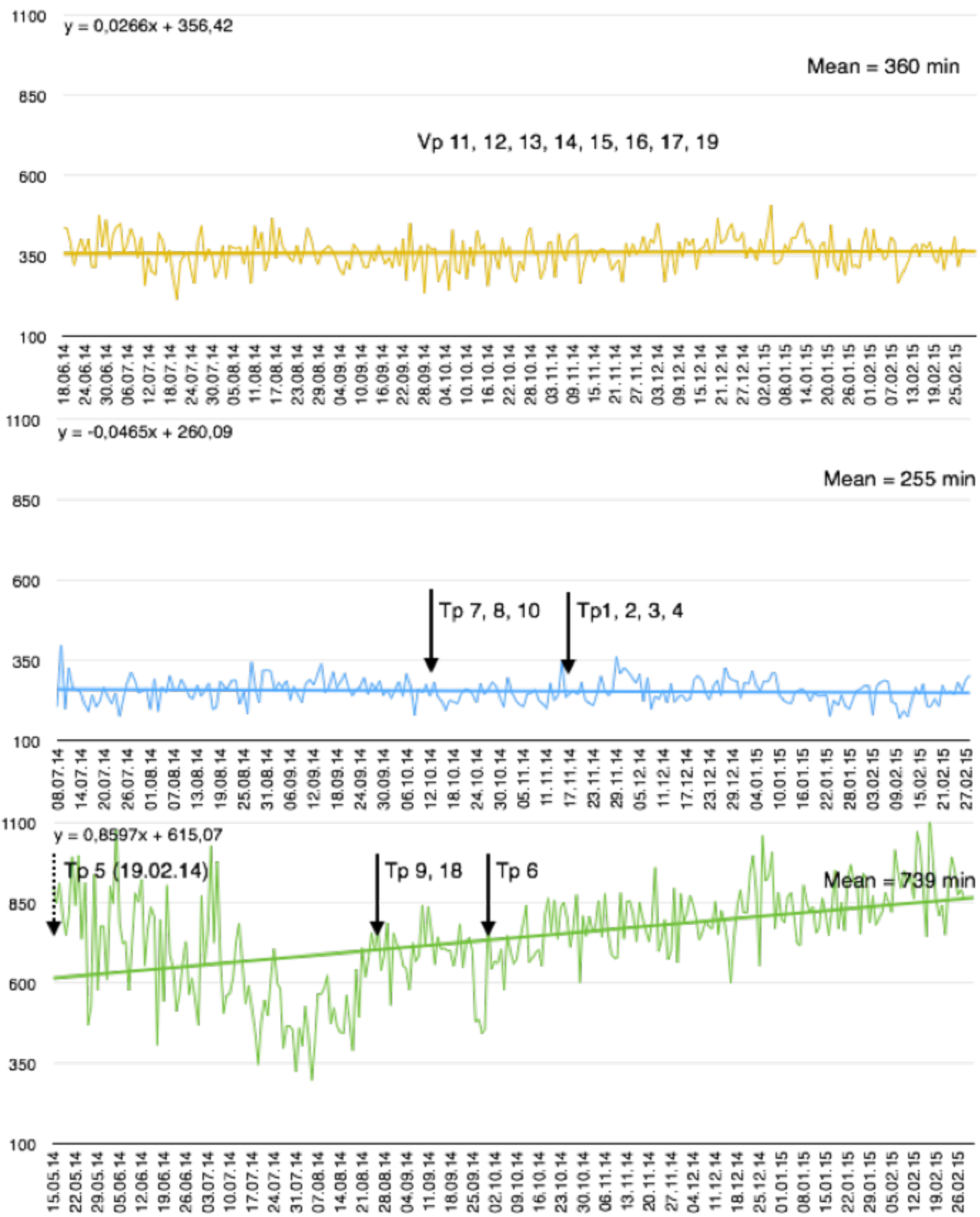

Figure 3: Number of minutes per day with at least one motion detection within the room zones, averaged for all persons of one group. Top: control group. Middle: lighting with day/night-rhythm. Bottom: lighting with daily structure rhythm. Arrows: start of light intervention for resp. test person.

The determination of the location of a person inside the flat is established based on the degree of movement. A stay in a particular room zone is assumed for that zone where the highest degree of movement at a specific time of day, one day or the average over several days was measured. The location of a person is calculated every half hour, which means that starting at 00:00 am every half hour it is determined in which room zone the degree of movement is highest and therefore assumed, that the person is located in that zone. One problem is that a person can stay in a room zone without any movement (e.g. while she´s sleeping). The PIR-sensors just recognize changes in temperature and therefore the determination of location with this evaluation logic can´t be done correctly all the time.

To minimize the error rate of the determination of location the degree of movement across all room zones and the zone outside the flat is compared on a daily basis. Because of the problem with the PIR-technic described above it can happen that all the minute meters show the value “false” or “0”, which means no movement or stay outdoors is registered for that time. In this case that minute meter is set to “true” or “1” which showed the last “true” or “1”. This is continued (and interpreted as a stay) until another minute meter is set to “true” or “1” after the registration of a movement.

The determination of the time spent outdoors follows an evaluation logic which assumes an absence if there´s no movement in the flat for a predefined time (e.g. 10 minutes) after a movement in the entrance area. In doing so, the registration of an absence during sleeping time can be avoided, because the last movement was in the bedroom, not the entrance area. Vice versa, the registration of a movement in the monitored area leads to a switch to “presence”. It is configurable how many releases are necessary for this because sometimes PIR-sensors make wrong releases.

Figure 4 shows the average degree of movement over a month of one person (October 2013, February 2014, February 2015) in four room zones (sleeping zone, bathing zone, living zone and kitchen zone), the zone outside the flat (time spent outdoors in minutes) and the summed up degree of movement across all zones (cumulative frequency polygon) from 0 am till 12 pm every half an hour.

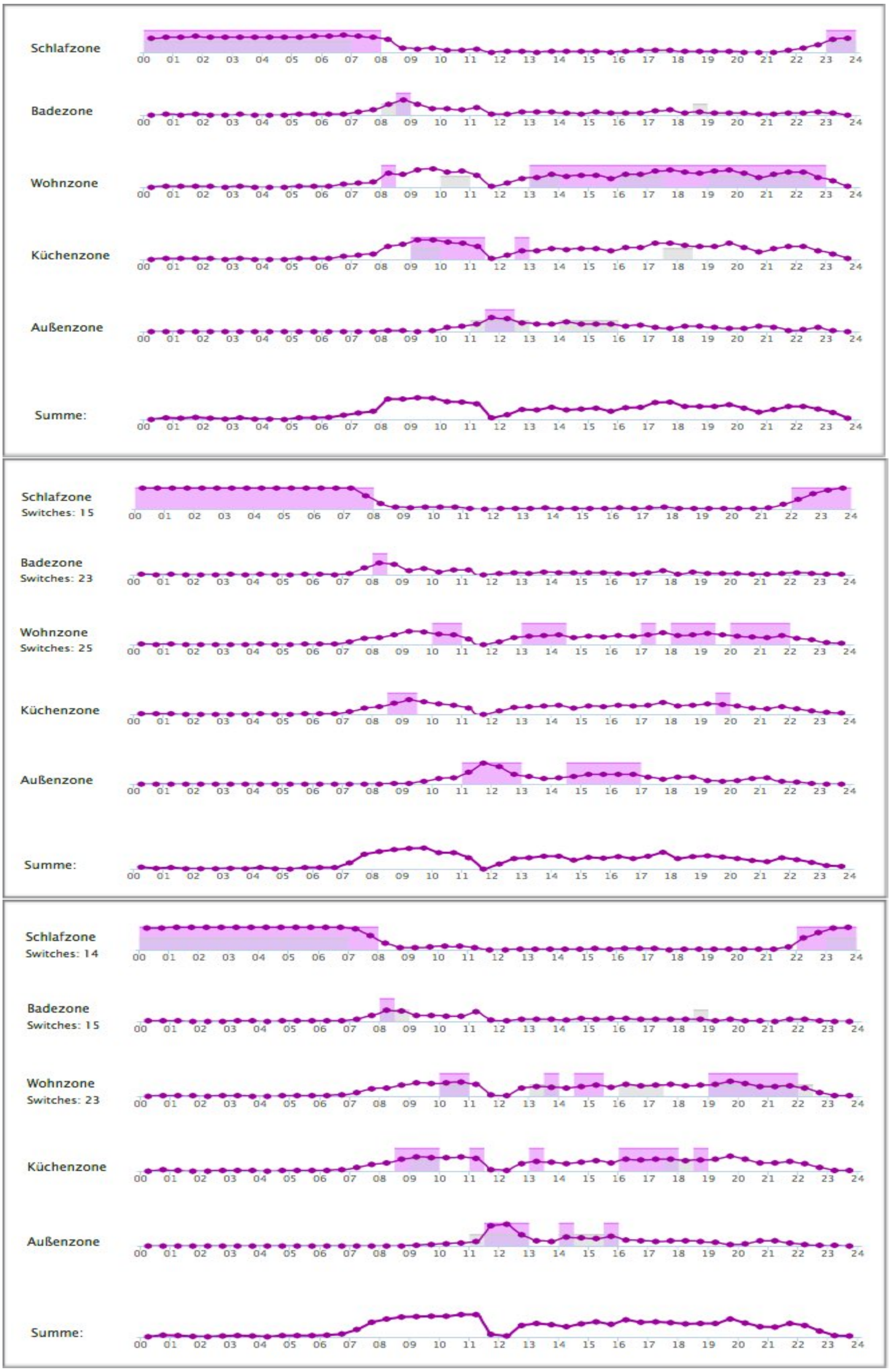

Figure 4: Daily structure of a single test person with daily structure light intervention identified for selected months. Highlighted areas mark the stays of this persons. Top: October 2013 (7 room zone stays, 1 outdoor stay). Middle: February 2014 – begin of light intervention (10 room zone stays, 2 outdoor stay). Bottom: February 2015 (12 room zone stays, 3 outdoor stay).

The coloured bars display the stays of the person determined by the described evaluation logic. At the beginning of data collection (October 2013) the person doesn´t have a fragmented daily structure – she just shows seven room zone stays and one stay outside. Especially the stay from 13pm until 23pm in the living zone is noticeable. Immediately after the first light intervention in February 2014, the person already shows ten room zone stays and two stays outside. After one year of light intervention, in February 2015, the person has 12 room zone stays and three stays outside. Such an increase isn´t expected usually for elderly people.

For both intervention groups and the control group the average degree of movement was calculated like for the single person described above. Then the time before the light intervention and the time after the light intervention and for the control group a similar timeframe (measurement period 1 and 2) were compared.

The results show only an increase in the amount for stays for the DS-group from M_{DS1} = 13,7 to M_{DS2} = 14,1 whereas in both other groups a slight decrease in stays is observable (from M_{CG1} = 13,8 to M_{CG2} = 13,6; from M_{DN1} = 13,1 to M_{DN2} = 12,4). A similar picture emerges if the time spent outdoors is compared – only the DS-group shows an increase in time spent outdoors (M_{DS1} = 288 minutes to M_{DS2} = 300 minutes; M_{CG1} = 292 minutes to M_{CG2} = 256 minutes; M_{DN1} = 318 minutes to M_{DN2} = 270 minutes). Univariate ANOVA shows for both parameters statistical significant differences ($p < .001$).

At the beginning of the study, the individual daily structure of each participant was ascertained to get a picture of the usual daily routine. To know about the initial situation of each person is important, because this information can serve as a leverage point for “improvements” and changes over time can be recognized. The description of the daily structure was done every half an hour. It was necessary to find a daily structure, which covers the daily differences at best. Holidays were not considered.

First, one month after the beginning of recording the PIR-data, the typically stays in the room zones and outside were measured according to the above described evaluation logic. Additional, the start of the sleeping time was assumed, if there wasn´t any movement in the flat for a particular time after a movement in the sleeping zone. Short interruptions of the sleep, e.g. if a person went to the toilet, were counted, but not interpreted as the end of the sleeping time. This was just the case, if a person left the sleeping zone for a longer time.

The determination of the location are probability statements, which means, it is established how likely the probability of a stay or movement in a specific room zone is. For a selected time the likelihood of stay will exist for several room zones but will be highest for just one room zone, which then will be identified as the location of stay.

After the determination of the daily structure a conversation with each participant was conducted to discuss, if the identified daily routine is applicable in his opinion, e.g. if he´s at most of the days at a specified time in a particular room zone. The aim was to better understand the daily structure of a person, i.e. to associate the structure with specific activities. If a participant was sure that there are deviations, the determined daily structure was corrected. With the subjects of the daily structure rhythm illumination, one person who takes care of them and one expert, a target daily structure was defined, which differed a little from the identified actual daily structure (e.g. more outdoor stays). For the subjects of the day-/night rhythm illumination and the control group the identified actual daily structure and the target daily structure were the same.

A comparison of the individual target daily structure with the always newly determined actual daily structure has been done to see how well they fit. If a person always is at the predefined time at a predefined location, the daily structure fit is 100 per cent. Since there was established just one daily structure for different weekdays and even holidays, the expectations regarding the fit of the target and actual daily structure shouldn´t be too high.

The daily structure fit of each group (for comparable timeframes) can be seen in figure 5. The average fitting is between 31 and 35 per cent. It can be seen clearly, that the fit within the CG group and the DN group decreases over time whereas it increases within the DS group. The degree of fit of the DS group isn´t much higher at the end than in the other two groups, but it has to be taken into account, that for the DS group the fit in the beginning was much lower because of the newly defined target daily structure.

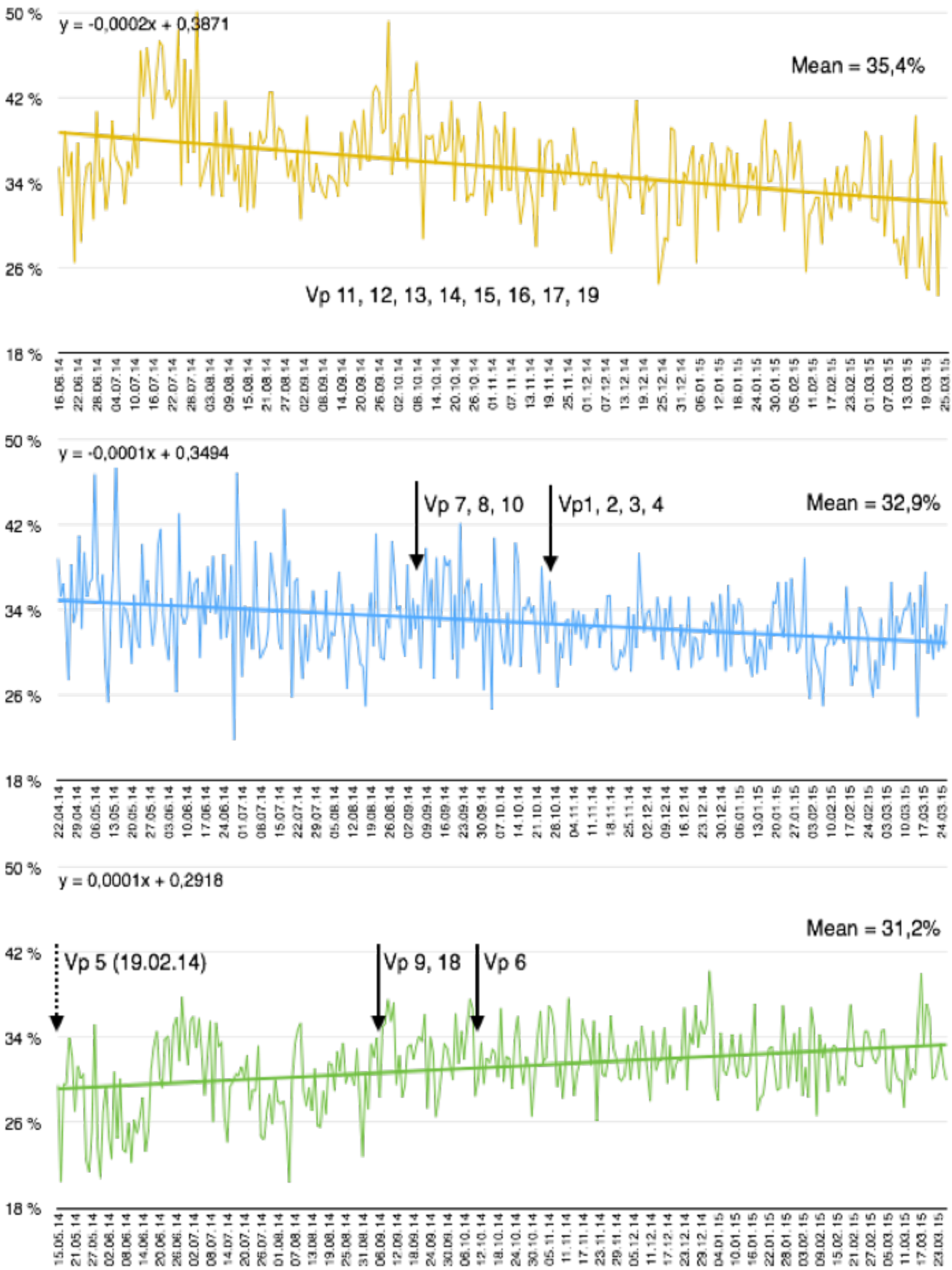

Figure 5: Daily structure fit (a comparison of the individual target daily structure with the always newly determined actual daily structure) in percent. Top: control group. Middle: lighting with day/night-rhythm. Bottom: lighting with daily structure rhythm. Arrows: start of light intervention for resp. test person.

If the time before the light intervention is compared with the time after the light intervention (for the control group two comparable timeframes – observation period 1 and 2) it can be seen, that the fit of the daily structure increases slightly for the DS group from M_{DS1} = 31% to M_{DS2} = 32% and decreases for the other two groups (from M_{CG1} = 37% to M_{CG2} = 34%; from M_{DN1} = 33% to M_{DN2} = 32%). The results of a calculation of the differences between the effective beginning of the stays and the effective end of the stays in the room zones with the target daily structure were similar. Die deviation of the beginning of the stay within the DS group decreases from M_{DS1} = 670 minutes to M_{DS2} = 637 minutes and increases from M_{CG1} = 531 minutes to M_{CG2} = 570 minutes for the CG and from M_{DN1} = 639 minutes to M_{DN2} = 703 minutes for the DN group. The deviation of the end of the stay decreases from M_{DS1} = 640 minutes to M_{DS2} = 635 minutes and increases from M_{CG1} = 562 minutes to M_{CG2} = 616 minutes and from M_{DN1} = 617 minutes to M_{DN2} = 678 minutes. Univariate ANOVA shows in the comparison of the two periods for all parameters statistical significant differences ($p < .001$ – $p = .016$).

5. Discussion

The experiences with Guiding Light highlights the advantages of LED illumination regarding controllability and light, if they are suitably programmed. The use of Guiding Light with programmed daily structure rhythm increased the motility (individual amount of body motion) and mobility (individual number of indoor and outdoor stays) of the participating residents. Furthermore, the increasing daily activity fits the individual daily structure better (individually planned locomotion). These findings are based on the analysis of PIR-sensor data, which were gathered continuously without any help of the participants. The participants said they hardly could recognize any changes due to the light installation. Therefore, it can be assumed that the effects of Guiding Light are not consciously recognized, maybe because the changes are evolving over a long period.

Nonetheless, a replication study with a bigger sample seems promising. The study indicates that people can be guided to specific places at particular times through a spatial and temporal configuration of the light intensity and light colour of LED-lamps. Further research is necessary to confirm the findings of Guiding Light and generalise the results that by means of coordinated interaction of ambient room lighting and focussed room zone lighting "the right amount of activity at the right time at the right place" can be achieved.

Our direct customers, to whom we will sell Guiding Light, are from customer segments along the value chain of estate industry that deal with housings for older persons. This includes planning organizations (e.g. communities/municipalities, architects, home adaptors, electrical planning engineers), creating companies (e.g. real estate/project developer, building industry/trade, general contractor), and management organizations (e.g. housing cooperatives, property companies, operators/carriers of retirement homes, social services, outpatient care services, physician, facility manager, building services engineers, telecommunication companies). Additionally/eventually we will sell Guiding Light to family members of older persons (possibly suffering from dementia illness). Direct consumers will probably reach financial support from health/care insurances, property/public/private funds, building societies, estate agents, or other private persons (e.g. family members) etc. This financial support is, however, not absolutely necessary, since with Guiding Light consumers will either receive economic relief or better profit as well as satisfied end users.

We are promising the following value proposition for customers and end users: Basically, we want to provide for our end users, older persons possibly suffering from dementia, support in mobility and in orientation at home as well as outside of their homes with Guiding Light. We can give evidence about positive impact on mobility through lighting through intelligent light guidance based on acquired individual data. Guiding Light will not only enhance older person's quality of life but also standard of living/working for all related persons (e.g. family members, health/care/social services) by means of saving time/money, optimizing services/support, and last but not least peace of mind concerning health and wellbeing of older persons entrusted to their care. Additionally, as an innovative living and residential form as well as sustainable health/care service Guiding Light will be a unique selling proposition for our customers (e.g. forward-looking living concept of housing cooperatives, modern care services of operators/carriers of retirement homes, innovative social services). From the technical side of view our solution will be unique because we are offering up-to-date building automation with modularity and scalability of AAL components (only needed modules have to be bought = pay for use). Easy installation into existing flats and houses help to keep costs and efforts for residents low. Finally, simplest interfaces and a mostly automated and ambient working system will avoid feelings of obtrusion and allow elderly and non-technology-affiliated people to use the system without problems.

Our customer relationship is mainly limited to planning organizations, creating companies, and management organizations (see customers segments). These direct customers need to know us as AAL solution developer with innovative products of high quality that provide valuable benefits for their own customers (residents) and let them earn money with that. If customer is aware of Guiding Light, he has to use it and sell it in combination with his products (e.g. buildings, flats, health/care services) as innovative and promising opportunities for customers with the proper needs. This means that on the one hand our customer has to use our expertise to create attractive bundles for his customers and on the other hand there should be an effort to advertise those AAL-solutions to the market. Our direct customer segments has to be the sender for the AAL-product, resp. Guiding Light. In return the customer can expect a know-how transfer regarding our solution, second level support, ongoing progress in development, maintenance etc. Our relationship to the end-user segments (primary and secondary) will be limited, because our direct customers will get in touch with them and will establish a customer relationship there and also provide first level support. Although within Guiding Light we can provide upselling possibilities directly for e.g. additional modules or devices.

We plan to generate revenues through Guiding Light by means of several activities along the value chain of estate industry. This includes consulting/planning activities to setup bigger projects (project based revenues). Since our main platform can work as a distribution network where other developers of AAL modules can distribute and sell their applications within our framework/environment and we as a platform provider can earn e.g. 30% of the revenue. Furthermore, we will generate revenues through implementing front-end hardware and software components (revenues from installation) and through initial profit margin for the hardware/sensors/equipment installed into the flat/houses. Our current business model deals with monthly service fees from the end consumer for used modules based on micropayment. Our long term intention is to bring Guiding Light to a mass market and to earn money based on micro payment. This requires the use or definition of standards to make installation, configuration and later extension of the product as easy as possible without the need of additional support from the outside.

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