Using Light Guiding to Structure Everyday Life

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Abstract. We present an approach using room lighting for strengthening individual daily structure or changing structure of daily routines if required. This new healing environment concept includes a monitoring system based on standard passive infrared presence sensors as well as a zonal and ambient room lighting system using direct and indirect lighting with variable light intensities and light colors.

Keywords: Ambient Assisted Living, Mobility, Lighting, Motion Detection.

1 Introduction

The "Harmonised European Time Use Survey" (Eurostat, 2009) shows that people normally have a well structured day. There exist, however, differences between nations, age, as well as gender and there might be also individual differences in daily structure but we can identify daily routines in every sub-sample. The characteristics in a structure range from day/night-rhythm to the regularity in doing specific things at certain times. Impairment in vitality, mobility and cognitive performance also leads to a loss of daily structure as a result of which people mostly have to change to assisted living residences (Sinoo et al., 2011). Consequently, day-structuring measures will become relevant interventions for those people (e.g. for older persons). In this paper we show an approach for healing environments (Huismann et al., 2012) using ambient and zonal room lighting as well as a solution for monitoring the impact of this lighting design on individual daily structure.

2 Lighting Design

There are many well documented psychophysiological effects of light on human (see Veitch & Galasiu, 2012). Light has a direct biological impact on sleep-wake regulation, cognitive performance and physical activity, improves visual performance (e.g. contrast sensitivity, visual acuity, color perception), spatial navigation, and indirectly influences emotions by means of brighten up our mood, creates a room atmosphere for better activation or relaxation and positively influences spatial orientation. Taken these lighting impacts together, light can lead to general wellbeing and health (Fig.1).

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There is some evidence, that spatial appearance manipulated by light also influences mobility as well as assumed temporal and spatial orientation. Figueiro et al. (2011) showed that ambient lighting and lighting cues can have positive effect on gait measures of older adults. Bieske & Dierbach (2006) give evidence that room lighting influences temporal and spatial orientation such as specifying the time of day and personal location within senior residence. People are rating the space of corridors more navigable under certain illumination (Hidayetoglu et al., 2012), and Wardano et al. (2012) show that certain lighting conditions increase duration of stay in well defined social situations.

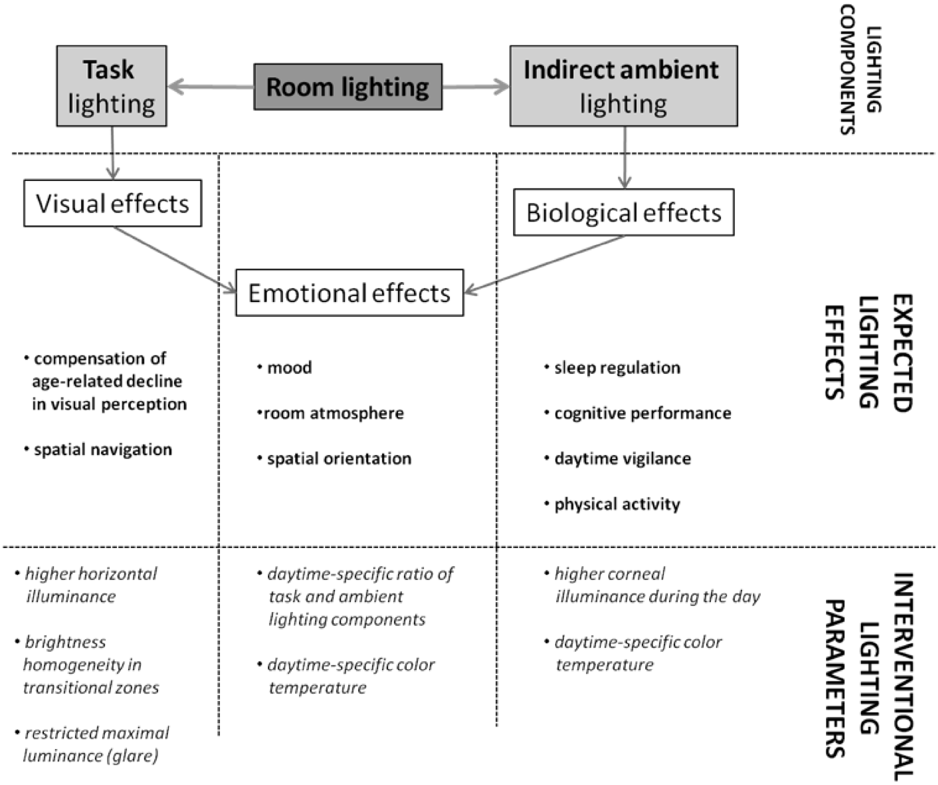

Fig. 1. Psychophysiological model of lighting effects on human

In order to design an environment with illuminated space in a way that supports structuring daily living we defined a lighting scenario which should influence circadian regulation, visual performance, subjective wellbeing as well as temporal and spatial orientation. This scenario consists of task and indirect ambient lighting components and aims at varying ambient and zonal light intensities and light colors over time within private residences. Ambient room lighting provides a higher illuminance level at eye level by means of glare-free indirect lighting components during day and warm-white light color during night and is primarily used as a chronobiological stimulus to regulate sleep-wake cycles, since there is strong evidence that circadian regulation can be influenced by the characteristics of bright light during the day and biological inactive light (e.g. warm-white light) in the evening (Veitch & Galasiu, 2012).

Zonal room lighting with glare-free spotlights will direct attention of residents to certain room zones by means of a higher horizontal illuminance level in the working area to maintain visual tasks and encourage time-of-day related activities, since there is evidence that rooms with distinct purposes and clearly legible meaning provides a space of perception that can better be memorized and may support individuals in their activities of daily living (Wardono et al., 2012). Furthermore, our lighting design is based on evenly lit transitional zones which will guarantee safer navigation and spatial orientation.

Finally our lighting concept aims at varying the color temperature and the amount of light provided either by the task lighting components or the ambient lighting components. Thus we are able to create recreational or stimulating room atmospheres according to daytime specific activities. This will be implemented by automatically triggering lighting by a pre-programmed lighting control system, which has been defined in advance on the basis of individual daily routines (see chapter 3). This includes 24-hours characteristic curves of light intensity and light color for each luminaire which will be turned on by the system, if there is not enough daylight available.

On the basis of such a prototypical activity rhythm, a person with impairments in spatial and temporal orientation could be softly reminded to start a certain activity at a certain time of the day prior to the actual start of the activity. There is, however, an option for manual control of lightings but after predefined delay automatic control will be activated again. Inhabitants are able to provide lighting conditions for optimal visual performance at any time even with totally unexpected events. Zonal lighting will induce unobtrusive stimuli for time-of-day related activities, e.g. smooth transition and contrasts. One example of such a smooth transition is a light alarm clock which starts around the usual wake-up time. The system will turn off all luminaires, if there is no person within the apartment in order to assure an energy-efficient lighting solution.

3 Room Activity Monitoring

Knowing about the individual daily structure of an inhabitant is a key requirement for providing such a lighting system. Besides interviews as basic information source for identifying such a daily structure, an automatic way of discovering changes to this structure is needed to allow for automatic or manual adjustments as well as ongoing evaluation purposes for the lighting system.

Actigraphy is used in a wide array of applications which include fitness or sleep-monitoring (see Ancoli-Israel et al., 2003), and could therefore also be well fitted for the purpose of identifying a daily structure. However, traditional accelerometer-based activity sensor devices have two major practical drawbacks: First, they have to be worn by the persons, mostly on a specific location like wrist, a belt, a foot-strap or in/on a shoe. Unfortunately, often persons don't like to wear such sensors or simply forget to put them on. Also these devices need care on the user's part, like charging them regularly. Second, while such sensors have very good resolution (typically sampling rate up to 20 Hz and acceleration in 3 axis) and a wide array of research has already been done on extracting information out of such signals (e.g, see Bosch et al., 2012), they don't tell in what location and context an activity was happening. One solution to the latter issue would be to add a separate tracking system that records where a person has been at specific times inside the apartment. By combining both information streams, some form of a daily structure could then be retrieved. However, the compliance issue mentioned in first place would still exist.

In an attempt to retrieve activity information in a way that doesn't require a participant to wear sensors and at the same time yields approximate information about the participant's location inside the apartment, we investigated the fitness of standard passive infrared (PIR) presence sensors for such a purpose. PIR-sensors typically yield on/off signals depending on the presence of humans (or, more precisely, depending on location changes of heat sources similar to human bodies) and are slow in reporting their status compared to accelerometers. However, by combining multiple sensors to cover relevant sectors in an apartment and by recording each sensors actuations it is possible to deduce some form of daily activity in an apartment (compare to Lymberopoulos, 2008). Even though the information delivered by the sensors itself is basic, by aggregating and relating sensor-actuations, one can get activity measures within a sector for a specific time period (e.g. number of actuations, duration of the on-phase), or sequences of actions among multiple sectors (e.g. person moves from the bed-room to the toilet an back).

In a small field test we investigated the basic applicability of this idea in a real world context. For this we equipped two apartments of two single elderlies with PIR sensors and a data logging facility. Figure 2 shows the room setup with a total of 12 PIR sectors. Each room was equipped with oneoffering four sections of detection and a minimum detection-interval of one second between actuations.

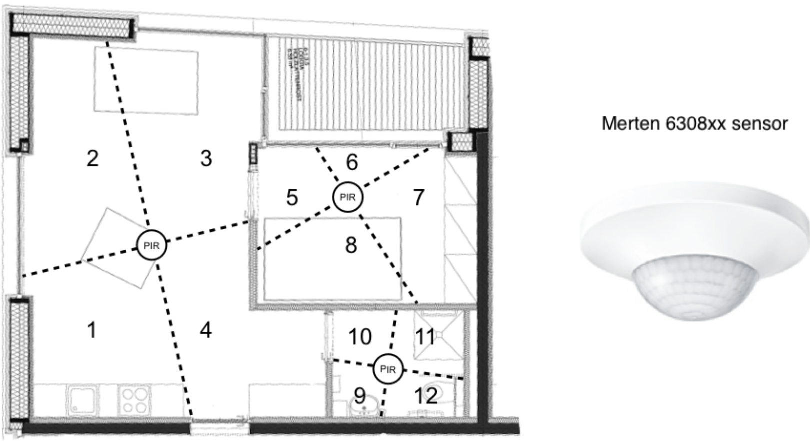

Fig. 2. Plan of test apartment with numbered PIR-sensor sections (total 12 sections)

To see if we could deduce daily structure parameters from the logged data, we evaluated data collected over a period of 6 month. Figure 3 shows a daily activity profile of four PIR-sectors in the living room on sundays averaged over 6 month. The x-axis shows the time whereas the y-axis the number of individual activations in a sector per 15 minutes time slot. One can clearly see the lack of activity from 11:45 to 12:15 hinting at a lunch break.

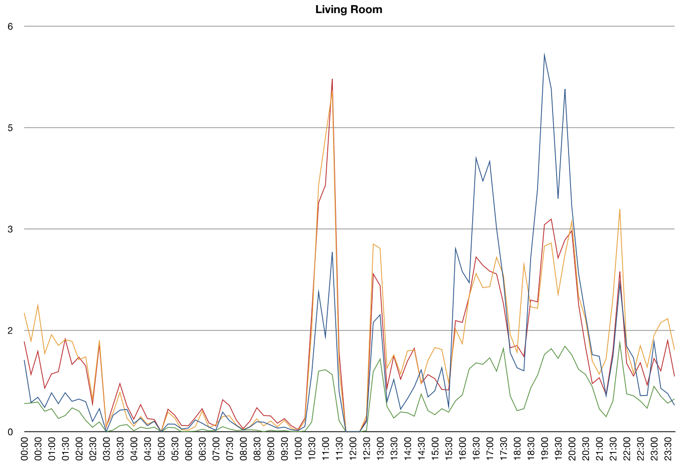

Fig. 3. Activity profile of the 4 PIR-sectors in living room for sundays averaged over 6 month

Figure 4 shows a daily activity profile for two typical days for one apartment. The maximum activity distribution in the separate sectors of the apartment indicate different daily actions on weekends (left side) and weekdays (right side). The x-axis shows the time whereas the y-axis shows the sector-number. Data for this chart has been aggregated over a period of 6 month.

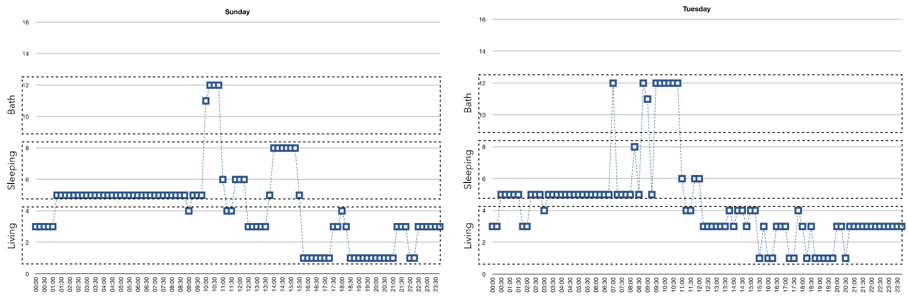

Fig. 4. PIR sector with maximum activity in a time slot of 15 minutes. A comparison between a typical Sunday and Tuesday (averaged over 6 months) show a shift in sleep time by have an hour earlier during weekdays.

Another interesting question was if there would be some detectable change within the daily activity profile between summer- and winter-months, as this is especially relevant in an application using light. Figure 5 shows a shift in sleep/wake times during two summer months and two winter months, meaning this system can in fact be used for detecting changes to the daily structure of a person, without the need for the person to wear or maintain any sensors at all.

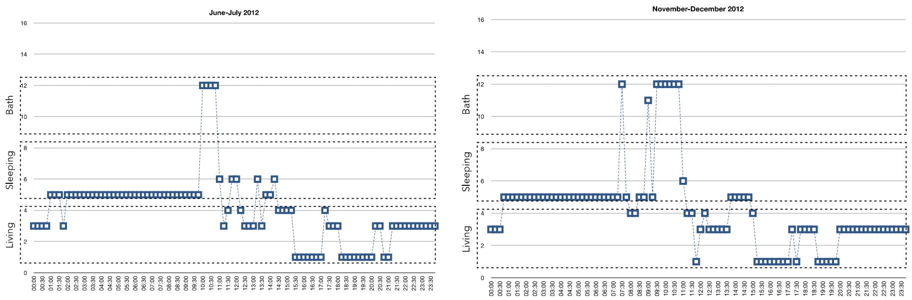

Fig. 5. PIR-sector with maximum activity in a time slot of 15 minutes. A comparison between summer and winter periods shows a shift of sleep-time by 15-30 minutes earlier in winter.

Among the parameters that can be deduced from activity data we recorded in this field study are sleep-/wake times (indicator of circadian rhythm), the time at which various sectors of an apartment feature the most presence (and therefore might be candidates for special light treatments), nightly actions like visiting the toilet or getting something from the kitchen, or the time at which a participant leaves the apartment or comes back (e.g. for getting lunch), and many more.

Despite these promising results, there are two obvious major drawbacks of this PIR-sensor based approach: First, it's only suitable for single person households without pets. Any additional heat-sources would cause additional actuations not related to the main person's actions. In our case, one workaround for this could be to automatically track situations where more than one person is present (e.g. by light barriers that allow for people counting at the entrance, or by observing other room parameters like CO2 levels) and exclude those from data evaluation.

Second, activity that's happening outside the apartment that might have a big effect on a person's health state cannot be tracked in this way. One way to overcome this issue would be to have optional wearable accelerometers that could deliver additional input when worn, but with the core system remaining still functional without them. In the Guiding Light project, we intend to use both solutions to these two drawbacks mentioned here.

4 Conclusion

Our pre-studies show, that we are able to detect individual daily structure within private residence by implementing standard passive infrared (PIR) presence sensors within rooms. Knowing about the individual daily structure of a person we are able to install a room lighting system, which follows the individual needs of an inhabitant. In the next phase we are able to discover whether our zonal and ambient lighting installation can help strengthening individual daily structure or is able to change structure of daily routines if required. Within the project "Guiding Light" we will evaluate whether these assumptions are valid in practice.

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