Components, Controls and Networking: Environmental Challenges of Human Centric Lighting

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Abstract

Human Centric Lighting takes biological effects of light on top of the visual performance into account. This makes the lighting story complex as some of the results need to be targeted to the individual to create the effects wanted. This article gives a guideline what should be focused on to get closer to human centric lighting in standard spaces like offices, educational applications, and shops and alike.

Human Centric Lighting

Definition(s)

Human Centric Lighting was introduced after a non-visual retina based light receptor has been discovered that is responsible for influencing the circadian rhythm. Since then lighting that respects or works with the biological effects of light is called "human centric".

I personally do not share, but respect this definition. I do prefer an integral view that takes into account also the visual tasks and the associated emotions of the humans involved. Therefore my definition would be: Human Centric Lighting is supporting our life best, and covers both the visual and the non-visual biological and emotional effects of lights.

Main Hopes

The main hope is to overcome the boring, fatiguing effects and all the dissatisfaction of some of the lighting that is realized every day and every day claimed to be "good lighting". Hope is to be able to create really supporting light, that helps us to be more effective, feel better and less worn out.

Main challenges

Many of the effects Human Centric Lighting is trying to benefit from are dynamic in nature. We are not used to use dynamics by purpose, as dynamics may be seen as distraction and waist of energy. In contrary we see today massive attempts to compensate any change and dynamics of natural light using loop-back-sensors. This is done to support the lighting codes that were set out as minimum infrastructure rules decades ago interpreting them as constant level requirement.

The visual and biological effects of lighting are individually different. Most spaces have to cover the needs of many individuals.

The investment into better lighting is part of the owners investment and not of the tenants that would benefit from it.

Do's and Don'ts.

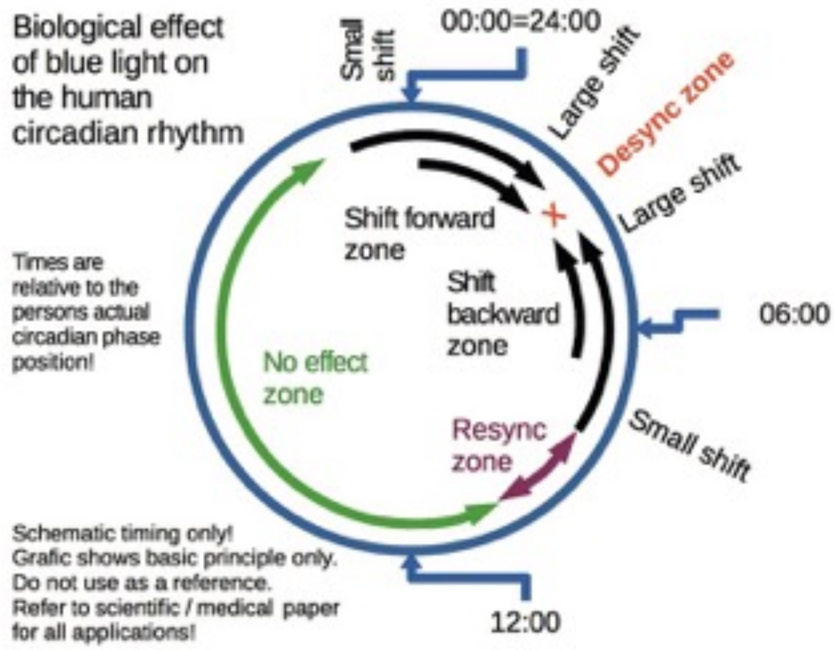
A quick run through the multiple dimensions of light and what to look at regarding the effects on humans.

Spectrum

The spectrum of the light allows us to see colors. The receptors in the eye have a wide spectral acceptance. This would systematically allow for narrow bandwidth emitters to save some energy by using resonant effects, but we must not overlook that some colors are made up by pigments that have narrow spectral reflectance, and may this may lead to misinterpretation of the color seen. The same applies for some glass coatings, that extinct narrow bandwidth and may lead to color effects (and even experienced darkness in some cases (like we had it when the first low pressure sodium lights came up in the early 1960ies, and glass coatings matched with the sodium lines.)

We know that the blue part of the light has some biological effects on humans. However this is no linear issue. The human sensitivity for this biological effect is non-linear dependent on the intensity of the specific wavelength at the receptor and on the timing regarding the actual phase position of the personal circadian rhythm it is applied to. Peak sensitivities are in the circadian morning and in the late evening. Generally spoken the blue part is helpful (and necessary) in early morning, adverse in late evening, and without much effect in late morning and afternoon.

Figure 1:

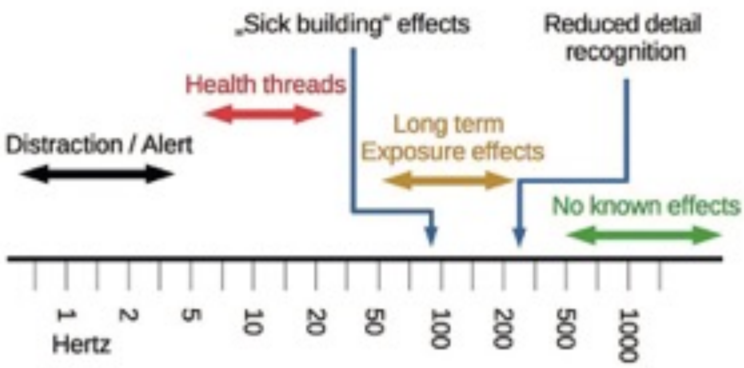


Conclusion: Be aware of the effects regarding color recognition created by small spectral emitters (e.g. LED and Lasers without Phosphors). Be aware of the biological effect (sleep depth, general alertness and the correlated effects) of the blue part of the spectrum on humans (and many animals); Most stable white LEDs have a comparatively high blue portion of emittance that compensates for poor green emittance.

Intermittent Light

The presence and intensity of the blue line of the spectrum is not the only biological effect we know. There are also known side effects of intermittent or stroboscopic light (depending on the frequency and depth of the dark phases) leading from a detectable reduction in visual contrast and angular resolution at higher frequencies (up to 400 Hz), unspecific headache and other symptoms showed as part of the sick building syndrome (shown for 100 Hz), and finally the possibility of triggered epileptic disease at lower frequencies (some Hz).

Figure 2:



Be aware that intermittent light may also be caused by moving across a light and shadow pattern!

Conclusion: Try to avoid intermittent light or continuous artificial intensity ripples between 1 Hz and 500 Hz. If they cannot be avoided try to have the (combined) ripple depth as low as possible. Watch out carefully for the parameters of LED drivers and especially PWM control.

Glare

When applying some intense blue light to achieve some circadian effects watch out for glare caused: Glare distracts and is uncomfortable, persons try to avoid it and this way ruin the intended effect… Watch out for glare caused by specular reflection of high intense sources (like High Power LED or Lasers etc) on glossy surfaces also.

Conclusion: glare, especially created by high intense point sources is adverse, and should be avoided both directly and regarding specular reflection.

Brightness

The brightness profile of the space seen affects the visibility. High local increments in the surrounding brightness may create areas with adverse viewing condition (experienced dark spots). Where it is difficult to detect persons or movements our biological defense mechanisms are triggered. This is adverse for concentration and an additional sink of human energy. The better the "experienced security", especially the confidence that we are able to identify an attacking enemy early enough, the less stress is caused by the environment. This is one of the reasons why we usually prefer "nicely lit environments". This is in close relation to acoustic (will I hear a possible attack?) and spatial layout (are there hidings I have no insight?) Please note that this biological mechanism is working always, there is no way to block it by knowledge, it has nothing to do with the probability of actual threads.

Please note that windows with high environmental brightness (e.g. sunshine lit white walls of opposite buildings) cause silhouette effects for those in the depth of the rooms. It may be wise to "lit the silhouettes" from inside to increase light quality and calm down our defense alertness.

Conclusion: Light up rooms nicely, and make sure all the surrounding is within good visibility.

Intensity:

Humans are made to compensate for a very wide range of intensity (at least 3 magnitudes) without even notifying it as long as transition is slow. However, with low and with very high intensities (as well as with low contrast or substantial glare) some energy is taken to allow for the compensation.

Nature never keeps intensity constant, the sky always changes. These changes are slow, much slower than we would actively note them, but they keep us awake and alert. Constant intensity as provided in many environments is different, and has been proven to take away concentration if applied for full office hours.

Lighting codes demand that installations need to provide a specific amount of light "when the user commands / needs it". Using manual control or override and dynamic scenario selection allows to both fulfill the code and provide light that is closer to what the human needs.

Conclusion: Make sure intensity is kept within useful limits. Do not be afraid of changing intensity, as long as changes are slow. Allow for manual control of dynamics and level override.

Color:

Humans do compensate for changing light color very well, as long as the colored source stays within useful limits. There is a known trouble with different colored light sources that create colored shadows, especially with lower illuminance levels. If there is no dominant color source present our internal white balancing algorithm goes crazy, leading to distraction, energy drain and is said to may cause headache if applied for longer.

Different colored sources arise easily close to windows. Natural light is usually different in color (and by the way steadily changing!) compared to artificial light. There is no trouble arising as long as one color is dominant or both sources are diffuse and this way avoid colored shadows. Ways out is to keep one of the sources dominant or adapt the color of the artificial light to the color of the natural light during the transition period.

Please note that this is closely linked to spectral issues shown in a different paragraph, and should be closely take into account, especially if some blue is added for the purpose of supporting circadian biology..

Conclusio: avoid colored (hard) shadows; have always a dominant source defining the color scheme.

Controls

Controls is a very wide field. See here some spotlight on the major issues regarding human centric lighting only.

Manual Control

Even in office cubicles humans are no "single task machines". Regarding lighting we have to note that different tasks and different humans have different lighting needs. Today we look for the best available compromise and try to cover all aspects with one single light setting. Manual control is the needed to go for more diverse lighting that comes closer to the human needs.

Manual control is often realized as kind of simple switch or dimmer, allowing for "more or less overall intensity". Regarding the diverse affects of intensity, brightness regime, color and dynamics this seems to be not sufficient. However I have to admit that more or less any sophisticated manual control offered today is much too complicated.

One way out are selectable scenarios that stand for the major tasks and possibly human types. These scenarios include the color and dynamic regime associated to the tasks. More research is needed to understand the main influencing parameter besides (or above) the overall intensity control to be able to provide the real manual control to the human.

Conclusion: Provide manual control, and provide useful scenario selection to cover tasks and different types of humans. Watch out for future results on interface design.

<u>Algorithmic Control</u>

To cover useful dynamics and to allow for adoption to the ever changing daylight and for time clock issues algorithmic control is needed. Please note that the parameters, and most likely even the algorithms themselves need to be set out for different tasks / scenarios different. (See paragraph on "manual control" for more detail).

Reliable input information is needed to apply the correct algorithms: Available daylight in its intensity and color profile (including reflected daylight as noted earlier in the "brightness" paragraph.), actual tasks and in some cases also actual user type e.g. the actual circadian phasing of the persons if circadian support should be provided.

This goes far beyond the presence, time clock and intensity loop-back controls algorithms we are used to as of today. Some research is needed to achieve a better approach and a close adaptation to the real needs. The full scale solution will take long, but every step in this direction allows for a more human centric solution. The path is there, we just need to move.

Conclusion: There is much headroom for human centric algorithmic lighting controls. Watch out for vendors that provide dynamic scenario control with manual selection, user identification and sophisticated daylight algorithms and that do some research and innovation towards human centric lighting controls. Allow for and be prepared for updating the algorithmic setup in the future alongside upcoming research results.

<u>Commissioning and Parameterization issues</u>

Actual commissioning and parameterization always limits the result quality to the abilities of the commissioning personnel. Any useful human centric setup needs sufficient knowledge and ability to work with the knowledge on human biological effects on site. More research will be needed to allow for a stepwise commissioning with lower competences on site and additional commissioning through the network together with some self-adjusting methods.

Conclusion: Human centric lighting needs sufficient high skills in design, commissioning and parameterization of the system to achieve promising results. More research is needed to get more with less effort.

<u>How to control Algorithmic control</u>

Algorithms usually have very technical parameters they are controlled with. This is due to the design of algorithms by technicians. For more efficient control we need some meta- parameters that are accessible for and easy to understand by the user, that in turn control a set of technical parameters. Much more research is needed to bridge the gap between technical parameters like "run-on-time", "auto-off-threshold" and alike and the words a user would use, like "aggressivity in energy saving" or "shadowing smoothness" etc.

Conclusion: Only basic algorithmic control that supports human centric lighting is available. The massive tables of difficult to understand parameters make it difficult to use. Watch out for future developments in meta-parameter control. This will allow the user to parameterize the systems in his words.

Future

<u>Steps</u>

Interface design makes the biggest difference. It is not only the geometric design and the placement of the controls; it's rather the step to help the user to influence the lighting in more result-oriented and human terms rather than in technical, circuitry and network oriented terms, both in manual and algorithmic control.

Algorithmic support is the most complex issue to deal with, as it affects all quality parameters at once. With upcoming plug-in possibility of software in the light points and internet-type connections that allow remote management of lighting nodes we will be able to drive the innovation cycle into more human oriented and less technical steps.

<u>Challenges</u>

There is a lot of research needed before we have agreed device features, methods and communications that support human centric lighting best. Especially the algorithmic research is difficult as of today, the usual controls networks like DALI or KNX have severe difficulties handling special algorithms with meta - parameters or special manual interaction.

On top of the scientific and technical challenges it is a difficult economic environment: The typical investor will try to keep the lighting installation as stupid as possible, as stupid installations looks as if they would deliver a cheap, easy and reliable system. Neither energy bills nor work force performance usually affect investors in the construction business..