Physiologically based control of the process of gentle light awakening

A B Fedortsov and M O Silivanov
Saint-Petersburg mining university, 21-line, Saint-Petersburg, 199106, Russia

E-mail: borisovitch-f@yandex.ru

Abstract. The well-being of a person and the efficiency of his production activities are largely determined by the correspondence of the biorhythms of a person to his working schedule. As it was established at the molecular and genetic level, the main physical factor that allows us to control human biorhythms is light (Nobel Prize 2017). Modern studies of ophthalmologists have found a third type of photoreceptors in human eyes, in addition to rods and cones. These receptors are not intended for receiving images, but primarily for correcting biorhythms, including controlling the process of awakening. The third type of receptors are sensitive mainly in the short-wave, blue region of the visible spectrum. In recent years light-emitting diodes have appeared. However, these devices do not take into account the current requirements for the spectrum of the awakening radiation, and even more so do not allow it to be adjusted during the awakening process according to the necessary program. We offer a technology for gentle awakening of the employee, based on modern concepts of ophthalmology and biorhythmology. The technology uses computer control of the physical factors of awakening-light and sound.

1. Introduction
An important factor of good psychophysiological state and high labour productivity is the correspondence between the circadian (daily) biorhythms of the employee and his working schedule [1–3]. Especially important is the good psychophysiological state of an employee in the mining industry due to the high labour intensity and the severity of the consequences in emergency situations [4–8]. The most well-known manifestation of the circadian rhythm is the alternation of sleep and wakefulness phases. The circadian rhythm is necessary to adjust the physiological processes and human behaviour to the requirements of the daily cycle. It anticipates daily changes in the length of daylight, temperature, and other conditions of existence and prepares the human body for the upcoming daily changes in the environment.

2. Physical factors and biorhythms
To date, it has been established that circadian rhythms in humans have an approximate 24-hour duration. Molecular genetic studies have shown [9] that biorhythm is influenced by light, temperature, sounds, humidity, physical activity, and even food intake (2017 Nobel Prize in Biology). Moreover, it turned out that the lighting has the strongest influence. The intensity, spectral composition, and pulsations of light are important. So, the blue component of the radiation spectrum has a stimulating effect, and the yellow one has a calming effect. The time of day and the nature of human activity determine
the requirements for the level of illumination and for the spectral composition of radiation [10, 11]. This is illustrated by the well-known figure 1.

![Figure 1. Daily (circadian) rhythms of a person in natural light.](image)

Modern data on the influence of light parameters on diurnal rhythms have led to the creation of fundamentally new "human" artificial lighting systems, designated by the term "Human Centric Lighting" (HCL-systems). Such lighting systems, affecting the daily biorhythms of people, contribute to increasing productivity and safety of their work, improve well-being and mood [12]. "Human Centric Lighting" systems change the colour temperature and light intensity during the day according to a preset program (figure 2). These factors affect a person's metabolic processes, immune system, blood pressure, body temperature, brain function, and much more. The effectiveness of a number of medications and their side effects depend on the time of day.

![Figure 2. The mechanism of light influence on human circadian rhythms.](image)

3. Synchronization of biorhythms with the working schedule
Unfortunately, the modern organization of labour activity does not always allow a person to wake up in accordance with their own biorhythms, which is called "in the sun". It is especially difficult for the
mining industry workers due to the multi-shift work schedule, as well as due to the fact that many Russian enterprises of the extractive industries are located in the Far North [13–15].

Traditionally, a mechanical alarm clock with an audible alarm was used to wake up. To mitigate the impact of sound, alarm clocks with adjustable volume and pitch were introduced. In the USSR, even an alarm clock "Nairi" was produced, with a music box. In it, the main signal is preceded by a soft playing of the melody [16]. This contributes to a smooth transition of the person to the waking mode. On the basis of microelectronic technology, a greater variety of audio signals has become possible. The next step was to turn on the table lamp along with the sound signal. Thus, light alarm clocks were created. The best such device is the Philips Wake-up Light HF3505 light alarm clock (figure 3).

![Figure 3. Alarm clock Philips Wake-up Light HF3505.](image)

The alarm clock emits a yellow light, the intensity of which increases from zero to a maximum in 30 minutes. The alarm clock has two sound options: birdsong and the rustle of the forest. Clinically proven effectiveness of the alarm clock.

On the basis of modern knowledge on the effects of light on biorhythms, it follows that the transfer of the human body to the wake-up mode is facilitated by blue light of increasing intensity. Moreover, the spectrum of this light should change the colour of the glow from dark purple to light blue, reproducing the colour change of the sky in the pre-dawn twilight.

The twilight light appears before dawn as a result of the scattering by the atmosphere of the rays of the Sun still below the horizon (figure 4). Since the amount of light scattering is inversely proportional to the fourth power of its wavelength, the blue rays that have the smallest wavelength in the visible spectrum are scattered most strongly (figure 5).

![Figure 4. The sky before dawn.](image)
In 1991, a group of researchers led by Forster and Provancio discovered a new, third type of photoreceptor in the eyes of people – ipRGC ganglion cells [17, 18], which are designed to awaken a person. They examined the effects of light on circadian locomotor rhythms in retinally degenerate mice (C57BL/6J mice homozygous for the rd allele: rd/rd). The sensitivity of circadian photoreception in these mice was determined by varying the irradiance of a 15 min light pulse (515 nm) given at circadian time 16 and measuring the magnitude of the phase shift of the locomotor rhythm. Experiments were performed on animals 80 days of age. Despite the loss of visual photoreceptors in the rd/rd retina, animals showed circadian responses to light that were indistinguishable from mice with normal retinas (rd/+ and +/+). While no photoreceptor outersegments were identified in the retina of rd/rd animals (80–100 days of age), we did identify a small number of perikarya that were immunoreactive for cone opsins, and even fewer cells that contained rod opsin. Using HPLC, they demonstrated the presence and photoisomerization of the rhodopsin chromophore 11-cis retinaldehyde. The rd/rd retinas contained about 2% of 11-cis retinaldehyde found in +/+ retinas. The unique inner retinal localization of melanopsin suggests that it is not involved in image formation but rather may mediate nonvisual photoreceptive tasks, such as the regulation of circadian rhythms and the acute suppression of pineal melatonin. The anatomical distribution of melanopsin-positive retinal cells is similar to the pattern of cells known to project from the retina to the suprachiasmatic nuclei of the hypothalamus, a primary circadian pacemaker. [17, 18]. These receptors are located in the retina of the eye as shown in figure 6.
colour of the glow of the sky from dark purple through blue to light blue (figure 6). The duration of twilight and the colour of the sky glow depend on the geographical latitude, the time of year and the state of the atmosphere (figure 7).
to the small screen, this method is not very effective, but it can be improved by recording a special sequence of actions on the phone "macro", according to which the phone will not only play the video at the desired time interval, but also broadcast it to a TV with SmartTV function. This method is more time-consuming and requires certain knowledge and skills in handling equipment, as well as the presence of a smartphone with the ability to record macros and a TV located in the bedroom. After testing these methods, their effectiveness and complexity, we decided to focus on the option of using a personal computer and the built-in program "task scheduler", because in this case there is no need to purchase additional hardware and software. Since currently almost every home has a desktop computer or laptop, it is possible to use this method even on trips or business trips, which is especially important, because due to long-distance flights, it is very easy to bring down the daily cycle, which will lead to poor health, and, accordingly, to unproductive work.

Let's look at the method we have chosen in more detail for the current version of Windows 10. First, you need to configure the computer so that when you press the power button, it does not turn off completely, but goes into sleep mode. Otherwise, the task scheduler will not be able to start when the computer is turned off, similar to the alarm clock on a regular smartphone. This function can be configured via the toolbar: power supply → sleep mode settings → change additional power settings. It is also possible to use the "sleep" or "sleep mode" button on the device itself, if it is available. Next, you need to start the task scheduler. There are several ways to find it. For example, on the keyboard, you need to press the Win+R key combination to open the "Run" window and enter "taskschd.msc" in it and start the process.

After opening the task scheduler, you need to create a new task, there are also two ways to do this. By clicking on the first line (in the right column), we can create a simple task that allows us to configure most of the functions we need: configure the repetition of our action for each day at a certain time, specifying the video file to run. The second line "create a task" allows you to increase the number of configurable additional functions and launch conditions.

Using any of these two functions, we create a task to turn on the video that you downloaded to your computer in advance at a certain time. Using the advanced settings, you can personalize your alarm clock by setting different turn-on times on weekdays and weekends, as well as choosing different videos. This method does not require a permanent connection to the Internet, you just need to download certain video files in advance. If your device has a small screen diagonal, it is possible to use a TV connection cable when travelling, because Ever devices that are not equipped with the SmartTV version are connected via an HDMi or VGA cable, which allows you to use them as the main computer screen and, accordingly, as an alarm clock.

5. Conclusion
Modern ideas of molecular biology and ophthalmology about the mechanisms of light exposure to human biorhythms have led to the development of a method of awakening, which consists in exposing the patient to a light stream of increasing intensity with a spectrum of light changing according to a given program (from purple to blue). The wake-up program can be selected by the patient himself and has a large number of options. The sound can also be selected according to the patient’s taste. The developed technology is implemented on electronic devices available in many families. In recent years, it has been established that the smoothness of awakening also depends on the sleep phase at which the moment of awakening occurs. To monitor sleep phases, a sensor installed in a wristband and connected to a computer is used. The combination of the system developed by us with such a sensor is promising if, instead of the exact wake-up time, you set an acceptable working interval. The equipment that implements the proposed principles of gentle awakening can be an integral part of the "smart home" system.

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