



**DAYLIGHT AS A BIOPHILIC ELEMENT IN WORK
ENVIRONMENTS**

İDİL BAKIR KÜÇÜKKAYA

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İDİL BAKIR KÜÇÜKKAYA

THESIS ADVISOR: PROF. DR. DENİZ HASIRCI

Ph.D. Exam Jury Members

Prof. Dr. Deniz HASIRCI

Assoc. Prof. Dr. Deniz DENİZ

Assoc. Prof. Dr. Başak KUNDAKÇI KOYUNBABA

Asst. Prof. Dr. İlker KAHRAMAN

Asst. Prof. Dr. Ecehan ÖZMEHMET

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Approval of the Graduate School

Prof. Dr. Mehmet Efe BİRESSELİOĞLU

I certify that this thesis satisfies all the requirements as a thesis for a Ph.D. degree.

Prof. Dr. Deniz HASIRCI

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for a Ph.D. degree.

Prof. Dr. Deniz HASIRCI

Ph.D. Exam Jury Members

Prof. Dr. Deniz HASIRCI

İzmir University of Economics

Assoc. Prof. Dr. Deniz DENİZ

İzmir University of Economics

Assoc. Prof. Dr. Başak KUNDAKÇI KOYUNBABA

Yaşar University

Asst. Prof. Dr. İlker KAHRAMAN

İzmir University of Economics

Asst. Prof. Dr. Ecehan ÖZMEHMET

Yaşar University

ETHICAL DECLARATION

I hereby declare that I am the sole author of this thesis and that I have conducted my work in accordance with academic rules and ethical behaviour at every stage from the planning of the thesis to its defence. I confirm that I have cited all ideas, information and findings that are not specific to my study, as required by the code of ethical behaviour, and that all statements not cited are my own.

Name, Surname: İdil BAKIR KÜÇÜKKAYA

Date: 29.01.2025

Signature:

ABSTRACT

DAYLIGHT AS A BIOPHILIC ELEMENT IN WORK ENVIRONMENTS

BAKIR KÜÇÜKKAYA, İDİL

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Since the emergence of the biophilia hypothesis, research has been conducted on aspects of biophilic design and how they might be applied in interior design. Daylight is one of the fundamental elements of biophilic design and has several physical and psychological impacts on human beings, having practical implications for office interiors. Consequently, this research explores biophilic design in open plan offices, focusing specifically on the impact of daylight on office workers. In order to examine and compare the role of daylight on mood, circadian rhythm, and well-being of office workers within the framework of biophilic design approach, realistic and comprehensive data was collected utilizing evidence-based methods. The study was carried out in real open-plan work environments in a university in Izmir-Turkey, at every hour of the day by regular measurements of sinus rhythm, ECG, oxygen level, sleep tracking, daily intake of daylight, by using smart watches in a specific climate. Questionnaires and photographic analyses were also carried out to support the data. The findings suggest a strong correlation of daylight and its effects on overall

wellbeing, with design guidelines for office interiors. This research may help raise awareness on biophilic design as well as daylight as a significant component. Moreover, both designers and leaders of institutions may utilize the findings, in order to design office environments, conducive to users' well-being. The research has various significant implications for future studies, with regards to new opportunities, that combine evidence-based methods with feedback from participants.

Keywords: Biophilic Design, Daylight, Mood, Circadian Rhythm, Well-being, Work environment.



ÖZET

OFİS MEKANLARINDA BİYOFİLİK UNSUR OLARAK GÜN IŞIĞI

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Biyofili hipotezinin ortaya çıkmasından bu yana, biyofilik tasarımın yönleri ve bunların iç mekan tasarımında nasıl uygulanabileceği üzerine araştırmalar yapılmıştır. Gün ışığı, biyofilik tasarımın temel unsurlarından biridir ve insanlar üzerinde çeşitli fiziksel ve psikolojik etkilere sahiptir, ofis iç mekanları için pratik etkileri vardır. Sonuç olarak bu araştırma, özellikle gün ışığının ofis çalışanları üzerindeki etkisine odaklanarak açık plan ofislerde biyofilik tasarımı araştırmaktadır. Gün ışığının ofis çalışanlarının modu, sirkadiyen ritmi ve esenliği üzerindeki rolünü biyofilik tasarım yaklaşımı çerçevesinde incelemek ve karşılaştırmak için kanıta dayalı yöntemler kullanılarak gerçekçi ve kapsamlı veriler toplanmıştır. Çalışma, İzmir-Türkiye'de bir üniversitede gerçek açık plan çalışma ortamlarında, belirli bir iklimde akıllı saatler kullanılarak günün her saatinde düzenli sinüs ritmi, EKG, oksijen seviyesi, uyku takibi, günlük gün ışığı alımı ölçümleri ile gerçekleştirilmiştir. Verileri desteklemek için anketler ve fotoğraf analizleri de yapılmıştır. Bulgular, gün ışığı ve gün ışığının genel esenlik üzerindeki etkileri ile ofis iç mekanları için tasarım kılavuzları arasında güçlü bir ilişki olduğunu göstermektedir. Bu araştırma, biyofilik tasarım ve bunun

önemli bir bileşeni olan gün ışığı konusunda farkındalık yaratılmasına yardımcı olabilir. Ayrıca, hem tasarımcılar hem de kurum liderleri, kullanıcıların esenliğine yardımcı olacak ofis ortamları tasarlamak için bulgulardan faydalanabilir. Araştırma, kanıta dayalı yöntemleri katılımcıların geri bildirimleriyle birleştiren yeni fırsatlar açısından gelecekteki çalışmalar için çeşitli önemli çıkarımlara sahiptir.

Anahtar Kelimeler: Biyofilik tasarım, Gün ışığı, Duygu durumu, Sirkadiyen ritim, Esenlik, Çalışma mekanları.



Dedicated to my dear daughter Ada Küçükkaya...



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LIST OF ABBREVIATIONS

EBR: Evidence-Based Research

ECG: Electrocardiogram

FFAD: Faculty of Fine Arts and Design

HRV: Heart Rate Variability

IUE: Izmir University of Economics

PANAS: The Positive and Negative Affect Schedule

SAD: Seasonal Affective Disorder

SGK: Sosyal Güvenlik Kurumu



CHAPTER 1: INTRODUCTION

“Biophilia hypothesis suggests that there is an instinctive bond between human beings and other living systems” (Wilson, 1984).

Biophilic design emphasizes the human affinity for nature and its elements, asserting that a connection to the natural environment is vital for physical and mental health. Daylight, being the most accessible and fundamental form of nature in built environments, provides an effective medium through which biophilic principles can be applied and also daylight helping indoor spaces to mimic the outdoors.

“People physiologically and psychologically prefer daylight mainly through levels of serotonin over artificial lighting as their primary source of illumination and it affects the satisfaction of people” (Ulrich, 2006).

In an era of rapid urbanization and a growing trend towards open-plan office environments, the interplay between design and well-being has become increasingly important. Office spaces are settings where individuals dedicate a significant portion of their day. The average workday for an employee is around nine hours, with the majority of that time spent in office buildings (Xue, 2014). Research has indicated that the physical conditions of an indoor environment can impact the health, well-being, comfort, satisfaction, and productivity of office workers. This dissertation, titled “Daylight as a Biophilic Element in Open Plan Offices”, aims to investigate how natural light, an integral part of biophilic design, can enhance and improve contemporary workspaces and open-plan office workers. With the decline of traditional office layouts and the emergence of open plan offices, employees are often deprived of the natural elements that promote mood and psychological well-being due to the presence of space dividers. Therefore, understanding how daylight can be effectively incorporated into open-plan offices can help not only to improve employee satisfaction, but also to help people heal through connecting with nature. The study especially focuses on the role of daylight on an office worker’s circadian rhythm, mood and well-being within the biophilic design approach. The main research question is,

how does daylight influence office workers' mood, circadian rhythm and emotional well-being who work in the same time period and a particular season?

Oldham and Daniel (1979) investigated how employees' reactions to their work evolved following their transition from a traditional office setting to an open-plan design, which lacks interior walls or partitions. They gathered data from 81 employees on three occasions: prior to the transition to the open office and two times afterwards. The findings indicated a significant decline in employee satisfaction and internal motivation after the shift to the open office layout.

Hedge (1982) conducted a thorough study on employee responses to their work surroundings. An extensive questionnaire was completed by 649 employees across all job levels who worked in open-plan offices on each of the five floors of an office building. The findings revealed a range of ambient environmental issues within these offices. Additionally, a definitive link between job characteristics and employees' perceptions of the office was established.

Wotten, Blackwell, Wallis, and Barkow (1982) studied how daylight influences job satisfaction by conducting interviews with 235 office workers. The findings revealed that a significant proportion (74%) preferred having a window close to their work areas.

Oldham and Rotchford (1983) investigated employees' attitudes toward open-plan offices, focusing on the connections between specific office features (such as openness, office density, workspace density, accessibility, and lighting) and various indicators of employee responses (including satisfaction, behavior during free time, and spatial markers). The study also explored how three categories of intervening variables influenced these relationships.

Heerwagen and Orians (1986) noted that the absence of windows can lead to negative psychological effects, as studies indicate that individuals in windowless offices tend to decorate their spaces with more than twice the number of visual materials.

Franta and Anstead (1994) investigated overall well-being in office buildings and

found that occupants in spaces with daylight and full-spectrum lighting experienced an improvement in their general well-being. These office environments offered specific advantages, such as enhanced health, lower absenteeism, higher productivity, cost savings, and greater employee preferences. The benefits to workers are so significant that many European countries mandate that employees be located within 27 feet (823 cm) of a window.

The presence of natural vegetation in the workspace or visible through windows can enhance stress reduction and improve attentional focus. According to the study, participants recorded lower blood pressure and reported feeling more attentive in a windowless room that contained plants compared to one that did not (Heerwagen et al., 1998).

Leather, Pyrgass, Beale, Lawrence (1998), investigate windows in the workplace sunlight, view, and occupational stress by using general well-being questionnaires. The questionnaire was assessed using Warr, Cook, and Wall's (1979) 15-item scale. The results showed a significant direct effect for sunlight penetration on job satisfaction, intention to quit, and general well-being. A view of natural elements (i.e., trees, vegetation, plants, and foliage) was found to buffer the negative impact of job stress on intention to quit and to have a similar, albeit marginal, effect on general well-being.

Stone (1999) assessed how lighting impacts melatonin levels, bodily rhythms, and mood through a systematic literature review. The findings indicate that the pineal gland's production of melatonin is directly affected by lighting conditions. Regular exposure to typical indoor lighting, along with occasional exposure to natural daylight, is believed to have little effect on circadian rhythms. However, prolonged exposure to consistently high light levels can disrupt certain bodily rhythms.

Fontoynt (2002) examines the perceived effectiveness of daylighting systems, comparing the performance criteria of artificial lighting with that of natural light. The findings indicate that suitable daylighting, when complemented by artificial lighting systems, meets the requirements for visual and psychological comfort.

“In healing environments, natural light can lessen mental and physical stress for patients, enhance employee productivity, and contribute a sense of spirituality and openness to indoor spaces “ (Edwards et al., 2002).

Küller (2002) explores a significant connection between daylight and mood, particularly highlighting the occurrence of seasonal affective disorder (SAD) in countries far from the equator during the winter months. Common symptoms of SAD include decreased activity levels, social withdrawal, and fluctuations in mood, notably an increase in feelings of sadness.

Leslie (2003) analyzes existing literature on daylighting, finding that the primary objective of using natural light is to cultivate a comfortable and productive work setting. Evidence suggests that natural light positively contributes to enhancing employee performance and productivity. Workers tend to favor natural light and views over enclosed buildings. Ulrich (2006) adds that people generally prefer daylight, largely due to its effects on serotonin levels, compared to artificial lighting, which impacts their overall satisfaction.

Ulrich (2007) conducted an experiment in which he presented colored slides of outdoor environments to two groups of mildly stressed participants. The groups were instructed to respond to 12 questions from the Zuckerman Inventory of Personal Reactions (ZIPERS) (Zuckerman, 1977), a comprehensive affective test that evaluates an individual's emotions and anxiety levels at the time of the assessment. The results carry several implications for environmental planning and design. Overall, the findings indicate that outdoor visual environments can significantly affect individuals' psychological well-being, highlighting the need for careful consideration of these factors in planning and design choices. While most planners are aware of the aesthetic elements of environments, there is direct empirical evidence demonstrating that aesthetic advantages can be quite significant.

George and Zhou (2007) examined the interaction between positive and negative moods and their effect on creativity within supportive environments through the use

of questionnaires, utilizing scales from the PANAS. They identified three different approaches that supervisors can adopt to create a supportive atmosphere: offering developmental feedback, demonstrating interactional justice, and exhibiting trustworthiness.

Küller (2007) studied how daylighting and human behavior influence luminous comfort in residential buildings by employing a comprehensive questionnaire consisting of seven to eight pages, along with measurements taken using lux meters, informed by neuro-psychological concepts. The participants' emotional well-being was evaluated using 12 scales, including: rested/tired; alert/drowsy; awake/sleepy; interested/bored; efficient/inefficient; devoted/indifferent; secure/anxious; friendly/angry; happy/sad; confident/hesitating; independent/dependent; and strong/weak. The findings regarding the impact of light and color were significant enough to warrant greater focus in future research. For practitioners, it can be essential to take into account both the seasonal effects and the proximity and distance to windows.

Veitch, Charles, Farley, and Newsham (2007) outline the factor structure of a measure assessing office environmental satisfaction and create a model that connects environmental satisfaction with job satisfaction. The data were gathered as part of the Cost-effective Open-Plan Environments (COPE) project, which included on-site physical measurements of each participants' workstation. A questionnaire was distributed to 779 occupants of open-plan offices across nine government and private sector buildings in five major cities in Canada and the United States.

Loftness (2008) emphasizes the significance of a thorough and knowledgeable design process when incorporating windows into buildings, ensuring that "windows become doors." This approach provides access to views, natural light, fresh air, breezes, and comfort from nature, passive survivability, outdoor spaces and activities, an expanded sense of space, circadian regulation, and the experiences of seasons, climate, as well as the sounds, smells, and vitality of nature.

Jahncke et al. (2011) investigated cognitive performance and restoration in open-plan offices. They examined the cognitive, emotional, and physiological impacts of two different noise levels in open-plan offices (high noise at 51 LAeq and low noise at 39 LAeq) during simulated work periods, followed by four restoration conditions: a river video with sound, just the river sound, silence, and office noise. The findings revealed that participants' memory performance decreased more in high noise conditions than in low noise conditions, leading to increased feelings of tiredness and reduced motivation in the high noise environment. A significant reduction in noise levels could alleviate the negative impacts of background noise in open-plan offices (Jahncke et al., 2011).

Mak and Cheung (2014) carried out a questionnaire survey to explore the impact of daylighting and human behavior patterns on subjective luminous comfort in housing units in Hong Kong. They found that luminous comfort is influenced by both behavior patterns and daylighting conditions. The results indicated that behavioral factors significantly affect luminous comfort for individuals who rate their satisfaction with daylighting as moderate. Among these factors, the use of artificial lighting emerged as the most important determinant of luminous comfort, with extensive use of artificial lighting throughout the day signaling inadequate daylighting conditions and resulting in lower luminous comfort (Xue, Mak, and Cheung, 2014).

Zadeh, Shepley, Williams, and Chung (2014) examined the physiological and psychological impacts of windows and daylight on registered nurses. Their findings corroborate existing evidence from both laboratory and field studies regarding the advantages of having windows and natural light. They suggest that windows and daylight may provide a micro-restorative effect, which could lead to reduced blood pressure, increased oxygen saturation, and beneficial effects on circadian rhythms, as indicated by body temperature and morning drowsiness.

Bian and Luo (2017) explored visual comfort metrics based on subjective responses in office settings in China. Their study was conducted in two side-lit office areas located in the perimeter zone of a laboratory building in Canton, China, under different sky conditions. They found that straightforward luminance metrics (such as workplane

luminance) and vertical eye illuminance were more effective than complicated glare indices (DGP/DGI) and luminance ratios. Additionally, the study established metric thresholds based on the findings.

Figueiro et al. (2017) examined how exposure to daylight affects sleep and mood among office workers. In their study, they utilized a device specifically calibrated to measure light that influences the circadian system (circadian effective light) to track individual light exposures of office workers and correlate them with their sleep patterns and mood. The research took place in five buildings managed by the US General Services Administration, with 109 participants (69 females), of whom 81 (54 females) participated in both winter and summer. The findings indicated that higher levels of circadian-effective light throughout the day were linked to increased phasor magnitudes, reduced symptoms of depression, and improved sleep quality.

Adamsson, Laike and Morita (2018), investigated seasonal variation in mood and behavior among a group of office workers in Sweden (56°N). Thirty subjects participated in this longitudinal study. The subjects kept a weekly log that included questionnaires for ratings of psychological well-being and daily sleep-activity diaries where they also noted time spent outdoors. The subjects reported seasonal variation concerning the pleasantness, variation and strength of the light in the offices and regarding the visibility in the rooms. The subjects spent most of their time indoors, relying on artificial lighting, which demonstrates the importance of the lighting quality in indoor environments.

Cajochen et al. (2018) studied the impact of daylight-mimicking LED lighting on various factors, including visual comfort, melatonin levels, mood, waking performance, and sleep. The research involved testing an LED lighting solution designed to replicate the daylight spectrum and its effects on visual comfort, circadian physiology, daytime alertness, mood, cognitive performance, and sleep. The results indicate that a daylight-LED solution has positive effects on visual comfort, daytime alertness, mood, and sleep quality in healthy participants.

Nie et al. (2021) developed an appropriate lighting environment aimed at stabilizing the circadian rhythm, cognitive performance, and mood of shift workers. The study examined the effects of dynamic daylight-like lighting on the rhythm, cognition, and mood of irregular shift workers within a controlled environment. It involved measuring plasma melatonin levels, activity counts, continuous performance tests, and mood assessed via a visual analogue scale to evaluate the subjects' rhythm, cognitive function, and mood. The results showed that after 38 days of shift work, there was a significant increase in the subjects' peak melatonin concentration, and their physiological and behavioral rhythms remained stable. Moreover, cognitive performance improved notably after night shifts compared to before. However, no significant changes in mood were observed throughout the 38-day period. These findings suggest that the designed light environment positively supports circadian rhythms, cognitive function, and mood during extended periods of shift work in a controlled setting.

1.1. The Aim of Study

According to the research in the literature, it has emerged that there is a connection between humans, nature and other living systems. The fact that people live in a built environment has increased their desire to turn to nature. These ideas are the beginning point of the biophilia approach.

The idea that connecting with nature benefits psychological health suggests that well-being can be promoted through restorative practices that improve mood and replenish energy lost through fatigue (Ulrich, 1979; Kellert, 2005). Extensive research over the years has pointed to lack of sunlight and disruptions in circadian rhythms as major contributors to Seasonal Affective Disorder (SAD).

The aim of this research is to examine and compare the role of daylight on mood, circadian rhythm and well-being of office workers within the framework of biophilic design approach in open-plan offices. The findings are intended to provide significant insights for implementing biophilic design principles that optimize natural light in open-plan office settings, thereby enhancing both environmental quality and office workers outcomes. Testing, measuring and data collection of these effects, which have

also emerged in previous studies, with new technological methods using evidence-based research methodology can also contribute to the literature. Earlier studies have mostly focused on creativity, satisfaction, productivity, visual comfort and energy efficiency. And, there are also studies addressing the mood or the circadian rhythm. However, studies in which mood and circadian rhythm are evaluated together within the biophilic design are scarce. Earlier studies examine the hospitals, nursing rooms, houses or the work environments. But the specific office type is not specified or not mentioned. Most of the studies cited above have focused on daylight, artificial light, color or windows in laboratory settings. Even if some of these studies involved highly elaborate experimental designs and measurements, it was felt appropriate to consider all these visual factors simultaneously under realistic working conditions and over a prolonged period of time. In order to ensure the validity of the outcome, the study carried out in a real open-plan office environment at different times at the day in a specific climate by considering climate, season and measurements of light. The evidence-based research (EBR) approach was used in this study because it suggests that, in addition, a systematic and transparent approach needs to be followed to explicitly use all earlier studies and to consider end-user perspectives. It is believed that findings are useful for designers of work environments, managers, improving the overall well-being of the users of these spaces. The study ended with practical guidelines that can be applied to a variety of work environments with different functions, in addition to contributing to literature.

According to the 2014 data of the Social Security Institution (SGK); *“There are more than 5 million office workers in our country, half of whom are public employees”*. The office workers, and especially public employees, spend most of the daylight hours in their offices instead of homes or the other places. If suitable conditions are not provided in these offices, especially open-plan offices (because these are complex interiors), they cannot benefit from the daylight they need to receive throughout the day. *“Consistent with the idea that reduced daytime light exposure might affect sleep quality and mood in office workers”*, (Boubekri et al, 2014) It is found that office workers situated near windows, who likely receive more natural light throughout the day compared to those in windowless offices, demonstrated greater overall activity

and, on average, slept about 46 minutes longer at night. The human sleep cycle, which is a type of circadian rhythm, adjusts according to light exposure (Millett, 2011).

Daylight has been linked with mood, stress, circadian rhythm and well-being. Therefore, in this study, Circadian rhythm, mood and well-being assessment techniques were used together and it was research in which they are evaluated. Daylight and mood were evaluated separately in previous studies, but a study in which the three studies were evaluated together is lacking. Since office workers spend most of their day and daytime in offices, examining the effects of both from a psychological point of view can bring a new direction to daylight effects. This was investigated in the study.

Since people spend the hours of their day when they can get the most efficient daylight in office spaces, the results of this study may contribute to the design of future offices and the reorganization of existing office spaces and can benefit company owners, institutes, public institutions, architects, interior designers, lighting designers and designers for future office designs. The results of this study can raise awareness on the healing of people by nature, biophilic design and ecological design. In the existing literature, the study differs from the others due to the use of new technology and evidence-based methods used in this study. As a result, office workers be able to receive daylight efficiently during the day.

What is proposed in this project is unique for the following reasons:

- The methods and tools used in this study have not been used together in other studies on this topic in the literature. Measurement and comparison of factors such as ECG, oxygen level, sleep monitoring, stress level, heart rate and temperature with smart watches has not been included in a study on biophilic design.
- As stressed by Ulrich (2017), studies that used to be limited mostly to hospitals or other health settings due to the EBR methods and requirements utilized, are now possible through new technologies. This method has been possible based on the relatively simple data collection techniques that smart watches have

enabled. That being stated, it is obvious that findings cannot be treated as clinically valid, but to provide accessible information enabling more rapid creation and dissemination of knowledge, and adding to literature in new methods being developed in the field.

- Evidence-based methods and tools include a PANAS measurement questionnaire, analysis of archival data, biological measurements (blood pressure, heart rate, temperature, oxygen saturation, ECG), light measurements in space, daylight measurements with the lighting program and data were analyzed and evaluated based on this evidence. These measurements in combination have not previously been tested under a biophilic approach in any office environment.
- While exposure to optimal levels of natural light is essential to our physical and mental well-being, a prolonged deficit can trigger the disruption of circadian rhythms, leading to severe affections, such as: Diabetes, Sleep disorders, Depression, SAD (seasonal affective disorder), Bipolar disorders, Obesity, Heart Disease (Rush, 2019). Unfortunately, people spend their days in office buildings that provide insufficient amounts of natural light, and which can cause the circadian rhythm cycle to be incomplete. which can lead to the health problems mentioned above. As a result of these measurements to be made in this project, the amount of daylight that daily office workers should receive can be calculated and its effects can be evaluated.

1.2. Research Questions and Hypothesis

- How does daylight influence mood, circadian rhythm, and well-being of office workers?
 1. Considering the connection between the circadian rhythm and the sleep patterns of people, does daylight in offices have an effect on sleep patterns?
 2. Are there relationships between daylight in open-offices and people's mood during the day?

3. Does the overuse or underuse of daylight in office spaces have effects on people's well-being?
 - What is the biophilic relationship of people and daylight in open-office interiors?
 - How can education institutes, companies, interior architecture profession benefit from a comprehensive understanding between people and interior daylight?

The research questions aim at understanding mood, circadian rhythm, and well-being of office workers considering daylight concepts in work environments and it serve to guide every step of the research process including the design of the research methodology, evaluation process and analysis of the research results. Based on the research question, the following hypothesis was developed:

“As a fundamental biophilic design element, daylight strongly influences the circadian rhythm, the positive mood and the negative mood and well-being of the office workers. The relationship of daylight to circadian rhythm is linked to the sleep patterns of office workers, so that it can be measured.”

1.3. The Methodology of Study

Firstly; to establish the conceptual framework for this study, research was carried out on how nature impacts human physiology and psychology, the restorative qualities of spaces, and the implementation of biophilic design principles in interior architecture. Afterwards, biophilic design effects in office spaces were examined. Finally, the relationship between humans and nature was emphasized. In this part of the study, information is given about the material and method determined for the evaluation of the selected office space and office workers mood and circadian rhythm.

An evidence-based research method has been used in the study. First, a literature review was conducted on the beginnings, philosophy, and current research in biophilic design, daylight, and close ties with human beings. This was followed by an assessment of drawings, information and visuals of the office spaces were collected. For the measurements to be made with smartwatches, reference test trials were

conducted with 2 participants. Then, biological measurements were made for 5 weeks. Measurements such as ECG (sinus rhythm), oxygen level, sleep monitoring, and daily amount of daylight received were made with smart watches. At the same time, measurements such as the light level on the table and at eye level in the area where the participants were sitting in the open office space were measured using a lux meter. Parallel with these tests, a questionnaire on the use of daylight in offices developed using Likert scales was opened to the participants. The PANAS test was also administered to the participants whose measurements were completed with the smartwatch. The results of all measurements, surveys and tests were compared and evaluated in detail. Psychological responses encompass our emotional well-being and mood. Physiological responses encompass our aural, musculoskeletal, respiratory, circadian systems and overall physical comfort. Physiological responses triggered by connections with nature include relaxation of muscles, as well as lowering of diastolic blood pressure and stress hormone (i.e., cortisol) levels in the bloodstream (Park et al., 2009). Therefore, the use of biological assessments was used in this study to measure emotional well-being and circadian rhythm. The psychological responses indicate emotional well-being and mood. Biological assessments (blood pressure, heart rate, temperature, oxygen saturation, and ECG) was conducted at discrete hourly intervals. Behavioral cues recorded in real time, and illumination levels was recorded hourly.

The mood was assessed based on 10 positive mood and 10 negative mood scales brought from PANAS. Watson, Clark, and Tellegen to provide a better, purer measure of the dimensions, developed the PANAS method in 1988. The ten positive mood scales are; attentive, active, alert, excited, enthusiastic, determined, inspired, proud, interested, and strong. The negative mood scales are; hostile, irritable, ashamed, guilty, distressed, upset, scared, afraid, jittery, and nervous. The PANAS was applied to 21 University employees working in the same campus, at the same time, both administrative and academic.

Psychological responses involve our emotional well-being and mood, while physiological responses relate to our auditory, musculoskeletal, respiratory, circadian systems, and overall physical comfort. Connections with nature can elicit physiological responses such as muscle relaxation and reductions in diastolic blood

pressure and stress hormone levels (e.g., cortisol) in the bloodstream (Park et al., 2009). Therefore, the use of biological assessments was used in this study to measure emotional well-being. The psychological responses indicate emotional well-being and mood. Biological assessments (blood pressure, heart rate, temperature, and oxygen saturation) conducted at discrete hourly intervals. Behavioral cues recorded in real time, and illumination levels recorded hourly.

Circadian rhythms influence the sleep-wake cycle by enhancing the secretion of the hormone melatonin, which induces sleepiness in response to reduced light detection by the optic nerves. They also impact hormone release, eating patterns, digestion, body temperature, and various other vital bodily functions. Biological clocks that run too fast or too slow can disrupt normal circadian rhythms. Irregular rhythms have been linked to a range of chronic health issues, such as sleep disorders, obesity, diabetes, depression, bipolar disorder, and seasonal affective disorder (Aydemir, 2011).

In this study, it was measured whether it is related to circadian rhythm by regular measurements of heart rhythm, ECG and body temperature and participants continued to wear the smartwatches during their nighttime sleep and sleep was measured to assess whether this is related to daily daylight intake. *“ While exposure to optimal levels of natural light is essential to the physical and mental well-being, a prolonged deficit can trigger the disruption of circadian rhythms, leading to severe affections, such as: Diabetes, Sleep disorders, Depression, SAD (seasonal affective disorder), Bipolar disorders, Obesity, Heart Disease ”* (Rush, 2019). People spend their days in office buildings that provide insufficient amounts of natural light, and which can cause the circadian rhythm cycle to be incomplete. Which can lead to the health problems mentioned above. As a result of these measurements and smartwatch data to be made in this project, the amount of daylight that daily office workers should receive can be calculated and its effects can be evaluated.

Apple watch calculates HRV and ECG by using the standard deviation of beat-to-beat measurements which are captured by the heart rate sensor. HRV is validated for users over the age of 18. (HRV) Heart Rate Variability is a measure of the variation in the time interval between heart beats. Researchers at the University of Waterloo in Canada

performed a comprehensive investigation of the ECG sensor on the Apple Watch and found that the data generated by this sensor is using to develop a reliable and precise tool for stress prediction. They identified a significant relationship between the ECG data particularly in terms of heart acceleration and deceleration and the stress levels reported by participants during the readings. Following this, machine learning algorithms were created using this data to establish a prediction model (Charlton, 2022). Taking this study as a reference, the mood and stress levels of office workers with smartwatches were calculated and its connection with daylight were compared.

The study was implemented in the campus of İzmir University of Economics. The university campus is located on the Balçova side of Izmir province in the Aegean region of Turkey. The university has 8 faculties, 2 colleges and 3 vocational schools. All office spaces used in the study are in the same campus but in different buildings. Working hours are the same and adapt to the same climatic conditions.

1.4. Milestones and Plan B

Performance was measured according to the availability of participants, following the rules of the study, correctly, the participants used the smartwatch and data was obtained, a smooth data collection process, participants were willing to share the measurement data, the smartwatches and data were returned to the researchers on time and intact. In reality, since the consent forms were filled beforehand and because the duration is relatively short no such occurrences are expected.

In conducting research in university settings, through funds, it is of key significance to highlight the continuous use of the technology provided through the funds. In the future, different projects can be carried out with the BAP equipment used in the project process. These measurements made in offices can also be applied to university students or can be used to conduct tests in different environments and different publications, conference papers and projects can be realized within the University. At the end of the project, the equipment will be delivered to the University.

The approach and method used in this study aim to create new data and methodology

for researchers, interior architects, architects and lighting designers, and thus, contribute to existing literature. Findings of this research was expected to create a base for a body of knowledge regarding the relationship between human and nature (daylight) in work environments. In addition, it establishes a base reference with respect to the effect of biophilic design and views on health and wellbeing of office workers. The use of natural light is one of the most important factors to be taken into consideration for open-plan office design. This finding of this research is believed to help raise awareness of the detailed factors that influence the luminous environment and also how designers can design the office environment according to the amount of daylight in the interior and how people react with nature in a work environment. Plan B strategies and methods are emphasized in the table 1 below.

Table 1. Plan B

1- In the implementation, the participant did not use the smartwatch incompletely and the data could not be obtained.	1- The measurement of the participant was repeated and the measurement schedule was updated. In addition, other daylight measurements and analyzes was made.
2- Disruption in the delivery process of the participants' smartwatch.	2- The measurement schedule updated.
3- The participant declines to share the measurement data	3- The information was removed from the data and a new participant was added instead.
4- Disruptions in case of loss or theft of equipment.	4- Warranty insurance can be provided for the equipment. Equipment can replace and the schedule can be updated and measurements can continue.

CHAPTER 2: BIOPHILIC DESIGN IN WORK ENVIRONMENTS

This chapter focuses on biophilic design and biophilic design elements and spatial characteristics in work environments. Working environments are the places where the "work" action takes place, which is an important part of people's lives and covers one's day.

As businesses expanded and the demand for office space grew, especially after the 19th century, companies began designing larger and more intricate office environments where many people could work together. Alongside this, rapid advancements in technology and the rising complexity of commercial operations led existing office setups to adapt and redefine themselves to meet new demands (Stallworth, 1996). According to the ANSI (American National Standards Institute) and IESNA (Illuminating Engineering Society of North America) (1993), workplaces are categorized into two main types: open-plan and private (or cellular) offices. In open-plan settings, where employees share a common area, a variety of tasks and activities can take place simultaneously. To ensure the right level of lighting, it's crucial to pinpoint specific areas where tasks are performed and to pay careful attention to luminance contrasts (ANSI/IESNA, 1993). Biophilic design is an approach that aims to improve people's physical and mental health by reconnecting them with nature. By integrating elements of nature into enclosed spaces such as offices and work environments, this design philosophy aims to increase workers' creativity, productivity and overall quality of life. Research shows the positive effects of interaction with nature on people's psychological health (Kellert, 2005; Ulrich, 1991).

According to the 2023 data of the Turkish Social Security Institution (SGK); there are more than 6 million office workers in our country, half of whom are public employees. The office workers, and especially public employees, spend most of the daylight hours in their offices instead of homes or the other places. If suitable conditions are not provided in these offices, especially open-plan offices (because these are complex interiors), they cannot benefit from the daylight they need to receive throughout the day.

The benefits of biophilic design in work environments are multiple:

- **Increased Productivity:** Having employees surrounded by natural elements encourages creative thinking and increases productivity (Berman et al., 2008).
- **Better Psychological Health:** Interaction with nature improves overall mental health by reducing levels of anxiety and depression (Kaplan, 1995).
- **High Job Satisfaction:** Offices with biophilic design elements increase employee job satisfaction and reduce absenteeism rates (Kellert, 2005).

Reflecting the notion that limited exposure to natural light during the day can impact sleep quality and mood among office workers, Boubekri et al. (2014) found that those who worked near windows and thus enjoyed more daylight tended to be more active and averaged about 46 minutes more sleep each night compared to their counterparts in windowless offices. This phenomenon is linked to the circadian rhythms, which naturally adjust in response to light levels (Millett, 2011).

2.1 Biophilic Design Concept

The Greek word “*Biophilia*”, meaning “*love of nature*”, was first introduced by the social psychologist Erich Fromm. In the 1980s, when American biologist Edward O. Wilson recognized the consequences of human separation from nature, the subject gained considerable attention. He proposed a new perspective that emphasized the importance of reconnecting people with the natural world. Wilson defined biophilia as “the innate emotional connection humans have with other living organisms”. He stated that “*life around us is more complex and beautiful than anything humanity can experience*” (Wilson, 1984).

Biophilic Design is an effort to incorporate the human tendency to connect with nature (called Biophilia) into the design of our buildings and environments (Wilson, 1984; Kellert and Wilson, 1993). The aim of this approach is to bridge the gap that exists between our modern urban environments and the human desire to interact with the natural world, emphasizing the importance of designing and constructing spaces that reflect and enhance our relationship with nature.

The concept of “Biophilic Design” aims to create a healthy living environment for humans as biological beings in built spaces. Like all species, humans have evolved in response to natural rather than artificial situations and these adaptations have become embedded in our biology over time. By addressing these natural biases in the contemporary design, biophilic design aims to increase the physical and mental health as well as the general well-being of individuals (Calabrese, 2015).

2.1.1 Human and Nature Relation

In ancient times, as a result of people living in nature finding and creating shelters for themselves, barriers began to emerge between nature and humans. With this formation, spaces have emerged and these shelters have turned into structures with the technology and techniques that have developed together with living spaces. As time progressed and buildings increased, people began to move away from nature. Especially in urban life, the lack of nature has increased as people start to spend most of their time in buildings. Some concepts have emerged to strengthen this weakening human-nature relationship. Biophilic design is one of these concepts.

The biophilia hypothesis was first introduced by psychoanalyst Erich Fromm in his 1973 book *The Anatomy of Human Destructiveness*, "*The psychological obsession with being attracted to things that are alive and vital.*" defined as. After that, in 1984, biologist Edward Wilson further developed the concept of biophilia in his book titled "Biophilia." He defined biophilia as "the rich and natural pleasure of being surrounded by living organisms." Wilson argued that the inherent attraction humans feel toward biological systems is rooted in our evolutionary history. Nature serves as a motivating force for humans to engage with life.

2.1.2. Biophilic Design: Integrating Nature into the Built Environment

Stefen Kellert, professor of social ecology, provided a set of criteria for the biophilic design. In his literature he mentioned “*six elements for biophilic design*” (Kellert, 2008):

- *Environmental features*

- *Natural shapes and forms*
- *Natural patterns and processes Light and space*
- *Place-based relationships*
- *Evolved human-nature relationships*

According to Kellert (2017), Biophilic Design aims to address the limitations of contemporary construction and landscaping by establishing a framework that facilitates meaningful interactions with nature in built environments. This approach seeks to create spaces that support human habitation while promoting a natural and modern atmosphere that emphasizes the health, fitness, and overall well-being of individuals.

“Three types of experience of nature signify the basic categories of Biophilic Design”. This include the *Direct Experience of Nature*, the *Indirect Experience of Nature*, and the *Experience of Space and Place* (Calabrese, 2017) (Figure 1).

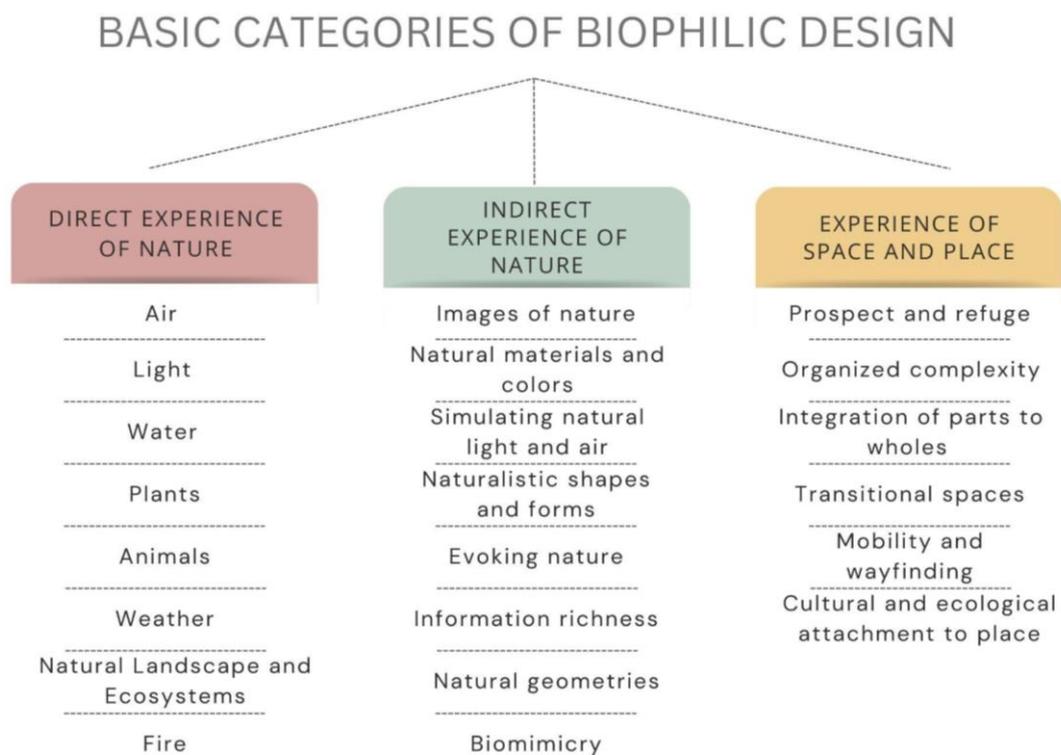


Figure 1. Experiences and Attributes of Biophilic Design (Source: Kellert, 2015)

2.1.3 Biophilic Design Elements

According to Kellert (2005), biophilic design consists of two dimensions. These are organic or naturalistic dimension and place-based or vernacular dimension. The two basic dimensions are related to six biophilic design elements; Environmental features, natural shapes and forms, natural patterns and processes, light and space, place-based relationships, evolved human-nature relationships. Light and space include natural light, filtered and diffused light, light and shadow, reflected light, light pools, warm light, light as shape and form, spaciousness, spatial variability, space as shape and form, spatial harmony, and inside-outside spaces.

As examples of biophilic design elements, studies have shown that ample access to natural light improves mood and reduces stress, increasing job satisfaction and reducing fatigue among workers in naturally lit spaces (Boubekri et al., 2014; Ulrich, 1984). In addition, integrating greenery and indoor plants into spaces and improving air quality has been shown to reduce stress and mental fatigue (Kaplan, 1995; Bringslimark et al., 2009). The inclusion of water and water-evoking designs in spaces not only provides aesthetics but also provides improvements that can increase focus and relaxation (Sullivan et al., 2021). These biophilic design elements contribute significantly to improving the quality of life of those living in built environments by nurturing their intrinsic connection with nature.

2.2 The Response of Biophilic Design in Work Environments

The literature proposes and develops the concept of biophilic design and is being reviewed incorporating how into it designed spaces gaining in the workplace as wellbeing, its productivity has and has been job proven satisfaction. The study has revealed that the use of natural elements like light and plants, outdoor landscapes can greatly enhance the well-being of workers. Studies have also revealed that employees reduce stress and anxiety levels in designed offices, improve biophilic mood, and increase cognitive elements (Berman et al., 2008; Kellert, 2005). A biophilic connection design not only creates nature and enhances the visual appeal of the environment, but also benefits positive mental effects and people's physical health,

resulting in higher levels of creativity and concentration among employees. It also helps to create sustainable workplaces built based on biophilic ideas and increases employee satisfaction and their commitment to their work (Lehmann et al., 2020). Therefore, the use of biophilic design in the workplace should also be seen as an important tool by organizations seeking to improve the health and effectiveness of their workforce.

Research indicates that incorporating natural elements into workplaces positively impacts mental health and office workers productivity. A study by Rachel Kaplan in 1993 involving 1,200 office workers found that those who had a view of nature from their windows experienced lower levels of dissatisfaction and were more motivated to work (Kaplan, 1993). Employees in windowless offices tend to introduce more natural decor into their spaces than those in offices with windows, likely as a way to compensate for their lack of access to nature (Heerwagen, and Orians, 1986). Additionally, the presence of natural vegetation either within the workspace or visible through windows can enhance stress reduction and improve focus. One study revealed that participants in a windowless room with plants exhibited lower blood pressure readings and greater attentiveness compared to those in a room without greenery (Heerwagen et al., 1998).

Employees in offices with daylight and full-spectrum lighting indicated an improvement in their overall well-being. Notable advantages of such office environments include enhanced health, lower absenteeism rates, higher productivity, cost savings, and greater employee preference. The benefits of natural light for workers are significant enough that several European countries mandate that employees work near a window (Franta, and Anstead, 1994). Consequently, daylight seems to be an essential requirement for humans, a topic that will be further examined in the next chapter.

CHAPTER 3: THE SIGNIFICANCE OF DAYLIGHT REGARDING CIRCADIAN RHYTHM, MOOD AND WELL-BEING IN WORK ENVIRONMENTS

This chapter focuses on how daylight affects mood, circadian rhythm and well-being in work environments and what are the other influences of daylight for example; performance, creativity, well-being.

3.1. The Effect of Daylight in Work Environments

“Light is the form of visible energy, getting from sunlight, or from a candle flame, or from an electric lamp” (Sezgin, 2011). Daylight is the natural light produced by sunlight entering the earth's surface. Studies have shown that this light has many improving effects on human health, psychological state and quality of life. Vitamin D from daylight is beneficial for bone health and the immune system when it reaches humans and is exposed at the right times. In addition, natural light helps regulate people's biological rhythms and can contribute to the reduction of psychological problems such as depression and anxiety (Kellert, 2005). Some studies have found that daylight has the potential to increase productivity in office and work environments. Some of them show that natural light improves the motivation, attention and general mood of employees in workplaces (Boubekri et al., 2014). In conclusion, daylight is a vital element for both physical and mental health, and adequate daylighting in today's office spaces, especially in open offices, can bring great benefits for human health and well-being.

Daylight encompasses the complete range of luminous qualities derived from both direct sunlight and diffuse skylight. In contrast to artificial lighting, daylight is incredibly dynamic, varying in intensity, color, diffusion, and direction not only throughout the day and across seasons but also in response to different weather conditions. Daylighting specifically refers to the lighting of indoor spaces using natural light that enters through openings in a building's exterior (Knoop et al., 2019).

Incorporating daylight is a crucial aspect of building design. It plays a significant role in office buildings, which are primarily occupied during the day. The primary goal of office lighting is to create a comfortable and efficient working environment (Binol, 2008). The fundamental objective of utilizing daylight is to foster a work setting that enhances comfort and productivity. Research has shown that natural light positively influences employee performance and overall productivity. Workers tend to favor spaces with natural light and views over those that lack these features (Leslie, 2003). Effective integration and management of daylight within an office building provide an optimal light spectrum for eye health. Eyestrain can be linked to the quality of light in a workspace and how well the eye can refocus (Franta, and Anstead, 1994). Individuals in built environments consistently appreciate the physiological and psychological advantages of both direct and diffused daylight, aligning with the fourth pattern of biophilic design. This favorable response stems from humans' reliance on vision for safety and resource acquisition (Kellert et al., 2008).

Research on health in office settings shows that effective daylighting can reduce the incidence of headaches, Seasonal Affective Disorder (SAD), and eyestrain (Franta and Anstead, 1994). Insufficient lighting levels are associated with headaches and SAD, but these issues diminish when appropriate spectral light improves lighting conditions. Nevertheless, eye strain remains the most prevalent health issue faced in office environments (Ott Biolight Systems, Inc., 1997).

According to the study of James, Honn, Gaddameedhi and Van dongen (2017), while exposure to optimal levels of natural light is essential to our physical and mental well-being, a prolonged deficit can trigger the disruption of circadian rhythms, leading to severe affections, such as:

- Diabetes
- Sleep disorders
- Depression
- SAD (seasonal affective disorder)
- Bipolar disorders
- Obesity

- Heart Disease

Research indicates that the working conditions in office settings significantly influence employees' performance and health, which in turn impacts their overall quality of life. As we move further into the information age, there has been a noticeable shift from traditional office buildings with private offices to open-plan layouts that promote user interaction. This design trend originated in the 1960s as the first decorative office style and emerged alongside the evolution of the concept (Bell et al., 2001).

Many individuals spend their workdays in office buildings that fail to provide adequate natural light, negatively impacting their health. Open-plan offices, in particular, rely on general lighting due to their design, which does not allow for personalized lighting adjustments or sufficient access to daylight. Additionally, light intake in these environments is often obstructed by furniture and various separations, further limiting the amount of natural light reaching workers. As a result, modern architectural trends favor open office spaces for their cost efficiency in construction and operation. Instead of utilizing traditional office furniture like cubicles or walls of varying heights, these designs favor floor-to-ceiling shelving. This not only encourages collaborative workspaces but also promotes shared lighting and ventilation, resulting in lower construction material usage and more economical designs.

Light plays a significant role in regulating the circadian rhythm, as illustrated in Figure 2. This figure demonstrates that the design of lighting can greatly affect health and well-being. To fully realize the benefits of circadian lighting, it is essential to comprehend the color spectrum of natural daylight (Rush, 2019).

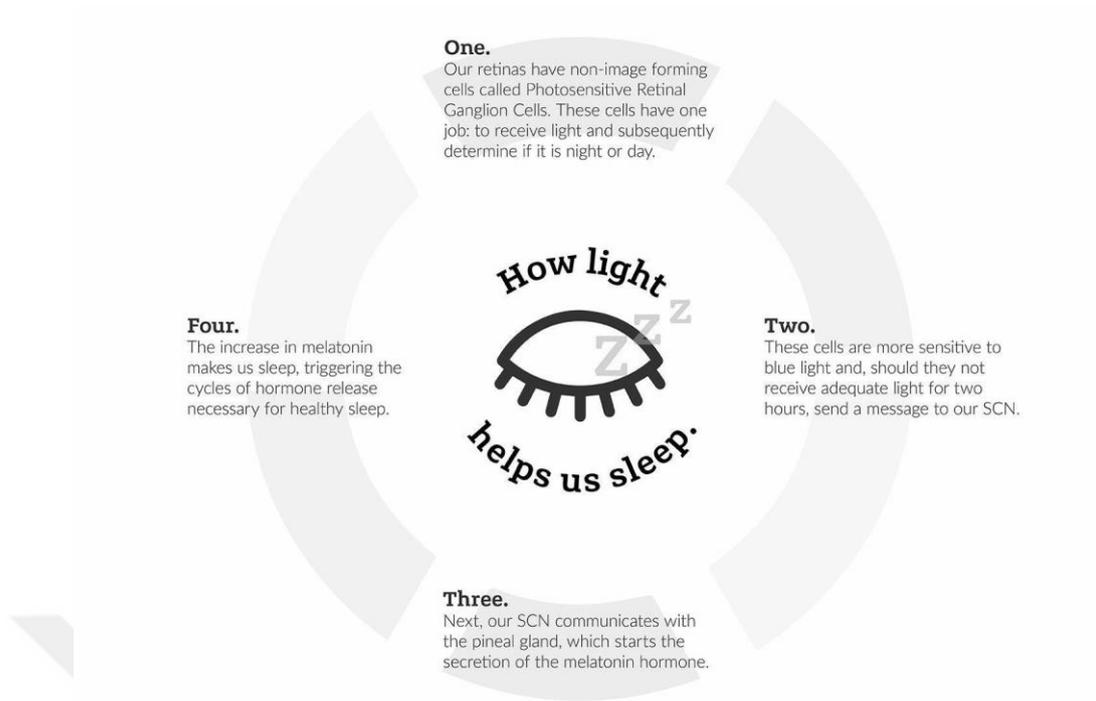


Figure 2. The science of light and health (Source: Rush, 2019)

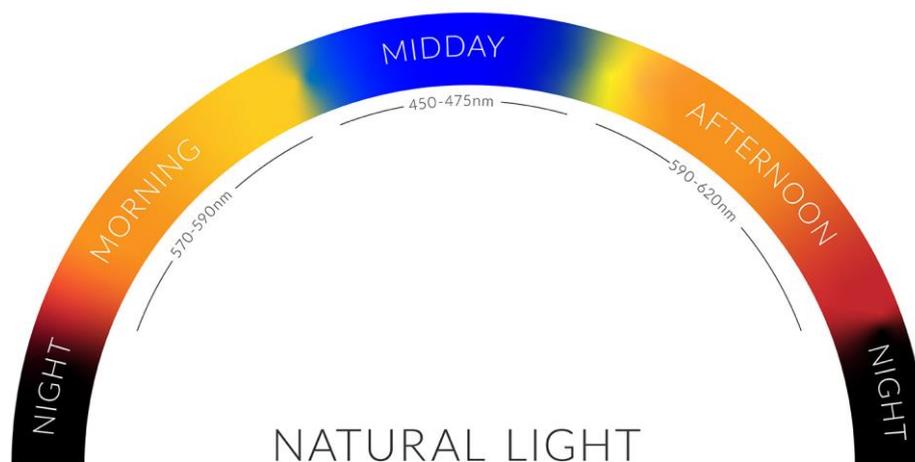


Figure 3. The science of light and health (Source: Rush, 2019)

Figure 3 illustrates how daylight shifts from a warmer color spectrum in the morning to a blue spectrum, which is dominant during the day, and then reverts to warmer tones in the evening. Our eyes and brain pick up cues from this natural day/night cycle, signaling our bodies when to be alert and when it's time to sleep. Consequently, exposure to bright blue light in the evening can interfere with sleep, while darker, warmer light in interior environments during the day may decrease alertness.

3.2. The Effect of Daylight on Mood

The influence of light operates through both retinal and extra-retinal pathways, highlighting its diverse and intricate effects that extend beyond mere vision. These effects include alterations in mood and behavior as well as physiological impacts on autonomic arousal and hormone levels (Stone et al., 1999). Research by Heerwagen and Orians (1986) has demonstrated that the absence of windows can lead to negative psychological outcomes, with findings showing that individuals in windowless offices tend to add over twice as many visual materials to their spaces. Additionally, there is a notable connection between daylight and mood, exemplified by the higher rates of seasonal affective disorder (SAD) observed in countries far from the equator during winter months. Common symptoms of SAD include decreased activity, social withdrawal, and mood changes, including heightened sadness (Küller, 2002).

3.2.1. Definition of Mood

“In a broad sense, “mood” may be defined as the affective background, and emotional color to our behaviors” (Davidson, 1994). Although the terms mood and emotion are often used interchangeably by the general public and even by psychologists to describe certain aspects of affect, the distinction between the two lies primarily in their duration and intensity (Davidson, and Ekman, 1994). Moods are defined as longer-lasting but less intense emotional states, whereas emotions are typically more intense and short-lived (Wessman, and Ricks, 1966).

Russell (1980), developed a theoretical model (figure 4) to demonstrate the different dimensions of mood states that he placed on a circular dimension that consisted of two axes: pleasantness/unpleasantness states (on the horizontal axis) and the degree of arousal (on the vertical axis).

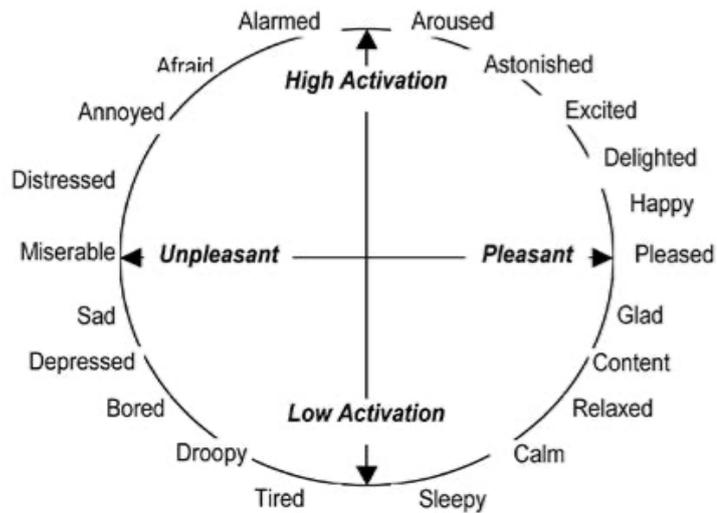


Figure 4. A circumplex model of affect (Source: Russell, 1980)

Affective categories were established through a combination of two axes. The first quadrant encompasses arousal-increasing and pleasant emotional states, represented by common terms like "happy," "excited," or "astonished." The second quadrant features arousal-decreasing yet pleasant states, reflected in words such as "content," "relaxed," or "calm." The third quadrant signifies arousal-decreasing and unpleasant states, illustrated by terms like "tired," "bored," "depressed," and "sad." Lastly, the fourth quadrant relates to arousal-increasing and unpleasant emotional states, including "distressed," "annoyed," or "afraid" (Russell, 1980).

In 1988, Watson, Clark, and Tellegen created the PANAS method based on the circumplex model. Watson and Tellegen proposed that moods and emotions can be evaluated across two dimensions: positive affect (PA) and negative affect (NA).

3.2.2. Assessment of Mood

Overall, the design and layout of work environments can have a significant impact on office workers' mood, stress levels, and job satisfaction. Employers should consider factors such as noise levels, lighting, air quality, office layout, and access to natural elements when they have their workspaces designed, to create a positive and productive work environment for their employees.

3.2.3. Mood in Work Environments

Several studies have explored the impact of work environments on office workers' mood. The design and layout of an office space, as well as factors such as lighting, temperature, noise levels, and office layout, can all play a role in shaping workers' moods and overall well-being.

One study by Hedge et al. (2004), found that factors such as noise levels, lighting, and air quality in the workplace significantly impacted workers' moods, with poor conditions leading to increased stress and decreased job satisfaction. Another study by Kim, and de Dear (2013), examined the impact of office layout on workers' mood and found that open-plan office layouts were associated with higher levels of stress and lower levels of job satisfaction compared to more private or partitioned office spaces.

Research by Jung et al. (2014), also highlighted the importance of natural elements in office design, such as plants and outdoor views, in promoting positive mood and well-being among office workers. Similarly, a study by Nieuwenhuis et al. (2014), found that access to natural light in the workplace was associated with improved mood, job satisfaction, and overall well-being among employees.

Daylight has been shown to have a significant impact on office workers' mood in work environments. Exposure to natural light, such as daylight, has been linked to improved mood, higher job satisfaction, and increased productivity among office workers.

One study by Boubekri et al. (2008), found that workers with access to daylight in their work environments reported higher levels of job satisfaction and lower levels of stress compared to workers without access to natural light. Another study by Veitch et al. (2006), showed that workers with access to daylight in their offices reported greater levels of well-being and alertness. Furthermore, exposure to natural light has been found to reduce symptoms of depression and increase overall satisfaction among office workers (Beauchemin, and Hays, 1996). A study by Hadi et al. (2012), found that office workers with access to daylight reported higher levels of job satisfaction and lower levels of fatigue compared to workers without access to natural light.

The presence of daylight in work environments has been associated with positive

effects on office workers' mood, job satisfaction, and productivity. It is important for employers to consider natural light exposure in office design to promote a healthy and productive work environment for their employees.

3.2.4. Effect of Mood on Performance

Numerous studies have investigated how work environments affect the moods of office workers. The design and arrangement of an office, along with elements like lighting, temperature, noise levels, and layout, can significantly influence employees' moods and overall well-being. For instance, Hedge et al. (2004) found that workplace conditions, including noise, lighting, and air quality, greatly impacted workers' moods, with unfavorable conditions resulting in heightened stress and lower job satisfaction. In a separate study, Kim and de Dear (2013) explored how office layout affects mood and discovered that open-plan designs were linked to increased stress and decreased job satisfaction compared to more private or partitioned workspaces.

Research by Jung et al. (2014) underscored the importance of incorporating natural elements, such as plants and outdoor views, into office designs to foster a positive mood and well-being among employees. Similarly, Nieuwenhuis et al. (2014) found that access to natural light in the workplace was associated with enhancements in mood, job satisfaction, and overall well-being.

Daylight significantly impacts office workers' mood in their work environments. Exposure to natural light has been correlated with improved mood, greater job satisfaction, and heightened productivity. For example, Boubekri et al. (2008) reported that workers who had access to daylight in their environments experienced higher job satisfaction and reduced stress compared to those without natural light. Veitch et al. (2006) also showed that employees with daylight access in their offices felt more alert and had better well-being. Furthermore, natural light exposure is known to alleviate depression symptoms and increase overall satisfaction among office workers (Beauchemin, and Hays, 1996). Hadi et al. (2012) found that workers exposed to daylight reported greater job satisfaction and less fatigue compared to those without access to natural light.

Overall, the presence of daylight in work settings is linked to positive impacts on

employees' mood, job satisfaction, and productivity. Therefore, it is essential for employers to consider incorporating natural light into office designs to cultivate a healthy and productive work environment for their staff.

3.2.5. Effect of Mood on Creativity

The mood of office workers can have a significant impact on their creativity in work environments.

A study conducted by Baas et al. (2008) examined the connection between mood and creativity, discovering that individuals in a positive mood were more inclined to engage in flexible thinking and develop creative solutions compared to those in neutral or negative moods. Research by Isen et al. (1985) further demonstrated that positive emotions can expand attention and cognitive processes, resulting in enhanced creativity. Moreover, George, and Zhou (2001) highlighted how a positive mood contributes to creativity by boosting intrinsic motivation, cognitive flexibility, and openness to new ideas. They found that individuals experiencing positive moods were more likely to exhibit exploratory behavior and come up with innovative solutions to challenges.

In another study, De Dreu et al. (2008) looked at the effects of positive and negative emotions on creativity within group contexts, emphasizing how a positive mood fosters collaborative creativity and idea generation among team members. Overall, mood plays a vital role in influencing the creativity of office workers in their work environments, with positive emotions enhancing creative thinking and the generation of ideas.

3.3. The Effect of Daylight on Circadian Rhythm

Many studies have been conducted to understand the effect of daylight on circadian rhythms. A person's circadian rhythm can be studied to understand human health and well-being because circadian rhythms govern the body's internal clock and regulate sleep-wake cycles, hormone release and various physiological processes. While it is easy to get daylight in the summer months, it is very difficult to get enough daylight in the winter months, especially for those who work indoors. Going out in the dark

hours and returning to work in the dark hours, working in unlit areas also make it difficult to get daylight. Exposure to natural light during the day is essential to synchronize these rhythms, as it affects the production of melatonin, a hormone responsible for promoting sleep. Studies have shown that adequate daylight exposure can help maintain the natural circadian cycle, leading to improved sleep quality and increased alertness during waking hours (Chellappa et al., 2019). Inadequate natural light, especially in modern work environments that rely heavily on artificial lighting, can disrupt these rhythms and lead to a number of health problems, including sleep disturbances, depression and reduced cognitive performance (Rüger et al., 2013). Including daylight in the design of office spaces and raising awareness among business owners can support the natural circadian rhythm and create a healthier and more productive environment for individuals.

3.3.1. Definition of Circadian Rhythm

“A circadian rhythm or circadian cycle, is a natural, internal process that regulates the sleep wake cycle and repeats roughly every 24 hours” (NICHD, 2019). The human sleep cycle is an example of a circadian rhythm and is shifted based on light levels (Millett, 2014). It is a system in our body that not only regulates sleep, but also schedules many functions.

Circadian rhythms are the mental, physical, and behavioral changes and patterns that occur throughout the day, as we and other living organisms respond to external stimuli. Research has demonstrated that exposure to light, especially blue light, can help maintain or even modify the body's circadian clock (Lowres, 2018). A circadian rhythm, also known as a circadian cycle, is a natural internal process that governs the sleep-wake cycle, repeating approximately every 24 hours (NICHD, 2019). The human sleep cycle serves as an example of such a rhythm, which is influenced by light levels (Millett, 2014). This system in our body regulates not only sleep but also schedules various physiological functions.

Figueiro et al. (2002) and Heerwagen (1990) assert that bright daylight possesses therapeutic benefits. It helps regulate circadian rhythms, boosts mood, supports neurological health, and influences alertness. Studies conducted in hospital

environments indicate that patients in well-lit rooms recover from illnesses more quickly, experience lower levels of pain, require fewer strong analgesics, and spend less time in the hospital compared to those in darker rooms, particularly those situated on the north side or in areas where nearby buildings obstruct sunlight (Walch et al., 2005). The advantages of sunlight can also be felt during brief outdoor walks on sunny days or through the design of spaces that incorporate daylight and sunlight within the interior (Heerwagen, 2009).

Light exposure to the retina influences human physiology and behavior by directly activating the brain's biological clock (Turek, 2016). In environments with constant darkness, the human circadian clock tends to free-run with a cycle that is typically just longer than 24 hours. To effectively advance and synchronize the biological clock to align with local time on Earth, consistent morning light exposure is essential (Jewett et al., 1997). Figure 5 represents humans' 24 hours daylight cycle. Between noon and midnight, humans have the best sleep. Between midnight and noon corresponds to the deepest sleep.

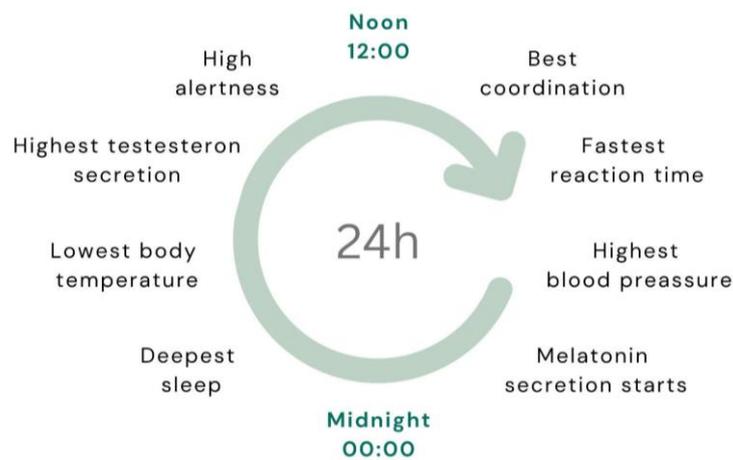


Figure 5. 24 Hour daylight cycle (Source: Ledsky, 2020)

3.3.2. Circadian Rhythm in Work Environment

Exposure to daylight is vital for regulating the circadian rhythms of office workers in their work environments. The circadian rhythm functions as the body's internal clock, overseeing the sleep-wake cycle, hormone production, and various physiological processes. Access to natural light, particularly in the morning, is key to synchronizing

the circadian rhythm, thereby enhancing overall health and well-being.

A study conducted by Boubekri et al. (2008) explored how daylight exposure affects office workers' circadian rhythms and found that those with access to natural light displayed more consistent sleep-wake cycles and greater alertness than their counterparts working under artificial lighting. This indicates that exposure to daylight can help sustain a healthy circadian rhythm and enhance sleep quality among office workers.

Research by Figueiro, and Rea (2012) also emphasized the role of light exposure in regulating circadian rhythms and supporting overall health. They revealed that exposure to bright light in the morning is crucial for aligning the circadian system, leading to improved sleep quality, alertness, and cognitive performance. Additionally, a study by Viola et al. (2008) investigated the effects of office lighting on circadian rhythms and discovered that workers with greater light exposure during the day had more stable circadian rhythms and better sleep quality than those exposed to lower light levels.

3.4. The Effect of Daylight on Well-being

The impact of daylight on well-being is one of the key lines of research pointing to the impact of natural light on physical and mental health. It has been emphasized in previous research that lack of daylight during the day can lead to some problems, especially in office workers. One of these studies, Keller's study, found that exposure to daylight significantly improves mood, reduces stress and improves overall psychological health. For example, exposure to natural light was associated with higher levels of serotonin, a neurotransmitter associated with feelings of happiness and well-being (Keller et al., 2004). In work environments, access to daylight has been found to increase productivity and job satisfaction while reducing fatigue and absenteeism (Boubekri et al., 2008). In addition, daylight plays an important role in regulating circadian rhythms that affect sleep quality and overall health (Chellappa et al., 2019).

3.4.1. Definition of Well-being

The well-being of a person is what is good for this person (Sumner, 2011). According to Naci and Ioannidis (2015), “Wellness refers to diverse and interconnected dimensions of physical, mental, and social well-being that extend beyond the traditional definition of health ”.

Well-being refers to the states of health, happiness, and prosperity, encompassing good mental health, high life satisfaction, a sense of purpose, and the ability to cope with stress. In broader terms, well-being is simply about feeling good (Davis, 2019).

Abraham Maslow (1962) was among the early psychologists to articulate the concept of “well-being,” focusing on the traits of self-actualized individuals. His definition of self-actualization anticipated the PERMA model, which outlines the attributes of a flourishing individual and forms the basis for Wellbeing Theory (WBT). In his book "Flourish" (2011), Seligman posited that a "meaningful life" could be categorized into three distinct areas, leading to the creation of the acronym PERMA (Figure 6). According to Seligman (2011), these five core components can guide people toward a life rich in fulfillment, happiness, and meaning. This model is not only applicable to individuals but can also be adapted for institutions to create programs aimed at enhancing cognitive and emotional skills.

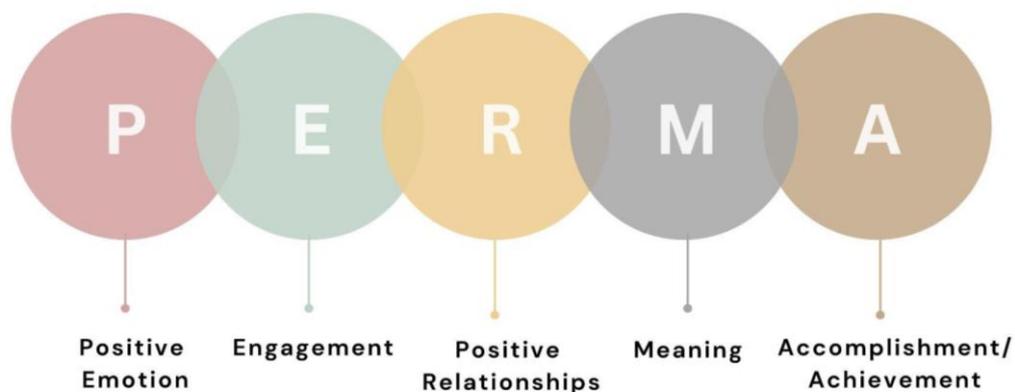


Figure 6. PERMA Model (Source : <https://optimisticspark.com/the-5-segments-of-positive-psychology-perma-model/>, 2011)

Positive emotions encompass a broad spectrum of feelings beyond just happiness and joy (Sze, 2015). This range includes emotions such as excitement, satisfaction, pride, and awe, among others. In the PERMA model, relationships refer to the sense of being supported, loved, and valued by others. The inclusion of relationships in this model stems from the understanding that humans are fundamentally social beings (Seligman, 2012).

Seligman (2012) elaborated on the concept of meaning as the feeling of belonging to something greater than oneself. Having a purpose in life enables individuals to concentrate on what truly matters, especially when confronted with significant challenges or adversity.

In the PERMA model, accomplishment is often referred to as achievement, mastery, or competence. A sense of accomplishment arises from setting and achieving goals, mastering a particular skill, and being self-motivated to complete tasks. This sense of achievement enhances well-being, as it allows individuals to reflect on their lives with pride (Seligman, 2012).

Carol Ryff's (1989) multidimensional model of psychological well-being (Figure 7) identifies six essential factors that contribute to overall well-being. This Six-factor Model of Psychological Well-being outlines the key elements that foster an individual's psychological well-being, satisfaction, and happiness.



Figure 7. The Six-factor Model of Psychological Well-being (Source: Ryff, 1989)

Psychological well-being encompasses positive relationships with others, personal mastery, autonomy, a sense of purpose and meaning in life, as well as opportunities for personal growth and development (Ryff, 1989). It is achieved through maintaining a balance that is influenced by both challenging and rewarding life experiences (Dodge et al., 2012).

Emotional well-being involves the capacity to employ stress-management and relaxation strategies, exhibit resilience, foster self-love, and cultivate emotions that contribute to positive feelings (Davis, 2019).

Emotional well-being refers to the emotional experiences of an individual (Kahneman, and Angus, 2010) and is shaped by various demographic, economic, and situational factors (Yang, and Ma, 2020). A decline in emotional well-being can lead to mental health issues such as stress, depression, and anxiety (Harvard Health Publications, 2010).

Much of the foundational psychological research on well-being has concentrated on the factors that contribute to individual differences in subjective well-being (Kahneman, Diener, and Schwarz, 1999). Subjective well-being is generally defined as how individuals assess their lives both at present and over extended periods, such as the preceding year (Diener, Oishi, and Lucas, 2003).

3.4.2 Well-being in Work Environments

Well-being in work environments is a multifaceted condition encompassing the physical, mental and emotional health of employees and significantly affects employee productivity and overall job satisfaction. Supporting the environment with natural elements, designing a healthy environment, ergonomic furniture and adequate light, especially daylight, are important factors in achieving this well-being. Research shows that environments that prioritize well-being led to lower stress levels and higher motivation among employees (Van der Voordt, and Jensen, 2021). Furthermore, the integration of biophilic design principles, such as the inclusion of natural elements (water, plants, organic materials, natural products, daylight), has been supported to lift employee mood and promote a sense of belonging in the workplace (Kellert, 2005).

The impact of daylight on well-being and the effects of natural light on physical and mental health have long been a subject of research. It has been emphasized in previous studies that lack of daylight during the day may cause some problems, especially in office workers. Various sources indicate that certain features of the physical environment can negatively impact the psychological well-being of office workers. Research in organizational and environmental psychology has found links between physical office conditions such as temperature, ventilation, lighting, and workstation design and employee attitudes and behaviors, particularly in relation to comfort, satisfaction, and turnover rates (Oldham, and Fried, 1987).

3.5. The Effect of Mood on Well-Being

Research consistently shows that exposure to natural daylight has a positive impact on mood and overall psychological well-being. In a study by Boubekri et al. (2014), it was found that workers exposed to more natural light in their workplaces reported increased energy levels, enhanced mood, and better general health compared to those with limited natural light. Daylight plays a crucial role in stimulating the brain's production of serotonin, a neurotransmitter that helps regulate mood, contributing to greater happiness and lower stress levels (Lambert et al., 2002). Additionally, natural light diminishes the occurrence of work-related discomforts such as eyestrain, headaches, and fatigue, which are often linked to extended exposure to artificial lighting (Veitch, and McColl, 2001). These benefits help create a more comfortable and productive work environment, ultimately improving job satisfaction and employee retention.

Browning et al. (2014) introduced the "14 Patterns of Biophilic Design" as part of a framework that connects human biological sciences and nature with the design of built environments. This framework provides a set of tools to enhance design opportunities and applications aimed at improving the health and well-being of individuals and society. While biophilia serves as the underlying theory, biophilic design as promoted by Kellert et al. (2008) and Beatley (2010) presents a sustainable design approach focused on reestablishing people's connection to the natural environment.

These patterns were established through extensive interdisciplinary research and are backed by empirical evidence along with the contributions of notable figures such as Christopher Alexander, Judith Heerwagen, Rachel and Stephen Kaplan, Stephen Kellert, Roger Ulrich, and others. Researchers analyzed over 500 publications related to biophilic responses to identify patterns that would be beneficial for designers working in built environments. The resulting 14 patterns can be applied in a variety of interior and exterior settings, offering flexibility in their use to suit different projects (Browning, Ryan, and Clancy, 2014). Each pattern outlines specific methods for integrating natural elements like daylight, vegetation, and water features into architectural and interior design. These patterns (table 3) are categorized under three main headings: Nature in the Space Patterns, Natural Analogues Patterns, and Nature of the Space Patterns.

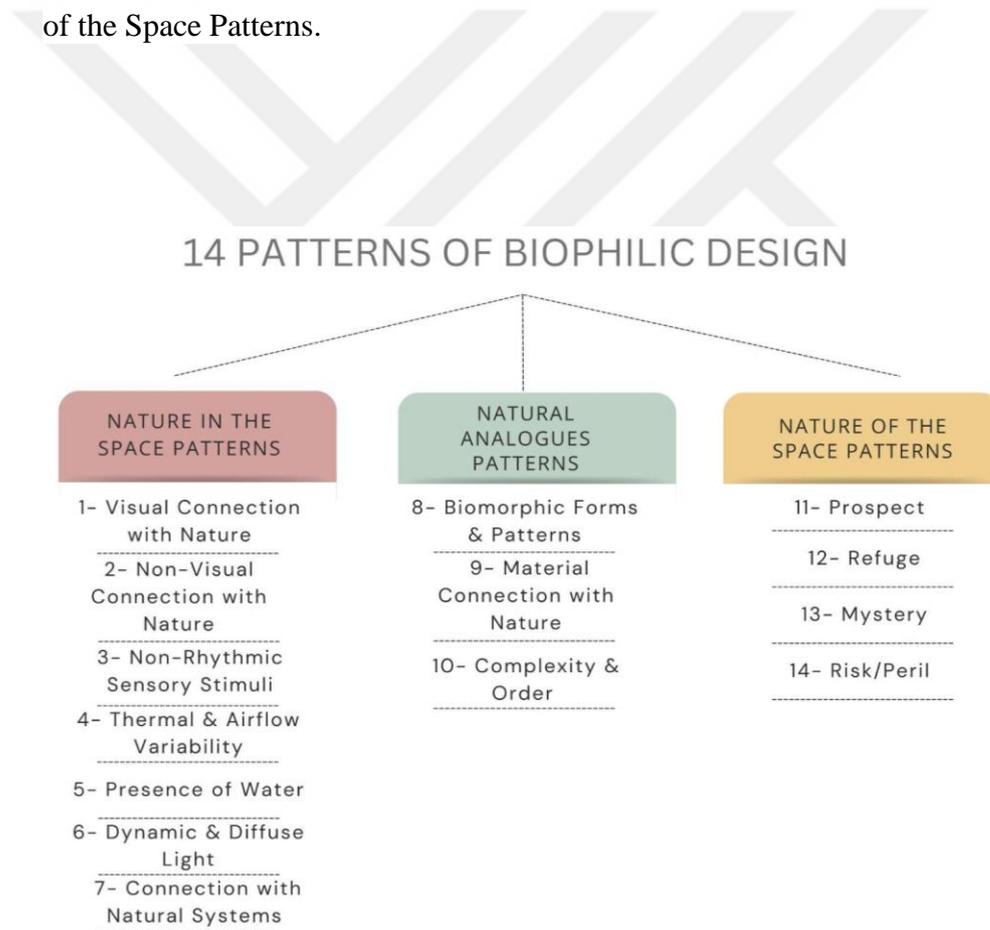


Figure 8. 14 Patterns of Biophilic Design (Source: Browning, Ryan, and Clancy, 2014)

CHAPTER 4: METHODOLOGY

4.1. Evidence-Based Research

Evidence-based research is of crucial importance as evidence to support topics in scientific research. Especially looking at Ulrich's 2007 research on biophilic design based on physiological data of patients in hospitals, it can be emphasized that evidence-based research is also important for biophilic approach. Presenting the case study for research with evidence strengthens the research.

“Evidence-based research is the use of prior research in a systematic and transparent way to inform a new study so that it is answering questions that matter in a valid, efficient, and accessible manner” (Robinson, 2009).

The evidence-based research approach focuses on ensuring that meaningful studies are carried out by carefully planning and designing new research while also considering how these new findings fit within the body of existing evidence (Robinson et al., 2021).

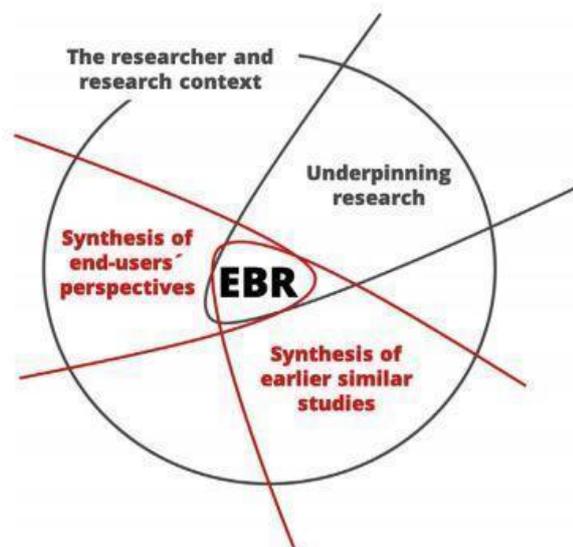


Figure 9: What EBR is and why is it important? (Source: Robinson KA et al.,2021)

Traditionally, researchers develop new research questions based on their scientific environment, personal interests, ambitions, and foundational knowledge in epidemiology and basic science. However, the evidence-based research approach

recommends that, alongside these factors, researchers should adopt a systematic and transparent method that explicitly incorporates previous studies and takes into account the perspectives of end users (Robinson et al., 2021) (Figure 8).

Figure 9 presents the three key phases of research and illustrates the use of an evidence-based research approach during the planning phase before the actual study (Robinson, 2021).

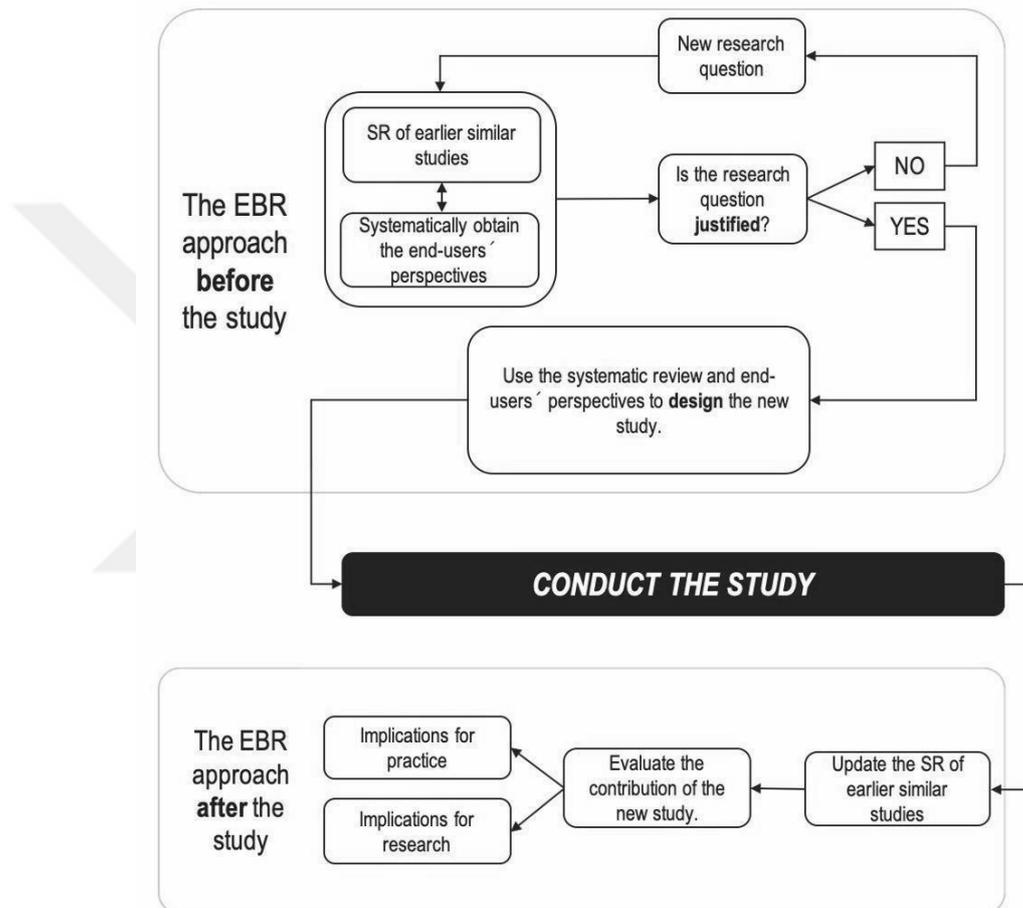


Figure 10. The evidence-based research approach and outline. *What Evidence-Based Research is and why is it important?* (Source: Robinson et al., 2021)

The first phase deals with the challenge of whether a research question is justifiable? (Robinson, 2021). The second phase is related to the case study.

Scientific research findings can provide valuable insights for designers in a variety of ways (Ulrich, 1997). Designing healthcare buildings presents a significant architectural challenge and interest in evidence-based design (EBD) has grown since

Ulrich's 1984 study on the impact of landscapes on patient well-being (Ulrich et al., 2008). Making informed design choices from the outset can improve occupant health (Huisman et al., 2012), enhance the quality-of-service delivery (Grazier, 1999), and reduce life-cycle costs (Harris, and Fitzgerald, 2015). This research highlights the importance of evidence-based design (EBD) in healthcare architecture and demonstrates that thoughtful design can enhance patient well-being, improve service efficiency and reduce costs.

4.2. The Positive and Negative Affect Schedule (PANAS)

In this study, the mood was assessed based on 10 positive mood and 10 negative mood scales brought from PANAS (The Positive and Negative Affect Schedule). Watson, Clark, and Tellegen developed the PANAS method in 1988 to provide a better, purer measure of the dimensions. The Positive and Negative Affect Schedule or (PANAS) is a scale that consists of different words that describe feelings and emotions. (Magyar-Moe, 2009). The positive mood scales are; attentive, active, alert, excited, enthusiastic, determined, inspired, proud, interested, and strong. The negative mood scales are; hostile, irritable, ashamed, guilty, distressed, upset, scared, afraid, jittery, and nervous.

The PANAS is widely used as a self-reported measure of affect in both clinical and community settings (Merz et al., 2013). This psychometric scale is designed to show the relationship between positive and negative emotions and people's mood in relation to specific personality traits. Participants using the PANAS assess their emotions by responding to a 20-item questionnaire.

Both clinical and non-clinical research has shown that the PANAS is a valid and reliable tool for measuring positive and negative emotions (Merz et al., 2013). It monitors the emotional state of clients on a weekly basis as they go about their daily lives. (Magyar-Moe, 2009). The PANAS can also serve as a tool to assess the immediate effects of therapy and outcomes linked to positive psychological exercises, interventions or activities. The scale is particularly effective in capturing momentary changes in affect when clients complete the questionnaire reflecting their current feelings. Participants rate their emotions using a 5-point scale (Figure 11) to indicate the relevance of various concepts (Mulder, P., 2018).



Figure 11. PANAS 5-point scale

Scores can range from 10-50 for both the Positive and Negative Affect with the lower scores representing lower levels of Positive/Negative Affect and higher scores representing higher levels of Positive/Negative Affect. (Watson, Clark, and Tellegan, 1988). The PANAS displays a very good internal reliability that is consistent with scores ranging from 0.86 to 0.90 for PA and 0.84 to 0.87 for NA. (Magyar-Moe, 2009). Additional versions of the PANAS scale (Figure 12) have been created over time (Mulder, P., 2018). A few of these are:

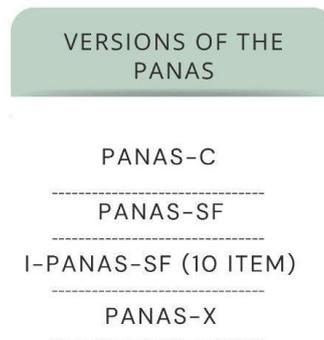


Figure 12. PANAS Versions

PANAS-X is an updated and more detailed version of the original assessment, created by Watson and Clark in 1994. One of its advantages is that it can be completed in about 10 minutes, making it a more efficient tool. The assessment is divided into three main sections:

The first section includes basic negative emotions like guilt, sadness, and fear. The

second section focuses on positive emotions, such as confidence, attentiveness, and joy. The third section covers other affective states, including surprise, tranquility, and shyness (Watson, and Clark, 1994).

Further studies have shown that the PANAS-X scales are consistent over time, demonstrating strong convergent and discriminant validity when compared with peer assessments. Additionally, they correlate well with similar measures of overall affect and are closely linked to personality traits and emotional responses (Watson, and Clark, 1994).



CHAPTER 5: CASE STUDY

This chapter outlines the approach to the application of the study, stages, challenges, as well as findings. This detailed account is aimed for transparency and further elaboration of the study for other researchers.

The preparation for the Case study started with application for the ethical report and Application for BAP 2024-03 (Scientific Research Project) processes in October 2023. Until the equipment arrives in September 2023, the documents, tables, and plan of the study were prepared, as well as the survey and PANAS tests. The participants of the study were interviewed and relevant examinations and research were conducted in the places where the tests would be conducted. The watches, measurements to be made and related details were prepared. A user guide prepared for smart watch usage was sent to the participants and information was provided on smart watch usage. This user guide can be accessed from the appendix. On September 23, 2024, trial measurements with smartwatches and sample study started. On the week of September 30, the experiment measurements started and a 5-week data was obtained from the participants with smart watches and light measurements. The measurements end at the end of the 6th week for open offices. It is collected data from the survey. The PANAS test was administered to all participants and end in week 7, which started on November 4. From the week starting November 11, results and evaluations started to be made and in parallel.

5.1 Method

An evidence-based research method was used in the study. First of all, a literature review was conducted and drawings, information and visuals of the office spaces were collected. For the measurements to be made with smartwatches, reference test trials were conducted with 2 participants. Then, biological measurements were made for 5 weeks. 21 open office workers performed biological measurements and sleep monitoring with smartwatches for 5 weeks. Participants wore the watches for 6 nights and 7 days. One participant continued to wear the smartwatch during the day and

during sleep for 6 weeks. The required data were obtained from these measurements. Participants' daytime sinus rhythms, oxygen levels, total hours of daylight received during the day and the amount of light at table and eye levels were measured for 1 week. At the same time, measurements such as the light level on the table and at eye level in the area where the participants were sitting in the open office space were measured using a lux meter. The weekly schedule of smartwatches measurements can be observed from table 2. In parallel with these tests, a questionnaire on the use of daylight in offices developed using Likert scales was opened to the participants. The PANAS test was also administered to the participants whose measurements were completed with the smartwatch. The results of all measurements, surveys and tests were compared and evaluated in detail.

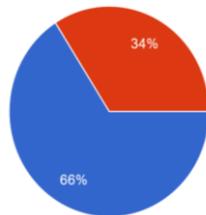
Table 2. Case study weekly schedule

WEEK 1 (23.09.24 - 29.09.24)			
Watch Code	Serial Number	Code	Notes
W01	DXRWY29PP2	E01	Not finish
W02	DD2WYWT401	D13	
W03	GH2L1243XV	E02	
W04	J1960X9034	D15	
W05	F03DJT9N7D	D20	
W06	FK6694TQXC	D12	
WEEK 2 (30.09.24 - 06.10.24)			
Watch Code	Serial Number		
W01	DXRWY29PP2	D09	
W02	DD2WYWT401	D05	
W03	GH2L1243XV	D14	
W04	J1960X9034	D15	
W05	F03DJT9N7D	D06	
W06	FK6694TQXC	D11	
WEEK 3 (07.10.24 - 13.10.24)			
Watch Code	Serial Number		
W01	DXRWY29PP2	D04	
W02	DD2WYWT401	D02	
W03	GH2L1243XV	D10	
W04	J1960X9034	D15	
W05	F03DJT9N7D	D03	
W06	FK6694TQXC	D01	
WEEK 4 (14.10.24 - 20.10.24)			
Watch Code	Serial Number		
W04	J1960X9034	D15	
Week 5 (21.10.24 - 27.10.24)			
Watch Code	Serial Number		
W01	DXRWY29PP2	D08	
W02	DD2WYWT401	D02	
W03	GH2L1243XV	C03	
W04	J1960X9034	D15	
W05	F03DJT9N7D	C02	
W06	FK6694TQXC	D07	
Week 6-7 (30.10.24 - 04.11.24)			
Watch Code	Serial Number		
W04	J1960X9034	D15	
W06	FK6694TQXC	D07	

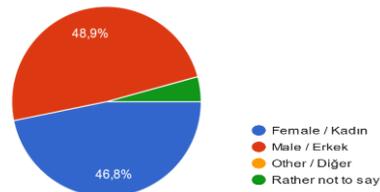
5.1.1. Participants

The study was implemented in the D Block Fifth Floor Open Office, C Block 9th floor Open office and E block Ground Floor Promotion Office. All office spaces used in the study are in the same campus, but some of them in different buildings. The participants consist of 16 research assistants, 3 administrative staff, 2 lecturers which working in the open office space of block D, C and E. 3 research assistants are working in the open office space of the 9th floor of block C, 13 research assistants and one administrative staff are working in the open office space of the 5th floor of block D and 2 administrative staff are working in the promotion office of Block E ground Floor. A total of 21 people, 17 women and 4 men, participated in the tests conducted with smart watches and the PANAS survey. A total of 47 people (figure 13) participated in the questionnaire, 66% of whom were female and 34% were male. 48.9 percent of the participants are between the ages of 35-49, 46.8 percent are between the ages of 20-34, and 4.3 percent of the participants are over the age of 64 (figure 14). 55.3 percent of the participants are high school graduates, 38.3 percent are associate's and bachelor's degree graduates, and 6.4 percent are postgraduates (figure 15). In addition, 61.7 percent of the participants work at Izmir University of Economics and 38.3 percent work at different institutions (figure 16). Lastly, the occupational distribution of these participants can be accessed from the graph in figure 17.

Gender / Cinsiyetiniz
47 yanıt



Age / Yaş
47 yanıt



● Female / Kadın
● Male / Erkek
● Other / Diğer
● Rather not to say

● 20 - 34
● 35 - 49
● 50 - 64
● 64 +

Figure 13. Gender distribution

Figure 14. Age distribution

Education / Eğitim
47 yanıt

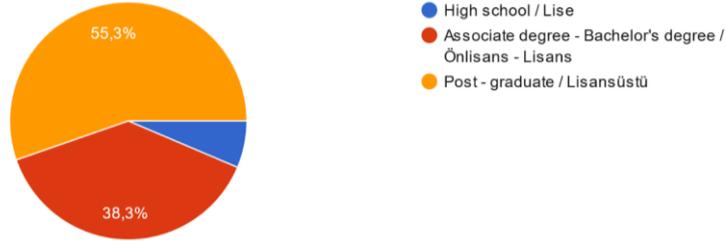


Figure 15. Education distribution

I work at Izmir University of Economics and I am a participant in the smartwatch test of this thesis.
/ İzmir Ekonomi Üniversitesinde çalışıyorum ve bu tez çalışmasının akıllı saat testinde katılımcıyım.
47 yanıt

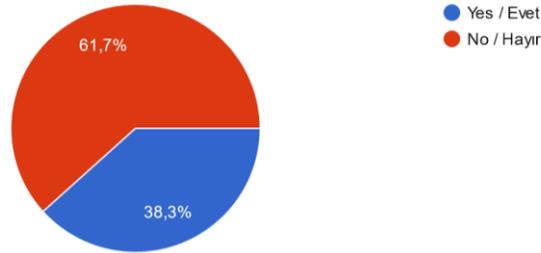


Figure 16. Test participants distribution

Profession / Meslek
47 yanıt

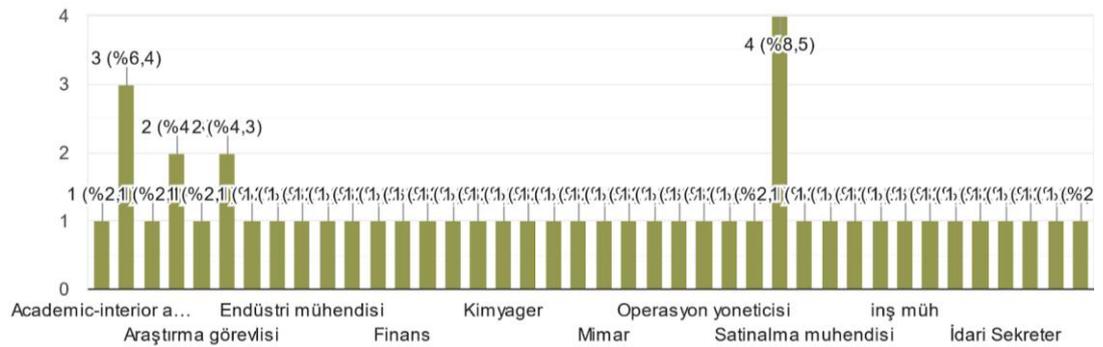


Figure 17. Profession distribution

5.1.2. Research Tools and Instruments

In the study, 6 smart watches purchased with a scientific research project (BAP), PANAS survey, questionnaire and a lux meter were used as research tools and instruments. First of all, when choosing the smartwatch, many watches were examined in terms of the details of the measurements and the ease of providing the data. As can be seen in table 3 below, after searching for 5 smartwatches that can perform the measurements, the Apple watch was the one that provided the most data to be measured and therefore this is the smartwatch chosen for the research.

In the measurements made with Apple watch, measurements such as ECG, oxygen saturation measurement and sleep tests, daily daylight intake could be made rapidly and practically, and Apple watch (HRV) Heart Rate Variability value was also measured in detail. *(HRV) Heart Rate Variability is a measure of the variation in the time interval between heart beats. Apple watch calculates HRV by using the standard deviation of beat-to-beat measurements which are captured by the heart rate sensor. HRV is validated for users over the age of 18.

	Apple Watch Series 9	Xiaomi Mi Watch	Huawei Watch 3 Pro	Samsung Galaxy Watch 4	Fitbit Versa 3
Daily record	✓	✓	✓	✓	✓
24 Hour Heart-rate monitoring	✓	✓	✓	✓	✓
Sleep monitoring	Using skin conductivity and temperature measurements	✓			✓
Stress level monitoring	With the stress monitor app	✓			
Breathing exercises	Aid mental health care, offering activities such as breathing exercises to offset stress signals, responding early to changes in mental health.	✓			
Oxygen saturation	✓	✓	✓	✓	✓
Vital signs	✓	✓			
ECG analysis	✓	✓	✓	✓	
High and varied heart rate notifications Irregular rhythm notification	HRV		✓		✓
Body temperature	✓		✓		
Blood pressure	With the app				
Heart rate	✓	✓	✓	✓	✓

Table 3. Smartwatches Comparison and Features, 2023

A team of researchers from the University of Waterloo, Canada, explored the Apple Watch’s ECG sensor in some depth and found that the Apple Watch ECG sensor data could be used to develop a robust and accurate stress prediction tool. Using the Apple Watch ECG sensor, the researchers found that there was a close association between ECG data, including heart acceleration and deceleration capacity, and participants’ reported stress levels at the time the readings were taken. Machine learning algorithms were then developed using this information to create a prediction model (Charlton, 2022).

Participants repeated the ECG measurements every hour during working hours. Electrocardiography (ECG) is a test that records the timing and strength of the electrical signals that make the heartbeat. These measurements were performed with

the skin conductivity tool by holding the participants' fingers to the watch wrist for 30 seconds (Figure 18). A report is displayed on the phone screen as a result of the measurement. In this report, the ECG result of the participant is analyzed and the number of sinus rhythms of the participant is based on (Figure19). As can be seen in Figures 20, 21 and 22, ECG results are sinus rhythm, atrial fibrillation, low or high heart rate, inconclusive or poor recording. If a poor measurement was made by the user, it was immediately detected and the ECG was repeated. Sinus rhythm values and oxygen saturation levels were measured every hour during the day. In a healthy individual over 18 years of age, the average sinus rhythm value is between 60 and 100 bpm (EDTH,2024). It is also seen that it can exceed 10 in rhythm-increasing activities such as sports, walking, etc.

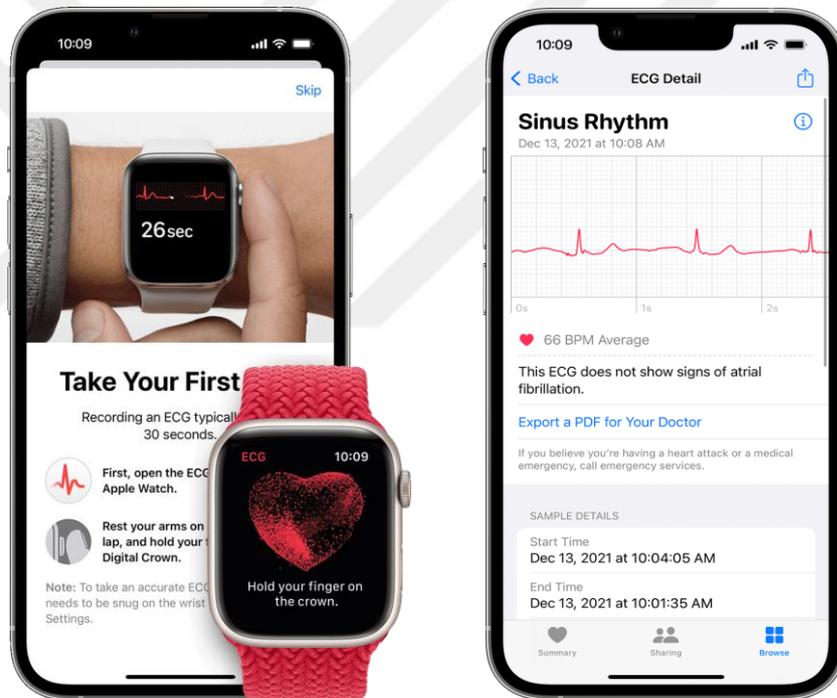


Figure 18. The results of ECG (Source: Apple guide, 2024) Figure 19. ECG Test (Source: Apple guide, 2024)

After a successful reading, you will receive one of the following type of results on your ECG app. Regardless of the result, if you aren't feeling well or are experiencing any symptoms, you should talk to your doctor.



Sinus rhythm

A sinus rhythm result means the heart is beating in a uniform pattern between 50 and 100 BPM. This happens when the upper and lower chambers of the heart are beating in sync. A sinus rhythm result only applies to that particular recording and doesn't mean your heart beats with a consistent pattern all the time. It also does not mean that you're healthy. If you're not feeling well or are feeling any symptoms, you should talk to your doctor.



Atrial fibrillation

An AFib result means the heart is beating in an irregular pattern. AFib is the most common form of serious arrhythmia, or [irregular heart rhythm](#). If you receive an AFib classification and you have not been diagnosed with AFib, you should talk to your doctor. The ECG app ver. 1 can check for AFib between 50 and 120 BPM. The ECG app ver. 2 can check for AFib between 50 and 150 BPM.

Learn more [about ECG app version availability](#) and find out which version you're using.



Figure 20. ECG Results 1 (Source: Apple guide, 2024)

Low or high heart rate

A heart rate under 50 BPM or over 120 BPM in ECG version 1 affects the ECG app's ability to check for AFib. In ECG version 2, a heart rate under 50 BPM or over 150 BPM can affect the ECG app's ability to check for AFib.

- A heart rate can be low because of certain medications or if electrical signals are not properly conducted through the heart. Training to be an elite athlete can also lead to a low heart rate.
- A high heart rate could be due to exercise, stress, nervousness, alcohol, dehydration, infection, AFib, or other arrhythmia.



Inconclusive

An inconclusive result means the recording can't be classified. It could be due to one of the following situations:

- In ECG version 1, your heart rate is between 100 and 120 BPM and you are not in AFib.
- You have a pacemaker or implantable cardioverter defibrillator (ICD).
- The recording may show signs of other arrhythmias or heart conditions that the app is not designed to recognize.
- Certain physiological conditions may prevent a small percentage of users from creating enough signal to produce a good recording.

Figure 21. ECG Results 2 (Source: Apple guide, 2024)

Poor Recording

This classification is unique to ECG version 2. Poor Recording means the result can't be classified. If you get a Poor Recording result, there are a few things you can try in order to get a better recording.

- Rest your arms on a table or in your lap while you take a recording. Try to relax and not move too much.
- Make sure that your Apple Watch isn't loose on your wrist. The band should be snug and the back of your Apple Watch needs to be touching your wrist.
- Make sure that your wrist and your Apple Watch are clean and dry. Water and sweat can cause a poor recording.
- Make sure that your Apple Watch is on the wrist you selected in Settings.
- Move away from any electronics that are plugged into an outlet to avoid electrical interference.

Figure 22. ECG Results 3 (Source: Apple guide, 2024)

The users were able to perform the oxygen saturation in 15 seconds every hour. This measurement was performed with the skin conductivity tool by holding the finger on the clock wrist as in the ECG measurement (figure 22). The blood oxygen level represents the percentage of oxygen your red blood cells carry from the lungs to the rest of the body. The majority of people have a blood oxygen level of 95 - 100%. However, some people live a normal life with blood oxygen levels below 95%. Slightly lower values while sleeping are expected, and some users might experience values below 95% (Apple guide, 2024).



Figure 23. Measurement of oxygen level in blood (Source: Apple guide, 2024)

The mood was assessed based on 10 positive mood and 10 negative mood scales brought from PANAS. Watson, Clark, and Tellegen to provide a better, purer measure

of the dimensions, developed the PANAS method in 1988. Since the PANAS is a self-report questionnaire, it can be difficult to assess people's mood accurately, as people can overstate or understate their experience of their moods (Thompson, 2007). The ten positive mood scales are; attentive, active, alert, excited, enthusiastic, determined, inspired, proud, interested, and strong. The negative mood scales are; hostile, irritable, ashamed, guilty, distressed, upset, scared, afraid, jittery, and nervous (Table 4). The results of PANAS were evaluated with Excel (2024) software. This test ask participants questions about how they felt during the previous week's workday (5 days).

The study by Gök, Selçuk, and Gençöz (2018) contributes to the existing literature and clinical practices by demonstrating that the PANAS is a measurement tool that effectively captures interpersonal and intrapersonal variations in effect, as assessed through multiple measures. The findings indicate that PANAS can be reliably employed to assess both types of differences in studies utilizing multiple measurements. They advise researchers to report both between-person and within-person reliability scores when using PANAS or similar repeated measures in longitudinal and diary studies.

Table 4. PANAS-SF Test

Indicate the extent you have felt this way over the past week.		Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
PANAS 1	Interested	1	2	3	4	5
PANAS 2	Distressed	1	2	3	4	5
PANAS 3	Excited	1	2	3	4	5
PANAS 4	Upset	1	2	3	4	5
PANAS 5	Strong	1	2	3	4	5
PANAS 6	Guilty	1	2	3	4	5
PANAS 7	Scared	1	2	3	4	5
PANAS 8	Hostile	1	2	3	4	5
PANAS 9	Enthusiastic	1	2	3	4	5
PANAS 10	Proud	1	2	3	4	5
PANAS 11	Irritable	1	2	3	4	5
PANAS 12	Alert	1	2	3	4	5
PANAS 13	Ashamed	1	2	3	4	5
PANAS 14	Inspired	1	2	3	4	5
PANAS 15	Nervous	1	2	3	4	5
PANAS 16	Determined	1	2	3	4	5
PANAS 17	Attentive	1	2	3	4	5
PANAS 18	Jittery	1	2	3	4	5
PANAS 19	Active	1	2	3	4	5
PANAS 20	Afraid	1	2	3	4	5

5.1.3 Office Descriptions

The case study is conducted in the open offices of a University in Izmir, Turkey. Conducting this study in Turkey contributes to the study in terms of a country that experiences all four seasons, so that the study can be observed and evaluated more comprehensively in all four seasons. İzmir is under the influence of the Mediterranean climate in terms of vegetation (Turkish Meteorological Service, 2024). In İzmir, the

summer season is hot and dry, and the winter is warm and rainy (İzmir governorship, 2024). During the study, the climatic conditions of İzmir is also be taken into account (Figure 23).

Climate data for İzmir (1991–2020, extremes 1938–2020)													[hide]
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	22.4 (72.3)	27.0 (80.6)	30.5 (86.9)	32.5 (90.5)	37.6 (99.7)	41.3 (106.3)	42.6 (108.7)	43.0 (109.4)	40.1 (104.2)	36.0 (96.8)	30.3 (86.5)	25.2 (77.4)	43.0 (109.4)
Average high °C (°F)	12.7 (54.9)	14.0 (57.2)	17.2 (63.0)	21.3 (70.3)	26.5 (79.7)	31.3 (88.3)	33.8 (92.8)	33.6 (92.5)	29.5 (85.1)	24.6 (76.3)	18.8 (65.8)	14.0 (57.2)	23.1 (73.6)
Daily mean °C (°F)	9.0 (48.2)	9.9 (49.8)	12.4 (54.3)	16.2 (61.2)	21.1 (70.0)	26.0 (78.8)	28.6 (83.5)	28.5 (83.3)	24.2 (75.6)	19.5 (67.1)	14.4 (57.9)	10.5 (50.9)	18.4 (65.1)
Average low °C (°F)	6.0 (42.8)	6.6 (43.9)	8.6 (47.5)	11.8 (53.2)	16.2 (61.2)	20.9 (69.6)	23.5 (74.3)	23.7 (74.7)	19.5 (67.1)	15.4 (59.7)	10.9 (51.6)	7.7 (45.9)	14.2 (57.6)
Record low °C (°F)	-8.2 (17.2)	-5.2 (22.6)	-3.8 (25.2)	0.6 (33.1)	4.3 (39.7)	9.5 (49.1)	15.4 (59.7)	11.5 (52.7)	10.0 (50.0)	3.6 (38.5)	-2.9 (26.8)	-4.7 (23.5)	-8.2 (17.2)
Average precipitation mm (inches)	127.5 (5.02)	107.2 (4.22)	77.8 (3.06)	50.1 (1.97)	32.9 (1.30)	14.4 (0.57)	3.0 (0.12)	6.7 (0.26)	23.5 (0.93)	56.5 (2.22)	99.6 (3.92)	131.3 (5.17)	730.5 (28.76)
Average precipitation days	11.57	12.00	10.23	9.00	7.10	3.67	0.67	0.83	3.07	6.67	9.07	13.30	87.2
Average relative humidity (%)	76	73	69	66	63	55	52	52	58	67	75	76	65
Mean monthly sunshine hours	139.5	146.9	204.6	237.0	300.7	345.0	381.3	359.6	291.0	235.6	174.0	130.2	2,945.4
Mean daily sunshine hours	4.5	5.2	6.6	7.9	9.7	11.5	12.3	11.6	9.7	7.6	5.8	4.2	8.0

Figure 24. Climate Data for İzmir (Source: Turkish Meteorological Service, 2023)

The duration of daylight in İzmir varies considerably throughout the year. In 2022, the shortest day occurred on December 22, featuring 9 hours and 29 minutes of daylight, while the longest day was on June 21, with 14 hours and 51 minutes of daylight (Weather Spark, 2024) (Figure 24).



Figure 25. Hours of Daylight and Twilight in İzmir (Source: Weather Spark, 2023)

The duration of time the Sun is visible is represented by the black line. The color bands, ranging from yellow at the bottom to gray at the top, indicate the following: full daylight, twilight (including civil, nautical, and astronomical), and full night (Weather Spark, 2024) (Figure 24).

The earliest sunrise occurs at 5:47 AM on June 13, while the latest sunrise is at 8:28 AM on January 6, which is 2 hours and 42 minutes later. The earliest sunset takes place at 5:50 PM on December 7, and the latest sunset is at 8:39 PM on June 28, occurring 2 hours and 49 minutes later. Notably, daylight saving time (DST) was not implemented in İzmir during 2022 (Weather Spark, 2024) (Figure 25).

Hours of	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Daylight	9.8	10.8	12.0	13.2	14.3	14.8	14.5	13.6	12.4	11.2	10.1	9.5
	h	h	h	h	h	h	h	h	h	h	h	h

Figure 26. Daylight Hours in İzmir (Source: Weather Spark, 2023)

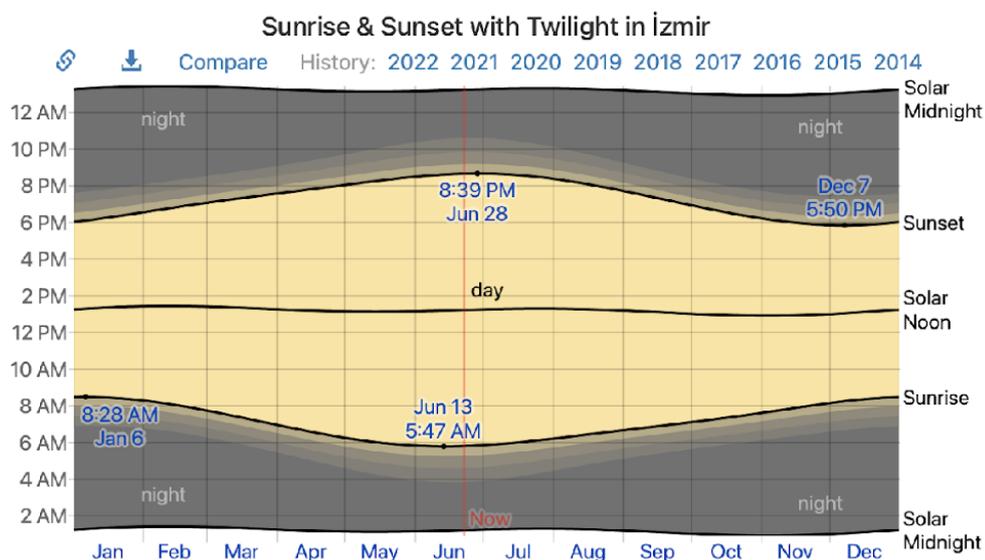


Figure 27. Sunrise & Sunset with Twilight in İzmir (Source: Weather Spark, 2023)

The solar day throughout the year 2022 is illustrated with black lines indicating the sequence from the previous solar midnight, sunrise, solar noon, sunset, and then the next solar midnight. The color bands, transitioning from yellow to gray, represent day, twilight (including civil, nautical, and astronomical), and night (Weather Spark, 2024) (Figure 26).

The study was implemented in the İzmir University of Economics campus at D Block Fifth Floor Open Office (Figure 27), C Block 9th floor Open office (Figure 28) and E block Ground Floor Promotion Office (Figure 29). The façade of Block C of the open offices faces east and the offices are located in the eastern area. The façade of Block D faces north. Its offices receive light from both south and north facades. The façade of Block E, like Block D, faces north and receives daylight from that façade. Office features; sizes, window sizes, table positions, partitions, furniture, artificial lighting, daylighting status differ from each other. 21 research assistants, 1 secretary, 6 lecturers are working in the open office space of Block D. 16 research assistants, 3 administrative staff, 2 lecturers are working in the open office space of block D, C and E. 3 research assistants are working in the open office space of the 9th floor of block C (Figure 30), 13 research assistants and one administrative staff are working in the open office space of the 5th floor of block D (figure 31) and 2 administrative staff are working in the promotion office of Block E ground Floor (figure32). So, the study could be performed with 37 participants.

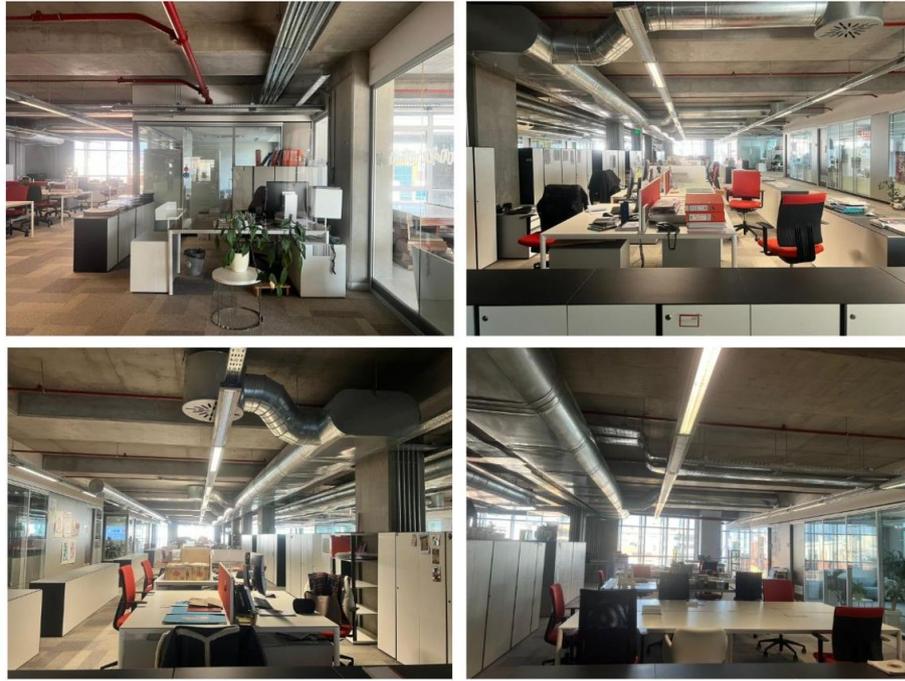


Figure 28. Block D – Open offices

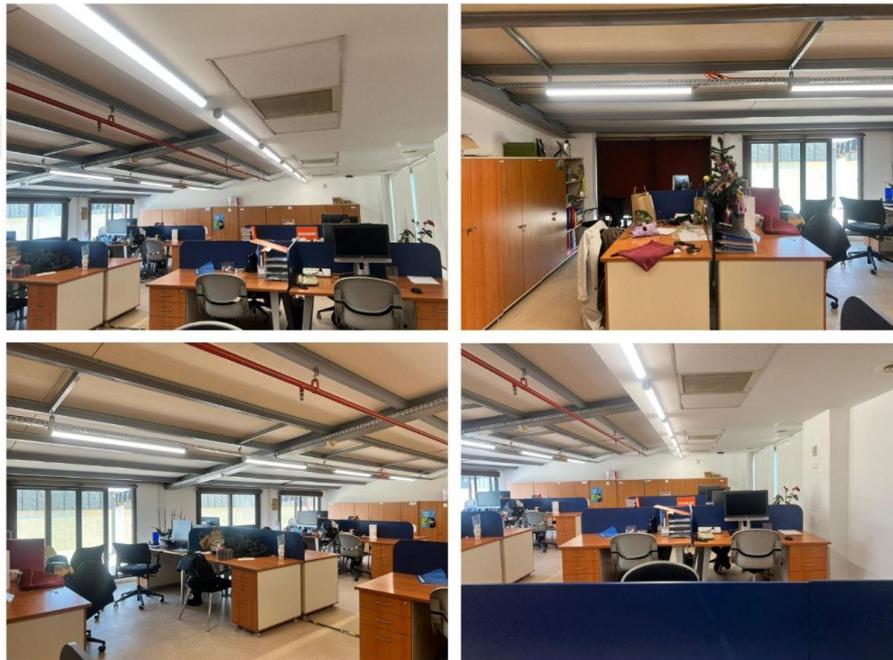


Figure 29. Block C – Open offices

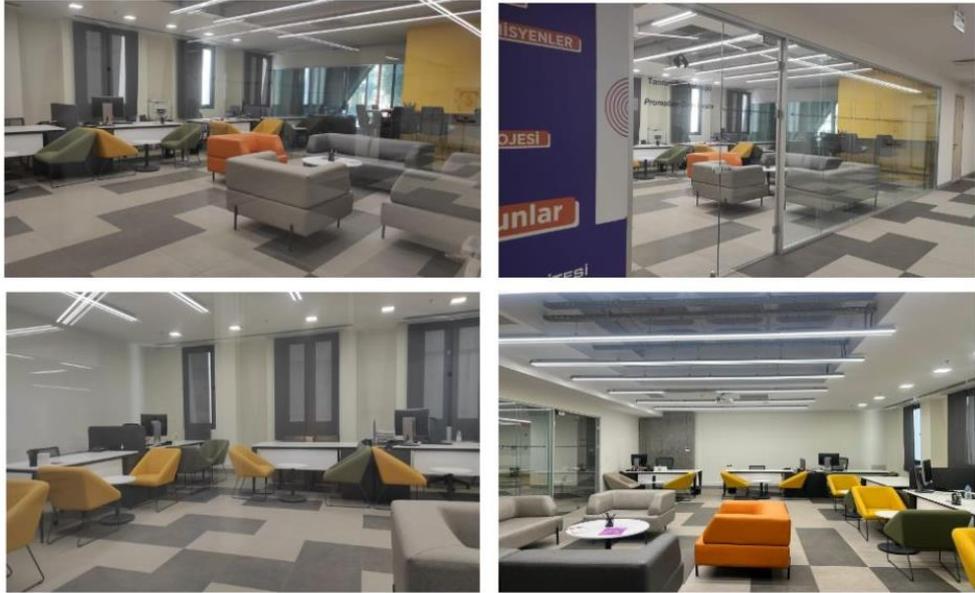


Figure 30. Block E – Open offices

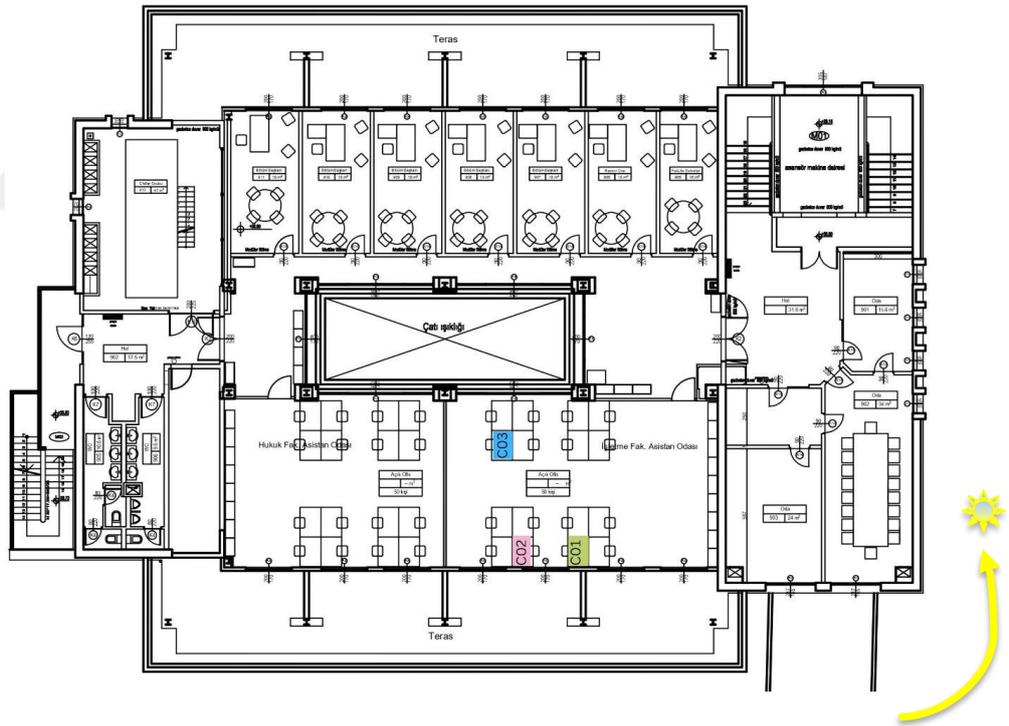


Figure 31. İzmir University of Economics – Plan Block C

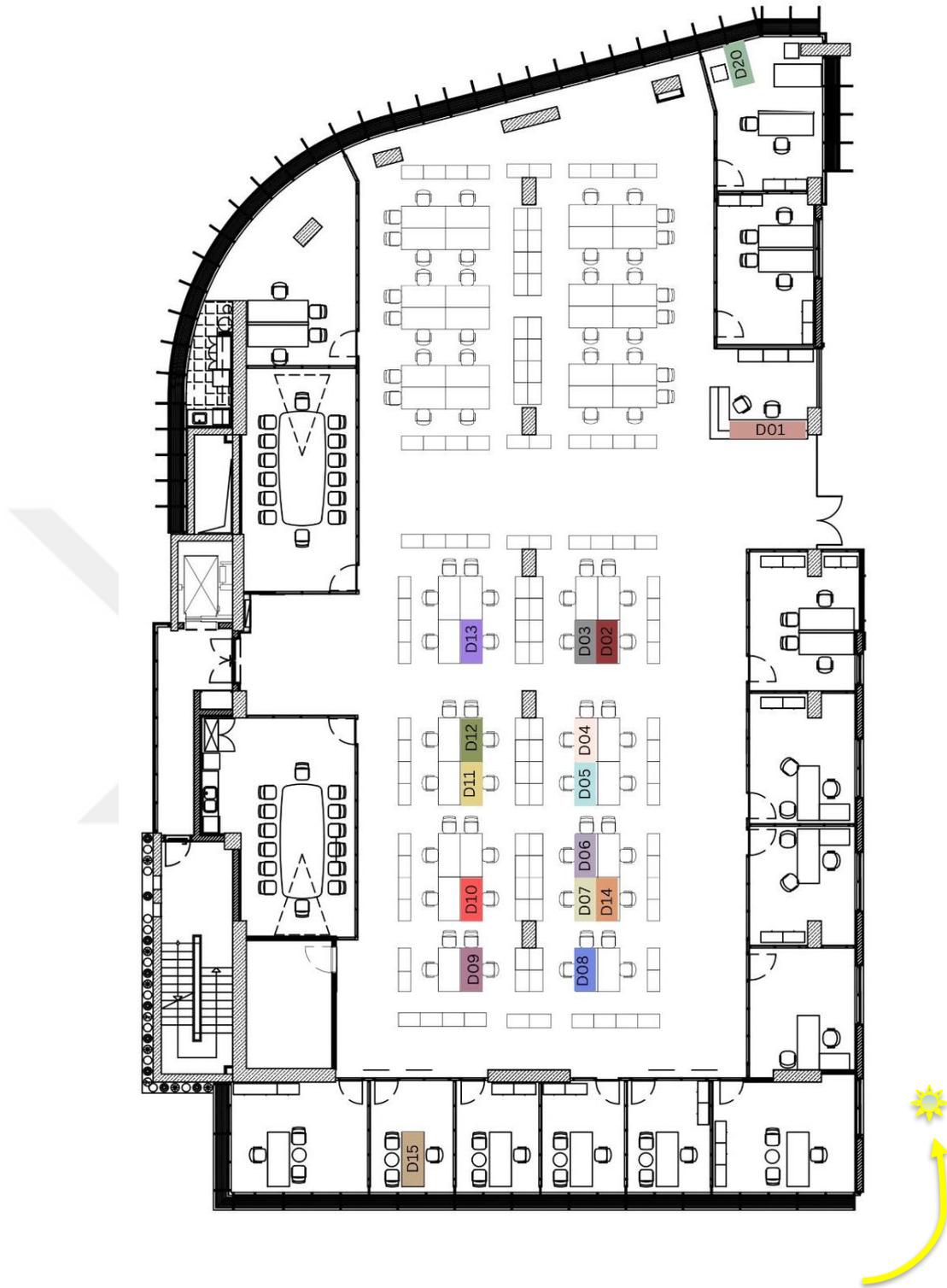


Figure 32. IUE – FFAD – Block D Plan

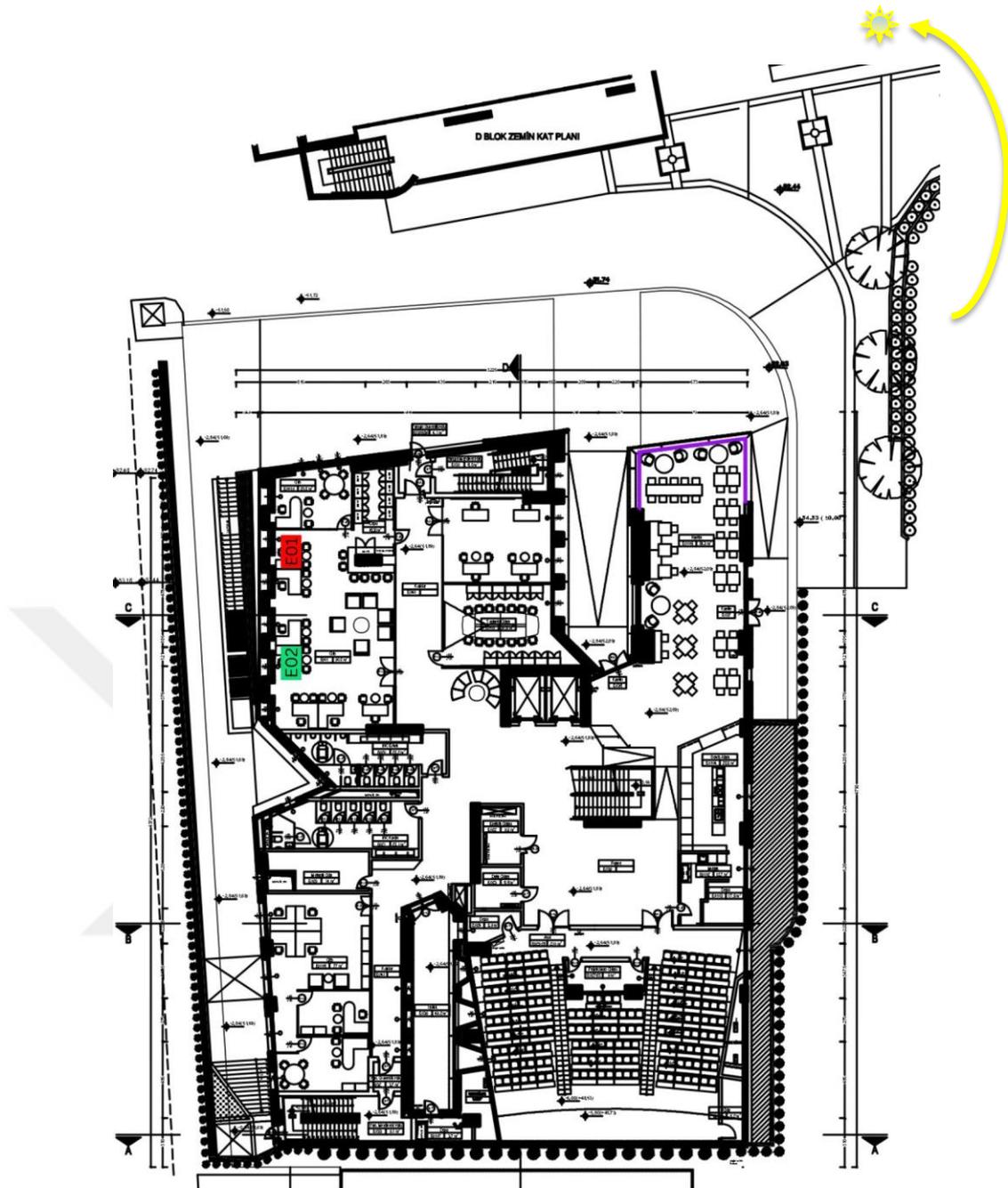


Figure 33. İzmir University of Economics – Block E Plan

5.2. Findings

21 open office workers performed biological measurements and sleep monitoring with smartwatches for 5 weeks. Participants wore the watches for 6 nights and 7 days. One participant continued to wear the smartwatch during the day and during sleep for 6 weeks. The required data were obtained from these measurements. Participants'

daytime sinus rhythms, oxygen levels, total hours of daylight received during the day and the amount of light at table and eye levels were measured for 1 week. Biological measurements and light measurements were performed every hour in the day. Biological measurements were followed by a PANAS test in the following week. The daily moods of the participants were determined by this PANAS test. In addition, in sleep measurements, data on how many hours of REM, core sleep, and deep, awake sleep the participants had during the night were obtained. In the results, these sleep durations were compared with the amount of daylight received daily and the effect of this on circadian rhythm was evaluated.

To strengthen the evidence-based methodology, data was collected from 2 types of participants. One is the biological measurements, PANAS test and participation in a general questionnaire with a group of 20 participants. The other user group was an online survey conducted across Turkey, which included only participants working in open offices. A group of 20 people were included in this survey and a total of 47 people participated in the questionnaire. The Questionnaire includes questions based on Likert scale, general demographic questions and interpretive questions. The results of the questionnaire are presented below in graphs. The survey included 31 female and 16 male participants.

While investigating the findings and data of the case study, we first proceeded from general to more specific comparisons. Firstly, the results of the questionnaire filled out by 47 people were examined, then the PANAS results were added and finally the data of physiological measurements made with smart watches with a group of 21 people were examined.

When the Questionnaire graphs were examined, it was found that 44.7 percent of the participants worked in the same office for more than 5 years, 23.4 percent worked between 1-12 months, 23.4 percent worked between 1-5 years, and 8.5 percent worked between 3-5 years (figure 33). At the same time, 48.9 percent of the participants work at a desk for 7-9 hours, 38.3 percent for 5-7 hours, and 8.5 per cent for 2-5 hours and the rest for more than 9 hours (figure34). It was pointed out that 55.3 percent of the respondents work with more than 10 people, 25.5 percent with 2-4 people, and 12.8 percent with 5-10 people and the rest with 1 person in their offices (figure35).

How long have you been working at this work environment? / Bu iş yerinde ne süredir çalışmaktasınız?
47 yanıt

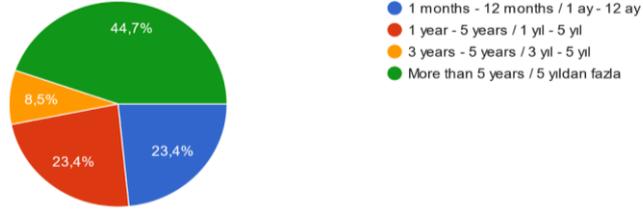


Figure 34. The chart of working period of participants

How many hours of your day do you spend at your desk in an open office? / Gününüzün kaç saatini açık ofisteki çalışma masanızda geçiriyorsunuz?
47 yanıt

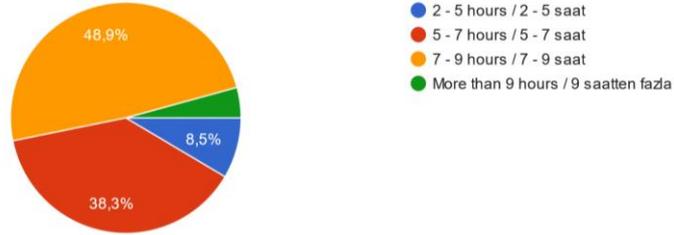


Figure 35. The chart of total time spent by participants at their desks

How many people other than you work in your work environment? / Çalıştığınız ortamda sizden başka kaç kişi çalışıyor?
47 yanıt

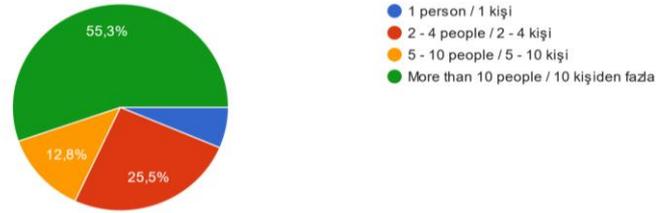


Figure 36. The chart of number of people in the office where the participants work
When the participants were asked about the importance of the physical elements in the office, most of the participants marked sound insulation as the most important, Adequate Ventilation as the second, adequate lighting as the third, an enclosed, private space as the fourth and being close to the window and seeing the outside as the last. When we look at this question, lighting was ranked 3rd and being close to the window was ranked 5th. As a result, the priority of employees in open offices is sound insulation (figure 36).

In the open office, can you rank the physical elements of the space listed below according to their importance for you? / Açık ofiste, aşağıda listelenen mekanın fiziksel elemanlarını sizin için önemine göre sıralayabilir misiniz?

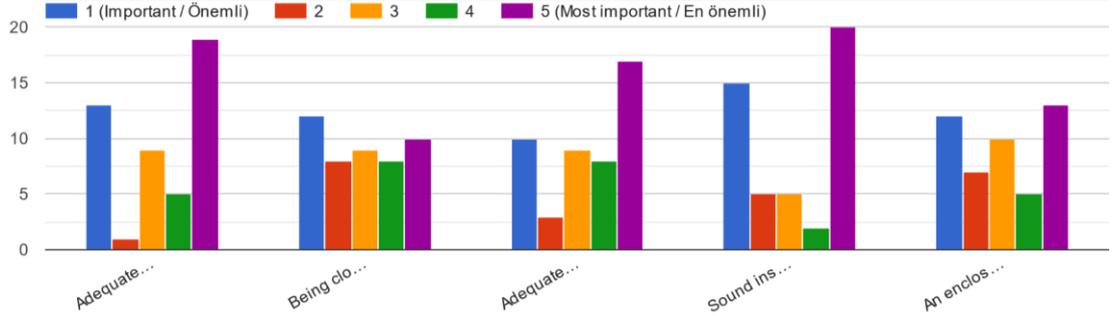


Figure 37. The chart of importance of the physical elements

34 percent of the participants use 50% natural and 50% artificial lighting in their offices, 29.8 percent use 70% artificial and 30% natural lighting, 14.9 percent use artificial lighting, 12.8 percent use 30% artificial and 70% natural lighting and the rest use only natural lighting (figure 37). While 85.1 percent of the respondents have a window in the wall in their office, 12.8 percent do not have a window in the wall and the rest have an opening in the ceiling (figure 38). 33.3 percent of the participants defined their distance to the window as 1 (very close), 31.1 percent as 5 (very far), 15.6 percent as 2, 11.1 percent as 3, and 8.9 percent as 4 (figure 39). While 76.6 percent of the participants do not use desk or extra lighting, 23.4 percent do use it (figure 40). Of those who use desk lighting, 70 percent use desk lighting and 30 percent use other extra artificial lighting.

What is the type of lighting in your work environment? / Çalışma ortamınızdaki aydınlatma türü nedir?
47 yanıt

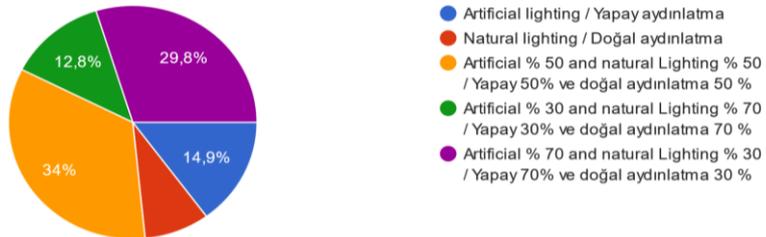


Figure 38. The chart of type of lighting in work environment

Are there any openings (windows, ceiling openings, skylights) in the open office where you work? / Çalıştığınız açık ofiste herhangi bir açıklık (pencereler, tavan açıklıkları, çatı pencereleri) var mı?
47 yanıt

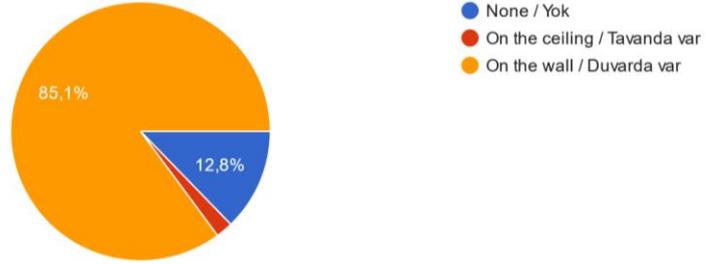


Figure 39. The chart of openings in work environment

If you have a window in an open office, can you evaluate your distance to the window? / Açık ofiste pencereniz varsa pencereye olan mesafenizi değerlendirebilir misiniz?
45 yanıt

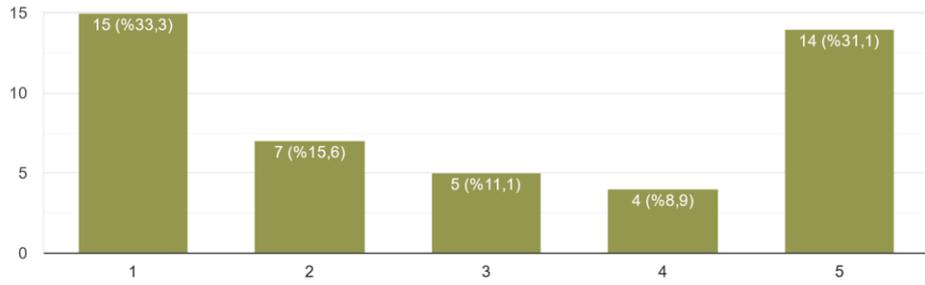


Figure 40. The chart of distance to the window in work environment

Do you use desk lighting or extra lighting in your open office? / Açık ofiste masa aydınlatması veya fazladan bir aydınlatma kullanıyor musunuz?
47 yanıt

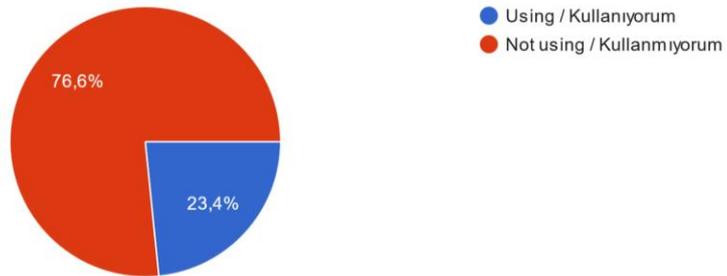


Figure 41. The chart of usage of desk or extra lighting

If you use extra lighting, please explain what it is. / Extra aydınlatma kullanıyorsanız ne olduğunu lütfen açıklayınız.

10 yanıt

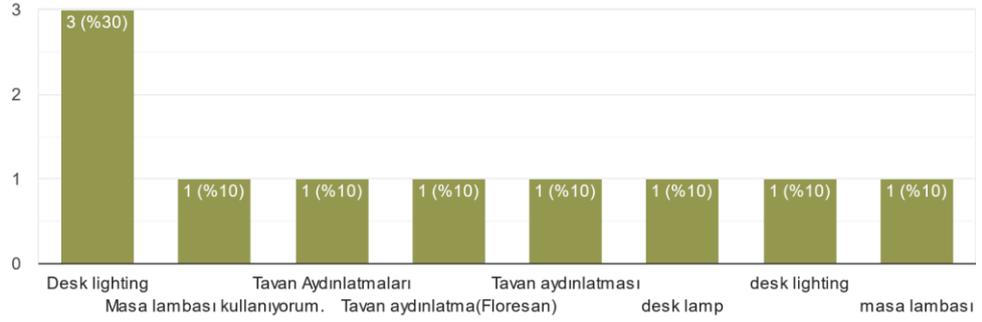


Figure 42. The chart of type of desk or extra lighting

While 48.9 percent of the participants preferred to use a combination of artificial and natural lighting while working, 44.7 percent preferred only natural lighting. The rest of the respondents marked only artificial light (figure 42). While 97.8 percent of the participants want the window in their working environment to be under their control, the rest do not (figure 43). Similarly, when asked about the shading element, 97.9 percent of the participants wanted to control it themselves and the rest did not (figure 44).

Which type of light do you prefer when you work? / Çalışırken hangi ışık tipini tercih edersiniz?

47 yanıt

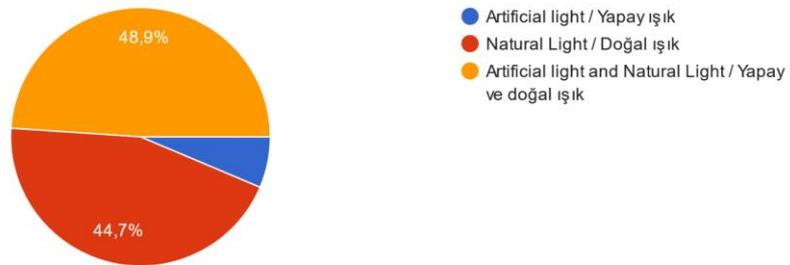


Figure 43. The chart of choice of lighting type

Do you prefer to have a window in your work environment that you control yourself? / Çalıştığınız ortamda kendi kontrolünüzde olan pencere olmasını tercih eder misiniz?
46 yanıt

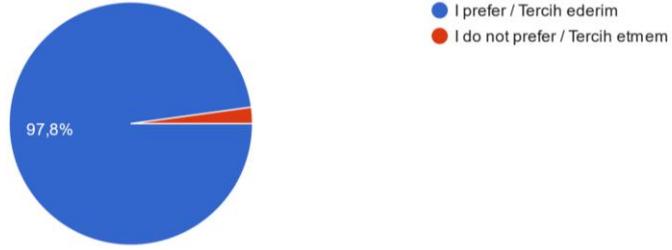


Figure 44. The chart of choice of window control

Would you prefer a shading element (curtains, blinds, etc.) in your open office that you control yourself? / Açık ofisinizde kendi kontrolünüzde bir g...leme elemanı (perde, stor vb.) tercih eder misiniz?
47 yanıt

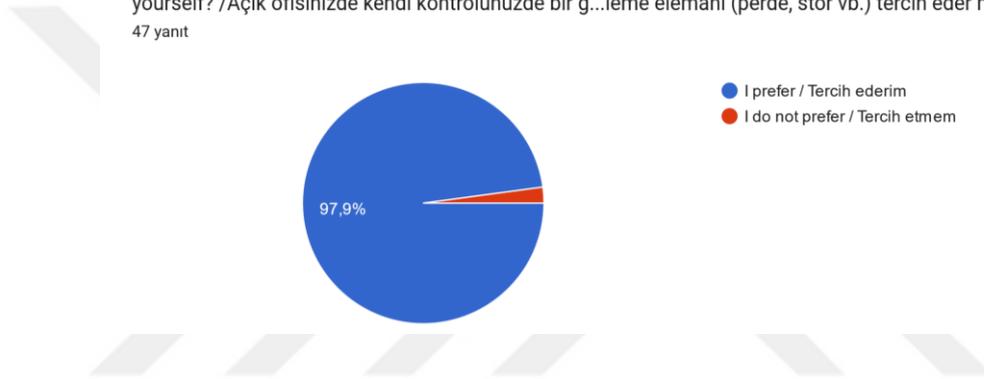


Figure 45. The chart of choice of shading element

Participants rated the importance of table lighting for them on a scale of 5 out of 5, with 5 being more and 1 being less. 34 percent of the participants marked 3, 21.3 percent 2, 17 percent 1, 14.9 percent 5, 12.8 percent 4 (figure 45). The importance of the level of illumination at the desk for the participants was also rated as average by 36.2 percent and high by 34 percent (figure 46). The amount of light coming into the desk was also rated as high by 5 out of 5, with 38.3 percent marking 3 and 34 percent marking 2 (figure 47).

Please rate the importance of the using desk lighting in your desk. / Lütfen çalışma masanızda masa aydınlatması kullanmanın önemini değerlendiriniz.

47 yanıt

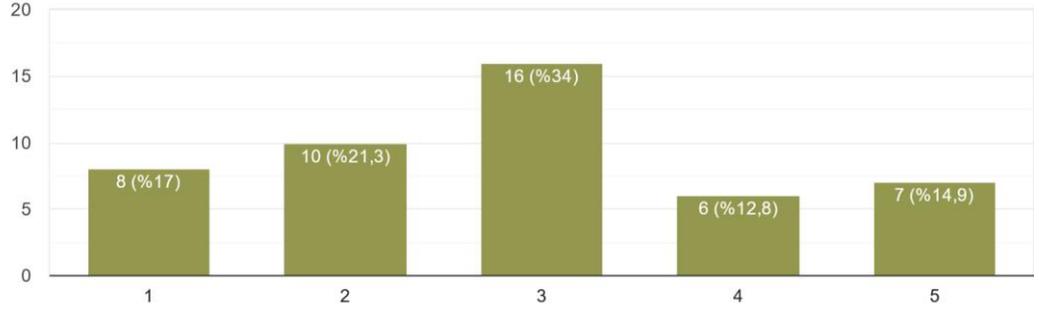


Figure 46. The chart of the importance of using desk light

How would you rate the general level of illumination at the desk where you work? / Çalıştığınız masadaki genel aydınlatma düzeyini nasıl değerlendirirsiniz?

47 yanıt

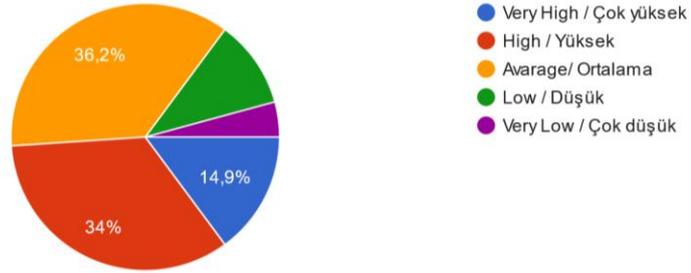


Figure 47. The chart of general level of illumination

Please rate the overall amount of light coming into your desk? / Lütfen masanıza gelen genel ışık miktarını değerlendirebilir misiniz?

47 yanıt

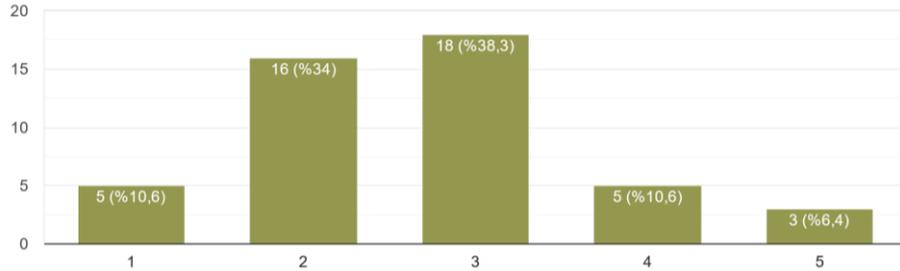


Figure 48. The chart of overall amount of light

Participants rated on a scale of 1 to 5, with 5 being very important, how components

such as illuminance level, color of light, daylight into the workspace, glare, and shadows cast on table surfaces, and glare affected their work. Participants generally rated 4 for glare, 3 for shadows cast into the workspace, and otherwise the ratings were lower (figure 48). For the amount of glare on their screens, ceiling lighting was marked as the most common, daylight as the 2nd most common, and table lighting as the 3rd most common (figure 49). When asked if there is an interior element that prevents light intake in the open office, 59.6% answered no, while 40.4% answered yes. When the participants who said that there is, were asked what the element was, they stated the divider, cabinet, glass door, table dividers, columns and walls, tables, fabric panels and curtains (figure 50).

Please mark how much the following components affect your work on your desk surface. / Lütfen çalışma masa yüzeyinizde, aşağıda belirtilen bileşenlerin çalışmanızı ne kadar etkilediğini işaretleyiniz.

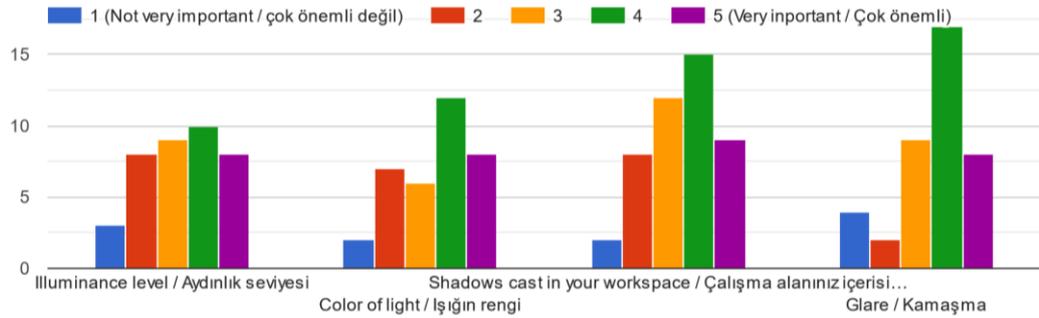


Figure 49. The chart of components on the desk surface

If there is glare on your screen, which of the following do you think is its source? / Ekranınızda kamaşma varsa, kaynağı sizce aşağıdakilerden hangisidir?

43 yanıt

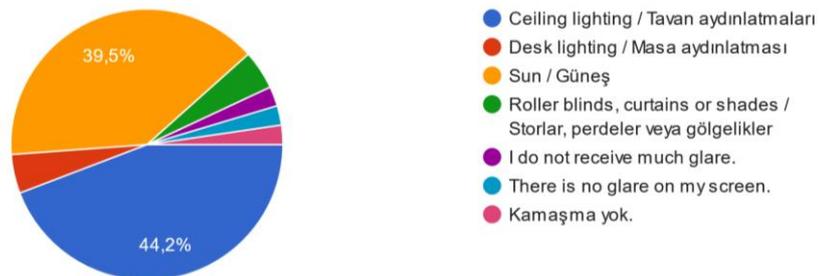


Figure 50. The chart of glare

In the open office, are there any interior elements (cabinet, separator, etc.) that prevent you from receiving daylight or artificial light? / Açık ofiste...en iç mekan elemanları (dolap, seperatör vb.) var mı?
47 yanıt

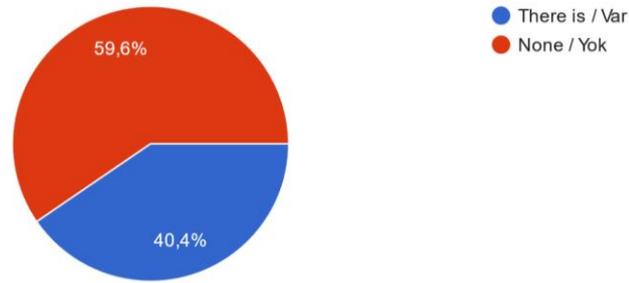


Figure 51. The chart of interior elements

Participants rated the disturbing reflections on their screens on a scale of 1 to 5, with 5 being the most. 34 percent were given a 3, 25.5 percent at 1, 21.3 percent at 2, and 14.9 percent a 4, and finally 4.3 percent a 5 (figure 51). Participants also rated the visual comfort problems they experienced due to lighting. 32.9 percent gave an average score of 1. 29.8 percent gave a score of 4 (figure 52). The participants responded to the effect of the lighting in the open office on their work as follows: 44.7 percent said it increases their work efficiency, 34 percent said it decreases their work efficiency and 19 percent said it does not affect their work efficiency (figure 53).

Please assess the disturbing reflections on your desk caused by daylight or artificial light during screen use. / Lütfen masanızda ekran kullanımı sırasında rahatsız edici yansımaları değerlendiriniz.
47 yanıt

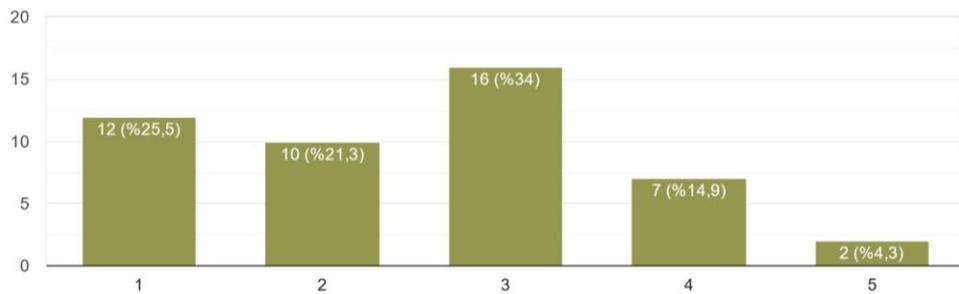


Figure 52. The chart of disturbing reflections

Please rate the visual comfort problems you experience due to lighting? / Lütfen Aydınlatma nedeniyle yaşadığınız görsel konfor sorunlarını değerlendiriniz.

47 yanıt

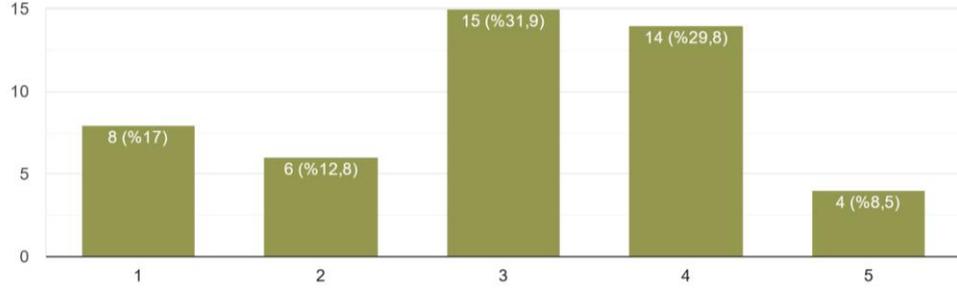
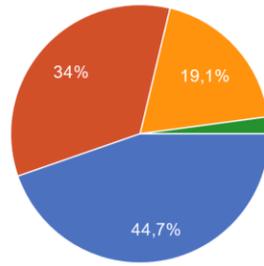


Figure 53. The chart of visual comfort problems

What is the impact of lighting in an open office on the work you do? / Açık ofisteki aydınlatmanın yaptığınız iş üzerindeki etkisi nedir?

47 yanıt



- It increases my work efficiency. / İş verimliliğimi artırır.
- It reduces my work efficiency. / İş verimliliğimi düşürür.
- No effect. / Etkisi yok.
- Şu anki koşullar iş verimliliğimi düşürmüyor ancak ofisimin aydınlık olması beni daha iyi hissettirir ve motivasyonumu artırır.

Figure 54. The chart of impact of lighting on the work

Participants rated from 1 to 5, with 5 being the most, how bright they would like their offices to be while working. The maximum score was 4 (figure 54). They also evaluated the effect of daylight in an open office on their mood. 40.4 percent marked 5, 31.9 percent 4 (figure 55). This high percentage shows that daylight affects the mood of office workers. Apart from that, the participants evaluated the effects of daylight on circadian rhythm, sleep, and mood. 31 people said that daylight definitely affects my mood, while 12 said that it does not. The majority said that they make an effort to get daylight and the average number said that they do not. In general, the answer “I change my location to get daylight” was equal in all scales. I work in different places in the office to get daylight was equally marked. The questions “Daylight increases my working efficiency and motivation, and helps me to be positive and creative” were also marked as strongly agree at a high rate (figure 56). While most of them said that it affects my sleep pattern and I fall asleep more easily on days when I get daylight,

some were undecided. Participants were undecided about whether not getting enough daylight affects my sleep and my heart rhythm. The majority also emphasized that not getting enough daylight affects their stress.

Please rate how bright you need the office to be in terms of daylight throughout the day. / Lütfen gün içinde çalışırken ofisin ne kadar aydınlık olmasına ihtiyacınız olduğunu değerlendiriniz.

47 yanıt

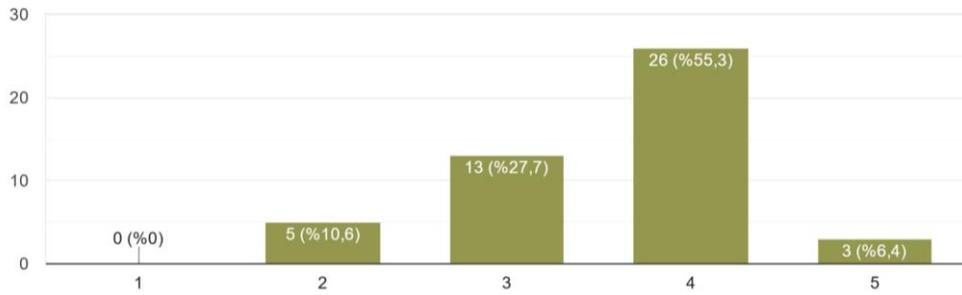


Figure 55. The chart of brightness in office

Please rate how much daylight affects your daily mood in the open office. / Lütfen açık ofiste gün ışığının günlük ruh halinizi ne kadar etkilediğini değerlendiriniz.

47 yanıt

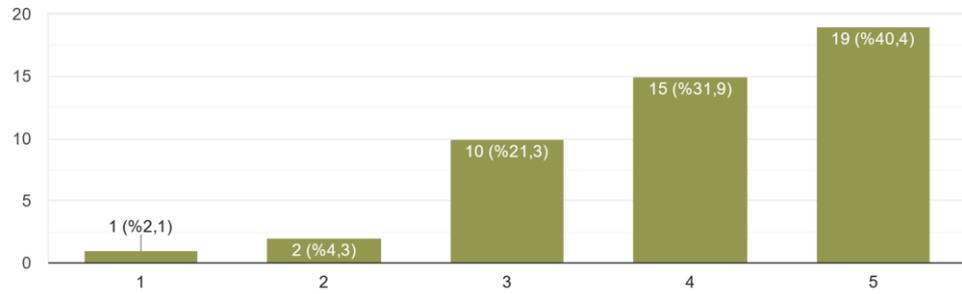


Figure 56. The chart of daily mood in the open office

Please choose the option that suits you in the questions below. / Lütfen aşağıdaki sorulardan size uygun olan seçeneği işaretleyiniz.

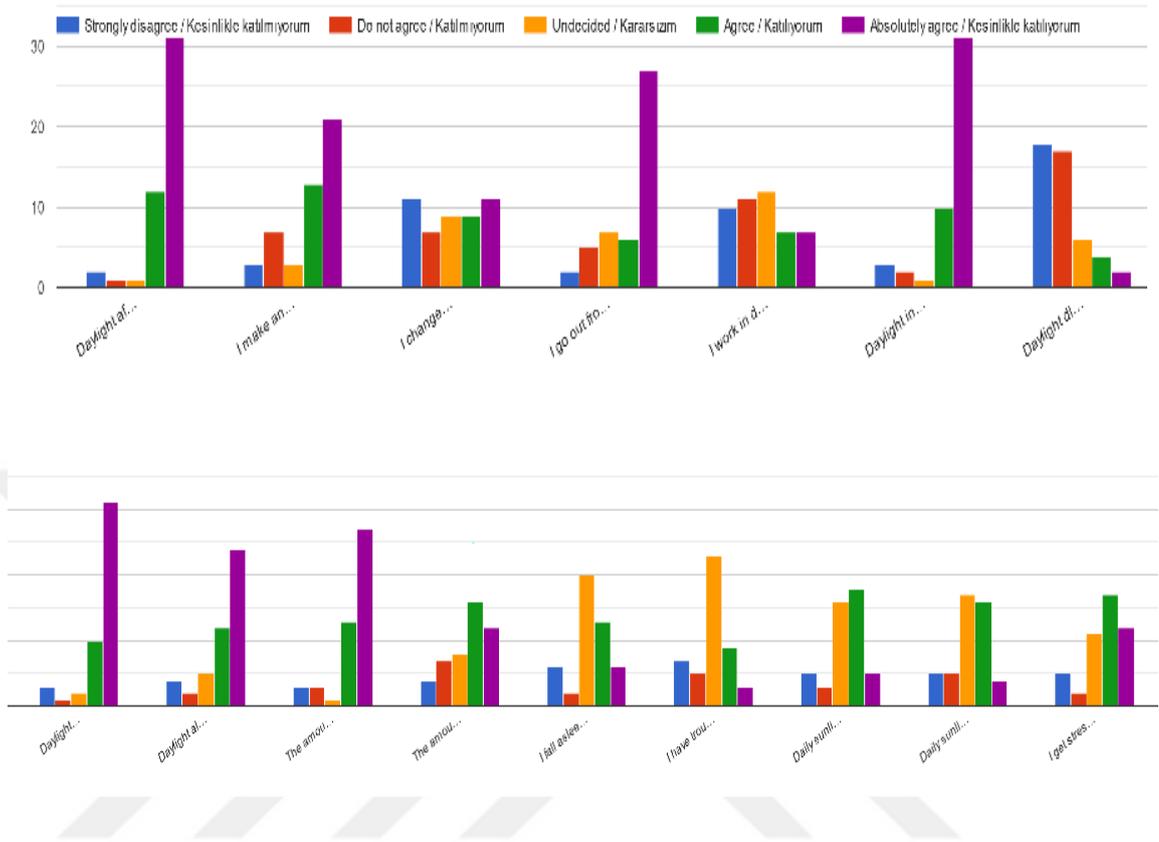


Figure 57. The chart of mood and sleep questions

Participants were asked some open questions, firstly asking them to mention any experiences they had of daylight affecting their mood or wellbeing at work. Overall, Daylight has an important positive effect on work motivation and general mood. Open-plan office workers state that getting enough sunlight increases work power and increases their motivation in the office. While insufficient natural light leads to negative health effects such as headaches, eye problems and fatigue, it has been stated that staying under artificial lighting for long periods of time causes distraction and tension. They emphasize that their mood is negatively affected when they feel a lack of sunlight, experiencing lower mood, increased stress and a general feeling of not feeling healthy. It has been emphasized that getting natural light increases motivation and positively affects work efficiency. It has been observed that having the opportunity to work in areas with daylight in particular has significant effects on employees' mood and motivation. Participants stated that sunlight plays an important role not only in

terms of physical health but also in terms of psychological well-being. In general, access to daylight emerges as a critical factor in improving the quality of life and work performance of office workers.

The responses regarding the impact of daylight on sleep patterns reflect the diversity of open-plan office workers' experiences. Some participants stated that daylight positively affects their sleep quality and that they have a more restful sleep when they are outdoors. However, some participants noted that daylight does not have a significant impact on their sleep patterns or that they do not have a definite opinion on this issue. Some stated that spending long periods of time under artificial light causes fatigue and that they experience headaches and excessive fatigue when they do not receive enough daylight. It was stated that getting natural light outdoors in particular helps them fall asleep more easily and improves their sleep quality at night. On the other hand, some participants think that daylight does not have much of an impact on their sleep patterns and that screen lights also play a role in this. Although the positive effects of daylight on mood and sleep quality are generally emphasized, there are also participants who do not have a clear opinion on this issue.

In addition, to discuss these issues further, the different responses underscore the complexity of human interactions with lighted environments. Several factors can contribute to these differences:

- **Individual Differences:** People's sensitivity to light and circadian rhythms can vary greatly. Genetic factors, lifestyle habits and personal preferences can influence how daylight affects a person's sleep.
- **Environmental Context:** The quality and quantity of daylight exposure in an open-plan office or outdoors can vary greatly, influencing individual experiences. For example, office layouts and window placements can influence the amount of natural light individuals receive.
- **The Role of Artificial Light:** The negative impact of prolonged exposure to artificial lighting highlights the need for better lighting solutions in workplaces. Incorporating natural light or using lighting that mimics daylight can reduce these effects.

- **Screen Time Impact:** The mention of screen light affecting sleep patterns suggests that electronic devices may be an important factor, interacting with daylight exposure in complex ways.
- **Perception and Awareness:** The subjective nature of sleep quality and personal awareness play a role. Respondents who do not pay attention to their sleep patterns or daylight exposure may be less accurate.

Another open-ended question asked three negative aspects that office workers feel uncomfortable with regarding the use of daylight, and when the results are examined, 3 main headings emerge.

1- **Brightness and Eye Disorders:** Employees stated that excessively bright daylight can cause glare and fatigue in the eyes. Especially when daylight hits the computer screen directly, it distracts them and causes headaches.

2- **Insufficient Daylight:** Some participants stated that their mood is negatively affected and their work motivation decreases when they don't get enough natural light in the office. Insufficient light, especially in winter and in cloudy weather, creates a negative mood.

3- **Lack of Lighting Control:** Many participants think that the lack of curtains or blinds to control daylight causes some problems. Failure to manage natural light properly increases the temperature of the work environment and makes concentration difficult.

These results emphasize the importance of daylight management in office environments.

The last survey question asked participants to provide their opinions on three positive aspects of using daylight in the office that make them feel good. The following 3 main headings emerged.

1- **Increased Motivation and Energy:** Participants stated that their motivation increased when exposed to daylight, they felt more energetic and worked more efficiently. They stated that they felt more positive and livelier, especially on days with natural light.

2- **Improved Mood:** Participants stated that daylight positively affected their mood, reduced their stress levels and made them feel more peaceful. It was emphasized that

sunlight provided a generally better mood and helped reduce depressive feelings.

3- Increased Sleep Quality: It was stated that daylight helped them sleep better at night and feel more refreshed in the morning. It was also stated that they could fall asleep better in the evenings when they received enough natural light, and that this situation positively affected their work skills.

These findings show that having enough daylight in the office environment has a significant positive effect on employees.

The PANAS - SF test was implemented the week after the participants' measurements with smartwatches lasting 5 working days. In the test, the participants were asked about their mood on the days of the measurements and were asked to rate 10 positive and 10 negative moods on a scale of 5. In Table 5, the total daily positive and negative mood values of participants D01, D02, D03, D04, D06, D08, D09 and D10, and in Table 6, the total daily positive and negative mood values of participants D11, D12, D14, D15, D20, C01, C02 and C03 are compared with the daily amount of daylight intake. The positive moods of participants coded D01, D02, D03, D05, D06 and D10 were higher than the negative moods on each day of the measurements (Table 5). While the positive moods of the participant coded D04 were higher than the negative moods for the other 4 days, on the 3rd day the negative moods were higher than the positive moods. While the positive moods of the participant coded D08 were higher than the negative moods during the other 3 days, the negative moods were higher than the positive moods on days 2 and 5. The participant coded D09 had higher negative moods on days 2, 3 and 4, but higher positive moods on days 1 and 5. Participants coded D15, D20, C01 and C02 had higher positive moods than negative moods for 5 days (Table 6). Participant coded D11 had higher negative moods on days 1, 2 and 3, but higher positive moods on days 4 and 5. Participant coded D12 had high positive moods for 4 days, but on the 4th day her positive and negative moods were equal. On day 4, it can be seen that the amount of daylight received by the participant also decreased, which may have an effect. Participant D14 had high positive moods for the first 3 days, equal moods on the 4th day and high negative moods on the 5th day. The participant coded C03 had high positive moods for 4 days, while only on the 2nd day his negative moods were higher than his positive moods.

Table 5. Participants' PANAS test results I

PARTICIPANT CODE	DAY	SCORE FOR POSITIVE MOOD	SCORE FOR NEGATIVE MOOD	DAYLIGHT INTAKE
D01	Day 1	38	10	142
	Day 2	37	10	71
	Day 3	39	10	116
	Day 4	40	10	53
	Day 5	36	13	145
D02	Day 1	34	18	45
	Day 2	33	15	123
	Day 3	31	13	49
	Day 4	33	14	81
	Day 5	36	17	195
D03	Day 1	28	18	76
	Day 2	23	19	104
	Day 3	34	11	109
	Day 4	26	12	57
	Day 5	27	16	24
D04	Day 1	27	16	
	Day 2	36	25	
	Day 3	28	38	
	Day 4	20	17	
	Day 5	37	20	
D05	Day 1	34	14	83
	Day 2	39	16	117
	Day 3	46	19	125
	Day 4	50	16	155
	Day 5	49	20	99
D06	Day 1	9	3	109
	Day 2	6	3	117
	Day 3	6	3	25
	Day 4	6	3	115
	Day 5	9	0	113
D08	Day 1	22	34	
	Day 2	21	29	
	Day 3	24	14	
	Day 4	33	18	173
	Day 5	17	19	31
D09	Day 1	26	23	36
	Day 2	22	24	35
	Day 3	20	22	65
	Day 4	20	23	48
	Day 5	16	27	22
D10	Day 1	32	25	14
	Day 2	23	11	47
	Day 3	25	20	98
	Day 4	33	18	123
	Day 5	17	15	99

Table 6. Participants' PANAS test results II

PARTICIPANT CODE	DAY	SCORE FOR POSITIVE MOOD	SCORE FOR NEGATIVE MOOD	DAYLIGHT INTAKE
D11	Day 1	24	25	155
	Day 2	19	20	128
	Day 3	21	22	181
	Day 4	27	21	203
	Day 5	25	19	133
D12	Day 1	26	15	43
	Day 2	21	13	62
	Day 3	17	11	84
	Day 4	16	16	66
	Day 5	20	11	106
D14	Day 1	23	13	26
	Day 2	17	11	82
	Day 3	16	11	69
	Day 4	12	12	81
	Day 5	10	12	46
D15	Day 1	45	10	242
	Day 2	44	10	119
	Day 3	46	10	266
	Day 4	45	14	128
	Day 5	49	9	246
D20	Day 1	24	14	285
	Day 2	28	10	249
	Day 3	22	12	
	Day 4	23	11	
	Day 5	22	10	
C01	Day 1	33	15	11
	Day 2	32	15	96
	Day 3	36	16	53
	Day 4	33	17	21
	Day 5	36	11	10
C02	Day 1	30	26	122
	Day 2	30	23	277
	Day 3	33	27	263
	Day 4	28	25	30
	Day 5	29	26	
C03	Day 1	23	16	30
	Day 2	12	14	36
	Day 3	29	10	49
	Day 4	21	11	48
	Day 5	31	10	36

Table 7 shows the measurements of 5 participants in detail in week 1. The measurements of the participant coded E01 could not be taken after the 1st day and the participant withdrew from the test. In Table 8, the amount of daylight received daily by the same participants is given in minutes and their sleep duration is also given in minutes.

Table 7. Week 1 participants' sinus rhythm, oxygen level and light measurements

WEEK 1 TIME	E01			E02			D12			D13			D15			D20									
	Sinus rhythm	Oxygen level	Lux level on desk	Sinus rhythm	Oxygen level	Lux level on desk	Sinus rhythm	Oxygen level	Lux level on desk	Sinus rhythm	Oxygen level	Lux level on desk	Sinus rhythm	Oxygen level	Lux level on desk	Sinus rhythm	Oxygen level	Lux level on desk							
DAY 1 (23.09.2024)																									
09:30	104	98	786	712	80	100	164	164	74	96	65	86	74	96	188	214	68	96	1000	700	78	96	790	700	
10:30	94	97	828	749	77	100	156	145	69	95	85	98	79	98	100	159	69	100	798	1000	72	98	811	691	
11:30			773	686	72	98	153	135	70	96	74	99	79	96	155	136	68	98	560	621	72	98	855	951	
13:30			775	825	83	99	237	202	86	94	70	107	84	99	160	106	61	98	481	550	93	95	1139	934	
14:30			745	766	87	97	229	176	83	95	100	95	74	99	168	122	60	96	379	423	90	98	969	1138	
15:30			930	954	88	99	250	249	83	96	76	93	74	97	165	147	63	96	249	234	72	98	1211	1118	
16:30			570	947	79	98	252	254	76	98	81	94	71	99	155	123	69	98	139	192	73	96	712	760	
AVERAGE	99	98	830	806	81	99	206	189	77	96	79	96	76	99	169	144	65	97	518	531	79	97	927	899	
DAY 2 (24.09.2024)																									
09:30			763	770	90	97	467	481	107	96	59	96	75	100	117	157	66	100	243	104	75	98	920	1145	
10:30			826	749	86	98	252	254	84	96	65	99	67	96	124	159	66	98	1200	969	62	100	1100	954	
11:30			803	796	73	98	490	531	82	95	67	99	70	100	159	155	61	96	243	259	66	97	889	892	
13:30			850	794	85	99	532	556	76	96	70	110	81	97	132	161	61	96	250	318	77	99	735	1032	
14:30			896	917	88	99	546	579	91	96	73	99	75	95	104	138	66	99	260	319	77	98	734	1021	
15:30					87	99	546	579	84	96	73	99	77	97	105	138	68	99	249	234	77	99	932	830	
16:30					79	98	540	554	84	98	80	99	69	100	104	138	69	100	139	192	71	98	712	760	
AVERAGE					84	98	482	505	87	96	70	100	73	98	121	149	66	98	369	342	72	98	860	948	
DAY 3 (25.09.2024)																									
09:30					76	98	481	486	107	96	82	89	72	99	128	129	67	99	1012	1102	91	97	698	748	
10:30					80	96	532	532	84	96	78	93	67	100	145	136	66	98	773	1200	81	96	811	951	
11:30					103	100	579	744	76	95	83	93	79	97	139	122	61	96	690	977	96	97	932	873	
13:30					83	97	546	579	91	96	73	99	82	96	104	138	66	99	410	406	91	97	734	1021	
14:30					83	98	540	554	84	96	73	99	78	97	105	138	68	99	235	278	84	96	932	830	
15:30					87	96	546	579	84	98	80	99	74	97	104	138	69	100	249	234	79	98	712	760	
16:30					84	98	560	589	87	96	76	93	76	98	120	131	65	98	620	697	86	96	789	902	
AVERAGE																									
DAY 4 (26.09.2024)																									
09:30					76	99	498	519	87	96	80	105	68	99	128	128	70	99	532	565	79	96	743	760	
10:30					82	98	532	532	80	97	86	96	70	100	153	156	68	98	481	550	75	96	1100	954	
11:30					73	98	696	648	81	97	81	97	78	97	142	140	67	96	379	423	86	97	889	892	
13:30							546	579	95	92	72	90	83	100	165	136	60	92	249	234	97	94	735	1032	
14:30							540	554	91	92	83	110						96	410	406	84	96	822	957	
15:30					80	99	546	579	91	92	81	96			160	151	70	99	235	278	87	93	946	930	
16:30							540	554	91	96	81	94			155	123	72	100	249	234	84	94	710	764	
AVERAGE					78	99	557	566	88	95	81	99	75	99	151	142	68	97	362	384	85	95	849	887	
DAY 5 (27.09.2024)																									
09:30					90	98	485	584	109	94	72	105	64	98	100	130	73	99				79	94	706	723
10:30							498	519	89	94	72	105	68	99	169	136						73	97	921	866
11:30					103	99	532	532	78	98	71	98	71	97	154	125	69	98				72	86	804	793
13:30					87	99	696	648	80	97	80	96	90	96	137	125	60	97	491	456			891	927	
14:30							546	579	94	97	80	96	88	98	155	105	63	98	410	406			734	987	
15:30							546	579	80	95	83	90	81	98	155	143	68	100	235	278			98	932	830
16:30							540	554	91	97	80	90	85	96	155	123	70	100	249	234	70	97	712	760	
AVERAGE					93	99	549	571	89	96	77	97	78	97	146	127	67	99	346	344	74	94	814	818	

Table 8. Week 1 participants' daylight intake and sleep tracking

WEEK 1 - Daylight intake	E01	E02	D12	D13	D15	D20
September 23		114	43	96	242	285
September 24		65	62	82	119	249
September 25		204	84	114	266	
September 26		183	66	90	128	
September 27		100	106	41	246	
September 28				37	188	
September 29				167	136	
WEEK 1 - Sleep	E01	E02	D12	D13	D15	D20
September 23						
In Bed			6hr 42 min	7hr 12 min	4hr 31 min	7hr 4 min
Awake			13 min	1hr 13 min	12 min	21 min
REM			1hr 38 min	1hr 14 min	53 min	1hr 20 min
Core			4hr 18 min	5hr 16 min	3hr 2 min	4hr 30 min
Deep			45 min	42 min	35 min	1hr 14 min
September 24						
In Bed		7hr 41 min	6 hr 43 min	6hr 57min	4hr 24 min	6hr 23 min
Awake		12 min	24 min	13 min	23 min	12 min
REM		1hr 50 min	1hr 38 min	1hr 6 min	1hr 3 min	1hr 27 min
Core		4hr 32 min	4hr 45 min	4hr 40 min	2hr 45 min	4hr 11 min
Deep		1hr 18 min	19 min	1hr 11 min	36 min	45 min
September 25						
In Bed		5hr 23 min	9hr 16 min	7hr 28 min	5hr 12 min	5hr 33 min
Awake		0	8 min	11 min	23 min	3 min
REM		1h 13 min	2hr 18 min	1hr 35 min	1hr 3 min	1hr 46 min
Core		2hr 49 min	5hr 43 min	4hr 48 min	2hr 45 min	3hr
Deep		1hr 21 min	1hr 14 min	1hr 5 min	36 min	46 min
September 26						
In Bed		7hr 14 min	8hr 22 min		4hr 53 min	6hr 40 min
Awake		28 min	4 min		21 min	7 min
REM		1hr 34 min	2hr 3 min		1hr 1 min	1hr 29 min
Core		4hr 36 min	5hr 47 min		3hr 28 min	4hr 27 min
Deep		1hr 3 min	32 min		24 min	44 min
September 27						
In Bed			8hr 9 min	7hr 4 min		7hr 15 min
Awake			2 min	1hr 47 min		5 min
REM			2hr 10 min	1hr 18 min		1hr 42 min
Core			5hr 10 min	5hr 7 min		4hr 15 min
Deep			48 min	38 min		1hr 18 min

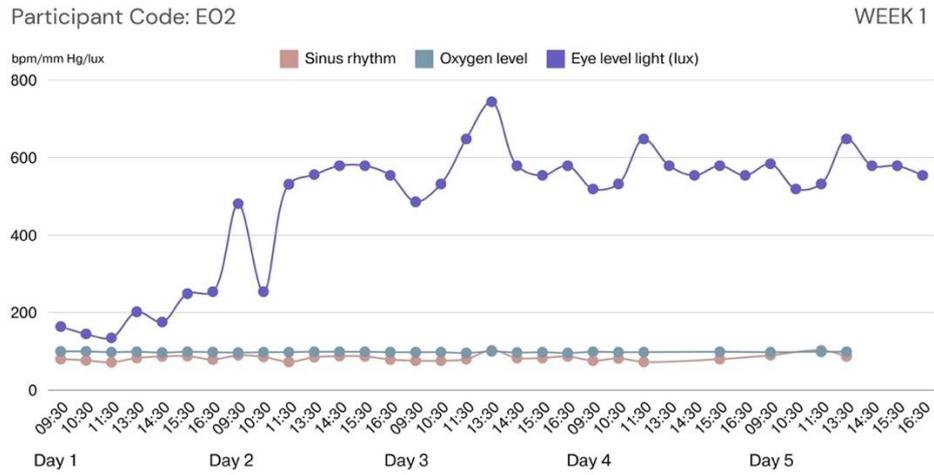


Figure 58. Week 1 Participant E02 Chart 1

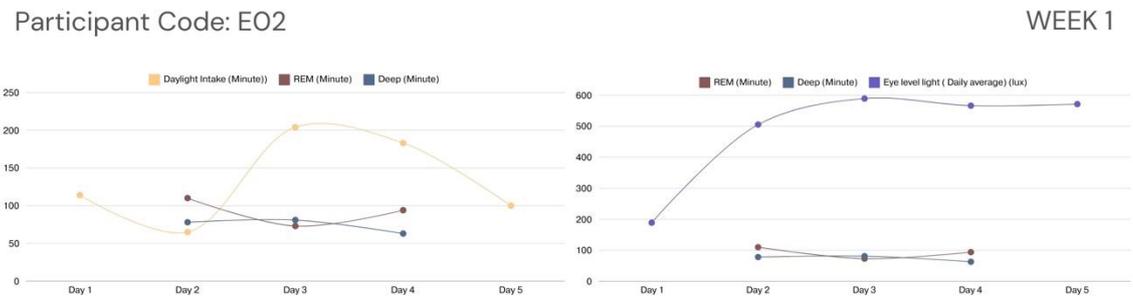


Figure 59. Week 1 Participant E02 Chart 2

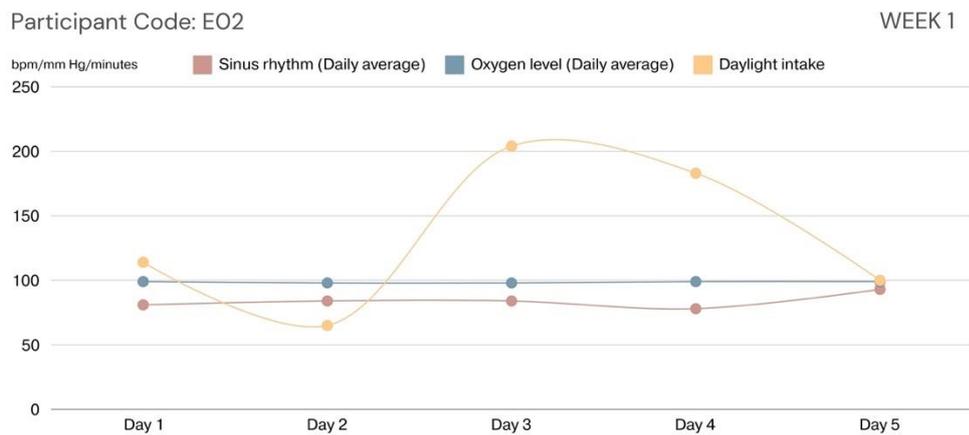


Figure 60. Week 1 Participant E02 Chart 3

E02 Participant Chart 1 (Figure 58) shows data over five days, tracking three variables: sinus rhythm, oxygen level, and eye level light (lux). Eye level light displays

significant variability throughout each day, with readings fluctuating from below 200 lux to over 600 lux. The highest fluctuations occur around the middle of the day, with more stable values in the mornings and the afternoons. Sinus Rhythm and Oxygen Level both maintain relatively stable across the five-day period. Values fluctuate slightly but remain constant compared to the light levels. Overall, the graph suggests a strong daily pattern in light exposure, while physiological measures like sinus rhythm and oxygen level remain constant irrespective of the light changes. This may indicate that these physiological measures are less directly affected by changes in environmental lighting at the levels observed according to this chart. Mood values of participant E2 could not be tested. Therefore, no conclusion about mood could be reached.

E02 Participant Chart 2 (Figure 59) follows four variables over five days. In the chart on left; daylight intake, REM sleep, and deep sleep has shown. Daylight intake shows a slight decrease over the five days. It starts above 100 minutes and gradually declines towards the end. Both REM and deep sleep minutes remain fairly consistent across the days. They exhibit minor variations, with little direct correlation to daylight intake or average light levels but the data from the 1st and 4th night of the participants' sleep measurements could not be retrieved from the watch. The user may not have worn the watch on those nights, the watch may have run out of battery, or the watch may not have been able to read the data due to other technical problems. In chart on right, the amount of light at the participants' eye level was measured every hour, but this chart uses the average amount of light received at eye level per day. Eye-Level Light (Daily Average Lux) line shows a steep initial rise and starts decreasing slightly after peaking around day 3. The daily average remains consistently high, indicating substantial light exposure. Overall, the charts indicate that while daylight intake decreases, the average eye-level light exposure stays quite high. REM and deep sleep durations show minimal fluctuations and remain stable without significant changes. There may be a potential correlation between increased daylight and light exposure and reduced variance in sleep patterns, but more data are needed for definitive conclusions but, it may still be insufficient to make an adequate determination about these measurements as the watch did not receive data for 2 nights.

E02 Participant Chart 3 (Figure 60) presents three variables over five days: sinus

rhythm, oxygen level, daylight intake. The amount of daylight received per day started with 114 minutes, decreased to 65 minutes, then increased to 204, the highest level, and then decreased again to 100 minutes on the 5th day. It suggests a reduction in time spent in daylight as the day's progress. Sinus Rhythm and Oxygen Level remain relatively stable across the five days with only minor fluctuations. In these small fluctuations, the sinus rhythm is observed to move with daylight. As the amount of daylight increases, the sinus rhythm decreases in a healthy way and progresses in stable conditions.

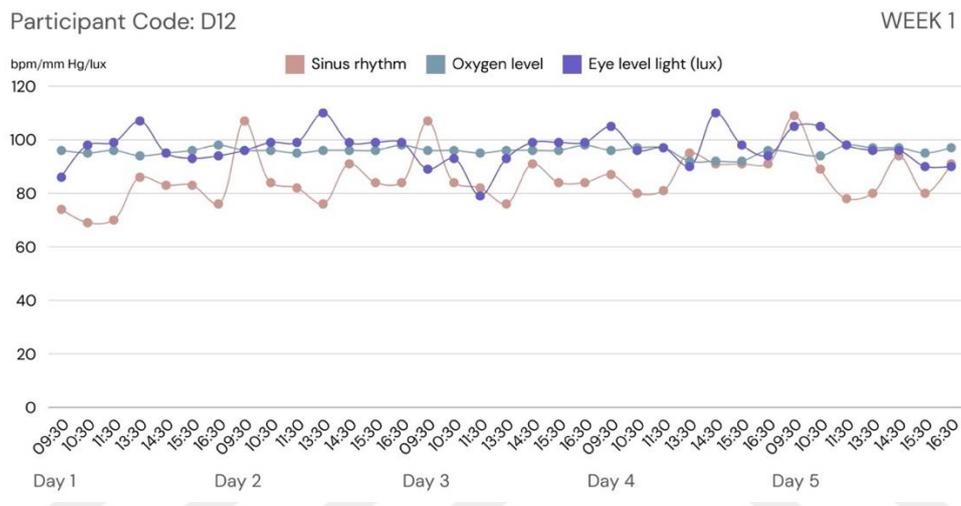


Figure 61. Week 1 Participant D12 Chart 1

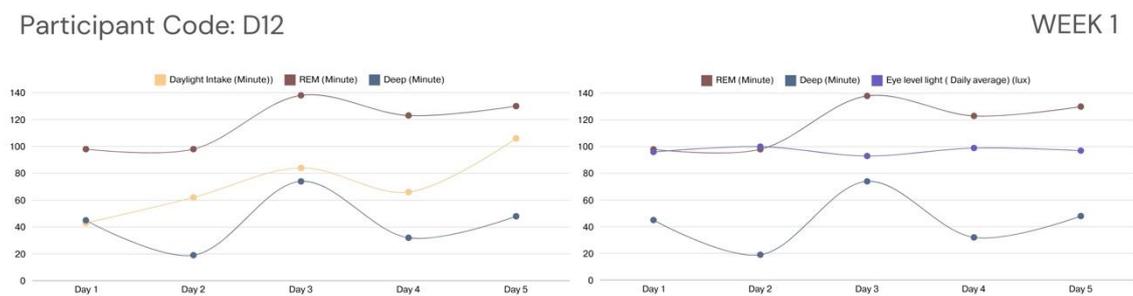


Figure 62. Week 1 Participant D12 Chart 2

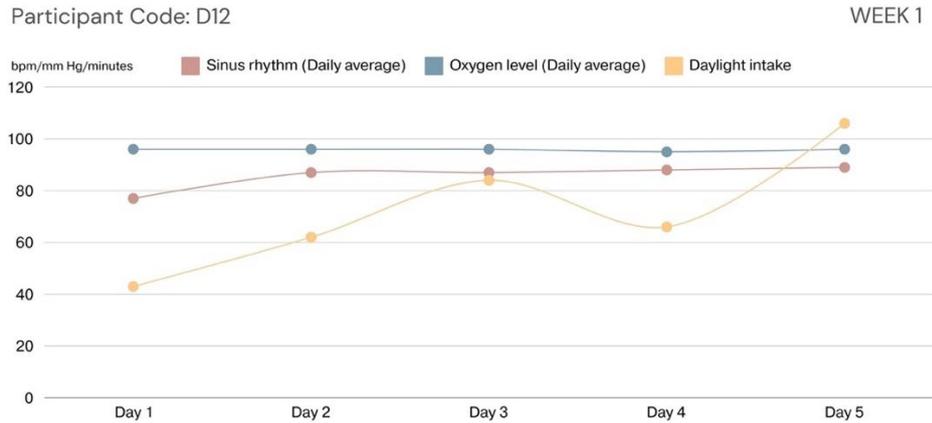


Figure 63. Week 1 Participant D12 Chart 3

D12 Participant Chart 1 (Figure 61) displays measurements of sinus rhythm, oxygen level and light at eye level (lux) over five days. Sinus rhythm and oxygen level are relatively stable with small variations. They maintain consistent average values throughout the week, indicating stable physiological conditions. Eye level light displays small, consistent fluctuations and remains within a similar range. This indicates a stable lighting environment with no significant changes. Overall, the chart reflects stability in both lighting conditions and physiological responses over the five-day period. There are no significant changes in any of the variables, indicating a stable daily routine for the participant.

D12 Participant Chart 2 (Figure 62) shows two charts of daylight intake, REM sleep, deep sleep, and eye-level light (lux) across five days. In the chart on left, daylight intake significantly increased and on day 4, it decreased again and peaked on day 5. REM sleep increased until day 3, peaked on day 3, decreased on day 4 and increased again on the last day. Deep sleep increased and decreased at the same rate as REM sleep and increased again on the last day. It progressed in direct proportion to daylight and REM sleep. In the right chart, eye level light remained generally stable, with only a slight fluctuation on day 3. REM sleep increased until day 3, peaked on day 3, decreased on day 4 and increased again on the last day. Deep sleep increased and decreased at the same rate as REM sleep and increased again on the last day. Overall, the charts suggest a correlation between increased daylight exposure and improvements in REM and deep sleep. The chart on the right shows that the effect of the total amount of illumination from daylight and artificial light at eye level on the

participants' sleep was not affected. Participants' sleep levels were only affected by the amount of daylight intake.

D12 Participant chart 3 (Figure 63) shows sinus rhythm, oxygen level and daylight intake over five days. On the first day, the average sinus rhythm value was 77 and oxygen level was 96, on the second day sinus rhythm value was 87 and oxygen level was 96, on the 3rd day sinus rhythm value was 87 and oxygen level was 96, on the 4th day sinus rhythm value was 88 and oxygen level was 95, on the 5th day sinus rhythm value was 89 and oxygen level was 96. The participants' 5-day average oxygen level remained stable overall with small fluctuations. On day 2 it decreased slightly, on day 3 it increased slightly, on day 4 it decreased slightly and on day 5 it was at its highest level. The fact that all measurements peaked on the last day may indicate a light effect for this participant, but in general, according to the graph, it can be observed that the participants' measurements remained stable.

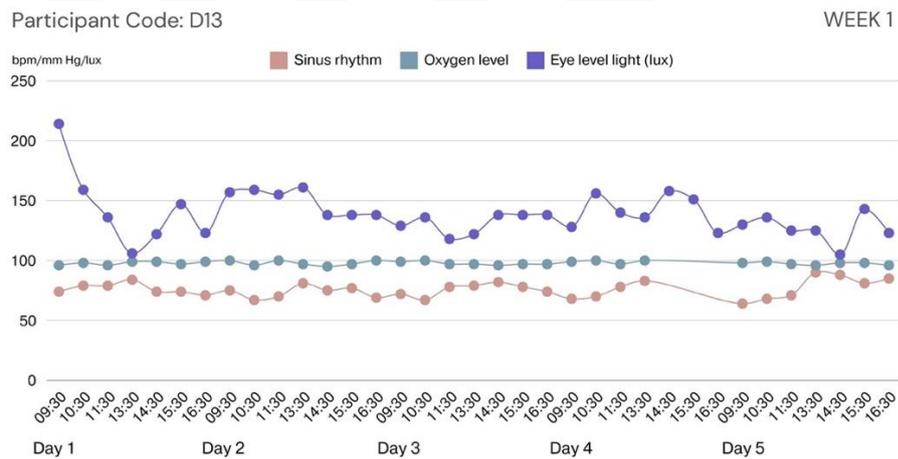


Figure 64. Week 1 Participant D13 Chart 1

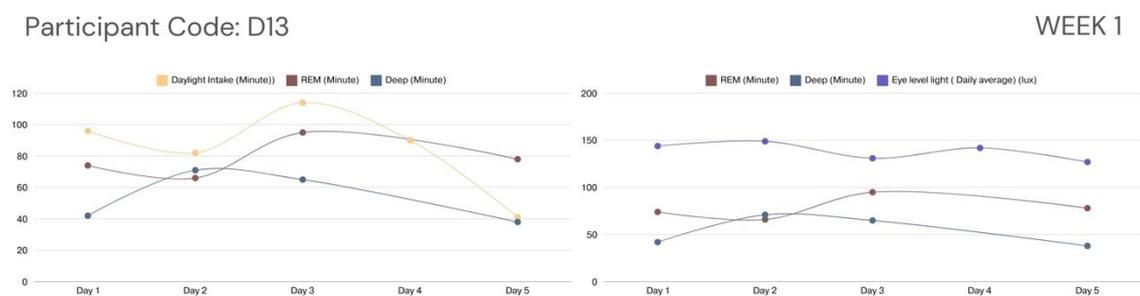


Figure 65. Week 1 Participant D13 Chart 2

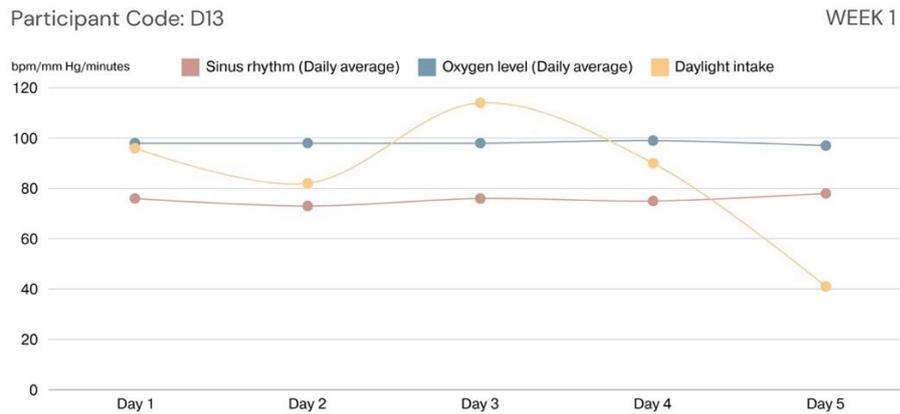


Figure 66. Week 1 Participant D13 Chart 3

On the D13 participant chart 1 (Figure 63) shows sinus rhythm, oxygen level, and eye-level light (lux) over five days. On the light level light line, high baseline levels gradually decline significantly on day 1, then fluctuate, maintaining a moderate range. On the first day, the average sinus rhythm value was 76 and oxygen level was 98, on the second day sinus rhythm value was 73 and oxygen level was 98, on the 3rd day sinus rhythm value was 76 and oxygen level was 99, on the 4th day sinus rhythm value was 75 and oxygen level was 99, on the 5th day sinus rhythm value was 78 and oxygen level was 97. Light variations are caused by daily weather conditions, cloud transitions, or ambient dividers. Sinus rhythm and oxygen level both remain relatively stable with minor fluctuations around their mean values. In these small fluctuations, the sinus rhythm is observed to move with light. As the number of light increases, the sinus rhythm decreases in a healthy way and progresses in stable conditions. It was observed that light intake was also high at the point where the oxygen level was the highest, so it can be argued that this participant was affected by light levels.

On the D13 participant chart 2 (Figure 64), daylight intake was initially high and decreased during the week in the chart on left. This may have been influenced by the change in light that the participant was exposed to outdoors and indoors. The change in weather conditions in the working environment, overcast weather may also have had an effect. In the chart on right, the daily average of light has remained relatively stable with a slight downward trend. Consistent light exposure indicates a controlled indoor lighting environment. REM sleep shows a slight decreasing tendency. A decrease may indicate changes in sleep quality or restfulness. Deep sleep duration started with low minutes but increased until mid-week and then decreased slightly.

Changes may be influenced by exposure to light or other environmental factors. Overall, this chart reflects a decline in daylight intake and consistent indoor light exposure, and some differences in sleep patterns. This may indicate the need for balanced light exposure to maintain optimal sleep quality and well-being. It may also be evidence that light affects the circadian rhythm cycle.

On the D13 participant chart 3 (Figure 65), daylight intake is observed to decrease from day 1 to day 5. As the week progresses, it is observed that the participants' exposure to daylight decreases. The constant levels indicate that the participant is generally in controlled indoor lighting environments. Sinus Rhythm and Oxygen Level Both remain comparatively constant throughout the week. This indicates consistent physiological conditions, probably unaffected by changes in light conditions. Overall, the charts indicate stable lighting conditions and physiological responses, with a significant reduction in natural daylight exposure towards the end of the week. Maintaining balanced light exposure may be crucial for optimal welfare and optimal biological values.

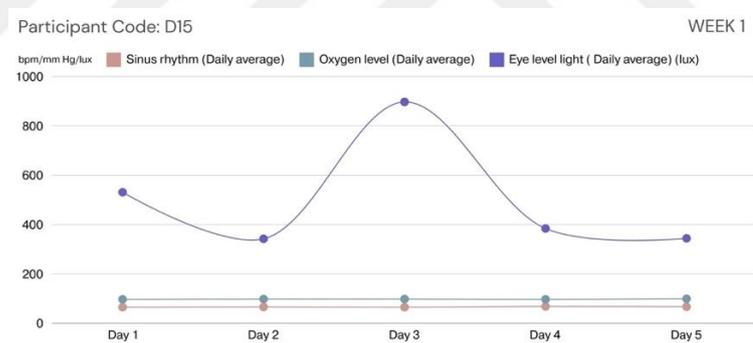


Figure 67. Week 1 Participant D15 Chart 1

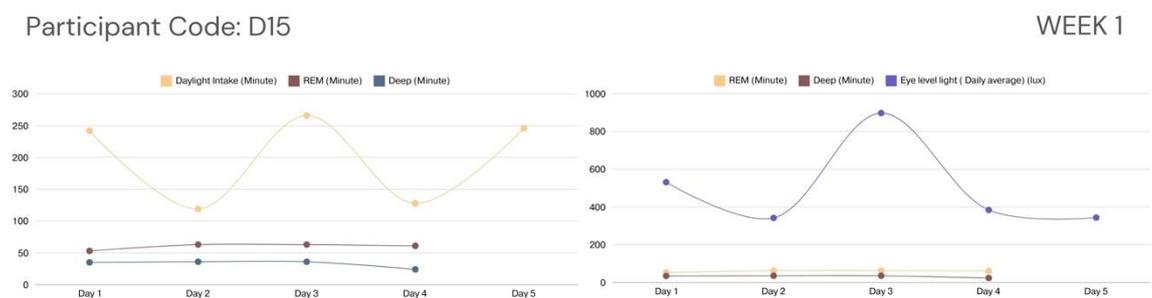


Figure 68. Week 1 Participant D15 Chart 2

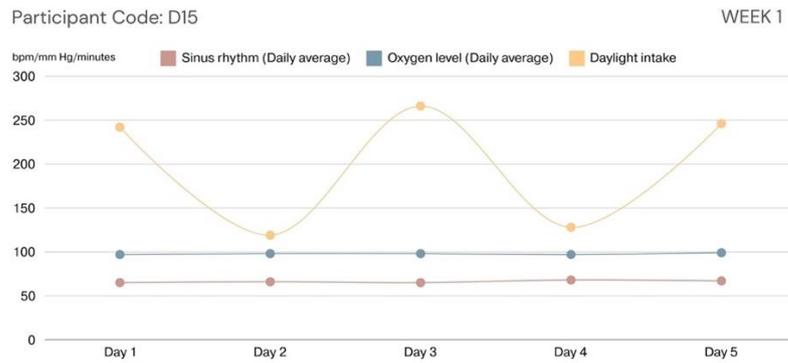


Figure 69. Week 1 Participant D15 Chart 3

In d15 participant chart 1 (Figure 67), There is a significant increase in Eye Level light level, reaching over 2000 lux on day 3, indicating a high level of light exposure. Fluctuations are also observed on other days, but in a more minor range. These variations suggest rotating exposure to bright and moderate light conditions. Sinus rhythm and oxygen level remained stable and monitored with little fluctuations for five days. The light level that this participant received in the office was higher compared to other participants and the sinus rhythm was generally stable and the oxygen level was high. On the first day, the average sinus rhythm value was 65 and oxygen level was 97, on the second day sinus rhythm value was 66 and oxygen level was 98, on the 3rd day sinus rhythm value was 65 and oxygen level was 98, on the 4th day sinus rhythm value was 68 and oxygen level was 97, on the 5th day sinus rhythm value was 67 and oxygen level was 99. It should be noted that this stability and regular measurements may be due to adequate daylighting, but it is also possible that other factors may contribute to good biological values.

In D15 participant chart 2 (Figure 68), the light at eye level (daily average Lux) reaches up to about 900 lux on day 3. This is a sign of intense light exposure on this day compared to other days. Daylight intake gradually decreased from day 1 to day 4, then slightly increased on day 5. REM and deep sleep remained relatively stable with minor changes throughout the week. Stable sleep measurements suggest that abrupt changes in light exposure, such as the peak on day 3, do not immediately affect sleep quality. Overall, the charts show changing light conditions, with a notable increase in light exposure on day 3. Despite this, sleep patterns remained consistent, which is thought to emphasize resilience or adaptation to light fluctuations.

In D15 participant chart 3 (Figure 69), light at eye level (daily average Lux) peaks sharply around 900 lux on day 3, indicating high light exposure. It decreases again on day 4, maintaining a lower level on the other days. Daylight intake shows a decreasing trend from day 1 to day 4, followed by an increase on day 5. This reflects the fluctuation in outdoor exposure or natural light availability. The light level that this participant received in the office was higher compared to other participants and the sinus rhythm was generally stable and the oxygen level was high. It should be noted that this stability and regular measurements may be due to adequate daylighting, but it is also possible that other factors may contribute to good biological values. At the same time, physiological responses such as sinus rhythm and oxygen levels remained consistent with the variability in light exposure, especially with the peak on day 3. This may indicate effective adaptation to lighting changes.

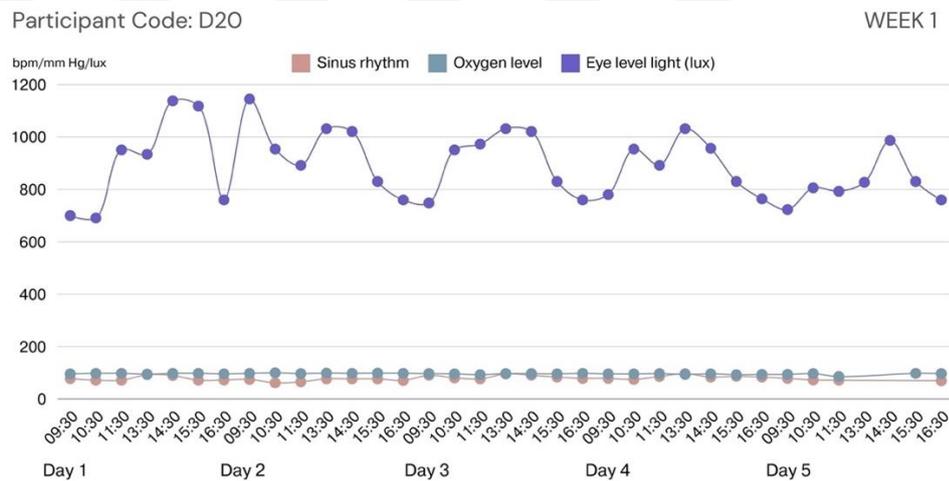


Figure 70. Week 1 Participant D20 Chart 1

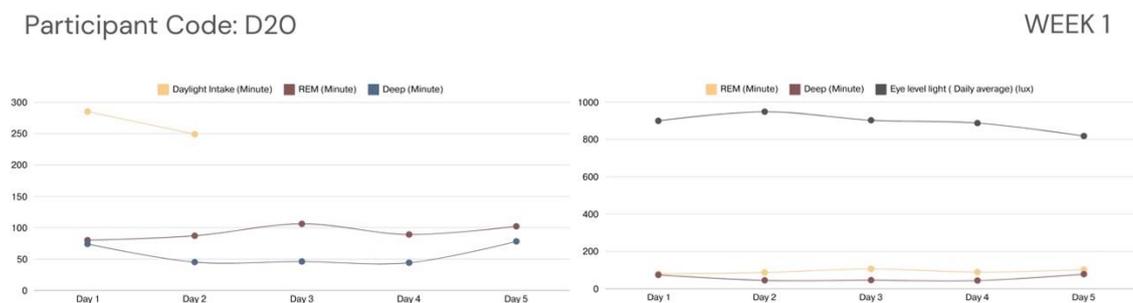


Figure 71. Week 1 Participant D20 Chart 2

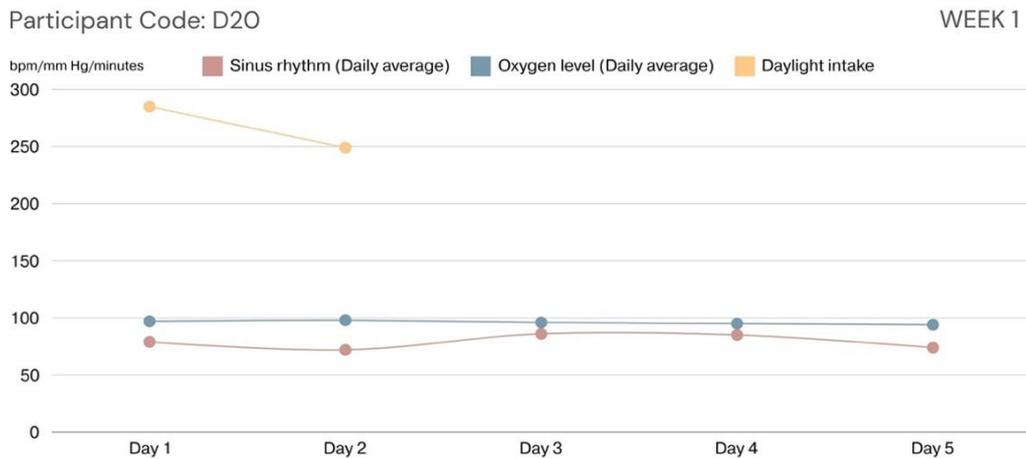


Figure 72. Week 1 Participant D20 Chart 3

In D20 participant chart 1 (Figure 70), light at eye level demonstrates significant fluctuations, especially on days 1 and 5, ranging from about 600 to 1200 lux. These swings suggest changes in light exposure, possibly due to environmental factors or changes in routine. Sinus rhythm and oxygen level variables remained relatively constant with minimal fluctuations over the five days. On the first day, the average sinus rhythm value was 79 and oxygen level was 97, on the second day sinus rhythm value was 72 and oxygen level was 98, on the 3rd day sinus rhythm value was 86 and oxygen level was 96, on the 4th day sinus rhythm value was 85 and oxygen level was 95, on the 5th day sinus rhythm value was 74 and oxygen level was 94. The ratio of these fluctuations in relation to light showed that in some cases the increase in light reduced the participants' sinus rhythm at a healthy rate. It can be said that the light reduced this participant to a calmer rhythm. Overall, while light exposure varied considerably, the consistent minimum increases and decreases in sinus rhythm and oxygen levels suggest a physiological effect resulting from these lighting changes. It can also be argued that there may be other factors affecting these physiological values.

In D20 participant chart 2 (Figure 71), light levels at eye level are quite high but show a gradual decrease over the period in the chart on right. This indicates a strong but slightly decreasing average light exposure each day. This may be due to seasonal transitions, climatic conditions and weather. In the chart on left, it was found that the participants' daylight intake level could not be measured by the watch after the 2nd day. This could be due to technical problems or because the participant was in daylight with the watch covered. Therefore, sleep levels after day 2 can only be compared with

daily average light data. Overall, the graphs indicate high but decreasing light exposure while maintaining stable sleep patterns, which may imply effective adaptation to changing light environments. As a result, when the sleep monitoring of the participant was evaluated with eye-level light, it was observed that deep sleep decreased with the increase in light from the first day to the second day, but the amount of REM sleep increased. On the 3rd day, the light decreased, but REM sleep increased but the level of deep sleep remained constant. On day 4, the light continued to decrease and REM sleep decreased but deep sleep increased slightly. On day 5, light decreased further but both sleep levels increased slightly.

In D20 participant chart 3 (Figure 72), the participants' daylight intake level could not be measured by the watch after the 2nd day. On the first day, the average sinus rhythm value was 79 and oxygen level was 97, on the second day sinus rhythm value was 72 and oxygen level was 98, on the 3rd day sinus rhythm value was 86 and oxygen level was 96, on the 4th day sinus rhythm value was 85 and oxygen level was 95, on the 5th day sinus rhythm value was 74 and oxygen level was 94. In general, sinus rhythm is stable. Although there are small fluctuations in the oxygen level, daylight intake measurement is not adequate and not much comparison can be made due to lack of data on the graph.

Table 9 shows the measurements of 5 participants in detail in week 2. In Table 10, the amount of daylight received daily by the same participants is given in minutes and their sleep duration is also given in minutes.

Table 9. Week 2 participants' sinus rhythm, oxygen level and light measurements

WEEK 2 TIME	D05			D06			D09			D11			D14			D15								
	Sinus rhythm	Oxygen level	Lux level on desk	Sinus rhythm	Oxygen level	Lux level on desk	Sinus rhythm	Oxygen level	Lux level on desk	Sinus rhythm	Oxygen level	Lux level on desk	Sinus rhythm	Oxygen level	Lux level on desk	Sinus rhythm	Oxygen level	Lux level on desk						
DAY 1 (03.09.2024)																								
09:30	81	100	18	94	100	295	238	72	99	182	123	69	98	50	75	60	99	200	160	68	99			
10:30	86	97	18	99	99	295	238	81	100	182	123	76	96	50	75	72	100	200	160	67	98	82	101	
13:30	87	99	19	112	96	286	294	72	99	188	96	76	96	51	148	69	97	185	149	62	98	636	150	
14:30	81	99	24	96	100	292	233	67	98	185	102	84	94	56	152	70	99	193	142	66	97	437	463	
15:30	78	97	36	94	95	289	238	74	99	175	90	55	159	70	94	196	145	68	99	340	357			
16:30	76	97	40	110	99	295	241	74	96	200	118	79	97	53	158	69	100	202	163	69	100			
AVERAGE	82	98	26	101	98	292	247	73	99	185	109	77	96	53	128	68	98	196	153	67	99	374	268	
DAY 2 (01.10.2024)																								
09:30			14	105	99	293	221																	
10:30	96	96	38	103	99	294	300					75	94											
11:30	85	100	9	111	108	291	233			214	90			56	148	64	96							
13:30	97	97	36	100	97	291	234	69	100	197	74	87	97	51	152	72	99	200	176	69	98	522	437	
14:30	79	98	24	96	98	292	233	74	100	185	102	84	95	56	152	67	99	193	142	68	97	437	463	
15:30	77	98	36	98	98	289	238	74	99	175	90	93	94	55	159	69	93	196	145	69	98	340	357	
16:30	81	93	40	100	97	295	241	74	99	200	118	71	97	53	158	62	99	202	163	70	99			
AVERAGE	86	97	28	100	98	292	251	72	100	194	95	82	95	54	154	66	98	198	157	70	98	433	419	
DAY 3 (02.10.2024)																								
09:30			14	12		293	221																	
10:30	86	100	38	107	99	294	300	70	100	216	107	81	99	51	164	72	99	195	156	70	97	1690	1256	
11:30	89	94	40	107	99	294	315	73	100	208	86			46	148	73	98	195	145	64	97	653	2100	
13:30	78	96	37	97	98	296	270	67	100	209	108	85	96	56	144	82	97	195	145	63	97	581	437	
14:30	76	96	37	97	98	298	275	63	98	209	108	80	98	56	128	87	93	195	145	68	97	279	463	
15:30	90	98	37	91	96	298	275	68	100	209	108			56	128	82	100	195	145	68	100	279	357	
16:30			40	101	98	295	241	71	100	200	118			53	158	79	100	202	163	69	100	279	357	
AVERAGE	84	97	35	101	98	295	271	70	100	207	103	80	98	52	148	79	98	196	152	68	98	633	807	
DAY 4 (03.10.2024)																								
09:30	112	97	14	12	119	292	221	65	100	199	88	72	87	44	164	79	100	196	165	70	100	672	682	
10:30	110	96	38	106	95	294	300	67	96	216	107			51	164	71	96	195	156	67	100	1690	1256	
11:30	91	96	40	106	95	294	315	71	98	208	86	70	97	46	148	70	99	195	145	64	97	653	2100	
13:30	107	99	37	104		296	270	71	100	209	108	81	96	56	144	97	95	195	145	64	97	581	437	
14:30	94	97	37	108		298	275	75	100	209	108	88	98	56	128	89	100	195	145	70	98	279	310	
15:30	92	100	37	108		298	275	71	96	209	108			56	128	84	93	195	145	78	98	279	310	
16:30	87	99	40	113	94	295	241	71	100	200	118			53	158	79	97	202	163	79	100	141	155	
AVERAGE	99	98	35	113	94	295	271	70	99	207	103	78	95	52	148	81	97	196	152	71	98	614	768	
DAY 5 (04.10.2024)																								
09:30			9	111	95	293	221			199	88	80	99	44	164	74	92	185	164					
10:30	82	98	12	102	99	292	196			199	103	83	89	50	164	82	100	185	157					
11:30										203	103	102	94	52	145	92	95	195	145					
13:30	63	78	12	104	98	291	194																	
14:30	86	97		108	96																			
15:30	84	100		108	99																			
16:30	80	96		101	97																			
AVERAGE	79	94	11	106	97	292	204			200	98	88	97	49	158	76	96	188	155					

Table 10. Week 2 participants' daylight intake and sleep tracking

WEEK 2 - Daylight intake	D05	D06	D09	D11	D14	D15
September 30	83	109	36	155	26	209
October 01	117	117	35	128	82	185
October 02	125	25	65	181	69	184
October 03	155	115	48	203	81	190
October 04	99	113	22	133	46	49
October 05	51					180
October 06	45					118
WEEK 2 - Sleep	D05	D06	D09	D11	D14	D15
September 30						
In Bed	5hr 45 min	5hr 45 min	7hr 41 min	6hr 28 min	6hr 35 min	5hr 26 min
Awake	2 min	0 min	11 min	9 min	10 min	8 min
REM	55 min	1hr 58 min	1hr 54 min	1hr 19 min	2hr 3 min	54 min
Core	3hr 4 min	2hr 46 min	4hr 58 min	4hr 26 min	3hr 31 min	3hr 32 min
Deep	1hr 45 min	1hr 1 min	48 min	43 min	1hr 1 min	59 min
October 01						
In Bed	5hr 14 min		7hr 8 min	5hr 13 min	6hr 46 min	5hr 42 min
Awake	2 min		14 min	1hr 2 min	18 min	31 min
REM	1hr 16 min		1hr 31 min	1hr 6 min	1hr 59 min	1hr 6 min
Core	2hr 35 min		4hr 30 min	3hr 12 min	4hr 8 min	4hr 6 min
Deep	1hr 22 min		1hr 7 min	55 min	38 min	30 min
October 02						
In Bed	5hr 46 min	6hr 47 min	7hr 54 min	7hr 13 min	6hr 49 min	4hr 45 min
Awake	2 min	1hr 15 min	0 min	4 min	8 min	19 min
REM	1hr 27 min	1hr 54 min	1hr 56 min	1hr 41 min	1hr 43 min	51 min
Core	3hr 3 min	4hr 21 min	5hr 9 min	4hr 23 min	4hr 22 min	3hr 17 min
Deep	1hr 15 min	32 min	49 min	1hr 8 min	43 min	37 min
October 03						
In Bed		5hr 13 min	7hr 30 min	5hr 40 min	6hr 33 min	4hr 50 min
Awake		0 min	3 min	4 min	11 min	16 min
REM		1hr 41 min	1hr 28 min	1hr 36 min	2hr 9 min	1hr 32 min
Core		2hr 44 min	5hr 5 min	2hr 50 min	3hr 16 min	2hr 28 min
Deep		48 min	56 min	1hr 13 min	1hr 8 min	49 min
October 04						
In Bed	4hr 21 min				6hr 56 min	
Awake	1 min				53 min	
REM	1hr 13 min				1hr 40 min	
Core	2hr 2 min				4hr 32 min	
Deep	1hr 5 min				44 min	

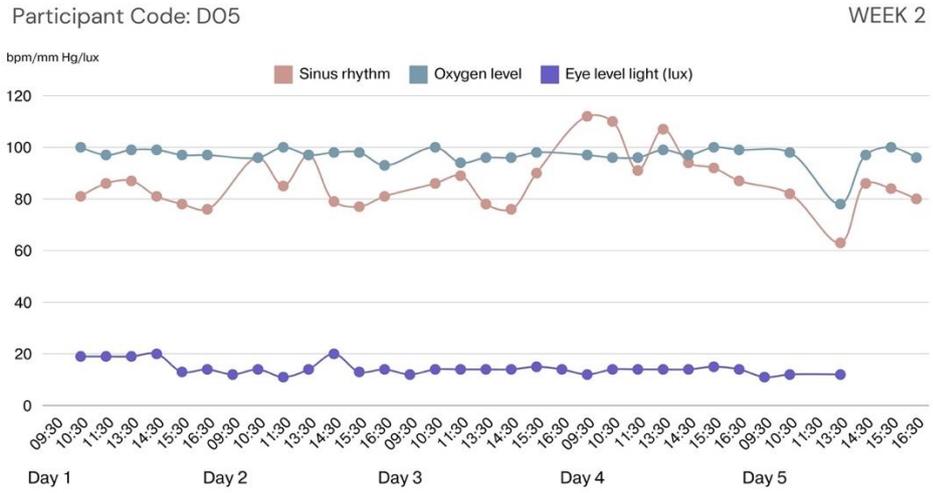


Figure 73. Week 2 Participant D05 Chart 1

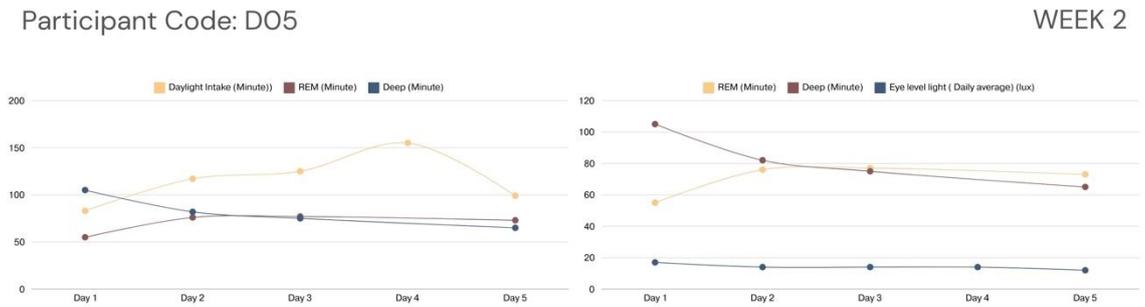


Figure 74. Week 2 Participant D05 Chart 2

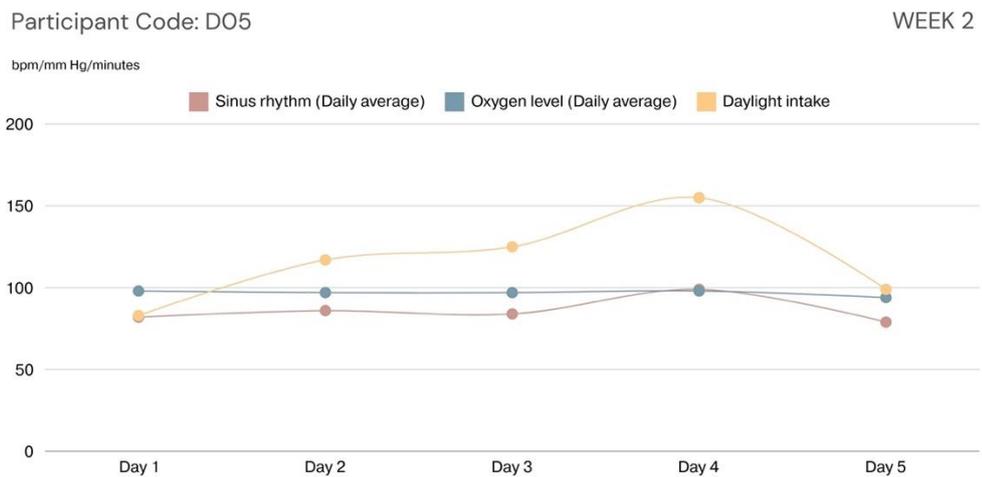


Figure 75. Week 2 Participant D05 Chart 3

In D05 participant chart 1 (Figure 73), light levels are generally low in the chart and

consistent across all days. In general, there are minimal changes. Sinus rhythm and oxygen level measurements are relatively stable with some swings. Sinus rhythm shows more variability, especially on days 3 and 4, generally fluctuating between 80 and 100 bpm/mm Hg. Oxygen level remains consistently close to 100, indicating stable physiological conditions. It is not clear whether these changes are exactly related to the light effect on this chart.

In D05 participant chart 2 (Figure 74), daylight intake increased from day 1 on left. It peaked on day 4 and decreased on day 5. It also points to fluctuations in outdoor exposure during the week. Eye-level light remained at a constant level from the first day in the chart on right. Sleep REM duration increased in direct proportion to daylight from day 1. After the 2nd day, it remained constant. Deep sleep duration is high on the first day and then decreases and continues at close levels with REM until day 5. Overall, daylight intake varies, while sleep patterns remain stable, highlighting potential flexibility in response to changing light exposure. Indoor light conditions remain consistent. In this chart, no clear effect is observed for the relationship between daylight intake and sleep values. Other factors affecting the participant may have had an influence on this.

In D05 participant chart 3 (Figure 75), the light at eye level is relatively low and constant compared to other variables. It reflects a stable indoor lighting situation. Sinus rhythm and oxygen level remained fairly stable with small fluctuations in both measurements. On the first day, the average sinus rhythm value was 82 and oxygen level was 98, on the second day sinus rhythm value was 86 and oxygen level was 97, on the 3rd day sinus rhythm value was 84 and oxygen level was 97, on the 4th day sinus rhythm value was 99 and oxygen level was 98, on the 5th day sinus rhythm value was 79 and oxygen level was 94. It shows consistent physiological conditions despite changes in light exposure. Overall, the charts show that while light intake varies, physiological measurements remain constant and effectively adapt to changes in exposure to light. Indoor lighting conditions can be said to be constant and controlled.

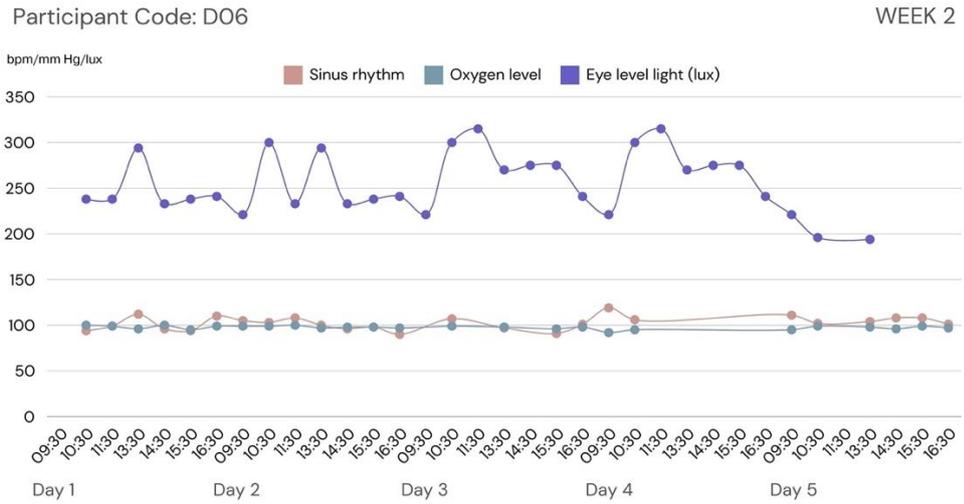


Figure 76. Week 2 Participant D06 Chart 1

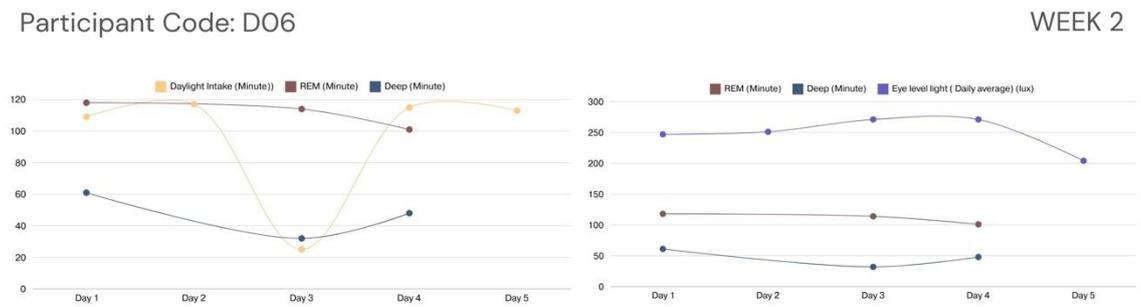


Figure 77. Week 2 Participant D06 Chart 2

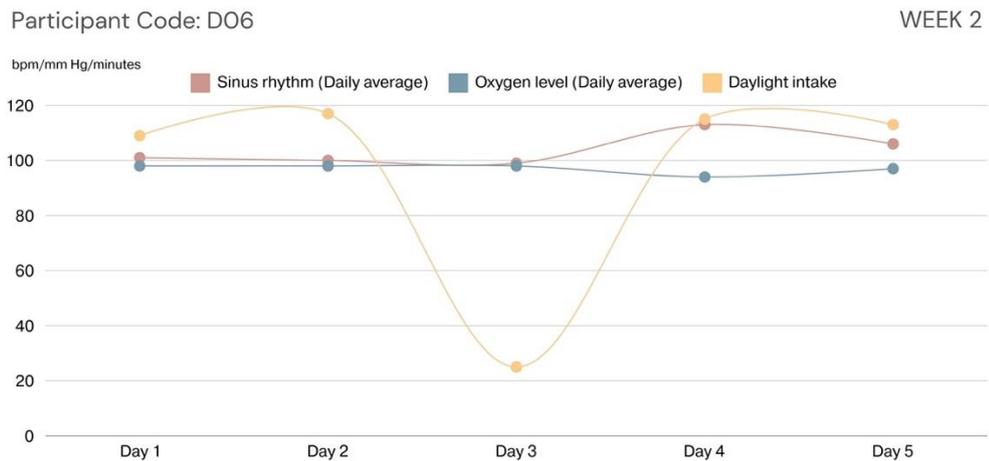


Figure 78. Week 2 Participant D06 Chart 3

In D06 participant chart 1 (Figure 76), light levels change significantly during the first

four days, peaking around midday. Associated with changes in natural light or illumination. It dropped significantly towards the afternoon of day 5. This could also be due to weather conditions. Sinus Rhythm is observed to remain relatively constant with small variations throughout the day. It has sometimes shown slight peaks that may be associated with physical or emotional activity. The oxygen level remained constant for five days without major deviations. On the first day, the average sinus rhythm value was 101 and oxygen level was 98, on the second day sinus rhythm value was 100 and oxygen level was 98, on the 3rd day sinus rhythm value was 99 and oxygen level was 98, on the 4th day sinus rhythm value was 113 and oxygen level was 99, on the 5th day sinus rhythm value was 106 and oxygen level was 97. For this participant, Light intensity does not appear to have a direct relationship with oxygen levels or sinus rhythm, which may indicate that the participants' physiological parameters were not affected by eye-level lux changes within the observed range. Sinus rhythm and oxygen levels were stable throughout the tracking period, indicating that there was no physiological stress or variation associated with exposure to external light during this period.

In D06 participant chart 2 (Figure 77) on left, Daylight intake increased in the first days and decreased considerably on day 3. It peaked on Days 4 and 5, indicating that the participant was more exposed to daylight on these days. On right, eye-level light started high on Day 1 and gradually decreased, reaching its lowest value on Day 5. There appears to be an inverse relationship between daylight intake and mean eye-level light intensity, possibly due to differences in measurement times or environmental conditions, or daylight intake increased because the clock is also measured outdoors. REM sleep was consistent between Days 1 and 3, with slight increases on Days 4 and 5. It can be considered relatively unaffected by daylight exposure or fluctuations in eye-level light intensity. Deep sleep decreased gradually throughout the week, reaching its lowest value on Day 5. This trend may indicate an inverse relationship with increasing daylight intake or light exposure over time. Overall, daylight exposure increases towards the end of the week, while REM sleep does not show a marked improvement and deep sleep actually decreases. This may indicate that prolonged exposure to daylight or light conditions later in the week may interfere with restorative sleep stages such as deep sleep. REM sleep remained relatively consistent throughout, suggesting that it was less affected by illumination or

daylight exposure in this particular dataset.

In D06 participant chart 3 (Figure 78), daylight intake peaked around day 2 and then decreased towards day 5. On day 3, a very significant decrease was observed. This suggests differences in exposure to natural light, possibly due to outdoor activities or changing routines. Both measures of sinus rhythm and oxygen level remain stable, suggesting consistent physiological conditions. The stability suggests minimal influence from changes in light exposure. Overall, while both daylight and indoor light exposure decreased over the week, physiological measures remain consistent, suggesting effective adaptation to changing light conditions.

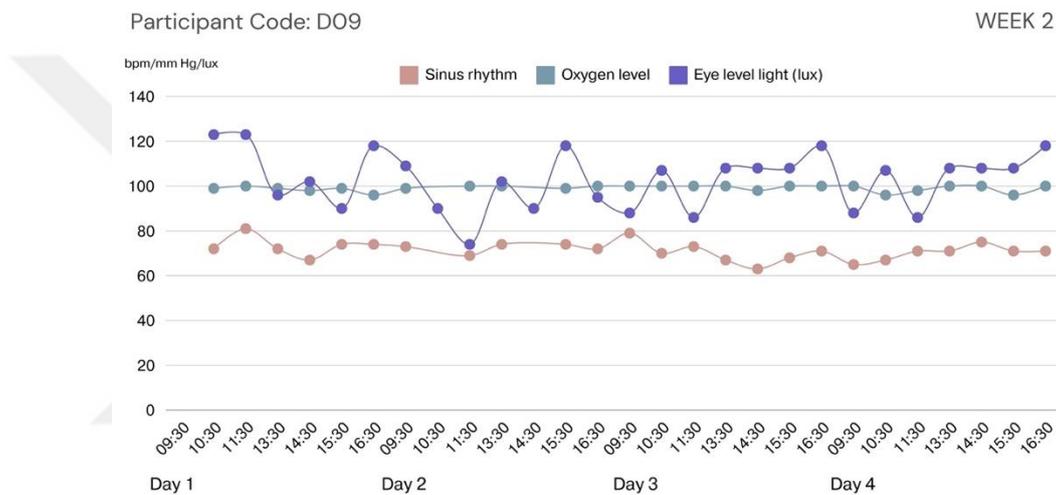


Figure 79. Week 2 Participant D09 Chart 1

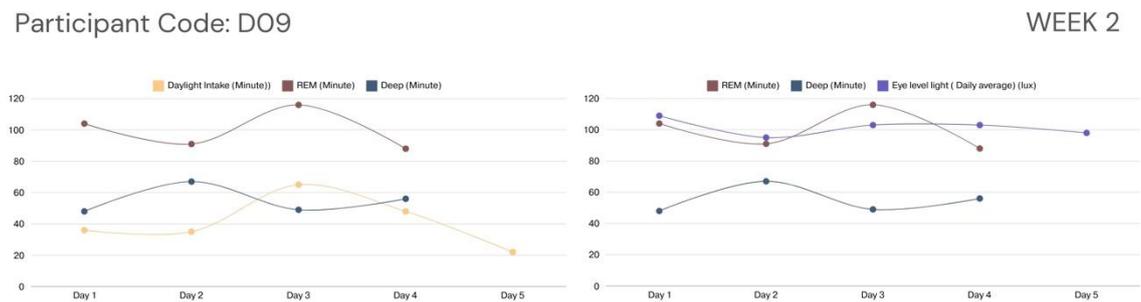


Figure 80. Week 2 Participant D09 Chart 2

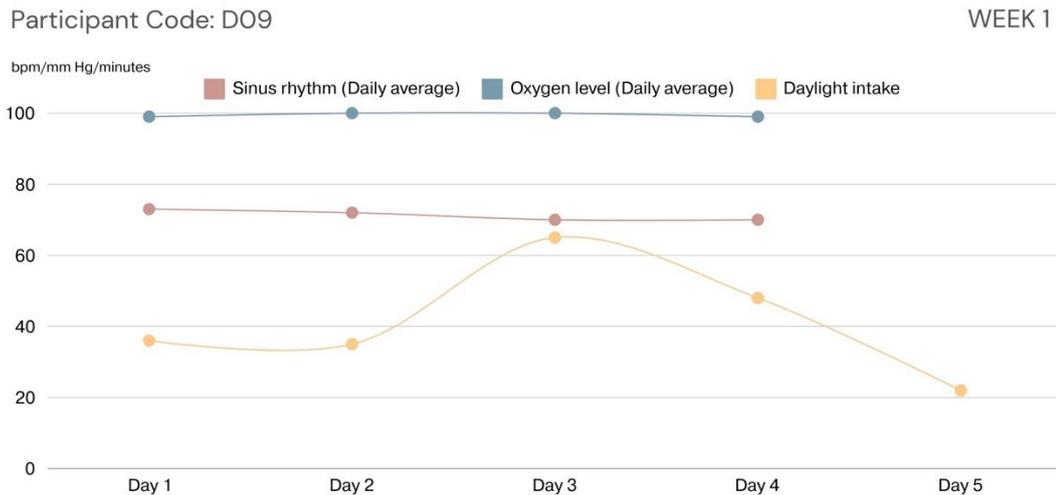


Figure 81. Week 2 Participant D09 Chart 3

In D09 participant chart 1 (Figure 79), the light at eye level fluctuates up and down throughout the day. The amount of light coming into the area where this participant was sitting may also have varied according to the amount of light coming in from the surrounding windows. Weather changes may also have had an effect. There is a cell office next to the participants' office desk and the door of this cell office is opened and closed from time to time. The light from this door may have had an effect. The sinus rhythm remained relatively constant with small fluctuations. On the first day, the average sinus rhythm value was 73 and oxygen level was 99, on the second day sinus rhythm value was 72 and oxygen level was 100, on the 3rd day sinus rhythm value was 70 and oxygen level was 100, on the 4th day sinus rhythm value was 70 and oxygen level was 99, on the 5th day sinus rhythm value was not measured. Consistent physiological conditions were observed despite changes in light exposure. Oxygen level is also stable and maintains a constant trend close to the average. It shows that changes in lighting have minimal impact on this physiological measure. Overall, the graph reveals that while lighting conditions change, sinus rhythm and oxygen levels remain consistent and show resistance to changes in environmental lighting.

In D09 participant chart 2 (Figure 80) on right, light at eye level starts high, peaks between days 1 and 2, and then gradually decreases. On left, Daylight Intake remained relatively low, peaking on day 3 and then decreasing substantially until day 5. This indicates that exposure to natural light is limited and decreasing. REM sleep peaks on day 2 and decreases thereafter. This indicates some fluctuation in sleep quality due to

light exposure. Deep sleep increased until day 3 and then decreased. The variability may be related to general illumination and daytime light exposure patterns. Overall, the charts show changing sleep patterns alongside decreasing light exposure, suggesting a potential link between light levels and sleep quality. Consistent daylight intake may help stabilize these patterns.

In D09 participant chart 3 (Figure 81), daylight intake was low and constant in the first days, increased significantly on day 3 and decreased the rest of the days until the end of day 5. This indicates a decrease in the time spent in natural light. Sinus rhythm and oxygen level remained constant with minimal fluctuations. It shows consistent physiological conditions despite changes in light exposure. Overall, while the graph indicates a decrease in both indoor and outdoor light exposure, it also shows that the participants' physiological responses remained stable and effectively adapted to changing light levels.

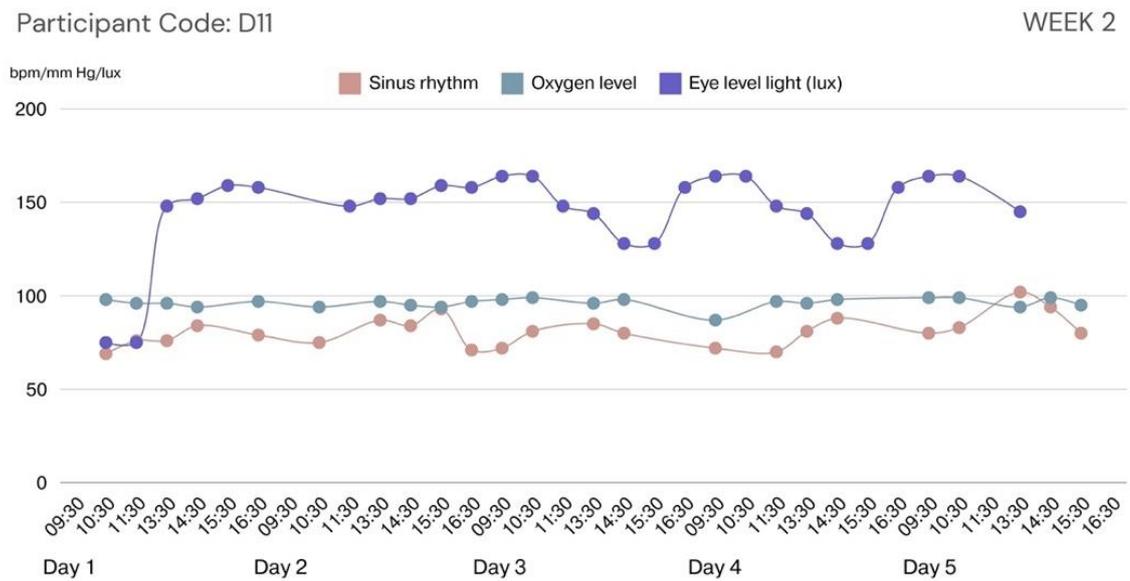


Figure 82. Week 2 Participant D11 Chart 1

Participant Code: D11

WEEK 2

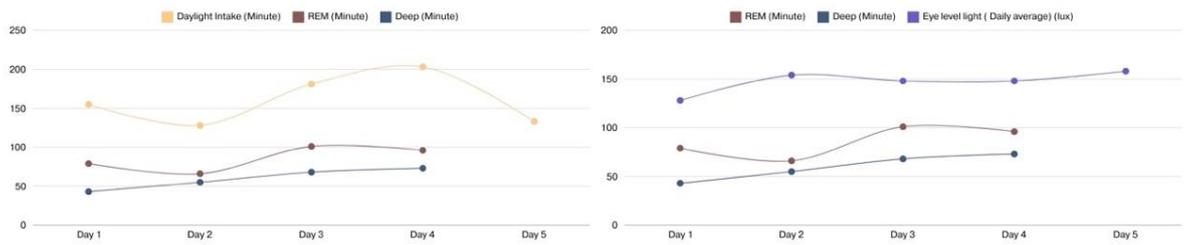


Figure 83. Week 2 Participant D11 Chart 2

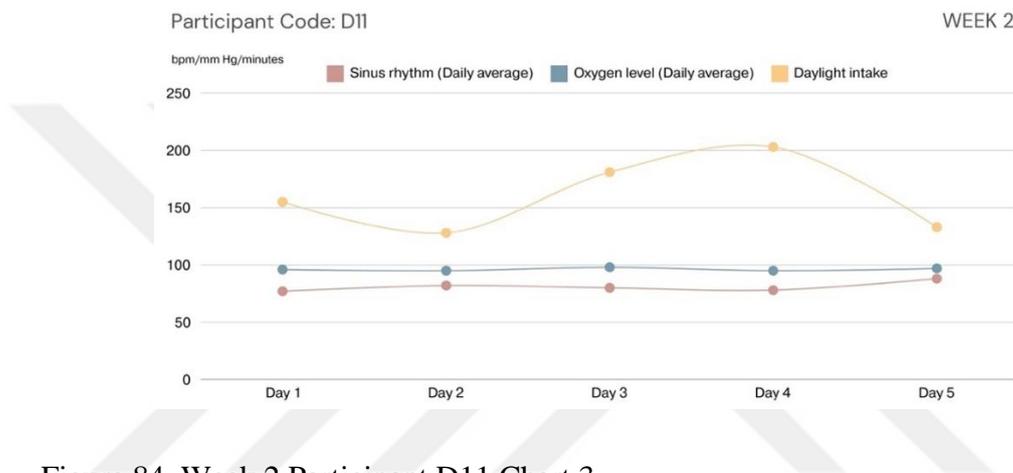


Figure 84. Week 2 Participant D11 Chart 3

In D11 participant chart 1 (Figure 82), the light at eye level showed fluctuations throughout the days, with some peaks and troughs. The participants' sitting position has a dynamic lighting environment, alternating between natural and artificial light. On the first day, the average sinus rhythm value was 77 and oxygen level was 96, on the second day sinus rhythm value was 82 and oxygen level was 95, on the 3rd day sinus rhythm value was 80 and oxygen level was 98, on the 4th day sinus rhythm value was 78 and oxygen level was 95, on the 5th day sinus rhythm value was 88 and oxygen level was 97. Sinus rhythm and oxygen level show relative stability with small fluctuations. This consistency suggests that changes in light exposure do not significantly affect these physiological measures. Overall, while the chart highlights a variable lighting condition, the physiological responses remain constant, suggesting good adaptation to the changing light environment.

In D11 participant chart 2 (Figure 83), daylight intake decreases from day 1 to day 2. It increased on day 3, peaked on day 4 and decreased on day 5. It shows an increase in

exposure to natural light in the middle of the week and a return to lower levels at the end. On the right, light at eye level remained relatively constant with small changes. The participant did not use the watch on the 5th night or there was a technical glitch with the watch, so sleep measurements for this night cannot be analyzed. On the days measured, REM sleep increased gradually, peaking on day 3 and then decreasing slightly. It seems to be associated with higher daylight exposure, which improves sleep quality. Deep sleep showed a slight and steady increase throughout the week. Suggesting a possible improvement in sleep depth consistent with the lighting pattern. Overall, this picture reveals a potential link between greater exposure to daylight and better REM and deep sleep, emphasizing the role of natural light in sleep quality.

In D11 participant chart 3 (Figure 84), daylight intake decreased going into day 2. From day 3 onwards it increased and peaked on day 4. This indicates a higher exposure to natural light in the middle of the week. On day 5 it decreased. Oxygen level measurements are stable throughout the week and show slight variations. In the chart, it is observed that as the amount of daylight received increases, the sinus rhythm value decreases and progresses in a stable state, and as the amount of daylight decreases, the rhythm level increases. The conclusion that can be drawn from this is that daylight positively decreases the sinus rhythm of this participant and keeps the participant calm. It was observed that the oxygen level was not related to daylight except on day 3. It was observed that the oxygen level increased as the daylight increased only on day 3, and it can be stated that this data is not sufficient for this participant to make an adequate inference.

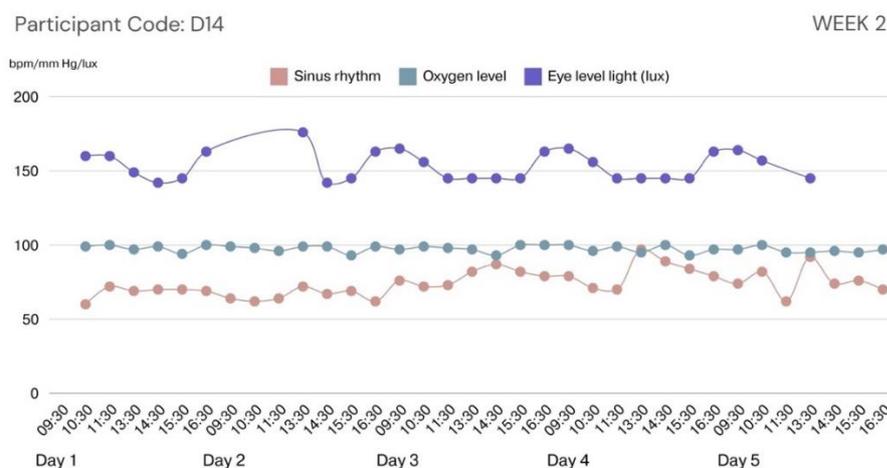


Figure 85. Week 2 Participant D14 Chart 1

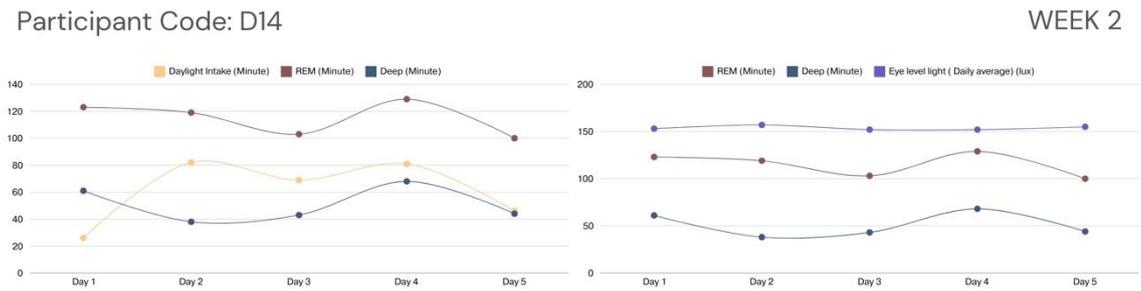


Figure 86. Week 2 Participant D14 Chart 2

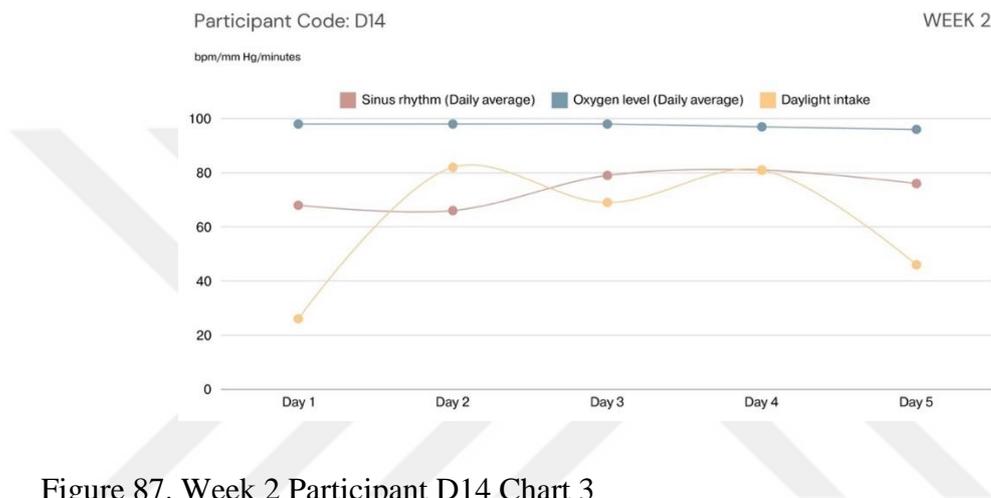


Figure 87. Week 2 Participant D14 Chart 3

In D14 participant chart 1 (Figure 85), the light at eye level showed marked fluctuations with peaks and troughs on each day. Opposite the participants' sitting place in the office, there is a glass cell office behind it. Daylight from here affects the participant depending on the weather conditions. This fluctuation in light is related to this. On the first day, the average sinus rhythm value was 68 and oxygen level was 98. On the second day sinus rhythm value was 66 and oxygen level was 98, on the 3rd day sinus rhythm value was 79 and oxygen level was 98, on the 4th day sinus rhythm value was 81 and oxygen level was 97, on the 5th day sinus rhythm value was 76 and oxygen level was 96. The sinus rhythm is generally stable with intense fluctuations, especially on days 3 and 5. It refers to consistent physiological conditions with small variations. Oxygen levels remain constant and hover around average. Despite changes in light levels, there is no clear pattern showing a decrease in sinus rhythm when light increases. Both sinus rhythm and light appear to operate independently without a strong relationship. Oxygen level remains constant and shows no significant increase or correlation with changing light levels. In conclusion, the data show no significant

correlation that increasing light decreases sinus rhythm or increases oxygen levels for this participant. A more detailed investigation or a greater variation in parameters may be required to effectively investigate these relationships.

In D14 participant chart 2 (Figure 86), Daylight intake peaked around day 2, dropped again on day 3, increased on day 4 and dropped significantly on day 5 in the chart on left. Light at eye level remained relatively constant throughout the week on the chart on right. The REM sleep line was found to increase and decrease in proportion to daylight intake, suggesting a possible correlation between increased daylight and improved REM sleep. Deep sleep remains fairly constant with slight changes and peaks slightly around day 3, indicating that it is little affected by light changes. Overall, the charts show that while indoor light remains constant, changes in daylight intake increase and positively affect REM sleep, especially in the middle of the week.

In D14 participant chart 3 (Figure 87), daylight intake peaked on day 2 and then decreased slightly on day 3 before increasing again on day 4 and then decreasing. Indicates varying natural light over exposure, with a peak in the middle of the week. Oxygen level remained generally stable with small fluctuations. Sinus rhythm decreased slightly on day 2 and increased slightly from day 3. This shows that physiological measurements are not significantly affected by changes in light exposure. Overall, the chart shows that physiological measurements remain stable while daylight exposure changes, emphasizing effective adaptation to lighting conditions.

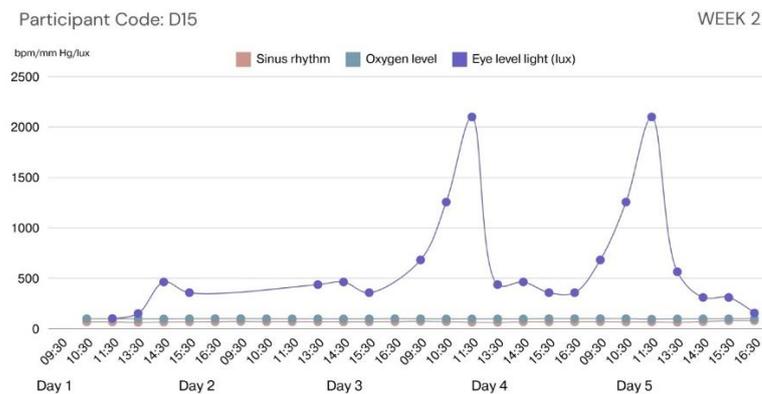


Figure 88. Week 2 Participant D15 Chart 1

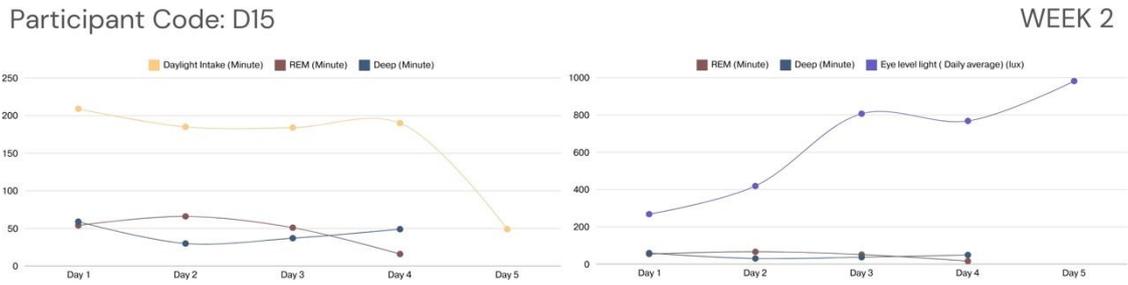


Figure 89. Week 2 Participant D15 Chart 2

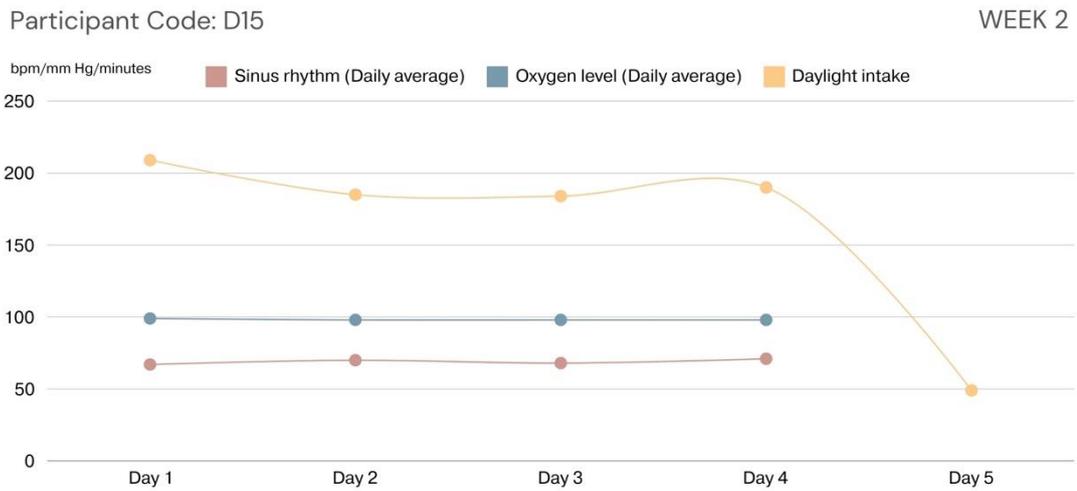


Figure 90. Week 2 Participant D15 Chart 3

In D15 participant chart 1 (Figure 88), the light at eye level shows significant increases on days 3 and 5, reaching 2500 lux. These intense light variations and fluctuations were caused by the fact that the participant occasionally turned on a desk lamp, turned on a lot of daylight and sometimes closed the curtains. Sinus rhythm and oxygen level remained stable with small fluctuations throughout the observation period. On the first day, the average sinus rhythm value was 67 and oxygen level was 99. On the second day sinus rhythm value was 70 and oxygen level was 98, on the 3rd day sinus rhythm value was 68 and oxygen level was 98, on the 4th day sinus rhythm value was 71 and oxygen level was 98. Overall, the chart highlights different periods of high light exposure with stable physiological parameters and shows good adaptation to changing light conditions. Despite the data, no sufficient relationship was found between the components.

In D15 participant chart 2 (Figure 89), the light at eye level showed a significantly increasing trend, peaking at around 1000 lux on day 5 in the chart on right. Daylight Intake starts at just over 200 minutes and gradually decreases until day 5 in the chart on left. Exposure to natural light decreased drastically as the week progressed. REM and deep sleep remained relatively stable with small fluctuations in both measures. It can be said that despite the changes in light exposure, sleep patterns were not significantly affected. The participants' sleep was not measured on the 4th night. There may have been a technical problem with the watch or the participant may have chosen not to wear the watch. Overall, the charts highlight increased indoor light exposure with stable sleep measurements, demonstrating resilience to lighting changes and a potential change in lighting strategy or environmental exposure.

In D15 participant chart 3 (Figure 90), daylight intake is initially just over 200 minutes but gradually decreases throughout the week. It shows a decrease in exposure to natural light, probably due to less time spent outdoors. Sinus rhythm and oxygen level remained stable with small fluctuations throughout the week. This stability suggests that changes in light exposure do not significantly affect these physiological indicators. Overall, the chart reflects increasing exposure to artificial or indoor light with decreasing daylight intake, while physiological measures remain consistent, showing resistance to these lighting changes.

Table 11 shows the measurements of 5 participants in detail in week 3. In Table 12, the amount of daylight received daily by the same participants is given in minutes and their sleep duration is also given in minutes.

Table 11. Week 3 participants' sinus rhythm, oxygen level and light measurements

WEEK 3 TIME	D01			D02			D03			D04			D10			D15							
	Sinus rhythm	Oxygen level	Lux level on desk	Sinus rhythm	Oxygen level	Lux level on desk	Sinus rhythm	Oxygen level	Lux level on desk	Sinus rhythm	Oxygen level	Lux level on desk	Sinus rhythm	Oxygen level	Lux level on desk	Sinus rhythm	Oxygen level	Lux level on desk					
DAY 1 (07.10.2024)																							
10:30	57	96	11	81	99	82	151	95	220	174	78	88	69	40	79	100	152	149	78	97	265	112	
11:30	62	96	13	54	96	81	139	96	208	155	62	94	69	40	76	99	152	149	59	96	217	89	
13:30	67	95	45	83	95	212	122	96	212	194	72	95	68	25	83	100	152	149	61	98	395	267	
14:30	62	90	44	76	97	201	141	73	208	165	68	88	75	30	103	98	153	98	64	100	96	433	
15:30	62	139	27	42	88	201	139	72	187	158	64	95	65	22	69	95	143	124	67	100			
16:30	70	99	25	29	97	202	133	76	223	175	72	95	69	20	85	96	174	122	68	100			
AVERAGE	63	96	28	78	97	163	138	74	209	170	69	96	69	30	83	98	154	120	66	99	243	225	
DAY 2 (08.10.2024)																							
09:30	68	94	30	40	97	198	101	73	214	173	80	96	61	32	85	98	180	176	79	100			
10:30	62	93	31	35	99	200	132	74	210	170	73	100	61	32	69	99	180	176	78	98			
11:30	64	97	32	28	100	201	141	78	208	165	72	99	57	25	75	97	108	112	76	98			
13:30	63	96	40	77	98	201	140	89	200	165	68	88	69	30	76	98	143	124	63	94			
14:30	70	94	44	40	97	201	139	73	223	175	61	97	17	34	70	95	150	128	66	100	271	288	
15:30	67	94	27	42	107	202	133	71	214	187	76	98	17	34	68	94	150	128	68	100	96	433	
16:30	63	99	25	40	97	201	132	76	208	170	70	98	53	33	74	97	154	105	71	98	254	393	
AVERAGE	65	96	33	38	98	201	132	76	208	170	70	98	53	33	74	97	154	105	71	98	254	393	
DAY 3 (09.10.2024)																							
09:30	66	97	30	40	97	208	152	98	214	173	76	99	70	24	81	100	180	129	69	100	541	574	
10:30	57	96	31	35	99	200	132	85	210	170	76	91	69	27	75	100	165	112	68	100			
11:30	54	95	43	35	100	201	118	80	206	165	81	100	69	27	73	100	115	68	99	706	1504		
13:30	66	100	43	30	98	200	133	82	200	165	87	93	87	45	84	99	165	94	67	98	996	477	
14:30	62	93	25	29	98	203	143	103	187	208	73	92	65	33	77	99	143	124	64	96			
15:30	62	93	25	29	98	204	129	72	223	201	62	35	74	100	74	100	174	125	70	98			
16:30	66	98	14	25	99	204	113	77	223	199	75	99	69	29	73	97	159	149	72	99			
AVERAGE	62	97	33	33	98	203	131	85	209	183	78	96	70	31	77	99	162	121	68	99	748	852	
DAY 4 (10.10.2024)																							
09:30	70	95	37	33	98	211	108	89	210	212	73	95	31	28	87	99	134	103	72	100			
10:30	61	94	32	28	97	200	132	76	206	173	76	97	48	28	90	97	166	112	70	98			
11:30	63	96	25	29	95	166	110	74	229	143	75	97	48	25	77	97	166	112	69	98			
13:30	60	93	29	38	96	132	131	74	228	206	69	89	12	19	88	96	152	160	68	97			
14:30	59	98	21	27	92	172	130	79	230	177	69	100	51	20	87	93	173	137	70	98			
15:30	62	100	33	48	96	114	131	78	233	197	74	98	13	22	85	96	173	120	72	99			
16:30	58	96	27	42	99	110	130	84	217	187	84	88	13	22	84	100	173	120	74	100			
AVERAGE	62	96	29	35	94	158	125	78	222	185	74	96	31	23	85	97	162	123	71	99			
DAY 5 (11.10.2024)																							
09:30	60	97		88	97			77	95		83	98			77	100							
10:30	57	95		88	97			75	98		70	98			70	100							
11:30	58	91		77	96			76	99		69	98			73	96							
13:30	70	94	37	37	96	209	99	82	97	224	189		9	50	80	84	173	130	82	98	643	547	
14:30	65	95	22	39	84	100	212	125	79	226	206	75	97	34	47	90	95	172	115	69	96	411	445
15:30	61	97	28	29	94	203	108	75	222	189	65	98	56	34	75	98	150	133	70	99	411	445	
16:30	43	97	14	25	83	203	105	78	214	187	69	99	56	34	72	95	150	133	72	100			

Table 12. Week 3 participants' daylight intake and sleep tracking

WEEK 3 - Daylight intake	D01	D02	D03	D04	D10	D15
October 07	142	45	76		14	120
October 08	71	123	104		47	108
October 09	116	49	109		98	224
October 10	53	81	57		123	253
October 11	145	195	24		99	240
October 12	222				1	204
October 13	218				4	140
WEEK 3 - Sleep	D01	D02	D03	D04	D10	D15
October 07						
In Bed	6hr 56 min	7hr 37 min	6hr 23 min		6hr 36 min	3hr 54min
Awake	7 min	15 min	7 min		34 min	7min
REM	1hr 51 min	2hr 1 min	49 min		1hr 18 min	29min
Core	4hr 46 min	5hr 8 min	4hr 50 min		4hr 16 min	2hr 49min
Deep	18 min	28 min	43 min		1hr 1 min	36min
October 08						
In Bed	6hr 59 min	7hr 11 min			6hr 54 min	3hr 47min
Awake	9 min	5 min			24 min	9min
REM	1hr 20 min	1hr 37 min			1hr 37 min	1hr 23min
Core	5hr 3 min	5hr 16 min			4hr 27 min	1hr 56min
Deep	35 min	18 min			50 min	28min
October 09						
In Bed	6hr 36 min	7hr 50 min	7hr 11 min		6hr 16 min	6hr 9min
Awake	43 min	56 min	28 min		13 min	1hr 37min
REM	1hr 15 min	2hr 1 min	53 min		50	47min
Core	4hr 19 min	4hr 54 min	6hr		4hr 26 min	4hr 41min
Deep	1hr 2 min	54 min	17 min		59 min	40min
October 10						
In Bed	6hr 18 min	6hr 49 min			8 hr	4hr 19min
Awake	46 min	49 min			0 min	10min
REM	1hr 24 min	1hr 42 min			1hr 55 min	1hr 6min
Core	4hr 11 min	4hr 34 min			5hr 10 min	2hr 48min
Deep	42 min				54 min	25min
October 11						
In Bed	7hr 20 min	7hr 3 min	4hr 50 min		7hr 17 min	
Awake	39 min	8 min	9 min		26 min	
REM	1hr 44 min	157	31 min		1hr 51 min	
Core	5hr 3 min	4hr 20 min	3hr 55 min		4hr 19 min	
Deep	32 min	45 min	23 min		1hr 7 min	

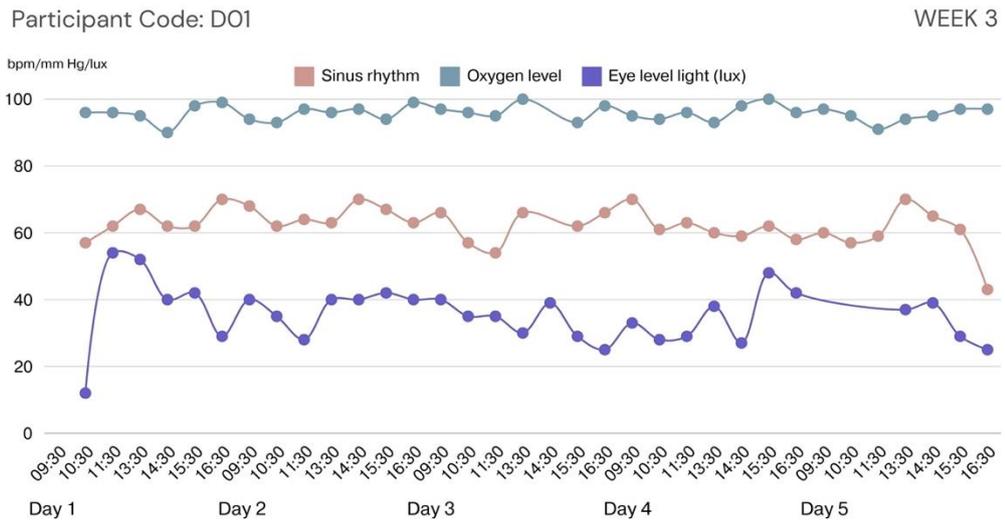


Figure 91. Week 3 Participant D01 Chart 1

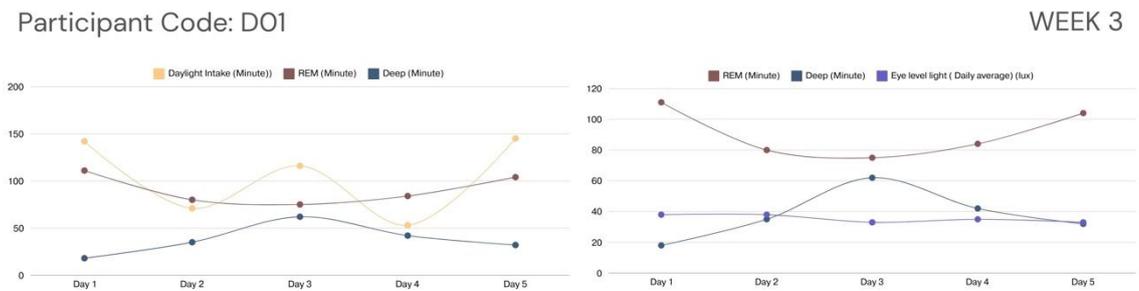


Figure 92. Week 3 Participant D01 Chart 2

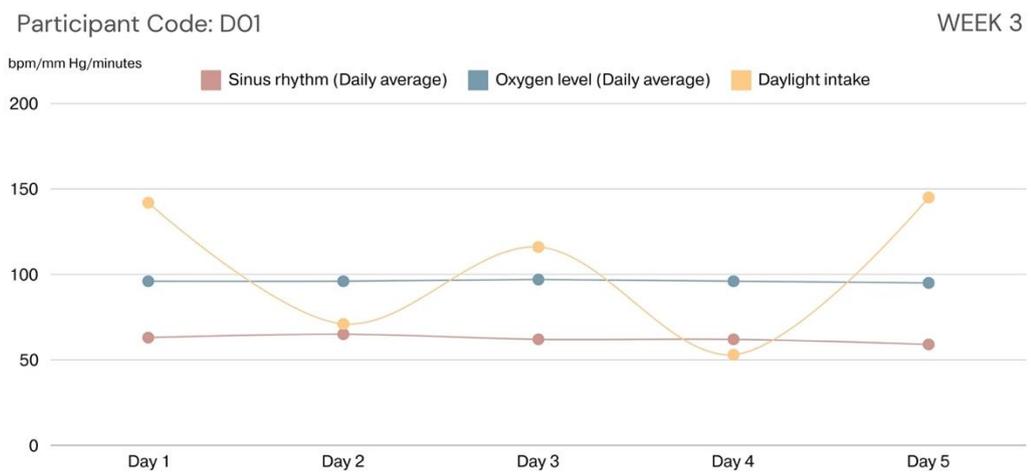


Figure 93. Week 3 Participant D01 Chart 3

In D01 participant chart 1 (Figure 91), the light at eye level exhibited noticeable fluctuations, particularly elevated on day 1 and day 4. Probably influenced by weather

changes during the day. The participant has a window on the left diagonal and receives daylight through it, so daylight in an environment other than artificial light has an effect. Sinus rhythm showed slight fluctuations and remained fairly constant for 5 days. It showed stable physiological conditions despite changes in light exposure. Oxygen levels remained consistent with minimal changes. On the first day, the average sinus rhythm value was 63 and oxygen level was 96. On the second day sinus rhythm value was 65 and oxygen level was 96, on the 3rd day sinus rhythm value was 62 and oxygen level was 97, on the 4th day sinus rhythm value was 62 and oxygen level was 96, on the 5th day sinus rhythm value was 43 and oxygen level was 97. It shows that changes in lighting conditions did not significantly affect oxygen levels. Overall, the expected correlation of increased light leading to a decrease in sinus rhythm and an increase in oxygen levels is not strongly supported by these data. According to this table, both sinus rhythm and oxygen levels do not seem to be affected by changes in light. Further research or data may be required for more precise information.

In D01 participant chart 2 (Figure 92), daylight intake starts high, decreases until day 3 and peaks on day 3 in the chart on left. It then decreased again and increased significantly again on day 5. REM sleep was low at the beginning and increased steadily throughout the period. It shows the potential positive effect of increased daylight towards the end of the week. Deep sleep peaks on day 3 and then decreases. This pattern suggests an association with initial daylight exposure. In the chart on right, light at eye level remains relatively constant but increases slightly over time. Together with a slight increase, it indicates consistent indoor lighting conditions. Overall, the charts show fluctuations in daylight intake with potential benefits for REM and deep sleep but no relation with eye level light suggesting that changing daylight exposure affects sleep patterns.

In D01 participant chart 3 (Figure 93), daylight intake starts high, decreases until day 3 and peaks on day 3. The greater amount of daylight at both ends of the week suggests that outdoor exposure is variable. Sinus rhythm and oxygen level remained relatively constant with minimal fluctuations. It shows consistent physiological condition affected by daylight variations. Overall, it was observed that the sinus level of this participant decreased when the daylight increased and the person reached a steady and relaxed heartbeat data, and when the daylight increased, the rhythms were faster. It can

be said that there is a direct proportion with daylight and that daylight has an effect.

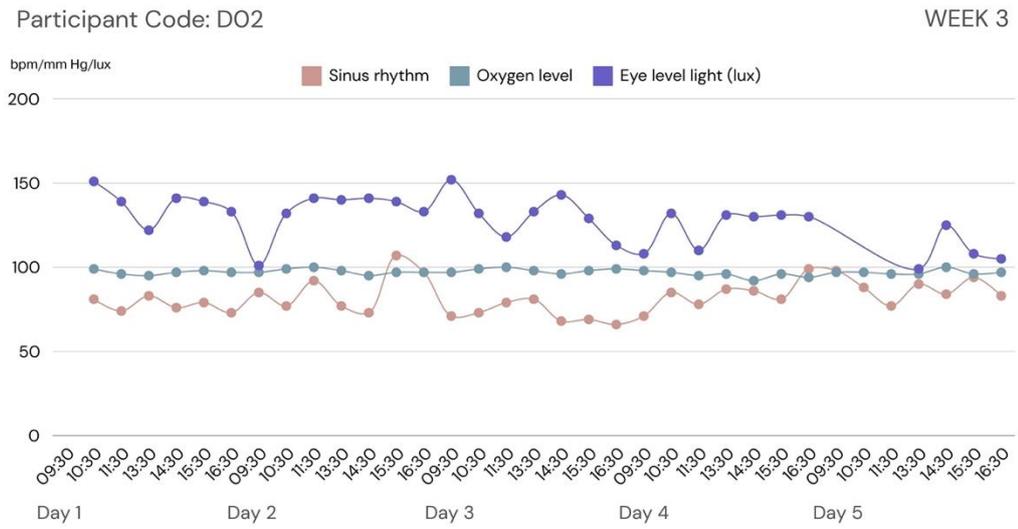


Figure 94. Week 3 Participant D02 Chart 1

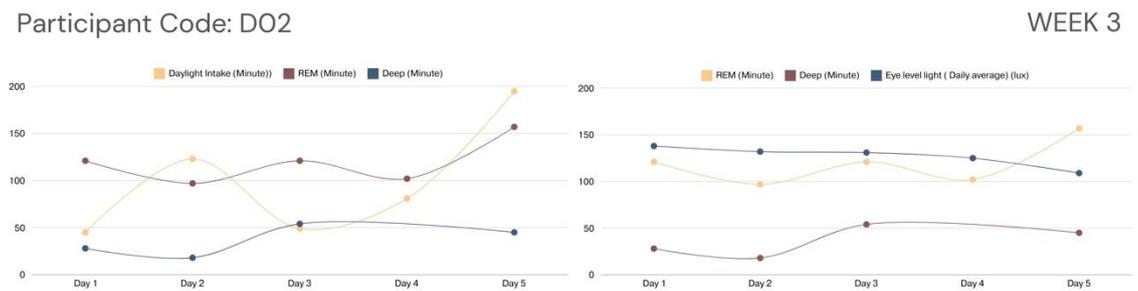


Figure 95. Week 3 Participant D02 Chart 2

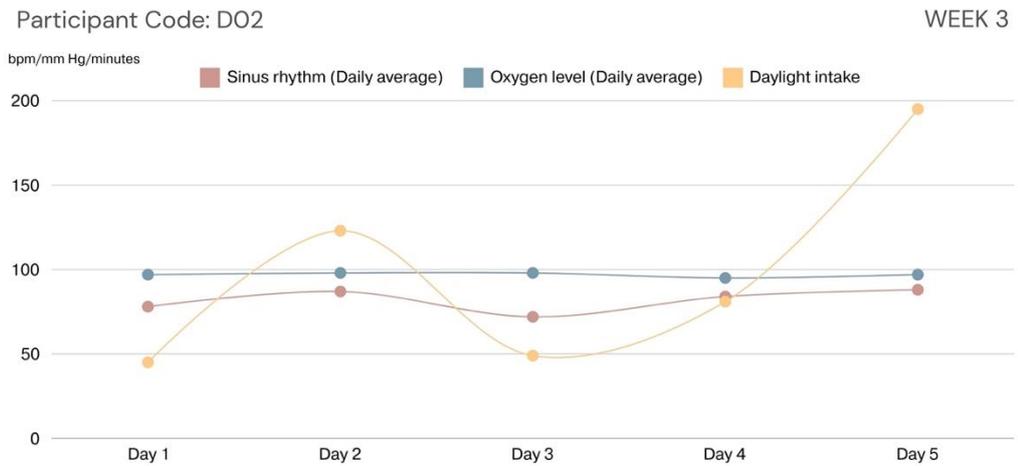


Figure 96. Week 3 Participant D02 Chart 3

In D02 participant chart 1 (Figure 94), the light at eye level fluctuated throughout the day with notable peaks and troughs. There were light fluctuations due to the presence of glass on the participants' right side and the weather, which varied according to seasonal conditions. Sinus rhythm also fluctuates slightly with different variations. On the first day, the average sinus rhythm value was 78 and oxygen level was 97. On the second day sinus rhythm value was 87 and oxygen level was 98, on the 3rd day sinus rhythm value was 72 and oxygen level was 98, on the 4th day sinus rhythm value was 84 and oxygen level was 95, on the 5th day sinus rhythm value was 83 and oxygen level was 97. Nevertheless, consistent physiological responses occurred despite changes in light exposure. Oxygen levels maintained a constant trend around 100 throughout the period. This may indicate that changes in lighting have minimal effect on oxygen levels. Overall, the chart shows that physiological measurements remain constant as lighting conditions change, effectively adapting to fluctuating light exposure.

In D02 participant chart 2 (Figure 95), the light at eye level fluctuated throughout the day with notable peaks and troughs in the chart on right. Daylight Intake increased sharply towards the fifth day, with a decrease only on day 3 and peaked at the end in the chart on right. It shows a significant increase in outdoor and indoor daylight exposure or changes in daylight duration. REM sleep increased gradually and showed a significant increase towards day 5. This pattern may be linked to increased daylight intake, potentially improving sleep quality. Deep sleep peaked around day 3 before decreasing slightly. Overall, the charts suggest that increased daylight exposure towards the end of the week positively influenced REM sleep and deep sleep also changed in relation to REM sleep.

In D02 participant chart 3 (Figure 96), daylight Intake increased sharply towards the fifth day, with a decrease only on day 3 and peaked at the end. It shows a significant increase in outdoor and indoor daylight exposure or changes in daylight duration. Sinus Rhythm and Oxygen level both remained stable with small fluctuations. The consistency suggests that these physiological measurements are relatively unaffected by changes in light exposure. Overall, the chart shows that daylight exposure increases by the end of the week, while indoor light remains constant and has no significant effect on physiological parameters.

Participant Code: D03

WEEK 3

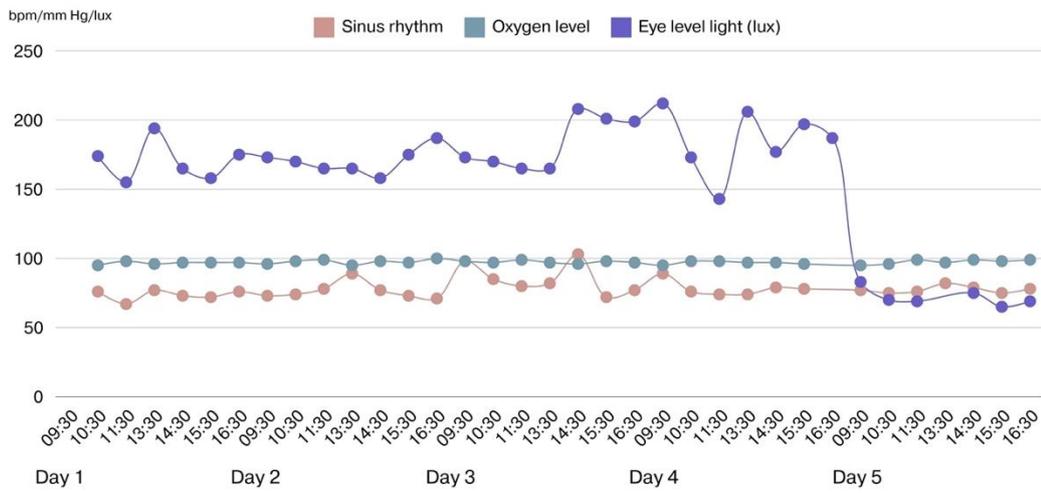


Figure 97. Week 3 Participant D03 Chart 1

Participant Code: D03

WEEK 3

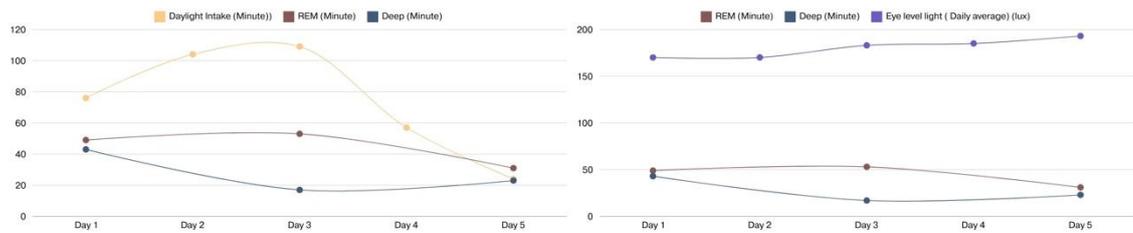


Figure 98. Week 3 Participant D03 Chart 2

Participant Code: D03

WEEK 3

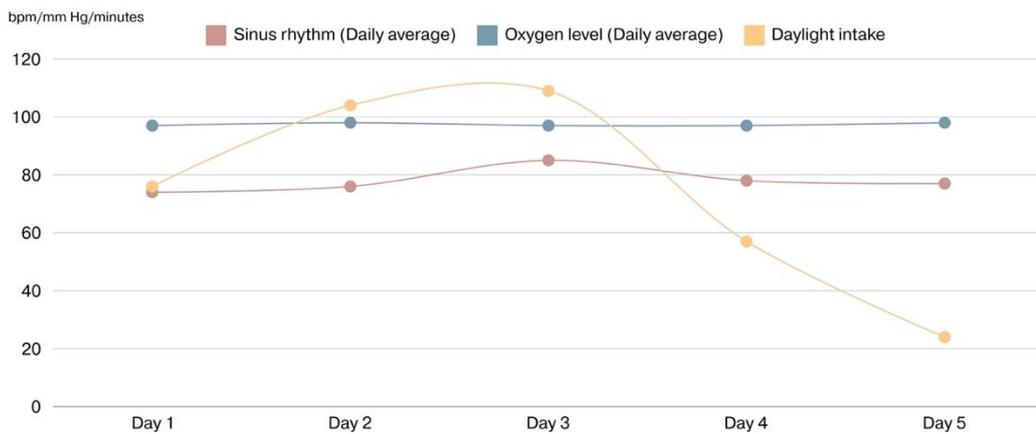


Figure 99. Week 3 Participant D03 Chart 3

In D03 participant chart 1 (Figure 97), light at eye level peaked especially in the early part of days 1 and 3, followed by marked fluctuations that declined on day 4. This may

be due to the fact that the participant was seated with a window to the left and was exposed to sunlight. Sinus Rhythm experienced small fluctuations throughout the week but remained generally stable. This indicates consistent physiological conditions despite changes in lighting. Oxygen level is also stable and maintains a constant trend close to the average. On the first day, the average sinus rhythm value was 74 and oxygen level was 97. On the second day sinus rhythm value was 76 and oxygen level was 98, on the 3rd day sinus rhythm value was 85 and oxygen level was 97, on the 4th day sinus rhythm value was 78 and oxygen level was 97, on the 5th day sinus rhythm value was 78 and oxygen level was 99. It shows that lighting changes do not significantly affect oxygen levels. Overall, the stability of sinus rhythm and oxygen levels despite changing lighting conditions suggests effective adaptation to different light environments.

In D03 participant chart 2 (Figure 98), light at eye level peaked especially in the early part of days 1 and 3, followed by marked fluctuations that declined on day 4 in the chart on right. Daylight intake peaks around day 3 and then decreases steadily towards day 5. Indicates various forms of exposure to natural light, with the highest on day 3 in the chart on left. REM sleep increased slightly at the beginning. Peaking on day 3 and then decreasing. One can speculate that higher daylight intake may improve REM sleep. Deep sleep also peaked on day 3 and then decreased, reflecting the pattern of daylight intake. This may indicate a possible link between increased light exposure and improved deep sleep. Overall, the charts suggest that increased daylight exposure in the middle of the week may be positively affecting sleep patterns, especially REM and deep sleep.

In D03 participant chart 3 (Figure 99), daylight intake peaks around day 3 and then decreases steadily towards day 5. Sinus rhythm and oxygen level both measurements remained stable with minimal fluctuation throughout the period. The consistent readings indicate that these physiological measurements were not significantly affected by changes in light exposure. Overall, the chart reflects a decrease in natural light exposure and a steady increase in artificial or indoor lighting, and the stable physiological responses suggest adaptation to lighting conditions. The data do not show the expected correlation where increasing daylight decreases sinus rhythm and increases oxygen levels. Both sinus rhythm and oxygen levels appear to be unaffected

by the changes in daylight intake observed in the chart. Further investigation with more data may be needed to explore these relationships more effectively.

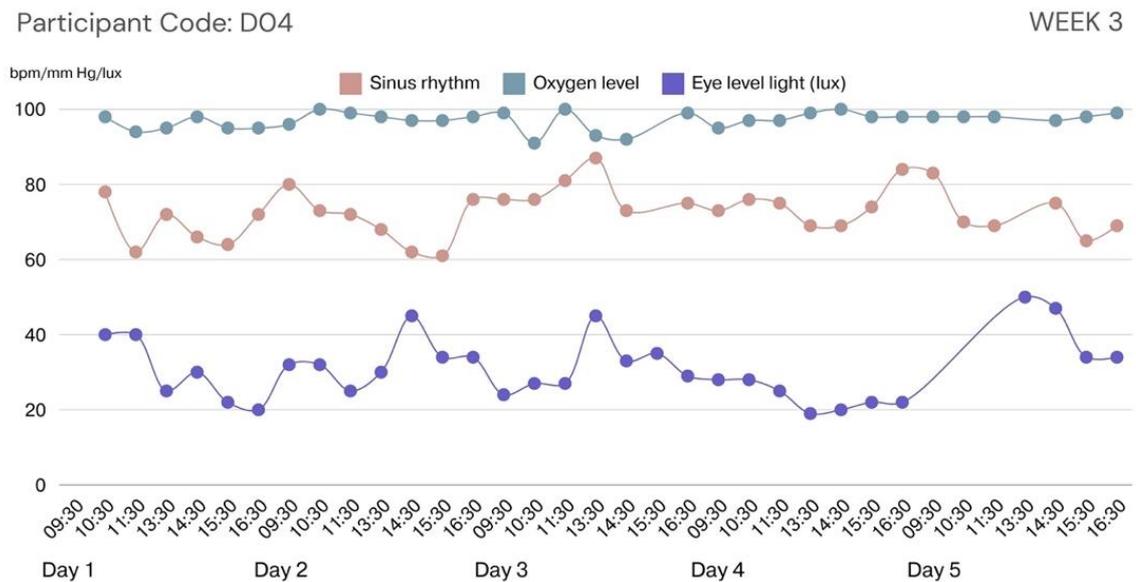


Figure 100. Week 3 Participant D04 Chart 1



Figure 101. Week 3 Participant D04 Chart 2

Participant D04 did not wear the watch during night sleep for personal reasons. Therefore, this participant was not analyzed for sleep.

In D04 participant chart 1 (Figure 100), the changing light at eye level shows fluctuations, with a particularly large increase on day 5. On the first day, the average sinus rhythm value was 69 and oxygen level was 96. On the second day sinus rhythm value was 70 and oxygen level was 98, on the 3rd day sinus rhythm value was 76 and oxygen level was 96, on the 4th day sinus rhythm value was 74 and oxygen level was 98, on the 5th day sinus rhythm value was 69 and oxygen level was 99. These

fluctuations were due to changes in daylight from the ambient windows. Overall, the data do not strongly support the hypothesis that increasing light cause's sinus rhythm to decrease and oxygen levels to increase. Both sinus rhythm and oxygen levels appear to be constant and unaffected by the light changes present in the chart. More data could clarify potential correlations.

In D04 participant chart 2 (Figure 101), since the participant did not wear the smartwatch sufficiently, data on daylight measurement and sleep could not be obtained, as observed in the chart.

Overall, the charts show that although there is a slight increase in light exposure towards the end of the week, physiological measurements remain stable and well adapted to the lighting conditions.

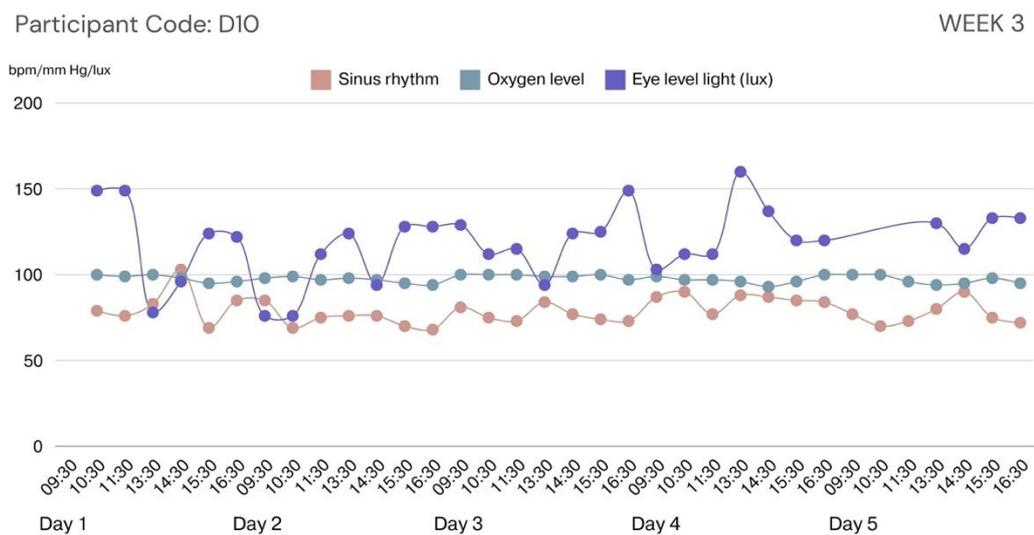


Figure 102. Week 3 Participant D10 Chart 1

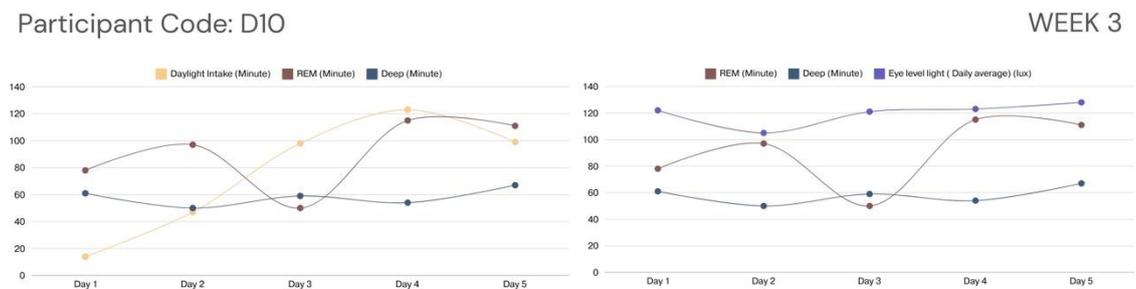


Figure 103. Week 3 Participant D10 Chart 2

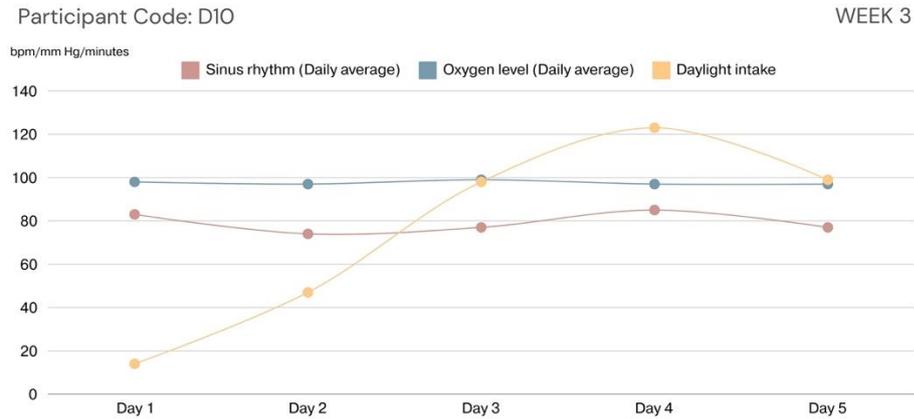


Figure 104. Week 3 Participant D10 Chart 3

In D10 participant chart 1 (Figure 102), light at eye level fluctuated with noticeable peaks throughout the day. It shows changes in lighting conditions due to changing natural light or office lighting adjustments. Sinus rhythm remained fairly constant with slight fluctuations. Consistent physiological responses were observed despite changes in light exposure. Oxygen levels maintained a constant average and reflected stability. On the first day, the average sinus rhythm value was 83 and oxygen level was 98. On the second day sinus rhythm value was 74 and oxygen level was 97, on the 3rd day sinus rhythm value was 77 and oxygen level was 99, on the 4th day sinus rhythm value was 85 and oxygen level was 97, on the 5th day sinus rhythm value was 72 and oxygen level was 95. These fluctuations were due to changes in daylight from the ambient windows. It showed that changes in lighting did not significantly affect oxygen levels. Overall, the chart reflected the variability in light exposure while physiological measurements remained constant, indicating effective adaptation to the office lighting environment.

In D10 participant chart 2 (Figure 103), daylight intake began with low values, peaked in the middle of the week, and then decreased in the chart on left. Light at eye level showed a decreasing trend from day 1 and increased towards the end of the week in the chart on right. Daylight changes altered light levels. REM sleep was observed to peak on day 2, then drop significantly on day 3, and then increase again. A link was evident between higher daylight exposure and improved REM sleep quality. Deep sleep increased steadily towards the end of the week, suggesting that adjusting light exposure can positively affect deep sleep. Overall, the charts suggest that variability

in light exposure and increases in the middle of the week potentially improve sleep quality. For this participant, adjustments in lighting appeared to be associated with sleep improvements, particularly deep and REM sleep.

In D10 participant chart 3 (Figure 104), daylight intake began with low values, peaked in the middle of the week, and then decreased. Sinus Rhythm remained relatively stable with a slight downward trend. Consistent physiological response indicates minimal impact from light changes. Oxygen levels maintained a stable average throughout the week. It reflects stable physiological conditions and demonstrates effective adaptation to light changes. Overall, the chart highlights those physiological measurements remained stable and showed robustness to changing light conditions, while daylight intake increased and influenced indoor lighting adjustment.

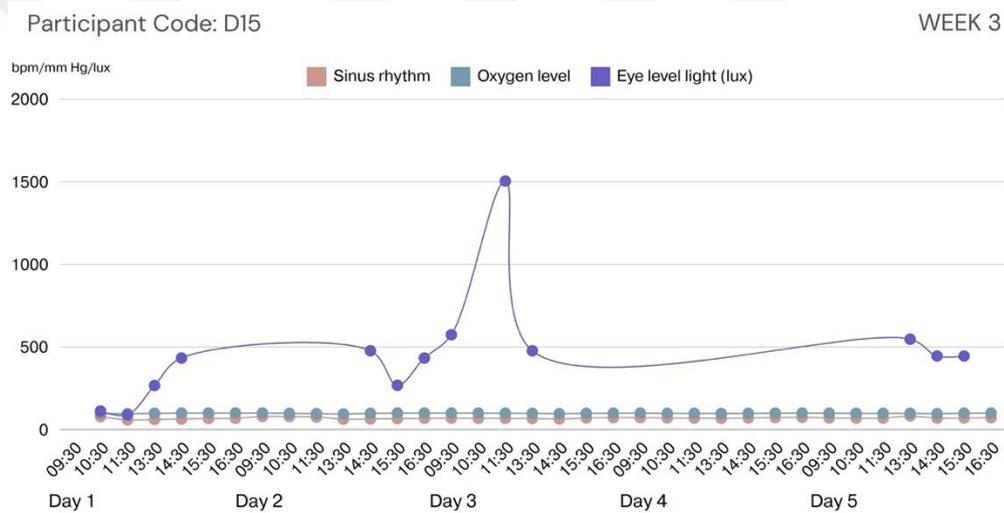


Figure 105. Week 3 Participant D15 Chart 1

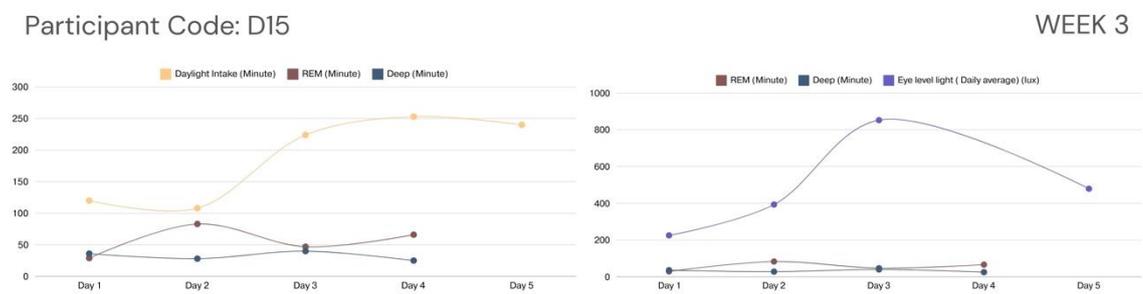


Figure 106. Week 3 Participant D15 Chart 2

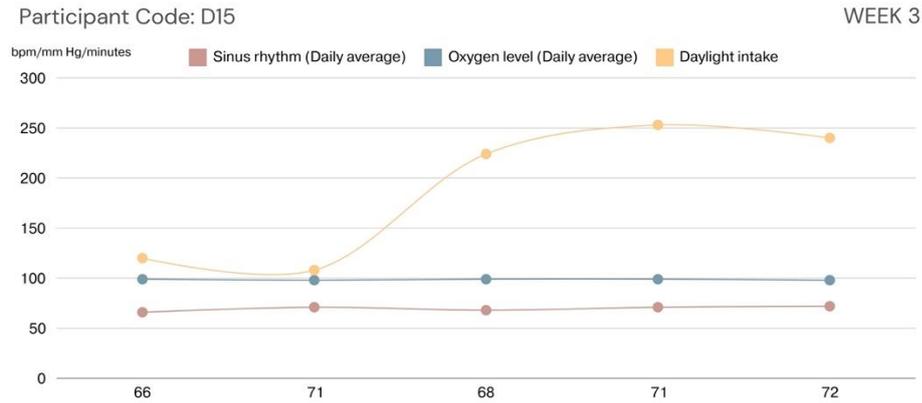


Figure 107. Week 3 Participant D15 Chart 3

In D15 participant chart 1 (Figure 105), light at eye level showed a significant increase on day 3, reaching over 1500 lux. This change was amplified by the midday temperature due to the climate and weather conditions of the region as the participant was sitting by the window. Sinus rhythm and oxygen levels also showed consistent stability with minimal fluctuations throughout the week. On the first day, the average sinus rhythm value was 66 and oxygen level was 99. On the second day sinus rhythm value was 71 and oxygen level was 98, on the 3rd day sinus rhythm value was 68 and oxygen level was 99, on the 4th day sinus rhythm value was 71 and oxygen level was 99, on the 5th day sinus rhythm value was 72 and oxygen level was 100. This stability suggests that the increase in light exposure did not significantly affect these physiological measurements. Overall, the chart highlights a significant increase in light exposure on day 3, with stable physiological responses and an effective resistance to sudden changes in lighting conditions.

In D15 participant chart 2 (Figure 106), light at eye level peaked significantly on Day 3 and then steadily decreased in the chart on right. As in the previous graph, the participant was seated by a window, which provided this interaction. Daylight exposure is consistent in the chart on left. REM sleep increased slightly towards the middle of the week but remained relatively stable. It was not significantly affected by changes in light exposure. Deep sleep remained stable with minor fluctuations. It indicates that there were no significant changes in sleep patterns despite changes in light exposure. Overall, the charts show a significant increase in indoor light exposure by the middle of the week, with stable sleep patterns effectively adapting to the lighting

conditions. Stable sleep and physiological values may also indicate that effective daylight exposure is beneficial.

In d15 participant chart 3 (Figure 107), daylight exposure is consistent. Sinus rhythm and oxygen levels show consistent stability with minor fluctuations. This stability suggests that these physiological measurements are not affected by changes in light exposure. Overall, the chart shows a significant increase in indoor light exposure without significant physiological changes, indicating effective adaptation to lighting conditions.

Table 13 shows the measurements of 1 participant in detail in week 4. In Table 14, the amount of daylight received daily by the same participants is given in minutes and their sleep duration is also given in minutes.

Table 13. Week 4 D15 participant sinus rhythm, oxygen level, light measurement

WEEK 4 TIME	D15		Daylight Intake
DAY 1 (14.10.2024)	Sinus rhythm	Oxygen level	158
10:30	71	96	
11:30	72	99	
13:30	70	97	
14:30	69	99	
15:30	70	100	
16:30	72	100	
AVERAGE	71	99	
DAY 2 (15.10.2024)	Sinus rhythm	Oxygen level	263
09:30	71	98	
10:30	70	96	
11:30	70	97	
13:30	68	96	
14:30	63	96	
15:30	68	100	
16:30	70	100	
AVERAGE	69	98	
DAY 3 (16.10.2024)	Sinus rhythm	Oxygen level	335
09:30	72	100	
10:30	71	98	
11:30	64	98	
13:30	63	97	
14:30			
15:30			
16:30			
AVERAGE	68	98	
DAY 4 (17.10.2024)	Sinus rhythm	Oxygen level	108
09:30	69	100	
10:30	68	99	
11:30	65	98	
13:30	64	97	
14:30	67	97	
15:30	69	99	
16:30	72	100	
AVERAGE	68	99	
DAY 5 (18.10.2024)	Sinus rhythm	Oxygen level	60
09:30	71	100	
10:30	70	100	
11:30	68	98	
13:30	64	96	
14:30	67	98	
15:30	69	100	
16:30			
AVERAGE	68	99	

Table 14. Week 4 D15 participant sleep tracking

WEEK 4 - Sleep	D15
October 14	
In Bed	4hr 45min
Awake	28min
REM	8min
Core	3hr 54min
Deep	43min
October 15	
In Bed	
Awake	
REM	
Core	
Deep	
October 16	
In Bed	3hr 2min
Awake	5min
REM	40min
Core	2hr 8min
Deep	14min
October 17	
In Bed	3hr 15min
Awake	2min
REM	35min
Core	2hr 34min
Deep	5min
October 18	
In Bed	
Awake	
REM	
Core	
Deep	

Participant Code: D15

WEEK 4

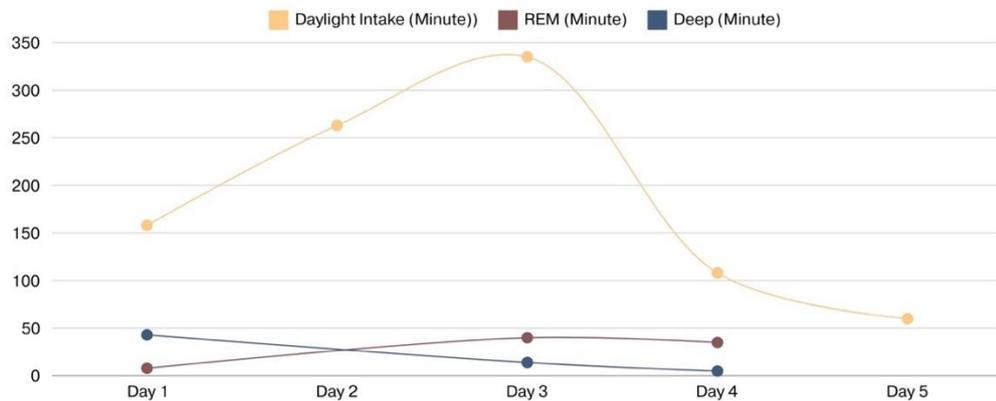


Figure 108. Week 4 Participant D15 Chart 1

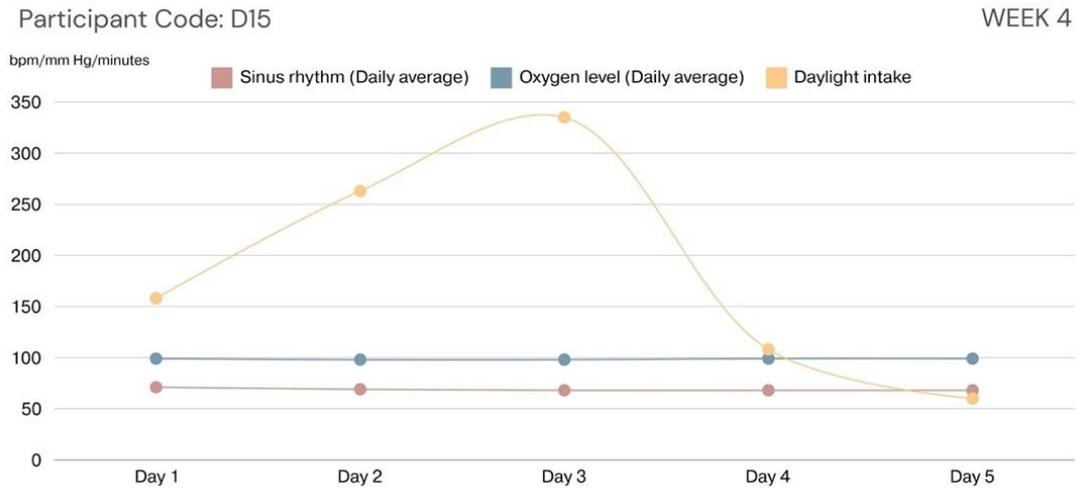


Figure 109. Week 4 Participant D15 Chart 2

In week 4, only the measurements of participant d15 continued. Light levels at eye level could not be obtained. The related charts were prepared on daily daylight intake amounts.

In D15 participant chart 1 (Figure 108), daylight intake peaked on day 3 and then decreased on day 5. The participant had maximum natural light exposure in the middle of the week. This was due to sunny weather conditions. REM sleep slightly increased from day 1 to day 2 and then leveled off. This suggests a potential benefit to REM sleep with increased daylight exposure. Deep sleep remained relatively stable with minor fluctuations. It was minimally affected by changes in light exposure, but consistent sleep quality was also indicated. Overall, the chart demonstrates that increased daylight exposure may initially increase REM sleep, while deep sleep was adequate.

In D15 participant chart 2 (Figure 109), daylight intake peaked on day 3 and then decreased on day 5. The participant had maximum natural light exposure in the middle of the week. Sinus rhythm remains constant throughout the period with little fluctuation. This indicates that changing daylight exposure does not significantly affect this physiological measure. On the first day, the average sinus rhythm value was 71 and oxygen level was 99. On the second day sinus rhythm value was 69 and oxygen level was 98, on the 3rd day sinus rhythm value was 68 and oxygen level was 98, on the 4th day sinus rhythm value was 68 and oxygen level was 99, on the 5th day sinus rhythm value was 68 and oxygen level was 99. Oxygen levels remain consistent and

constant across all days. It shows that changes in daylight exposure have minimal effects on oxygen levels. Overall, the chart shows that despite the peak in daylight exposure, physiological parameters remain constant and adapt effectively to changing light conditions.

Table 15 shows the measurements of 1 participant in detail in week 5. In Table 16, the amount of daylight received daily by the same participants is given in minutes and their sleep duration is also given in minutes.



Table 15. Week 5 participants' sinus rhythm, oxygen level and light measurements

WEEK 5 TIME	C01			C02			C03			D07			D08			D15			
	Sinus rhythm	Oxygen level	Lux level on desk	Sinus rhythm	Oxygen level	Lux level on desk	Sinus rhythm	Oxygen level	Lux level on desk	Sinus rhythm	Oxygen level	Lux level on desk	Sinus rhythm	Oxygen level	Lux level on desk	Sinus rhythm	Oxygen level	Lux level on desk	
DAY 1 (21.10.2024)																			
10:30	67	98	282	80	99	535	79	100	900	72	100	163	92	100	224	65	98	2167	
11:30	66	97	282	80	96	535	70	99	900	868	100	184	70	98	210	62	98	1406	
13:30	64	99	388	84	97	156	71	97	958	943	98	165	90	96	153	70	99	682	
14:30	78	95	390	82	99	160	77	100	960	951	99	181	78	99	229	72	99	414	
15:30	81	96	890	70	97	696	77	94	920	997	85	94	88	96	249	73	100	397	
16:30	71	97	928	75	100	940	62	96	920	997	75	96	94	90	225	73	100	346	
AVERAGE	71	97	527	79	98	504	73	98	926	937	79	98	102	89	215	69	99	902	
DAY 2 (22.10.2024)																			
09:30	79	97		95	100		94	98		70	96		88	95		72	100		
10:30	89	97		85	100		89	99		86	97		87	98		71	98		
11:30	71	98		79	95		87	100		70	97		85	97		69	98		
13:30	82	99		67	98		74	99		81	97		85	97		59	97		
14:30	75	99		72	97		82	100		93	98		84	98		65	97		
15:30	70	98		75	97		76	99		100	97		85	100		70	99		
16:30	71	97		78	98		66	98		81	98		74	98		72	99		
AVERAGE	77	98		79	98		81	99		83	97		84	98		68	98		
DAY 3 (23.10.2024)																			
09:30	86	98		73	93		64	100		83	99		97	96		69	100		
10:30	68	98		95	96		68	100		84	96		91	99		67	99		
11:30	77	95		91	95		70	96		87	97		78	100		66	98		
13:30	69	97		68	96		109	97		79	99		80	100		69	99		
14:30	67	96		80	99		88	98		95	97		84	98		69	100		
15:30	66	99		69	99		76	98		84	98		87	99		70	100		
16:30	73	98		77	100		76	98		82	97		83	99		72	100		
AVERAGE	72	97		79	97		79	98		85	98		86	99		69	99		
DAY 4 (24.10.2024)																			
09:30																			
11:30																			
10:30	92	97	1130	745	104	870	83	99	978	1062	81	98	74	94	237	69	100	445	
11:30	82	98	1140	883	85	940	82	100	975	865	84	99	159	83	240	65	100	1711	
13:30	91	97	1180	900	80	950	115	98	978	868	84	99	163	93	235	63	99	501	
14:30	80	94	928	675	87	95	90	97	1030	1049	85	98	154	76	225	61	99	619	
15:30	84	96	928	675	84	96	95	100	1042	1054	86	97	152	82	223	65	100	377	
16:30	81	97	925	684	83	940	89	99	1030	1049	101	97	129	94	225	68	100	346	
AVERAGE	85	97	1052	758	88	1014	91	99	1002	1001	84	98	151	84	234	65	100	628	
DAY 5 (25.10.2024)																			
09:30	71	97	282	162	83	940	87	98	900	868	80	97	124	118	248	70	100		
10:30	78	100	354	427	81	99	1083	601	954	1062	76	98	179	86	236	69	100		
11:30	67	99	354	428	88	96	1093	601	954	1062	70	96	173	80	230	69	99		
13:30	85	99			76	98	87	98	920	997	88	97	183	76	222	63	98	625	
14:30							89	97	627	900	87	94	141	71	245	64	100	577	
15:30							86	97			81	98	146	78	230	69	100	308	
16:30											78	98	181	75	246	70	100	195	
AVERAGE	75	99	330	339	82	1035	84	98	871	978	80	97	161	83	237	68	100	432	

Table 16. Week 5 participants' daylight intake and sleep tracking

WEEK 5 - Daylight intake	C01	C02	C03	D07	D08	D15
October 21	11	122	30			307
October 22	96	277	36			40
October 23	53	263	49	161		203
October 24	21	30	48	192	173	126
October 25	10		36	119	31	81
October 26						7
October 27						87
WEEK 5 - Sleep	C01	C02	C03	D07	D08	D15
October 21						
In Bed		6hr 24 min	5hr 39min	4hr 59min	8hr 14min	4hr 34min
Awake		9min	19min	32min	50 min	14min
REM		1hr 46min	55min	1hr 8min	2hr 4min	38min
Core		3hr 17min	3hr 20min	2hr 40min	5hr 32min	3hr 9min
Deep		1hr 21min	1hr 24min	1hr 11min	38min	47min
October 22						
In Bed	5hr 56 min	8hr 19min	7hr 16min	7hr 16min	8hr 24min	
Awake	7min	8min	26min	6min	4min	
REM	1hr 6min	1hr 57min	1hr 45min	1hr 31min	2hr 10min	
Core	4hr 19min	5hr 2min	4hr 39min	4hr 53min	5hr 21min	
Deep	31min	1hr 19min	51min	52min	52min	
October 23						
In Bed		7hr 6min			8hr 40min	4hr 16min
Awake		9min			11min	56min
REM		2hr 25min			1hr 42min	1hr 3min
Core		4hr 9 min			6hr 8min	2hr 38min
Deep		31min			50min	35min
October 24						
In Bed		5hr 25min	5hr 1min	4hr 39min	8hr 38min	
Awake		2min	9min	3hr 48min	10min	
REM		1hr 7min	1hr 13min	6min	2hr 1min	
Core		4hr 4min	3hr 25min	4hr 16min	5hr 35min	
Deep		13min	22min	17min	1hr 1min	
October 25						
In Bed				6hr		
Awake				6min		
REM				1hr 14min		
Core				3hr 50min		
Deep				56min		

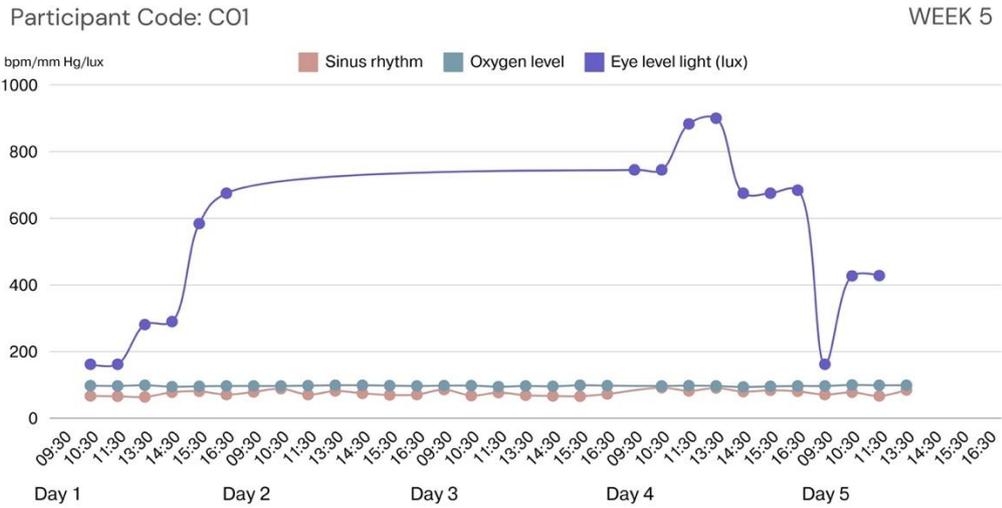


Figure 110. Week 5 Participant C01 Chart 1

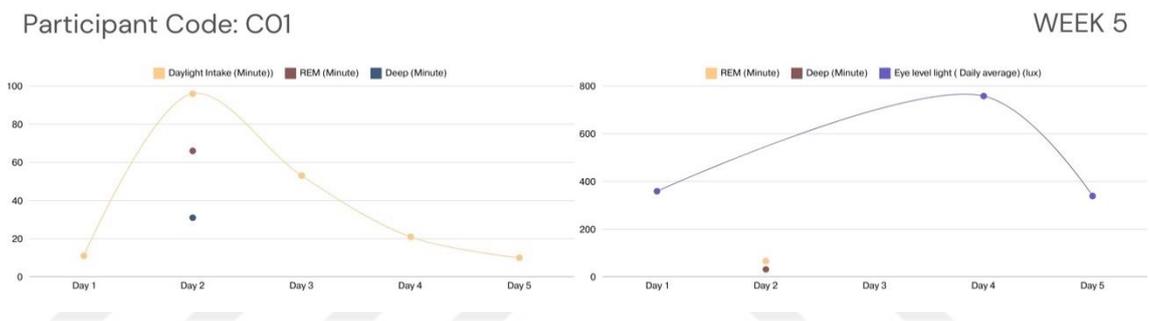


Figure 111. Week 5 Participant C01 Chart 2

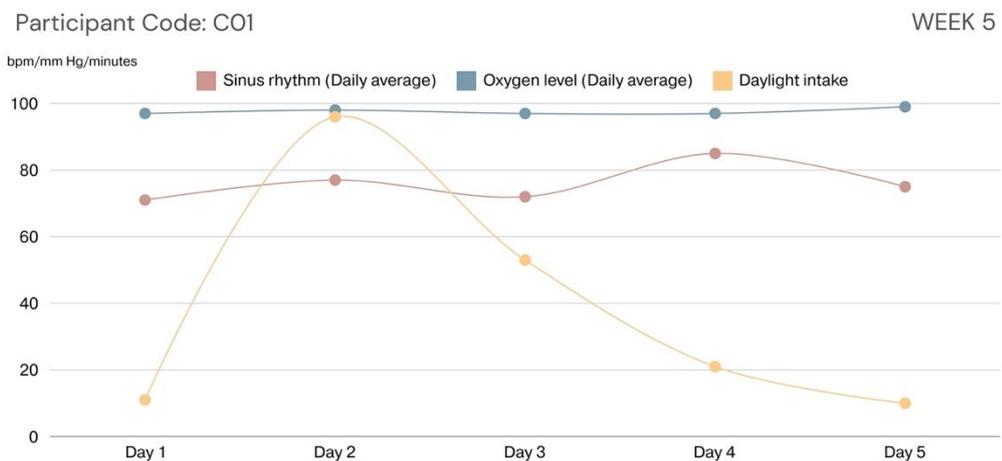


Figure 112. Week 5 Participant C01 Chart 3

In C01 participant chart 1 (Figure 110), light at eye level increases significantly on Day 1, remains high until Day 5, then drops sharply. The participant is seated in a

sunny location. The participant has been exposed to high light levels for an extended period. Sinus rhythm and oxygen levels remain stable throughout the week with no noticeable fluctuations. On the first day, the average sinus rhythm value was 71 and oxygen level was 97. On the second day sinus rhythm value was 77 and oxygen level was 98, on the 3rd day sinus rhythm value was 72 and oxygen level was 97, on the 4th day sinus rhythm value was 85 and oxygen level was 97, on the 5th day sinus rhythm value was 75 and oxygen level was 99. This shows that despite the changes in light levels, physiological measurements are unaffected, indicating effective adaptation. Overall, the chart shows a period of decline following the high light exposure, with physiological stability showing resistance to light changes.

In C01 participant chart 2 (Figure 111), light levels at eye level peaked around day 4 and then decreased sharply on day 5 in the chart on right. Daylight exposure remained low and relatively constant throughout the week in the chart on left. No clear information can be given for REM and Deep sleep measurements because the participants' measurements were recorded by the watch for only one night. The participant may have removed it while sleeping or there may have been other technical issues.

In C01 participant chart 3 (Figure 112), daylight exposure remained low and relatively constant throughout the week. Sinus Rhythm and oxygen levels remained stable with little change. This consistency suggests that fluctuations in light exposure did not significantly affect these physiological measurements. Overall, the chart shows a dynamic pattern under artificial light exposure with constant physiological parameters, reflecting effective adaptation to light changes.

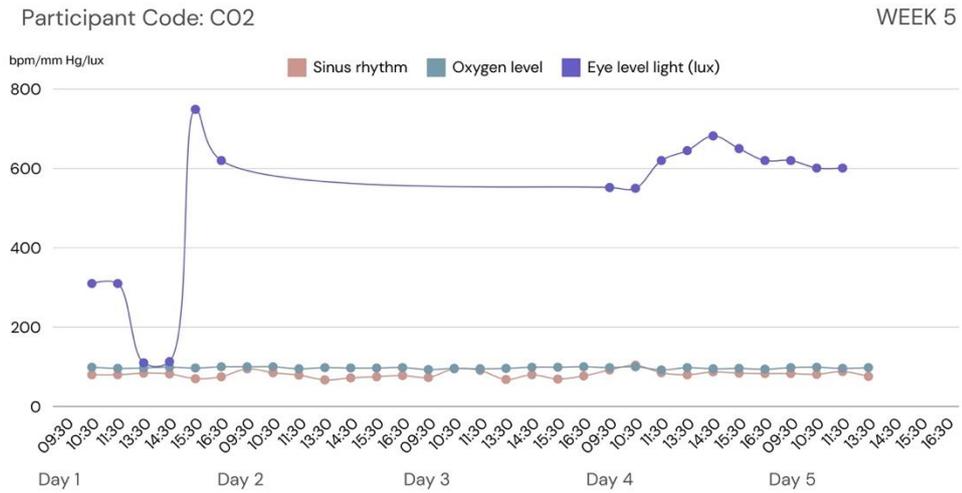


Figure 113. Week 5 Participant C02 Chart 1

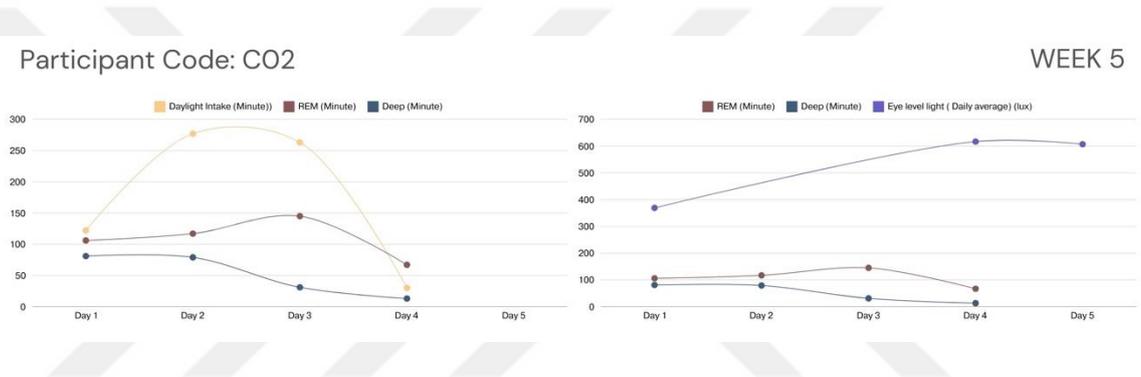


Figure 114. Week 5 Participant C02 Chart 2

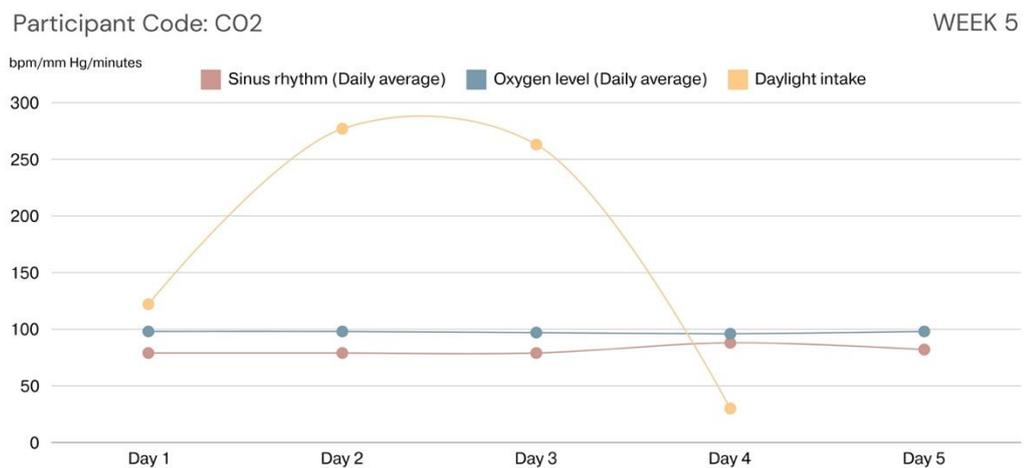


Figure 115. Week 5 Participant C02 Chart 3

In C02 participant chart 1 (Figure 113), light at eye level increased sharply on day 2, reaching approximately 600 lux before increasing again and decreasing slightly again. The participants’ desk had floor-to-ceiling glass on the left side, providing ample

daylight exposure. Sinus rhythm and oxygen levels remained stable with minimal fluctuations throughout the week. This stability suggests that the initial increase in light exposure did not significantly affect these physiological measurements. On the first day, the average sinus rhythm value was 79 and oxygen level was 98. On the second day sinus rhythm value was 79 and oxygen level was 98, on the 3rd day sinus rhythm value was 79 and oxygen level was 97, on the 4th day sinus rhythm value was 88 and oxygen level was 96, on the 5th day sinus rhythm value was 82 and oxygen level was 98. Overall, the chart highlights consistent levels, stable physiological responses, and resilience to light changes following initial high light exposure.

In C02 participant chart 2 (Figure 114), light at eye level increased steadily, peaking on day 4 and decreasing slightly on day 5 in the chart on right. Daylight exposure peaked around day 3 and then decreased. REM sleep showed a slight increase, peaking in the middle of the week and then decreasing in the chart on left. It is thought that the increased daylight exposure was beneficial for the participant. Deep sleep was high on day 1 and then decreased steadily throughout the week. It suggests a possible decrease in sleep quality as the week progressed, which may be linked to changes in lighting. Overall, the charts show that indoor light levels increased, with the intensity of daylight exposure positively affecting REM sleep in the middle of the week. Meanwhile, deep sleep decreased, suggesting possible effects from changing light conditions.

In C02 participant chart 3 (Figure 115), daylight exposure peaked around day 3 and then decreased. Sinus Rhythm and oxygen levels remained stable with little change throughout the period. Consistency suggests that these physiological measurements were not significantly affected by lighting changes. The data do not support the hypothesis that increased light decreases sinus rhythm and increases oxygen levels. Sinus rhythm and oxygen levels remain constant and are not affected by changes in daylight intake. Further research or additional data may be required for deeper insights.

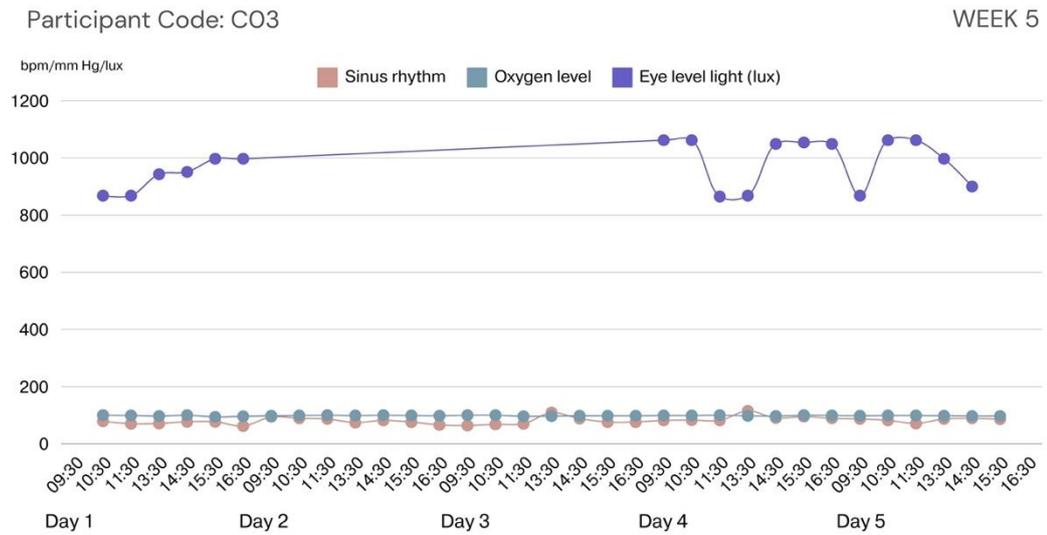


Figure 116. Week 5 Participant C03 Chart 1

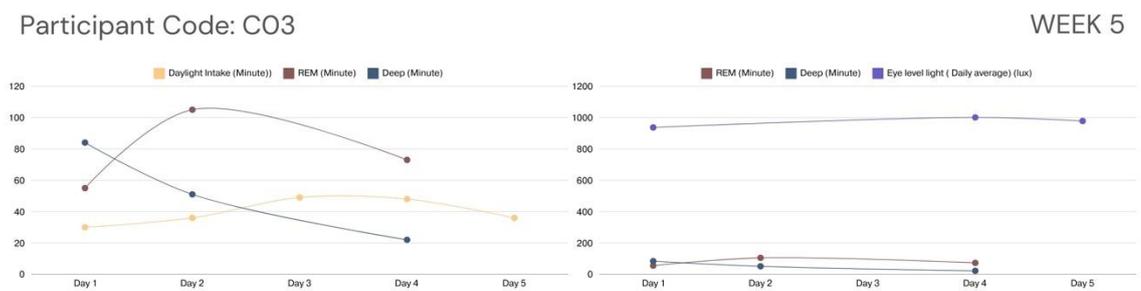


Figure 117. Week 5 Participant C03 Chart 2

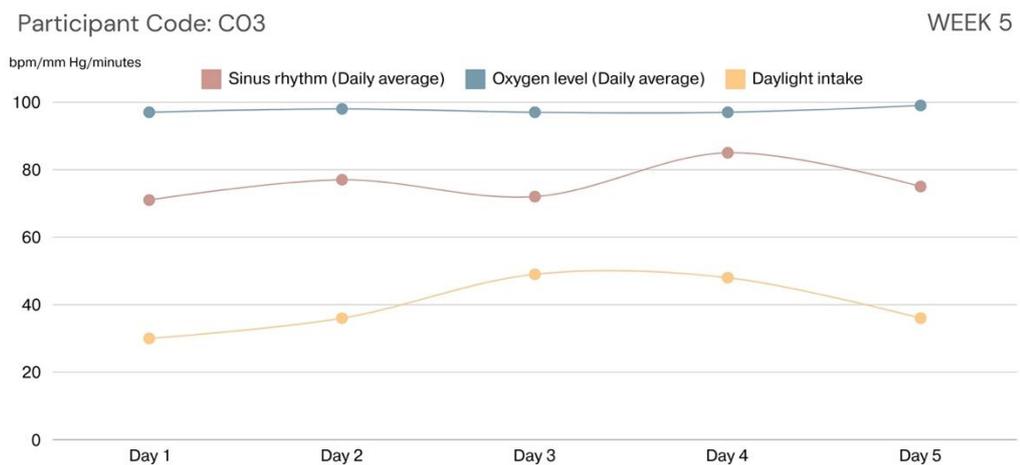


Figure 118. Week 5 Participant C03 Chart 3

In C03 participant chart 1 (Figure 116), light at eye level started high and then

remained high with some fluctuations at approximately 1000 lux. This was due to the participant being close to the window and receiving a lot of daylight. There was also a lot of artificial lighting in the participants' office space. Sinus rhythm and oxygen levels remained stable and consistent throughout the week. On the first day, the average sinus rhythm value was 73 and oxygen level was 98. On the second day sinus rhythm value was 81 and oxygen level was 99, on the 3rd day sinus rhythm value was 79 and oxygen level was 98, on the 4th day sinus rhythm value was 91 and oxygen level was 99, on the 5th day sinus rhythm value was 84 and oxygen level was 98. This suggests that physiological measurements were not affected by changes in light exposure. Overall, the chart shows a constant high light level, with physiological measurements remaining stable and allowing effective adaptation to bright light conditions.

In C03 participant chart 2 (Figure 117), light at eye level remained consistently high throughout the week at around 1000 lux in the chart on right. Daylight exposure remained constant throughout the day in the chart on left. Given the high level of light at eye level, the participant may have covered the watch while working or the watch may not have measured enough daylight due to technical issues. REM and deep sleep showed minimal change and remained low. Consistent high light levels do not significantly improve sleep quality. Overall, the chart reflects a constant, bright lighting environment with constant sleep measurements, indicating adaptation to lighting conditions without major effects on sleep quality.

In C03 participant chart 3 (Figure 118), daylight exposure remained constant throughout the day. Sinus rhythm and oxygen levels remained stable with little fluctuation. This suggests that consistently high indoor lighting did not significantly affect these physiological measurements. Overall, the chart indicates a stable, bright lighting environment with low natural light exposure. The stability of physiological measurements suggests effective adaptation to lighting conditions without adverse effects.

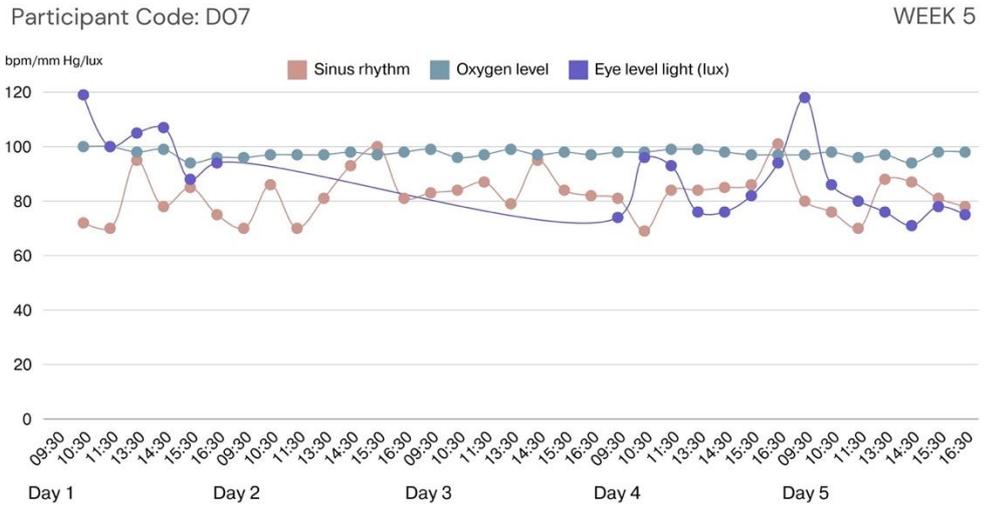


Figure 119. Week 5 Participant D07 Chart 1

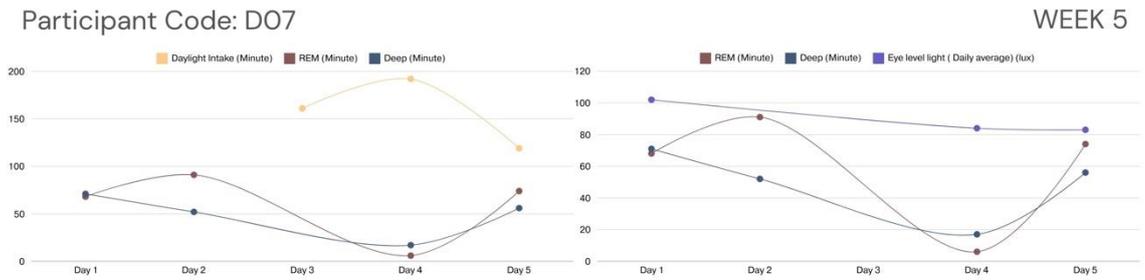


Figure 120. Week 5 Participant D07 Chart 2

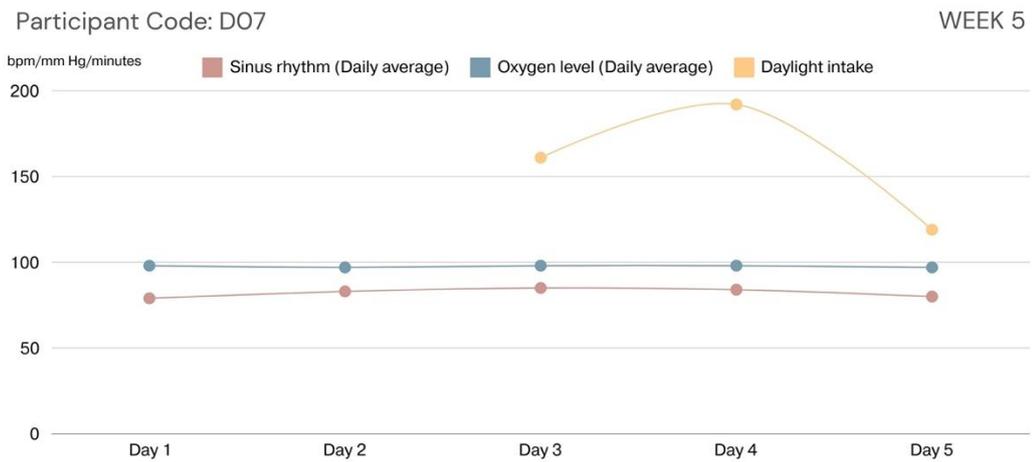


Figure 121. Week 5 Participant D07 Chart 3

In D07 participant chart 1 (Figure 119), light at eye level fluctuates continuously with a noticeable increase on day 5. Variable lighting conditions were experienced,

probably due to changes in natural or artificial light exposure throughout the day. Sinus rhythm remained generally stable but showed minor fluctuations. On the first day, the average sinus rhythm value was 79 and oxygen level was 98. On the second day sinus rhythm value was 83 and oxygen level was 97, on the 3rd day sinus rhythm value was 85 and oxygen level was 98, on the 4th day sinus rhythm value was 84 and oxygen level was 98, on the 5th day sinus rhythm value was 80 and oxygen level was 97. Consistent physiological responses were observed despite changes in light exposure. Oxygen levels maintained a constant trend around 100 and showed little change. It was observed that light changes did not significantly affect oxygen levels. Overall, the chart reflected the variability in lighting conditions while physiological measurements remained stable and adapted effectively to the changing light environment.

In D07 participant chart 2 (Figure 120), this participant did not calculate the hours of daylight exposure for the first 2 days in the chart on left. Daylight exposure increased from day 3 onwards, increased by day 4 and decreased significantly by day 5. There were no major changes in eye-level light throughout the week in the chart on right. REM sleep showed a slight upward trend, peaking around day 2 before decreasing. No light-related effects were observed. Deep sleep generally moves in tandem with REM sleep. Overall, it can be concluded that increased indoor light did not affect the quality of REM and deep sleep as exposure to outdoor light decreased.

In D07 participant chart 3 (Figure 121), Daylight exposure increased from day 3 onwards, increased by day 4 and decreased significantly by day 5. Sinus rhythm and oxygen levels also remained stable and showed minimal changes. Consistency suggests that changes in daylight exposure did not significantly affect these physiological measurements. Overall, the chart reflects stability in indoor lighting and physiological responses, with a brief increase in daylight exposure observed in the middle of the week.

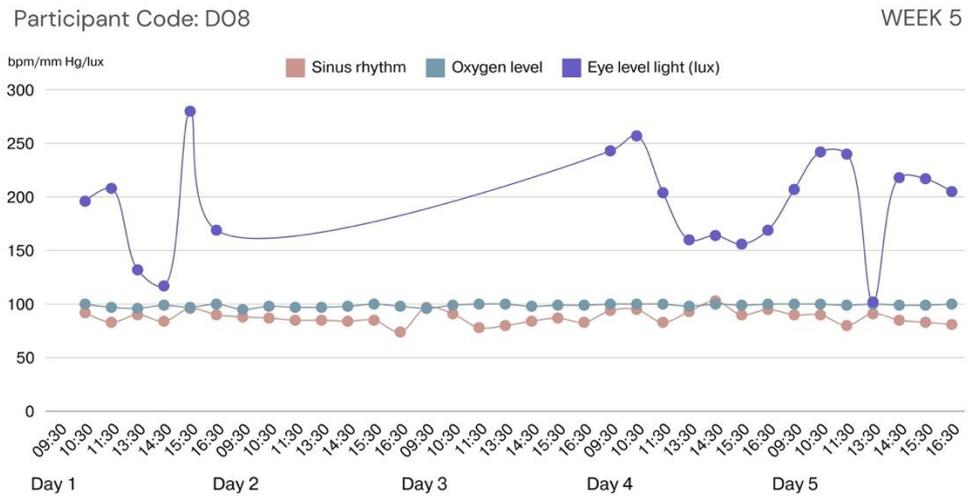


Figure 122. Week 5 Participant D08 Chart 1

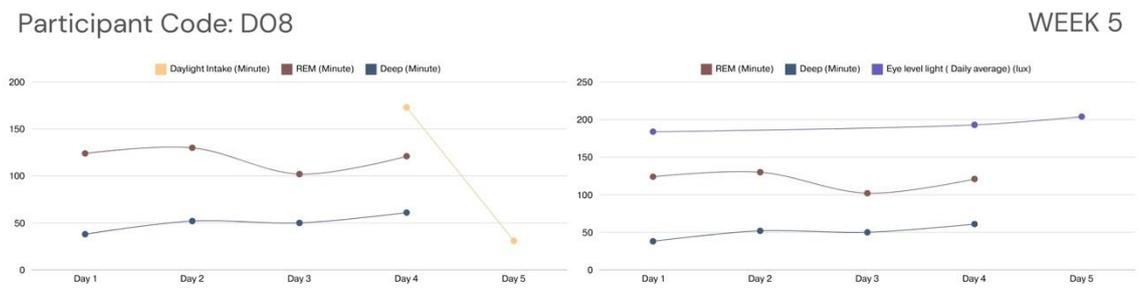


Figure 123. Week 5 Participant D08 Chart 2

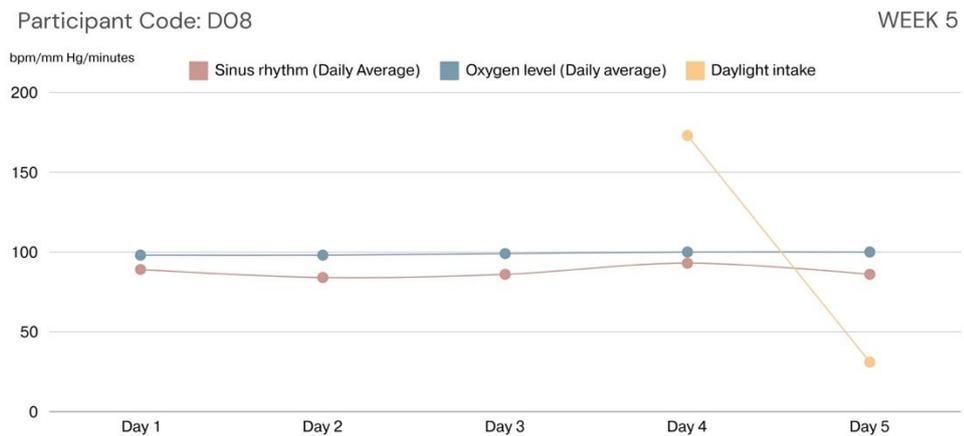


Figure 124. Week 5 Participant D08 Chart 3

In D08 participant chart 1 (Figure 122), light at eye level showed significant increases on days 2 and 4. It can be said that environmental factors, weather changes, may have

affected. Sinus rhythm remained stable with small fluctuations. Consistency indicates that changes in light exposure have little effect on sinus rhythm. Oxygen levels remained stable throughout the week. On the first day, the average sinus rhythm value was 89 and oxygen level was 98. On the second day sinus rhythm value was 84 and oxygen level was 98, on the 3rd day sinus rhythm value was 86 and oxygen level was 99, on the 4th day sinus rhythm value was 93 and oxygen level was 100, on the 5th day sinus rhythm value was 86 and oxygen level was 100. It was observed that changes in light levels did not significantly affect oxygen levels. Overall, the chart shows that physiological measurements remained stable despite changes in light exposure and adapted effectively to changing light conditions.

In D08 participant chart 2 (Figure 123), the amount of daylight was not measured by the watch for the first 3 days. There may have been a technical glitch or the participant was wearing clothing that covered the upper surface of the watch. Daylight exposure was high on day 4 but then dropped sharply in the chart on left. Light at eye level was generally consistent with a small increase on the last day in the chart on right. REM sleep showed a slight increase trend and peaked around day 2. Deep sleep also showed a slight increase, following a similar trend to REM sleep. Sleep levels were proportional to the light increases and were adequate. There was a potential improvement in deep sleep with changing lighting conditions. Overall, the charts show that increased indoor lighting may positively affect REM and deep sleep as daylight exposure decreases.

In D08 participant chart 2 (Figure 124), daylight exposure was high on day 4 but then dropped sharply. Sinus Rhythm and oxygen level both remain stable with minimal changes. Fluctuations in daylight and indoor light levels do not significantly affect these physiological measurements. The data does not provide sufficient data as daylight intake is not available every day.

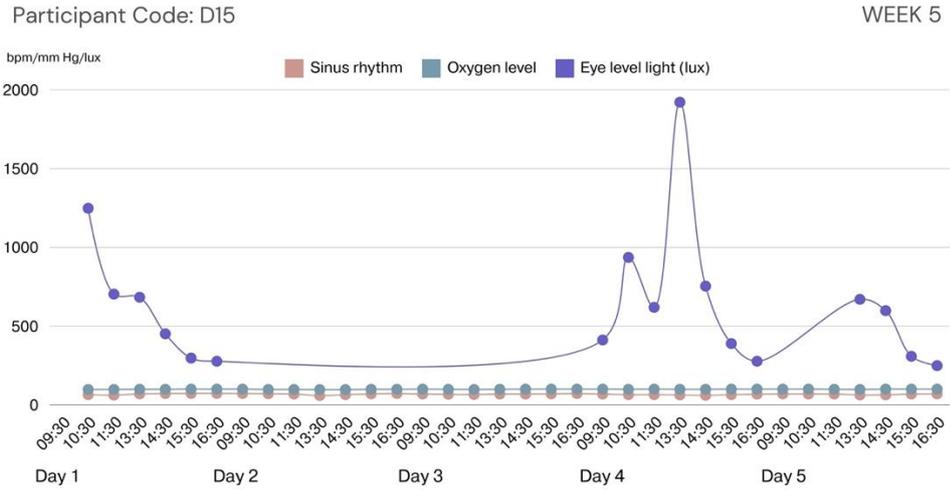


Figure 125. Week 5 Participant D15 Chart 1



Figure 126. Week 5 Participant D15 Chart 2

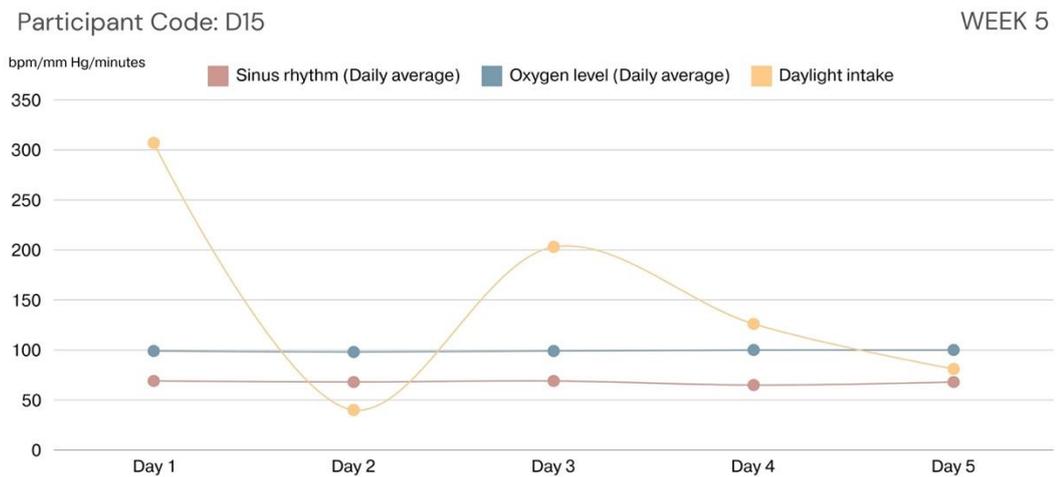


Figure 127. Week 5 Participant D15 Chart 3

In D15 participant chart 1 (Figure 125), The light at eye level started high on the first day, then remained constant for 2 days, peaked on day 5 and then decreased sharply

on day 5. Sinus Rhythm and oxygen level both measurements remain stable and show little variability over the period. On the first day, the average sinus rhythm value was 69 and oxygen level was 99. On the second day sinus rhythm value was 68 and oxygen level was 98, on the 3rd day sinus rhythm value was 69 and oxygen level was 99, on the 4th day sinus rhythm value was 65 and oxygen level was 100, on the 5th day sinus rhythm value was 68 and oxygen level was 100. This stability suggests that the sudden increase in light exposure did not significantly affect these physiological measures. Overall, the chart shows that despite the increase in light levels on day 3, physiological responses remain consistent and effectively adapt to bright lighting conditions.

In D15 participant chart 2 (Figure 126), Light at eye level peaks around day 3 and then declines in the chart on right. Daylight Intake decreased steadily throughout the week in the chart on left. REM and deep sleep levels showed minimal variability and remained low. Since the sleep test could not be performed on some days due to technical reasons, insufficient data could not be provided and a comparison may not be possible.

In D15 participant chart 3 (Figure 127), daylight Intake decreased steadily throughout the week. Sinus Rhythm and oxygen level both measurements remain stable and show little variability over the period. Overall, the chart highlights that exposure to light from both the environment and natural daylight is decreasing and physiological responses are stable, suggesting effective adaptation to changing conditions.

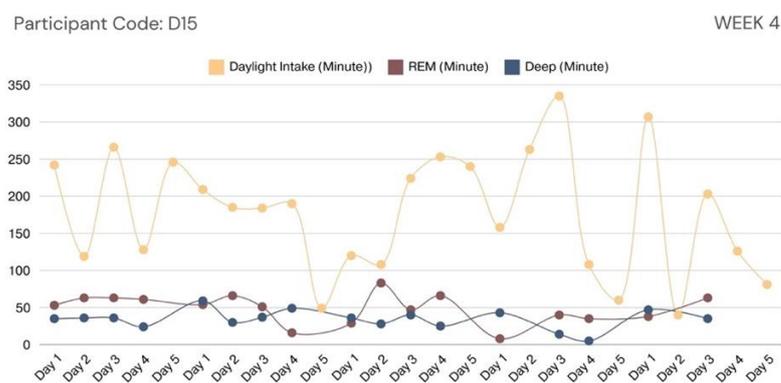


Figure 128. Participant D15's 5-week overall chart 1

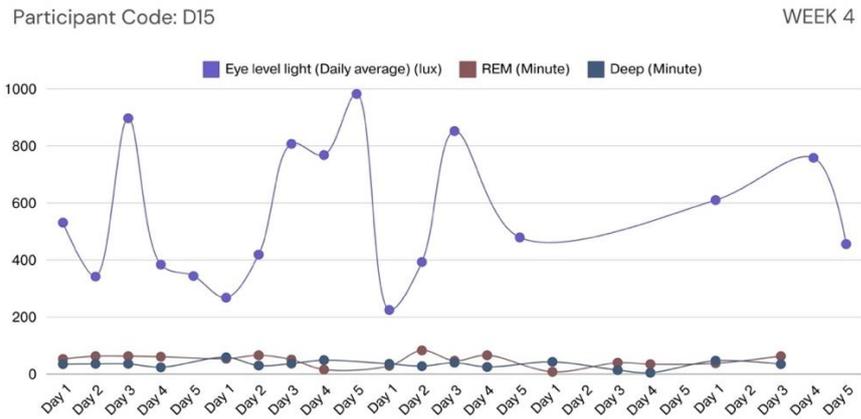


Figure 129. Participant D15's 5-week overall chart 2

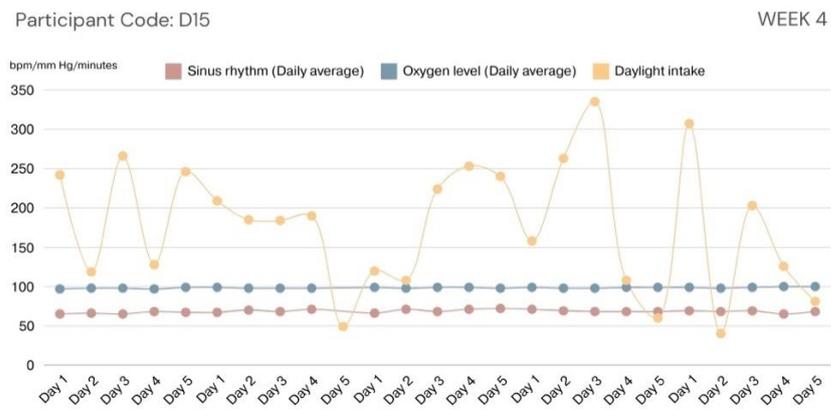


Figure 130. Participant D15's 5-week overall chart 3

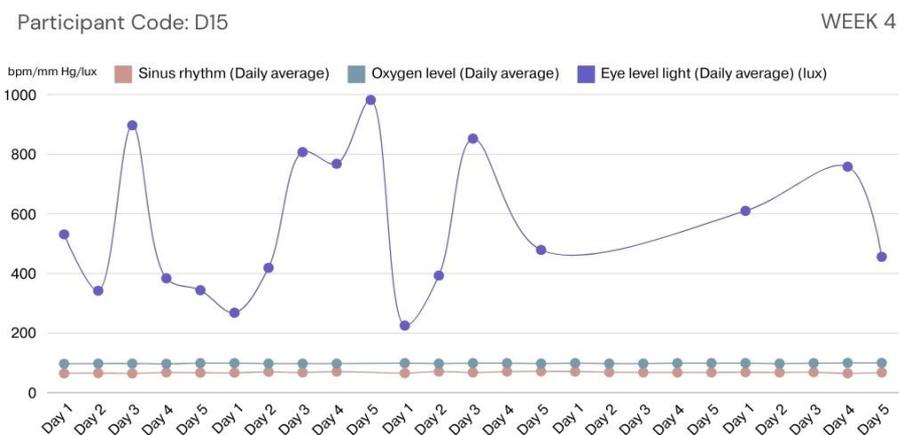


Figure 131. Participant D15's 5-week overall chart 4

Participant D15 participated in the tests for 5 weeks continuously. The 5-week monitoring period of an open office worker was considered to provide an additional layer for evidence-based research.

When the first chart of this participant (Figure 128) is analyzed, it has been observed that the daylight rises during the first and 3rd weeks and then rises and falls at small intervals. Daylight intake shows significant fluctuations. On certain days it reaches peaks of about 300 minutes. High intakes are followed by a cyclical pattern with declines. The lowest points were below 50 minutes on certain days. REM Sleep is fairly stable, between 20 and 60 minutes. Although there are slight variations, it generally maintains a consistent average. The level of deep sleep shows more variability than REM sleep. Similar to REM, it mostly ranges from 20 to 60 minutes. Both measures of sleep, REM and deep sleep, do not show large fluctuations and maintain relatively stable patterns, indicating stable sleep stages with small variations. The chart generally shows the differences between daylight exposure and sleep consistency over the given periods.

When the second chart of this participant (Figure 129) is analyzed, it has been observed that the light at eye level rises during the first and 3rd weeks and then rises and falls at small intervals. REM sleep remained relatively stable with slight increases on certain days. It can be emphasized that despite the fluctuations in daylight and light exposure, the levels of REM and deep sleep remained stable for this participant, although the levels were small. Overall, the chart highlights the variability in light conditions without a significant impact on sleep quality and demonstrates effective adaptation to environmental changes.

When the third chart of this participant (Figure 130) is analyzed, daylight intake shows a fairly consistent pattern across weeks but also varies from day to day. Sinus rhythm and oxygen level both measurements remained constant over the weeks with little change. It shows that fluctuations in light levels do not significantly affect these physiological measurements. Looking at the measurements daily from the weekly data on the tables, it is actually observed that the sinus rhythm decreases as daylight increases towards noon and increases as daylight decreases. This was regularly observed for weeks. Since the chart shows the average of these increases and decreases, they provide a consistent average. In general, the chart emphasizes stable physiological responses to averaged conditions, but when these physiological measurements are examined day by day, they are thought to be related to daylight.

When the last chart of this participant (Figure 131) is analyzed, it has been observed

that the light at eye level rises during the first and third weeks and then rises and falls at small intervals. Sinus rhythm and oxygen level both measurements remained constant over the weeks with little change. It shows that fluctuations in light levels do not significantly affect these physiological measurements. Looking at the measurements daily from the weekly data on the tables, it is actually observed that the sinus rhythm decreases as daylight increases towards noon and increases as daylight decreases. This was regularly observed for weeks. Since the graphs show the average of these increases and decreases, they provide an average. In general, the chart emphasizes stable physiological responses to averaged stylish conditions, but when these physiological measurements are examined day by day, they are thought to be related to light. The stable sinus and oxygen levels provide a reliable baseline to assess the impact of varying light conditions.

To sum up, a total of 21 people, 17 female and 4 males, participated in the tests conducted with smart watches and the PANAS survey. Since the male participant coded E01 had technical problems with the use of the watch, the test was cancelled on the 3rd day of the test and the number of participants decreased to 20 participants. In order to provide more detailed and longer data, user D15 continued the test for 5 weeks.

As a result, when the charts were analyzed as a result of the PANAS, questionnaire, sinus rhythm, oxygen level and the light at eye level, the following results were obtained.

Participant C01 reported that daylight affects her daily mood but she does not make much effort to reach daylight. As a result of the PANAS test, the participants' positive moods were higher than negative moods. It was observed that on days when the amount of daylight the participant received increased, her positive moods also increased. At the same time, the participant mentioned that she could fall asleep easily and had a good quality sleep on days when she had enough daylight, but since the participants' sleep measurements could not be accessed because of the technical issues, no comment can be made.

Participant C02 reported that daylight affects her daily mood and that she makes an effort to reach daylight. As a result of the PANAS test, the participants' positive moods were higher than negative moods. At the same time, the participant mentioned that she

could fall asleep easily and had a good quality sleep on days when she had enough daylight. When compared with the graph, it supports the positive effect of daylight on the participants' sleep.

Participant C03 reported that daylight affects her daily mood, but he/she does not make any effort to reach daylight. As a result of the PANAS test, the participants' positive moods were higher than their negative moods except for Day 2. Only on Day 2, negative moods were higher than positive moods. On the days when the participants' positive moods were very high, the amount of daylight received was also high. The participant also reported that daylight did not affect their sleep. Comparison with the graph shows that daylight does not really affect the participants' sleep.

Participant D01 reported that daylight affects her daily mood a lot but he/she does not make an effort to reach daylight. As a result of the PANAS test, the participants' positive moods were significantly higher than her negative moods. It was observed that on days when the amount of daylight the participant received increased, her positive moods also increased. At the same time, the participant mentioned that she could fall asleep easily and had a good quality sleep on days when she had enough daylight. Comparison with the result in the graph supports this effect. It is seen that the participant is definitely affected by daylight in terms of sleep.

Participant D02 reported that daylight affected his daily mood and that he made a lot of effort to reach daylight. As a result of the PANAS test, the participants' positive moods were higher than negative moods. The participant also mentioned that daylight had an effect on her sleep. Comparison with the result in the graph supports this effect.

The participant coded D03 mentioned in the questionnaire that daylight affects her mood and sleep level. As a result of the PANAS test, the participants' positive moods were higher than negative moods. Compared to the result in the graph, this result supports this effect. It was observed that daylight may have a positive effect on a person's sleep.

Participant D05 reported that daylight affected her daily mood a lot and that she made an effort to reach daylight. As a result of the PANAS test, the participants' positive moods were higher than negative moods. It was observed that on days when the

amount of daylight the participant received increased, her positive moods also increased. At the same time, the participant mentioned that she could fall asleep easily and had a good quality sleep on days when she had enough daylight. Compared to the result in the graph, there was no support for this effect. The participant may have been influenced by other external factors in terms of sleep.

Participant D06 reported that daylight affects her daily mood a lot, but she does not make an effort to reach daylight. As a result of the PANAS test, the participants' positive moods were higher than her negative moods. At the same time, the participant mentioned that the amount of daylight affects her sleep, but not in relation to falling asleep. Compared to the result in the graph, the participants' sleep was slightly affected by daylight. It is necessary to conduct more detailed and comprehensive research to make a conclusion that this participant was definitely not affected.

Participant D07 reported that daylight affects his daily mood but he/she does not make an effort to reach daylight. Since the participant did not fill out the PANAS test, no comments can be made about mood. At the same time, the participant mentioned that on days when she had enough daylight, she could fall asleep easily and had a good quality sleep. Compared to the result in the graph, there is no support for this effect. The participant may have been influenced by other external factors in terms of sleep. It was observed that daylight may have a positive effect on a person's sleep.

Participant D08 reported that daylight affects her daily mood and that she makes an effort to reach daylight. At the same time, she stated that he was in a more positive mood on days when he received daylight. PANAS results also support this. This participant was exposed to little light during the week and his negative moods were higher than his positive moods for 4 days. This test result proves the effect of daylight on this participants' daily mood. The participant also indicated in the questionnaire that her sleep patterns, level and speed of falling asleep were also affected by the amount of daylight she received daily. The positive effect of light on the REM level of the participant in the graphs also supports the survey results.

Participant D10 reported that daylight affects her daily mood but she does not make an effort to reach daylight in the questionnaire. At the same time, she stated that he was in a more positive mood on days when he received daylight. PANAS results also

support this. At the same time, the participant stated that she had difficulty falling asleep on days when she could not get enough daylight and that daylight had an effect on sleep. The participants' sleep test results also support this. It was reported that the participant had no knowledge that daylight affects sinus rhythm or oxygen levels.

Participant D11 reported in the questionnaire that daylight affects his daily mood and sleep patterns. It was observed that the participants' negative moods were generally higher than his positive moods for 5 days. This may be due to the fact that he/she receives less light than the other participants. The result of the PANAS test proves the survey result. At the same time, the sleep question in the questionnaire results and the light effect seen in the graph are of the same nature. It can be said that the participant is clearly affected by light.

The participant coded D12 reported that he prefers daylight as lighting in the office area. In the questionnaire, he reported that daylight affects his daily mood a lot and that when he cannot get daylight, he goes out and gets daylight. When we look at the PANAS test, we can observe that this participants' daily positive mood level is high except for Day 4, and on Day 4, positive and negative moods are equal. The fact that the amount of daylight she received on other days decreased on Day 4 confirms the effect of these results. At the same time, the fact that this participant stated that daylight affects the amount and levels of sleep and the amount of daylight received in the graphs shows the effect on sleep.

Participant D14 reported that daylight affected her daily mood and that she made a lot of effort to reach daylight. As a result of the PANAS test, the participants' positive moods were higher than negative moods in the first 3 days. On the 4th day their moods were equal and on the 5th day their negative moods were higher than their positive moods. When the PANAS result was compared with the amount of daylight, it was observed that daylight did not affect the rose mood. At the same time, the participant marked that daylight did not affect his/her sleep too much, but he/she also selected the option "I fall asleep more easily on days with sufficient daylight". Compared to the result in the graph, this result supports this effect. In other words, on days when the participant received more daylight, the participants' sleep levels also increased. It was positively effective.

Participant D15 reported that daylight affects her daily mood a lot. As a result of the PANAS test, the participants' positive moods were higher than negative moods. It was observed that on days when the amount of daylight the participant received increased, his positive moods also increased. At the same time, the participant mentioned that she could fall asleep easily and had a good quality sleep on days when she had enough daylight. Compared to the result in the graph, there was no support for this effect. The participant may have been influenced by other external factors in terms of sleep. This participant was also observed 4 weeks longer than the other participants. As a result of the interview with the participant, the participant stated that the sinus rhythm was actually low in the morning when the amount of daylight was low and high in the afternoon when the amount of daylight was high and realized that this cycle repeated on most days. Although no such effect was observed in the graphs, this effect can be further investigated in further studies.

The participant coded D20 reported that daylight affects her daily mood a lot and that she makes an effort to reach daylight when she cannot get enough daylight. As a result of the PANAS test, the participants' positive moods were higher than her negative moods. The participant lives in a location with a lot of daylight. The effect of this may have been positive. At the same time, the participant mentioned that on days when she had enough daylight, she could fall asleep easily and had a good quality sleep. The amount of daylight intake of the participant could not be adequately compared with the sleep data due to technical problems.

In all 20 participants, it was found that the amount of light at eye level taken daily in the first chart did not affect sinus rhythm and oxygen levels. In all 20 participants, both measurements remained stable according to the light levels. This shows that they have made an adaptation in the amount of light they receive daily. When the values of the D20 participant who was exposed to the most daylight were analyzed, it was determined that the values were more regular and the sinus rhythm measurements were calmer and lower, but getting this result in one person out of 20 does not prove that there is an effect. In the second chart, which examined the effect of daily daylight intake, eye-level lights on sleep quality, it was revealed that the sleep of 14 out of 20 participants was positively affected by the light levels.

To sum up in total, it was found that the sleep quality of 15 participants was related to light. The sleep tests of two participants could not be tested due to technical reasons, so as a result, it is observed that 15 out of 18 participants were affected. This may indicate the need for balanced light exposure to maintain optimal sleep quality and well-being. It may also be evidence that light affects the circadian rhythm cycle. The effect of the average amount of light received on sinus rhythm and oxygen level analyzed in the third chart was the same as in the first chart. All 20 participants had very small fluctuations in sinus rhythm and oxygen levels and remained constant. It should be noted that this stability and regular measurements may be due to adequate daylighting, but it is also possible that other factors may contribute to good biological values.

5.3. Discussion

According to the results of the questionnaire, the mood, motivation, creativity, sleep patterns and circadian rhythm of 70 percent of the participants were affected by light. They were generally undecided about sinus rhythm and oxygen levels. When the PANAS-SF test was analyzed, it was observed that participants sitting in locations with good light generally marked the positive modes more and the negative modes less. Of course, since the PANAS-SF test was administered to the participants one week after the end of the test, it is thought that some participants may have experienced uncertainty. In addition, there are many factors that affect people other than daylight for model evaluation. These factors can also be addressed in future studies. As a result of the smartwatch measurements, it was observed that artificial and daylight had no effect on the participants' oxygen levels and sinus rhythms. In the questionnaire filled out by the participants, it was determined that the majority were undecided about the effect of light on these data.

This research highlights how integrating daylight into open - plan work environments can greatly improve not only the physical aspects of workspace design, but also the psychological and physiological health of workers. As indicated in the findings, daylight emerged as a critical factor in improving mood, regulating circadian rhythms and promoting overall well-being. By measuring positive and negative moods as well as direct measures of physiological responses, this research provides strong evidence supporting the idea that access to daylight is a vital component of a healthy working

environment. The findings regarding circadian rhythms further underscore the importance of daylight. Evidence gathered through various biological measurements highlights the essential role that environmental factors, such as access to natural light, play in regulating these rhythms, thus promoting better health outcomes.

The use of wearable technology to monitor physiological indicators, including ECG and oxygen levels, sleep monitoring tests, provides a comprehensive insight into how daylight affects office workers. By collecting data at multiple points throughout the day, the research highlights the dynamic nature of light exposure and its effects on individuals. This approach not only strengthens the validity of the findings, but also sets a precedent for future work in the field of biophilic design and open-plan office workers' wellbeing.

Finally, this research highlights the importance of fostering a relationship with nature in office environments. Evidence-based data suggests that work environments that encourage exposure to natural elements such as daylight can increase employees' sense of well-being and mood and impact on sleep quality. Establishing this relationship can lead to a more engaged and satisfied workforce and ultimately improve employees' work patterns and quality of life.

The following Conclusion chapter discusses how the study has responded to the Research Questions set forth at the beginning of this PhD dissertation. Moreover, future research implications for researchers and design guidelines for designers are provided, in order to create effective biophilic work environments.

CHAPTER 6: CONCLUSION

After the COVID-19 pandemic, there was a great need to reconnect to nature and reintroduce natural elements into the office space to enhance wellbeing and mood. Moreover, recent technological advancements, such as the development of smart watches, have made collection of “evidence” for evidence-based approaches accessible. Information such as blood pressure, oxygen levels, and other physical changes in the human body may be recorded, and analyzed in connection to digital recordings of daylight in the office interior. Combined with surveys, enabling psychological feedback from participants, it is now possible, as applied in this study, to access and analyze specialized criteria, as a base to create more effective office interiors. Therefore, the study contributes to literature not only in terms of the findings, but also the applied methods and techniques. The discussion below aims to break this contribution down into defined units.

This dissertation has explored the complex relationship between biophilic design, particularly the role of daylight and its effects on office workers in open-plan environments. Through a detailed examination of 14 biophilic design models proposed by Terrapin, emphasis is placed on how daylight serves as a fundamental element in improving the overall well-being of workers. The use of evidence-based methods, including biological measurements, light assessments, surveys and archival data analysis, provided valuable insights into how varying daylight levels affect mood, circadian rhythms and overall health and well-being.

In order to form a base for this study and determine the method, the existing literature was analyzed and investigated in a systematic way. The analysis and details of earlier studies related to this research depicts 9 keywords associated with this study, the methods and the results. In the table; Wotten et al. (1982) researched the impact of daylight on job satisfaction with interviews with 235 office workers. One may observe that a percentage (74%) preferred to have a window located near their workspaces. Oldham and Rotchford (1983) investigate relationships between office characteristics and employee reactions with surveys and questionnaires by using 19 office samples. They found that the design of office settings can have substantial implications for the

way people react in offices. Heerwagen, and Orians (1986) researched the use of visual décor in windowed and windowless offices by conducting a detailed content analysis of wall decor used in 75 offices on the University of Washington campus. They discovered that occupants of windowless space used twice as many (195 versus 82) visual materials to decorate their offices.

Research indicates that individuals in windowless offices tended to use more landscape imagery and less urban imagery compared to those in offices with windows. A study by Boubekri, Hull, and Boyer (1991) examined the effects of window size and sunlight exposure on the moods and satisfaction levels of office workers through questionnaires conducted in a standard-sized office. The findings revealed that window size did not significantly influence emotional well-being or satisfaction; however, sunlight penetration notably affected feelings of relaxation for those seated sideways to windows, displaying an inverted U-shape relationship. Similarly, Leather et al. (1998) investigated the role of windows, sunlight, and views in the workplace, utilizing a well-being questionnaire based on Warr, Cook, and Wall's 15-item scale. Their results showed a significant positive effect of sunlight exposure on job satisfaction, intent to quit, and overall well-being. Views of natural elements, such as trees and vegetation, were found to mitigate the negative effects of job stress on turnover intentions and positively contributed to general well-being, though to a lesser extent. Lastly, Stone (1999) conducted a systematic literature review on the effects of lighting on melatonin production, circadian rhythms, and mood. The review concluded that lighting conditions directly influence melatonin production by the pineal gland. While normal indoor lighting, including periodic exposure to daylight, typically does not disrupt circadian rhythms, extended exposure to high levels of light could potentially lead to a misalignment of certain bodily rhythms.

Fontoynt (2002) examines how daylighting systems compare to artificial lighting in terms of perceived performance, focusing on their effectiveness and comfort. The findings indicate that well-designed daylighting, when complemented by artificial lighting, can enhance both visual and psychological comfort. Edwards and Torcellini (2002) provided a comprehensive review of literature that highlights the effects of daylighting in buildings, while Leslie (2003) also conducted a literature review on this topic. In a related study, Ulrich (2007) presented colored slides of outdoor scenes to

two groups of mildly stressed participants, who then completed the Zuckerman Inventory of Personal Reactions (ZIPERS) to assess their emotions and anxiety levels. The results revealed significant implications for environmental planning and design, suggesting that visual exposure to outdoor environments can positively affect psychological well-being. As a result, it's essential for planners to consider these influences in their design choices. The study emphasizes the importance of aesthetic elements in environments, which empirical evidence shows can greatly enhance the overall experience.

George and Zhou (2007) conducted a study examining how positive and negative moods influence creativity in supportive environments, utilizing questionnaires based on the PANAS scales. They identified three key ways supervisors can foster a supportive atmosphere: by offering developmental feedback, demonstrating interactional justice, and being trustworthy. Küller (2007) investigated the effects of daylight on human behavior and luminous comfort in residential settings through an extensive questionnaire and lux meter measurements rooted in neuropsychological concepts. The emotional well-being of participants was evaluated across 12 scales, including feelings such as rested/tired and happy/sad. The study highlighted the significant impact of light and color on well-being, emphasizing the importance of considering seasonal variations and access to windows for practitioners. Similarly, Xue, Mak, and Cheung (2014) explored how daylighting and human behavior affect luminous comfort in residential buildings, finding that behavioral factors significantly influence comfort levels among individuals who rate their daylighting satisfaction as moderate. The reliance on artificial lighting emerged as a critical factor, indicating that prolonged use of artificial illumination correlates with inadequate daylighting and diminished comfort.

Zadeh et al. (2014) conducted a study on the effects of windows and daylight on the physiological, psychological, and behavioral health of acute-care nurses. Using a quasi-experimental approach with various data collection methods including biological measurements, behavioral mapping, and archival data analysis the findings reinforced previous evidence from both laboratory and field studies regarding the advantages of windows and daylight. These benefits may include a micro-restorative effect, such as reduced blood pressure, increased oxygen saturation, and positive

influences on circadian rhythms and morning sleepiness.

Similarly, Bian, and Luo (2017) explored visual comfort metrics based on subjective feedback in office environments in China. Their research took place in two side-lit office spaces within a laboratory building under different sky conditions. They found that simple luminance metrics, like work plane luminance and vertical eye illuminance, were more effective than complex glare indices (DGP/DGI) and luminance ratios. Metric thresholds were also established from these results.

The advantages of implementing biophilic design elements, especially daylight, in interior spaces are well-documented, with numerous studies indicating improvements in physical health, reduced blood pressure, enhanced mood, decreased illness, increased job satisfaction, creativity, motivation, improved concentration, and better social interactions (Ulrich et al., 1992). This highlights the significance of daylight as a vital component of biophilic design.

The approach and method used in this study can help in terms researchers, interior architects, architects and designers, and thus, contribute to existing literature. Findings of this research can create a base for a body of knowledge regarding the relationship between human and daylight in work environments. In addition, it establishes a base reference with respect to the effect of biophilic design and views on health and wellbeing of office workers. The use of natural light is one of the most important factors to be taken into consideration for open-plan office design. This research should help to raise awareness of the detailed factors that influence the luminous environment and also how designers can design the office environment according to the amount of daylight in the interior and how people react with nature in a work environment.

This research explores biophilic design in work environments, focusing specifically on the impact of daylight in open-plan offices. Biophilic design, which integrates natural elements into built spaces to enhance human well-being, has shown promise in improving occupant health, productivity, and satisfaction. However, there remains a need for evidence-based methods to quantify the effectiveness of these design principles, especially regarding daylight exposure. Results demonstrate how optimal daylight access not only enhances visual comfort but also aligns with natural circadian rhythms, thus promoting employee well-being and performance. This work contributes

to a growing body of evidence supporting biophilic design's efficacy, providing actionable insights for architects, designers, and organizations seeking to foster healthier, more productive workspaces.

In conclusion, as the demand for healthier and more engaging office environments rises, the insights gained from this study should serve as a guiding framework for future architectural and design practices. Moving forward, it is critical to continue researching and implementing biophilic design strategies that accommodate the essential role of daylight in nurturing a thriving work atmosphere. The implications of this research extend beyond mere aesthetics; they serve to inform a more holistic approach to workplace design that values human health and the intrinsic connection to the natural world.



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APPENDICES

Appendix A. CURRICULUM VITAE

Idil Bakır Küçükkaya is an industrial product designer and academic working at the İzmir University of Economics (IUE), Department of Interior Architecture and Environmental Design since 2018. She received her bachelor's degree in Industrial Product Design (2011) from Yeditepe University and master's in Interior Architecture Program (2015) from Yaşar University. Her research interests include biophilic design sustainability, environmental behavior studies and interior lighting.

Teaching Experience:

2018- Present- Research Assistant

İzmir University of Economics

Faculty of Fine Arts and Design

Department of Interior Architecture and Environmental Design

Appendix B. Questionnaire

Biophilic Design - Daylight Research

Welcome!

Thank you for joining us in our journey in understanding the effects of daylight in open plan offices within the biophilic design approach.

For the scientific nature of the research, it is extremely important that you answer the questions sincerely. Please answer the questions if you work in an open plan office.

*** The information provided by the people participating in the questionnaire will be kept strictly confidential and will not be used for any commercial purpose.**

Thank you in advance for your valuable contributions.

*İzmir University of Economics
Graduate School, Ph.D. in Design Studies
İdil BAKIR KÜÇÜKKAYA*

Thesis advisor: Prof. Dr. Deniz HASIRCI

Hoş geldiniz!

Biyofilik tasarım yaklaşımı çerçevesinde açık plan ofislerde gün ışığının etkilerini anlama yolculuğumuzda bize katıldığınız için teşekkür ederiz.

Araştırmanın bilimsel niteliği açısından soruları içtenlikle yanıtlamanız son derece önemlidir. Lütfen açık planlı bir ofiste çalışıyorsanız soruları yanıtlayın.

*** Ankete katılan kişilerin verdikleri bilgiler kesinlikle gizli tutulacak ve herhangi bir ticari amaçla kullanılmayacaktır.**

Değerli katkılarınız için şimdiden çok teşekkür ederiz.

*İzmir Ekonomi Üniversitesi
Lisansüstü Eğitim Enstitüsü, Tasarım Çalışmaları - Doktora Programı
İdil BAKIR KÜÇÜKKAYA*

Danışman: Prof. Dr. Deniz HASIRCI

* Zorunlu soruyu belirtir

Demographic Information / Demografik Bilgiler

1. Gender / Cinsiyetiniz *

Yalnızca bir şıkkı işaretleyin.

- Female / Kadın
 Male / Erkek
 Other / Diğer
 Rather not to say

2. Age / Yaş *

Yalnızca bir şıkkı işaretleyin.

- 20 - 34
 35 - 49
 50 - 64
 64 +

3. Education / Eğitim *

Yalnızca bir şıkkı işaretleyin.

- High school / Lise
 Associate degree - Bachelor's degree / Önlisans - Lisans
 Post - graduate / Lisansüstü

4. **Profession / Meslek ***

5. **I work at Izmir University of Economics and I am a participant in the smartwatch test of this thesis. / İzmir Ekonomi Üniversitesinde çalışıyorum ve bu tez çalışmasının akıllı saat testinde katılımcıyım. ***

Yalnızca bir şıkkı işaretleyin.

Yes / Evet

No / Hayır

6. **If you answered yes to the question above, please write down the participant number given to you, consisting of one letter and one number. / Yukarıdaki soruya evet dediyse lütfen size verilen bir harf ve bir sayıdan oluşan katılımcı numarasını yazınız.**

Exposure to Daylight / Gün Işığına Maruz Kalma

7. **How long have you been working at this work environment? / Bu iş yerinde ne süredir çalışmaktasınız? ***

Yalnızca bir şıkkı işaretleyin.

1 months - 12 months / 1 ay - 12 ay

1 year - 5 years / 1 yıl - 5 yıl

3 years - 5 years / 3 yıl - 5 yıl

More than 5 years / 5 yıldan fazla

8. **How many hours of your day do you spend at your desk in an open office? / ***
Gününüzün kaç saatini açık ofisteki çalışma masanızda geçiriyorsunuz?

Yalnızca bir şıkkı işaretleyin.

- 2 - 5 hours / 2 - 5 saat
- 5 - 7 hours / 5 - 7 saat
- 7 - 9 hours / 7 - 9 saat
- More than 9 hours / 9 saatten fazla

9. **How many people other than you work in your work environment? / Çalıştığınız ***
ortamda sizden başka kaç kişi çalışıyor?

Yalnızca bir şıkkı işaretleyin.

- 1 person / 1 kişi
- 2 - 4 people / 2 - 4 kişi
- 5 - 10 people / 5 - 10 kişi
- More than 10 people / 10 kişiden fazla

In the open office, can you rank the physical elements of the space listed below according to their importance for you? / Açık ofiste, aşağıda listelenen mekanın fiziksel elemanlarını sizin için önemine göre sıralayabilir misiniz? *

Her satırda yalnızca bir şıkkı işaretleyin.

	1 (Important / Önemli)	2	3	4	5 (Most important / En önemli)
Adequate Ventilation / Yeterli Havalandırma	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Being close to the window, being able to see out / Pencereye yakın olmak, dışarıyı görebilmek	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Adequate lighting / Yeterli aydınlatma	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sound insulation / Ses yalıtımı	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
An enclosed, private space / Kapalı, size özel bir alan olması	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

11. **What is the type of lighting in your work environment?** / Çalışma ortamınızdaki *
aydınlatma türü nedir?

Yalnızca bir şıkkı işaretleyin.

- Artificial lighting / Yapay aydınlatma
- Natural lighting / Doğal aydınlatma
- Artificial % 50 and natural Lighting % 50 / Yapay 50% ve doğal aydınlatma 50 %
- Artificial % 30 and natural Lighting % 70 / Yapay 30% ve doğal aydınlatma 70 %
- Artificial % 70 and natural Lighting % 30 / Yapay 70% ve doğal aydınlatma 30 %

12. **Are there any openings (windows, ceiling openings, skylights) in the open office where you work?** / Çalıştığınız açık ofiste herhangi bir açıklık (pencereler, tavan açıklıkları, çatı pencereleri) var mı? *

Yalnızca bir şıkkı işaretleyin.

- None / Yok
- On the ceiling / Tavanda var
- On the wall / Duvarında var

13. **If you have a window in an open office, can you evaluate your distance to the window?** / Açık ofiste pencereniz varsa pencereye olan mesafenizi değerlendirebilir misiniz?

Yalnızca bir şıkkı işaretleyin.

1 2 3 4 5

Clos Far / Uzak

14. **Do you use desk lighting or extra lighting in your open office?** / Açık ofiste masa aydınlatması veya fazladan bir aydınlatma kullanıyor musunuz? *

Yalnızca bir şıkkı işaretleyin.

- Using / Kullanıyorum
 Not using / Kullanmıyorum

15. **If you use extra lighting, please explain what it is.** / Extra aydınlatma kullanıyorsanız ne olduğunu lütfen açıklayınız.

16. **Which type of light do you prefer when you work?** / Çalışırken hangi ışık tipini tercih edersiniz? *

Yalnızca bir şıkkı işaretleyin.

- Artificial light / Yapay ışık
 Natural Light / Doğal ışık
 Artificial light and Natural Light / Yapay ve doğal ışık

17. **Do you prefer to have a window in your work environment that you control yourself?** / Çalıştığınız ortamda kendi kontrolünüzde olan pencere olmasını tercih eder misiniz? *

Yalnızca bir şıkkı işaretleyin.

- I prefer / Tercih ederim
 I do not prefer / Tercih etmem

18. **Would you prefer a shading element (curtains, blinds, etc.) in your open office that you control yourself?** / Açık ofisinizde kendi kontrolünüzde bir gölgeleme elemanı (perde, stor vb.) tercih eder misiniz? *

Yalnızca bir şıkkı işaretleyin.

- I prefer / Tercih ederim
 I do not prefer / Tercih etmem

19. **Please rate the importance of the using desk lighting in your desk.** / Lütfen çalışma masanızda masa aydınlatması kullanmanın önemini değerlendiriniz. *

Yalnızca bir şıkkı işaretleyin.

- 1 2 3 4 5
Not Very important / Çok önemli

Perception and Impact of Daylight / Gün Işığının Algılanması ve Etkisi

20. **How would you rate the general level of illumination at the desk where you work?** / Çalıştığınız masadaki genel aydınlatma düzeyini nasıl değerlendirirsiniz? *

Yalnızca bir şıkkı işaretleyin.

- Very High / Çok yüksek
 High / Yüksek
 Average/ Ortalama
 Low / Düşük
 Very Low / Çok düşük

21. **Please rate the overall amount of light coming into your desk? / Lütfen masanıza gelen genel ışık miktarını değerlendirebilir misiniz?** *

Yalnızca bir şıkkı işaretleyin.

1 2 3 4 5

Very Dim / Loş

22. **Please mark how much the following components affect your work on your desk surface. / Lütfen çalışma masa yüzeyinizde, aşağıda belirtilen bileşenlerin çalışmanızı ne kadar etkilediğini işaretleyiniz.** *

Uygun olanların tümünü işaretleyin.

	1 (Not very important / çok önemli değil)	2	3	4	5 (Very important / Çok önemli)
Illuminance level / Aydınlık seviyesi	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Color of light / Işığın rengi	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Shadows cast in your workspace / Çalışma alanınız içerisinde oluşan gölgeler	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Glare / Kamaşma	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

23. **If there is glare on your screen, which of the following do you think is its source?** / Ekranınızda kamaşma varsa, kaynağı sizce aşağıdakilerden hangisidir?

Yalnızca bir şıkkı işaretleyin.

- Ceiling lighting / Tavan aydınlatmaları
 Desk lighting / Masa aydınlatması
 Sun / Güneş
 Roller blinds, curtains or shades / Storlar, perdeler veya gölgelikler
 Diğer: _____

24. **In the open office, are there any interior elements (cabinet, separator, etc.) that prevent you from receiving daylight or artificial light?** / Açık ofiste, gün ışığı veya yapay ışık almanızı engelleyen iç mekan elemanları (dolap, seperatör vb.) var mı? *

Yalnızca bir şıkkı işaretleyin.

- There is / Var
 None / Yok

25. **If you answered "yes" to the question above, please explain what a divider is.** / Üstteki soruya "var" olarak yanıt verdiyseniz lütfen bölücünün ne olduğunu açıklayınız.

26. **Please assess the disturbing reflections on your desk caused by daylight or artificial light during screen use.** / Lütfen masanızda ekran kullanımı sırasında günışığı veya yapay ışıktan kaynaklanan rahatsız edici yansımaları değerlendiriniz. *

Yalnızca bir şıkkı işaretleyin.

1 2 3 4 5

Bare Extremely / Çok

27. **Please rate the visual comfort problems you experience due to lighting?** / Lütfen Aydınlatma nedeniyle yaşadığınız görsel konfor sorunlarını değerlendiriniz. *

Yalnızca bir şıkkı işaretleyin.

1 2 3 4 5

Bare Extremely / Çok

28. **What is the impact of lighting in an open office on the work you do?** / Açık ofisteki aydınlatmanın yaptığınız iş üzerindeki etkisi nedir? *

Yalnızca bir şıkkı işaretleyin.

- It increases my work efficiency. / İş verimliliğimi artırır.
- It reduces my work efficiency. / İş verimliliğimi düşürür.
- No effect. / Etkisi yok.
- Diğer: _____

A circadian rhythm or circadian cycle, is a natural, internal process that regulates the sleep–wake cycle and repeats roughly every 24 hours (Nichd, 2019). The human sleep cycle is an example of a circadian rhythm and is shifted based on light levels (Millett, 2014). It is a system in our body that not only regulates sleep, but also schedules many functions. /

Sirkadiyen ritim veya sirkadiyen döngü, uyku-uyanıklık döngüsünü düzenleyen ve kabaca her 24 saatte bir tekrar eden doğal, içsel bir süreçtir (Nichd, 2019). İnsan uyku döngüsü sirkadiyen ritme bir örnektir ve ışık seviyelerine göre değişir (Millett, 2014). Vücudumuzda sadece uykuyu düzenleyen değil, aynı zamanda birçok işlevi de programlayan bir sistemdir.

Image: Circadian Rhythm 24 Hours Cycle (Smith, 2021)



30. **Please rate how much daylight affects your daily mood in the open office. /** *
Lütfen açık ofiste gün ışığının günlük ruh halinizi ne kadar etkilediğini değerlendiriniz.

Yalnızca bir şıkkı işaretleyin.

1 2 3 4 5

Bare Extremely / Çok fazla

31. **Please choose the option that suits you in the questions below. / Lütfen aşağıdaki ***
sorulardan size uygun olan seçeneği işaretleyiniz.

Her satırda yalnızca bir şıkkı işaretleyin.

	Strongly disagree / Kesinlikle katılmıyorum	Do not agree / Katılmıyorum	Undecided / Kararsızım	Agree / Katılıyorum	Absolutely agree / Kesinlikle katılıyorum
Daylight affects my daily mood. / Gün ışığı günlük ruh halimi etkiler.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I make an effort to get daylight in the office. / Ofiste gün ışığı almak için çaba sarf ederim.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I change my location to get daylight in the open office. / Açık ofiste gün ışığı almak için yerimi değiştiririm.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I go out from time to time to get daylight from the office. / Ofisten gün ışığı almak için zaman zaman dışarı çıkarım.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I work in different places to get daylight	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

in the office. /
Ofiste gün ışığı
almak için farklı
yerlerde
çalışırım.

Daylight
increases my
work efficiency.
/ Gün ışığı iş
verimliliğimi
artırır.

Daylight
distracts me
when I work at
my desk. / Gün
ışığı masamda
çalışırken
dikkatimi
dağıtır.

Daylight makes
me more
positive in the
office. / Gün
ışığı ofiste beni
daha pozitif
yapar.

Daylight allows
me to be more
creative in the
office. / Gün
ışığı ofiste daha
yaratıcı olmamı
sağlar.

The amount of
sunlight I get
during the day
affects my
motivation. /

Gün içinde
aldığım güneş
ışığı miktarı
motivasyonumu
etkiler.

The amount of
daylight I get
during the day
affects my
sleep patterns.
/ Gün içinde
aldığım gün
ışığı miktarının
uyku düzenimi
etkiler.

I fall asleep
easier on days
when I get
regular
sunlight. /
Düzenli güneş
ışığı aldığım
günlerde daha
kolay uykuya
dalabiliyorum.

I have trouble
sleeping on
days when I do
not get enough
daylight. /
Yeterince gün
ışığı almadığım
günlerde
uyumakta
zorlanırım.

Daily sunlight
intake affects
my circadian
rhythm. /

Günlük güneş
ışığı alımının
sirkadiyen
ritmimi etkiler.

Daily sunlight
intake affects
my heart
rhythm. /
Günlük güneş
ışığı alımının
kalp ritmimi
etkiler.

I get stressed
on days when I
do not get
enough
daylight. / Gün
ışığı yeterli
miktarda
alamadığım
günlerde stresli
olurum.

32. Please briefly describe your experience, if any, of daylight having a significant *
impact on your mood or well-being at work. / Lütfen gün ışığının iş yerindeki
ruh halinizi veya refahınızı önemli ölçüde etkilediğine dair deneyimleriniz varsa
kısaca anlatınız.

Günlük güneş
ışığı alımının
sirkadiyen
ritmimi etkiler.

Daily sunlight
intake affects
my heart
rhythm. /
Günlük güneş
ışığı alımının
kalp ritmimi
etkiler.

I get stressed
on days when I
do not get
enough
daylight. / Gün
ışığı yeterli
miktarda
alamadığım
günlerde stresli
olurum.

32. **Please briefly describe your experience, if any, of daylight having a significant *
impact on your mood or well-being at work. / Lütfen gün ışığının iş yerindeki
ruh halinizi veya refahınızı önemli ölçüde etkilediğine dair deneyimleriniz varsa
kısaca anlatınız.**

33. **Please briefly describe your experience if you think daylight has a significant impact on your sleep patterns.** / Lütfen gün ışığının uyku düzeninizi önemli ölçüde etkilediği düşünüyorsanız bu konudaki deneyimlerinizi kısaca açıklayın. *

34. **Please write down 3 negative aspects that bother you about the use of daylight in the work environment.** / Lütfen çalışma ortamında gün ışığı kullanımı konusunda sizi rahatsız eden 3 olumsuz yönü yazınız. *

35. **Please write down 3 positive aspects that make you feel good about the use of daylight in the work environment?** / Lütfen çalışma ortamında gün ışığı kullanımı konusunda kendinizi iyi hissetmenizi sağlayan 3 olumlu yönü yazınız. *

36. **Thank you for your help and support!**
If you have any questions, please don't hesitate to contact with us.
Contact:

Have a nice day full of daylight!

Yardımlınız ve desteğiniz için teşekkür ederiz!
Herhangi bir sorunuz varsa, lütfen bizimle iletişime geçmekten çekinmeyin.
İletişim:

Gün ışııyla dolu güzel bir gün geçirin!

Bu içerik Google tarafından oluşturulmamış veya onaylanmamıştır.

Google Formlar

APPENDIX C - User Manual for Participants

Izmir University of Economics Graduate School
Ph.D in Design Studies

**DAYLIGHT AS A BIOPHILIC ELEMENT
IN WORK ENVIRONMENTS**
by
İDİL BAKIR KÜÇÜKKAYA
Thesis Advisor: Prof. Dr. Deniz HASIRCI



**APPLE WATCH SERIES 9 USER MANUAL
FOR PARTICIPANTS**

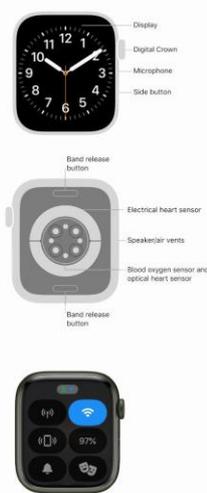
DESIGN STUDIES
IZMIR UNIVERSITY OF ECONOMICS GRADUATE SCHOOL

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- 04 [BLOOD OXYGEN LEVEL](#)
- 05 [ECG \(ELECTROCARDIOGRAMS\)](#)
- 06 [24 HOUR HEART RATE MONITORING](#)

*All information and images taken from apple watch user guide.

Apple Watch 9



- Display
- Digital Crown
- Microphone
- Side button
- Band release button
- Electrical heart sensor
- Speaker/air vents
- Blood oxygen sensor and optical heart sensor
- Band release button

01



Control Center gives you instant access to silent mode, Do Not Disturb, Wi-Fi, flashlight, and more—just like on iPhone. To open Control Center, press the side button.

01

General Information

Apple Watch Gestures

In addition to using the Digital Crown and side button, you can use these basic gestures to interact with Apple Watch.

- Tap: Touch one finger lightly on the screen.
- Swipe: Move one finger across the screen—up, down, left, or right.
- Drag: Move one finger across the screen without lifting.

Check Remaining Power

To see remaining power, press the side button to open Control Center.



View the percentage of remaining battery life.



- Turn on: If your Apple Watch is off, press the side button until the Apple logo appears (you might see a black screen for a short time first). The watch face appears when Apple Watch is on.

- Turn off: Normally, you'll leave your Apple Watch on all of the time, but if you need to turn it off, press and hold the side button until the sliders appear, tap at the top right, then slide the Power Off slider to the right. When your Apple Watch is turned off, you can press and hold the Digital Crown to see the time.

02

General Information

If you want to move your Apple Watch to your other wrist or prefer the Digital Crown on the other side, adjust your orientation settings so that raising your wrist wakes your Apple Watch, and turning the Digital Crown moves things in the direction you expect.

1. Open the Settings app on your Apple Watch.
2. Go to General > Orientation.



Connect Apple Watch to a Wi-Fi network

By connecting your Apple Watch to a Wi-Fi network, you can continue to use many of its features, even when you don't have your iPhone with you.

02

Choose a Wi-Fi network

1. Press the side button to open Control Center.
2. Touch and hold , then tap the name of an available Wi-Fi network. Wi-Fi networks compatible with Apple Watch are 802.11b/g/n 2.4GHz.
3. If the network requires a password, do one of the following:

- Use the keyboard on Apple Watch to enter the password (on supported models only, not available in all languages).
- Use your finger to scribble the password characters on the screen. Use the Digital Crown to choose uppercase or lowercase characters.
- Tap , then choose a password from the list.
- Use the keyboard on your iPhone to enter the password.

4. Tap Join

03

Apps on Apple Watch

How you open an app depends on which view you choose

Grid view: Tap the app icon. Turn the Digital Crown to see more apps.



List view: Turn the Digital Crown, then tap an app.



— Turn the Digital Crown to browse the apps.
— Tap to open an app.

03

To return to the Home Screen from an app, press the Digital Crown once, then press it again to switch to the watch face

04

Apps on Apple Watch

App icon	App name	For more information
	Activity	See Track daily activity with Apple Watch .
	Alarms	See Alarms .
	App Store	See Get apps from the App Store on Apple Watch .
	Audiobooks	See Add audiobooks .
	Blood Oxygen (not available in all regions; Apple Watch Series 6, Apple Watch Series 7, Apple Watch Series 8, and Apple Watch Series 9 only)	See Set up Blood Oxygen .
	Calculator	See Calculator .
	Calendar	See Calendar .
	Camera Remote	See Camera Remote .
	Compass (Apple Watch SE and Apple Watch Series 3 and later only)	See Compass .
	Contacts	See See contacts on your Apple Watch .
	Cycle Tracking	See Use Cycle Tracking .

03

04

Apps on Apple Watch

App icon	App name	For more information
	ECG	See ECG .
	Find Devices	See Find Devices .
	Find Items	See Locate an AirTag .
	Find People	See Find People .
	Heart Rate	See Heart Rate .
	Home	See Control your home .
	Mail	See Read mail and write and reply to mail .
	Maps	See Maps .
	Medications	See Medications .
	Memoji	See Memoji .
	Messages	See Read messages and send messages .
	Mindfulness	See Practice mindfulness .
	Music	See Add music .
	News (not available in all regions)	See News .
	Notes	See Notes .
	Now Playing	See Now Playing .
	Phone	See Use Phone and make phone calls .

03

05

Apps on Apple Watch

App icon	App name	For more information
	Photos	See View photos.
	Podcasts	See Add podcasts.
	Newsstand	See Newsstand.
	TV	See Control Apple TV.
	Settings	Look for this icon for references to relevant settings throughout the guide.
	Shortcuts	See Use shortcuts.
	Sleep	See Track your sleep.
	Stocks	See Stocks.
	Stopwatch	See Stopwatch.
	Timer	See Quickly set a timer.
	Tips	See View tips on Apple Watch.
	Voice Memos	See Voice Memos.
	Watch Tutorials (not available in all regions)	See Watch Tutorials.
	Wallet	See About Wallet and Apple Pay.
	Weather	See Weather.
	Workout	See What's new in Workout.
	World Clock	See World Clock.

03

06

Blood Oxygen Levels



The Blood Oxygen app periodically measures your blood oxygen level throughout the day if background measurements are turned on, but you can also take an on-demand measurement at any time.

1. Open the Blood Oxygen app on your Apple Watch.
2. Rest your arm on a table or in your lap, and make sure your wrist is flat, with the Apple Watch display facing up.
3. Tap Start, then hold your arm very still during the 15-second countdown.
4. At the end of the measurement, you receive the results. Tap Done.

04

07

ECG (Electrocardiograms)



1. Open the ECG app on your Apple Watch.
2. Rest your arm on a table or in your lap.
3. With the hand opposite your watch, hold your finger on the Digital Crown, then wait while Apple Watch records the ECG.

05

You don't need to press the Digital Crown during the session.

At the end of the recording, you receive a classification. You can then tap Add Symptoms and choose your symptoms. Tap Save to note any symptoms, then tap Done. To view your results on iPhone, open the Health app on iPhone, tap Browse at the bottom right, then tap Heart > Electrocardiograms (ECG).

Important: To ensure the best reading after swimming, showering, heavy perspiration, or washing your hands, clean and dry your Apple Watch. It may take one hour or more for your Apple Watch to completely dry. ECG is designed to function between 32° and 95° F (0° and 35° C).

08

24-Hour Heart Rate Monitoring



24-Hour heart rate monitoring

It can be check heart rate any time using the watch B. It can be also observe resting, walking, breathe, workout, and recovery rates throughout the day.

Apple Watch uses green LED lights to measure the heart rate during workouts and Breathesessions, and to calculate walking average and Heart Rate Variability (HRV).

06

09

APPENDIX D - Ethical Committee Approval

SAYI: B.30.2.İEÜ.0.05.05-020-339

22.01.2024

KONU : Etik Kurul Kararı hk.

Sayın Prof. Dr. Deniz Hasırcı ve İdil Bakır Küçükkaya,

“**Ofis Mekanlarında Biyofilik Unsur Olarak Günışığı**” başlıklı projenizin etik uygunluğu konusundaki başvurunuz sonuçlanmıştır.

Etik Kurulumuz 25.12.2023 tarihinde sizin başvurunuzun da içinde bulunduğu bir gündemle toplanmış ve Etik Kurul üyeleri projeleri incelemiştir.

Sonuçta 22.01.2024 tarihinde “**Ofis Mekanlarında Biyofilik Unsur Olarak Günışığı**” konulu projenizin etik açıdan uygun olduğuna oy birliğiyle karar verilmiştir.

Gereği için bilgilerinize sunarım.
Saygılarımla,

Prof. Dr. Murat Bengisu
Etik Kurul Başkan