ISSN 3034-2864 (online)

Complex System and Future Technologies in Neuroscience

Collection of abstracts

Саратовский национальный исследовательский государственный
университет имени Н. Г. Чернышевского

КОМПЛЕКСНЫЕ СИСТЕМЫ И БУДУЩИЕ ТЕХНОЛОГИИ В НЕЙРОНАУКЕ

Сборник тезисов докладов

Выпуск 1

Материалы международной летней школы «Комплексные системы и будущие технологии в нейронауке – CSFTN’24»

Санкт-Петербург, 29–30июня 2024 г.

Саратов
2024

Saratov State University

COMPLEX SYSTEM AND FUTURE TECHNOLOGIES IN NEUROSCIENCE

Collection of abstracts

Issue 1

Materials of the International Summer School on “Complex System and Future Technologies in Neuroscience – CSFTN’24”

St. Petersburg, June 29–30, 2024

Saratov
2024

УДК: [[612.82:577.25]+616.831-08](082)
ББК: 28.70+56.12:53.5я43
С73

С73 **Комплексные системы и будущие технологии в нейронауке** : сборник тезисов докладов / редакционная коллегия: О. В. Семячкина-Глушковская (ответственный редактор), В. Б. Дорохов, Э. И. Кайбелева (ответственный секретарь). – Саратов : Саратовский университет [издание], 2024. – Выпуск 1 : Материалы международной летней школы «Комплексные системы и будущие технологии в нейронауке – CSFTN'2024», Санкт-Петербург, 29–30 июня 2024 г. – 68 с. : ил. URL: https://sgu.ru/nauchnye-izdaniya-sgu/sborniki-i-prodolzhayuschiesya-izdaniya/complex-system-and-future/csftn-2024. – Режим доступа: Продолжающиеся издания СГУ на сайте www.sgu.ru.
ISSN 3034-2864 (Online). – Изображение. Текст : электронные.
DOI: https://doi.org/10.18500/CSFTN-24

В сборнике представлены тезисы докладов конференции CSFTN'24, посвященные будущим технологиям в нейробиологии для изучения мозга как сложной системы и разработки перспективных терапевтических стратегий лечения заболеваний головного мозга во время сна. В книге приведены тезисы приглашенных устных и стендовых докладов. Официальным языком конференции является английский.

Для студентов медицинских, биологических и биофизических специальностей, а также для ученых и врачей, работающих в области нейрофизиологии.

Сборник издан при поддержке Российского научного фонда (грант № 23-75-30001).

Сборник тезисов конференции CSFTN'24 доступен на веб-сайте конференции
https://lymphacomplex.com/publication

ISSN 3034-2864 (Online)

UDC: [[612.82:577.25]+616.831-08](082)
BBK: 28.70+56.12:53.5я43
C73

R e v i e w e r s :
Denis E. Bragin (Albuquerque, New Mexico),
https://orcid.org/0000-0003-4894-0061, SPIN: 3797-3471, AuthorID: 115893
Edik U. Rafailov (Birmingham, GB), https://orcid.org/0000-0002-4152-0120
Vladimir B. Dorokhov (Moscow, Russia),
https://orcid.org/0000-0003-3533-9496, SPIN: 6689-4538, AuthorID: 89361

C73 **Complex System and Future Technologies in Neuroscience** : collection of abstracts / editorial board: O. V. Semyachkina-Glushkovskaya (executive editor), V. B. Dorokhov, E. I. Kaybeleva (executive secretary). – Saratov: Saratov University [edition], 2024. – Issue 1: Materials of the International Summer School "Complex system and future technologies in neurobiology – CSFTN'24", St. Petersburg, June 29–30, 2024 – 64 p. : il. URL: https://sgu.ru/nauchnye-izdaniya-sgu/sborniki-i-prodolzhayuschiesya-izdaniya/complex-system-and-future/csftn-2024. – Access mode: Continuing publications of the SGU on the website www.sgu.ru.
ISSN 3034-2864 (Online). - Image. Text: electronic.
DOI: https://doi.org/10.18500/CSFTN-24

The collection presents abstracts from the CSFTN'24 conference, dedicated to future technologies in neurobiology for studying the brain as a complex system and developing promising therapeutic strategies for treating brain diseases during sleep. The book contains abstracts of invited oral and poster presentations. The official language of the conference is English.

The collection is intended for students of medical, biological and biophysical fields of training, as well as for scientists and doctors involved in the field of neurophysiology.

The collection was published with the support of the Russian Science Foundation (grant No. 23-75-30001).

CSFTN'24 conference collection of abstracts are on the conference website
https://lymphacomplex.com/publication

ISSN 3034-2864 (Online)

Contents

Adushkina V. V., Zlatogorskaya D. A., Ilyukov E. V., Myagkov D. A., Tuktarov D. V.
Photobiomodulation during sleep as a promising technology for activation of brain's tissue drainage **CSFTN-24-1**

IlyukovE. V., BlokhinaI. A., MyagkovD. A., TuktarovD. V., PopovS. V.,InozemtsevT. S., TerskovA. V., EvsyukovaA. S., AdushkinaV. V.,ZlatogosrkayaD. A.
Automatization of experimental scenario via wireless data transfer protocols **CSFTN-24-2**

Merkulova K. O., Litvinenko E. S., Postnov D. E.
Cortisol-mediated influence of meal on the sleep-wake cycle: The model study **CSFTN-24-3**

Fedosov I. V., Semyachkina-Glushkovskaya O. V.
Wavelength selection for Alzheimer disease treatment with LED based transcranial photobiomodulation **CSFTN-24-4**

Navolokin N. A., Kaibeleva E. I., Sarantseva E. I., Fadeev P. V.
3D atlas of the lymphatic system of the brain **CSFTN-24-5**

Guyo G. A., Pavlov A. N.
Effects of anesthesia in rat electrocorticograms **CSFTN-24-6**

Semiachkina-Glushkovskaia A. I., Zlatogorskaya D. A., Adushkina V. V.
An automated tracking system for analysis of mouse memory and locomotor activity **CSFTN-24-7**

Kurbako A. V., Ishbulatov Yu. M., Vahlaeva A. M., Prokhorov M. D., Gridnev V. I., Bezruchko B. P., Karavaev A. S.
Testing a method for detection of synchronization between the low-frequency oscillations in the cardiovascular signals on the model dataset **CSFTN-24-8**

Blokhina I. A., Ilyukov E. V., Dmitrenko A. V.
Photobiomodulation of lymphatic removal of toxins from the mouse brain during deep sleep **CSFTN-24-9**

Zlatogorskaya D. A., Adushkina V. V., Myagkov D. A., Tuktarov D. V., Ilyukov E. V.
Photobiomodulation of the brain during sleep to improve neurocognitive abilities of mice **CSFTN-24-10**

Evsyukova A. S., Terskov A. V., Blokhina I. A., Adushkina V. V., Zlatogorskaya D. A.
Night photostimulation of clearance of beta-amyloid from the brain of mice with Alzheimer's disease **CSFTN-24-11**

Popov S. V., Ilukov E. V.
System for photobiomodulation under EEG control **CSFTN-24-12**

Tsoy M. O., Borovkova E. I., Sidorov V. V., Semiachkina-Glushkovskaya O. V.
Non-invasive way to identify dynamics of blood microcirculation oscillations and oxidative metabolism in the peripheral link across sleep stages **CSFTN-24-13**

Merkulova K. O., Postnov D. E.
The mathematical model: Local sleep vs power naps **CSFTN-24-14**

Terskov A.V., Evsyukova A.S., Manzhaeva M.B., Shirokov A.A., Fedosov I. V.
Lymphatic clearance of red blood cells from human and mouse brain tissue following intraventricular hemorrhage **CSFTN-24-15**

Myagkov D. A., Tuktarov D. V., Zlatogorskaya D. A., Adushkina V. V.
New automated operant wall technology for measuring social motivation in mice **CSFTN-24-16**

Evsyukova A. S., Terskov A. V., Fedosov I. V., Shirokov A. A.
Non-invasive technology for increasing the permeability of the blood-brain barrier **CSFTN-24-17**

Blokhina I. A., Terskov A. V., Shirokov A. A.
Molecular mechanisms of phototherapy of glioblastoma in rats **CSFTN-24-18**

Lysenko A. A., Sarantseva E. I.
Phototherapy of intraventricular hemorrhages in mice **CSFTN-24-19**

Tuktarov D. V., Myagkov D. A.
Using a phenotyping system to identify Alzheimer's disease and the effectiveness of its treatment **CSFTN-24-20**

Shirokov A. A., Blokhina I. A., Terskov A. V., Evsyukova A. S., Fedosov I. V., Semiachkina-Glushkovskaya O. V.
Mechanisms of phototherapy for Alzheimer's disease during sleep and wakefulness: the role of meningeal lymphatics in removing beta-amyloid from the brain of 5xFAD male mice **CSFTN-24-21**

Tuzhilkin M. A., Blokhina I. A., Adushkina V. V., Zlatogorskaya D. A., Manzhaeva M. B., Krupnova V. V., Dmitrenko A. V., Terskov A.V., Evsyukova A.S.
Mechanisms of phototherapy for Alzheimer's disease in mice during sleep and wakefulness **CSFTN-24-22**

Dmitrenko A.V., Blokhina I.A.
Intranasal delivery of liposomes to the brain **CSFTN-24-23**

Dubrovsky A. I., Dmitrienko A. V., Fedosov I. V.
The study of fluorescent dye diffusion in murine brain tissue using confocal microscopy-based fluorescence recovery after photobleaching **CSFTN-24-24**

Myagkov D. A., Tuktarov D. V., Zlatogorskaya D. A., Adushkina V. V.
Technology of concussive brain injury in laboratory animals **CSFTN-24-25**

Terskov A.V., Shirokov A.A., Fedosov I.V.
Transcranial photosensitizer-free laser treatment of glioblastoma in rat brain **CSFTN-24-26**

Tuktarov D. V., Myagkov D. A.
Device for creating concussive brain injury in rodents **CSFTN-24-27**

Manzhaeva M. B., Blokhina I. A., Terskov A. V., Zlatogorskaya D. A., Adushkina V.V., Evsyukova A.S.
EEG markers activation of the lymphatic drainage system of the brain **CSFTN-24-28**

Shirokov A. A., Blokhina I. A., Terskov A. V., Evsyukova A. S., Navolokin N. A., Fedosov I. V., Semiachkina-Glushkovskaya O. V.
Different effects of phototherapy of rat glioma during sleep and awake **CSFTN-24-29**

Elizarova I. V., Navolokin N. A., Shirokov A. A., Fedosov I. V., Semiachkina-Glushkovskaya O. V.
Lymphatic structure in the human brain **CSFTN-24-30**

Krupnova V.V., Blokhina I.A., Dmitrenko A.V., Terskov A.V., Evsyukova A. S., Adushkina V. V., Zlatogorskaya D. A., Dubrovsky A. I., Tsoi M. O.
Activation of the brain's lymphatic drainage system during sleep in rats **CSFTN-24-31**

Manzhaeva M. B., Blokhina I. A., Terskov A. V., Dubrovsky A. I.
Photostimulation of neonatal and adult rodent brain lymphatic vessels for therapy of intraventricular hemorrhage **CSFTN-24-32**

Inozemtsev S. T., Dubrovsky A. I., Dmitrienko A. V., Fedosov I. V.
Mathematical modeling of diffusion in the lymphatic system of the brain **CSFTN-24-33**

Daniltseva V.N., Sarantseva E.I.
Technology of lymphatic delivery of liposomes to brain tissue and study of carrier accumulation in mouse glioma tissues **CSFTN-24-34**

Yakunina A.V., Iskra T.D.
Maturation of venous and lymphatic processes of cerebrospinal fluid removal from the mouse brain at different stages of ontogenesis **CSFTN-24-35**

ManyshevaZh. A., Navolokin N. A.
Technology for preserving brain function in conditions of sleep deficiency and aging **CSFTN-24-36**

Sonina C.
Photobiomodulation of brain waste removal system **CSFTN-24-37**

Lectures

Hramov A.
Functional brain networks for diagnosis of mental disorders: A perspective from complex network theory and machine learning **CSFTN-24-L1**

Tingting Yu
Tissue optical clearing for whole-organ imaging in neuroscience **CSFTN-24-L2**

Larin K. V.
Recent advances in optical coherence elastography **CSFTN-24-L3**

DiDuro J.
Therapeutic potential of photobiomodulation therapy for neurological and neuropsychiatric disorders: A glymphatic perspective **CSFTN-24-L4**

Pavlov A. N.
Studying electrocorticograms based on the concept of rhythms coordination **CSFTN-24-L5**

YakushevaT.
The role of the cerebellum in spatial navigation **CSFTN-24-L6**

Rafailov E. U.
Photonics technologies for biomedical applications: Imaging, diagnostics and treatments **CSFTN-24-L7**

SidorovV. V.
Changes in the regulation of cutaneous blood microcirculation during sequential changes in sleep phases (pilot study) **CSFTN-24-L8**

PoluektovM.
Objective sleep estimation by polysomnography - from speculations to clinical implication **CSFTN-24-L9**

Dorokhov V. B.
Neurotechnologies for the nonpharmacological treatment of sleep disorders **CSFTN-24-L10**

Postnov D. E.
Spatiotemporal sleep dynamics and neurogliavascular unit signaling:

Recent evidence calls for a new paradigm **CSFTN-24-L11**

Diduk S. V.
Therapeutic monoclonal antibodies for the treatment of neurodegenerative diseases. Modern approaches, challenges and prospects **CSFTN-24-L12**

Bragin D. E.
Photobiomodulation in the treatment of traumatic brain injury **CSFTN-24-L13**

Verbitsky E. V.
The role of synaptic homeostasis in the sleep-wake cycle **CSFTN-24-L14**

Semyachkina-Glushkovskaya O.V.
Technologies of the future in neuroscience **CSFTN-24-L15**

Rudych P.
The observer effect for MRI experiments **CSFTN-24-L16**

Madaeva I. I.
Pattern of “sleep spindles” in obstructive sleep apnea patients **CSFTN-24-L17**

Kalinkin A.
Sleep medicine of the future **CSFTN-24-L18**

Zaikin A.
Analysis of medical data with synolitic networks **CSFTN-24-L19**

Photobiomodulation during sleep as a promising technology for activation of brain's tissue drainage

Victoria Vyacheslavovna Adushkina✉, Daria Andreevna Zlatogorskaya, Egor Vladislavovich Ilyukov, Dmitry Andreevich Myagkov, Dmitry Viktorovich Tuktarov

Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
✉adushkina.info@mail.ru

Photobiomodulation (PBM) is a promising technology for therapy of brain diseases. PBM is based on the use of red or near-infrared light. PBM has been recognized as safe by the U.S. Food and Drug Administration. Traditionally, it was thought that the mechanisms of therapeutic effects of PBM are an increase in metabolism and microcirculation of brain tissue as well as reduction in oxidative stress and inflammation. Recently, it is assumed that PBM can also stimulate functions of brain's drainage, which is an important maintaining of brain homeostasis. Classically, PBM is used during wakefulness. However, it is known that brain's drainage is most active during deep sleep. It is obviously to hypothesize that PBM during deep sleep might have stronger effects on brain's drainage than PBM during wakefulness. Therefore, in this study, we compare the PBM effects on brain's drainage of adult male mice during sleep and wakefulness.

To study brain's drainage, fluorescein isothiocyanate-dextran FITC-dextran 70 kDa (FITCD, Sigma, St Louis, United States) was injected into the right later ventricle (AP - 1.0 mm; ML - 1.4 mm; DV - 3.5 mm). FITCD was injected at a rate of 0.1 μL/min using microinjector (Stoelting, St. Luis, USA) with a Hamilton syringe with a 29-G needle (Hamilton Bonaduz AG, Switzerland). The ex vivo confocal analysis of FITCD spreading in the whole brain performed using Nikon A1R MP microscope (Tokyo, Japan) and the two-channel cortical EEG system for the control of deep sleep or non-rapid eye moved sleep (NREM) as described in our previous study (Biomed Opt Express, 2024, 15(1), 44–58).

Our results found that NREM was associated with stronger diffusion of FITCD in both dorsal and ventral aspects of the brain as well as by its accumulation in the deep cervical lymph nodes compared with wakefulness. The PBM during sleep induced a greater increase in the FITCD distribution in the brain and its removal from the brain to the deep cervical lymph nodes than PBM during wakefulness. In sum, our findings revealed that PBM during sleep stimulates brain's drainage stronger than during wakefulness.

Key words: neurotechnology, medicine, photobiomodulation, lymphatic system, sleep.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 23-75-30001).

Automatization of experimental scenario via wireless data transfer protocols

Egor Vladislavovich Ilyukov✉, Inna Andreevna Blokhina, Dmitry Andreevich Myagkov, Dmitry Viktorovich Tuktarov, Sergey Valerievich Popov, Timofey Sergeevich Inozemtsev, Andrey Vitalievich Tereskov, Arina Sergeevna Evsyukova, Victoria Vyacheslavovna Adushkina, Daria Andreyevna Zlatogoskaya

Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
✉egor.re01@mail.ru

As experiments become more complex, it may be necessary to create custom devices to automate data collection or other experimental processes. The most popular solution for scientific custom devices at present is the UART interface. There are many libraries available for various programming languages and commercial modules to convert UART to USB, making it easy to use. However, when researchers face challenges in networking these devices, wired solutions become cumbersome and inconvenient. Additionally, there are experiments in which wired solutions cannot be used due to specific experimental protocols.

The idea of the Internet of Things (IoT) has become increasingly popular across a wide range of industries due to the rapid development of wireless interfaces. The Bluetooth Low Energy (BLE) interface stands out from other wireless interfaces due to its low power supply, support for multiple devices, and ease of use. Commercially available modules can create a Bluetooth-UART bridge without requiring specific knowledge of circuit engineering.

Researchers have the opportunity to network their lab environment, automate experimental scenarios, and collect data from any custom device via any device that can receive BLE. This allows for efficient data collection and analysis. This work presents an easy way to begin developing for BLE. Also, we propose a modular EEG platform featuring a Bluetooth low energy wireless interface, catering to both implantable and tethered applications while facilitating seamless task-specific modifications.

Keywords: programming, Bluetooth Low Energy interface, experimental data collection and analysis.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 22-15-00143).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-3

Cortisol-mediated influence of meal on the sleep-wake cycle: The model study

Ksenia Olegovna Merkulova✉, **Elena Sergeevna Litvinenko**, **Dmitry Engelevich Postnov**

Saratov State University, Department of Optics and Biophotonics, (Saratov, Russia)
✉merksenia@gmail.com

A human is constantly affected by a large number of external and internal factors in his daily life. All this directly or indirectly affects a person's internal rhythms. One of the most susceptible to influences is the rhythm of secretion of the hormone cortisol. In particular, it is affected by physical activity, psycho-emotional state, stress, meal, etc. In addition, cortisol has a clearly defined circadian rhythm. One interesting and actively researched phenomenon is that cortisol levels respond to every meal, accompanied by a release of insulin. Thus, meal appears to be important factor influencing ultradian rhythms of cortisol secretion. Cortisol, in turn, affects the switching between wakefulness and sleep. Thus, meal appears to be a factor influencing the characteristics of the sleep-wake cycle.

In this work, we develop a model-theoretical approach to studying the effect of cortisol on the synchrony between the circadian rhythm and the sleep-wake cycle. We previously published work showing that cortisol can cause desynchronization between them. In this case, the contribution of cortisol should exceed 15% of the total level of lateral neuronal activity. Adding fluctuations can further destabilize the situation, for example, lead to the appearance of "excess activity" - days with early awakening and late falling asleep.

Our current task is to study the connection between dynamic patterns of cortisol generation and meal. The results of the computational experiment, on the one hand, allow for a clear interpretation in terms of typical behavioral patterns, and on the other hand, they open up the prospect of using special diets for a targeted shift and stabilization of the sleep-wake cycle.

Key words: cortisol, meal, sleep-wake cycle, circadian rhythm, mathematical model.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 23-75-30001).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-4

Wavelength selection for Alzheimer disease treatment with LED based transcranial photobiomodulation

Ivan Vladlenovich Fedosov✉, **Oxana Valerievna Semyachkina-Glushkovskaya**

Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
✉fedosov_optics@mail.ru

Alzheimer's disease (AD) is an age related brain pathology that is accompanied by progressive memory loss. With the global ageing of population the number of people over 65 with AD is doubling every 5 years dramatically increasing the need for efficient AD treatment technologies. However currently proposed pharmacological therapies for AD have failed to show effectiveness and safety.

The alternative approach can be based on non pharmacological technologies like non-invasive transcranial photobiomodulation PBM. As it was recently discovered PBM is capable for effective stimulation of lymphatic removal of vastes and toxins, including AD related amiloid-β (Aβ). Furthermore, it was demonstrated that the efficiency of PBM based activation of brain lymphatics increases if the stimulation is performed during deep sleep of the patient. Thus the concept of night photobiomodulation during sleep has been proposed for AD treatment.

In contrast to conventional PBM techniques widely used for clinical and ambulatory physiotherapy the novel approach requires for compact lightweight and safe autonomous light emitting devices suitable for overnight placement on patients head while ensuring comfortable sleep. These devices could be controlled via wireless interface to be activated once deep sleep stage was detected with a smart bracelet or other sleep tracking wearable instrument. Among the numerous actual engineering problems related with design of these novel instruments the proper selection of the light source plays central role since it defines future cost and performance of the technology.

In this paper we discuss the optimal selection of wavelength for transcranial near infrared PBM of AD during deep sleep of the patient. We review researches and clinical studies to date and also present original results obtained with the use of 880 nm, 1050 nm and 1300 nm LEDs on animal models of AD. We also discussed the impact of pulsed mode of photostimulation vs continuous wave one on the effectiveness and safety of PBM of AD during sleep.

Key words: neurotechnology, medicine, photobiomodulation, Alzheimer's disease, LED, sleep.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 23-75-30001).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-5

3D atlas of the lymphatic system of the brain

Nikita Alexandrovich Navolokin[1,2]✉, Elmira Ismailovna Kaibeleva[3], Elena Ivanovna Sarantseva[4], Petr Vladimirovich Fadeev[5]

[1]Saratov State Medical University, Department of Pathological Anatomy (Saratov, Russia)
[2]Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
[3]Saratov State University, Department of Genetics (Saratov, Russia)
[4]Saratov State University, Department of Physiology of Humans and Animals (Saratov, Russia)
[5]Saratov State University, Department of Information Resources and Systems of the Volga Regional Center for New Information Technologies (Saratov, Russia)
✉ nik-navolokin@yandex.ru

The lymphatic system of the meninges was discovered few years ago. This discovery was a turning point in neuroscience, radically changing scientific concepts about drainage and immune processes in the central nervous system. Our Russian research group conducted pioneering research on the opening of lymphatic vessels directly in the brain tissues, and also laid the foundation for the development of digital and interactive technologies for the in vivo study of the functions of cerebral and meningeal lymphatic vessels. The opening of the lymphatic vessels in the brain puts an end to the dogma about the absence of the lymphatic network of the central nervous system, and also changes the emphasis in the dominant glymphatic theory today, which arose as a filling in the gap in knowledge about the lymphatic vessels of the brain and the mechanisms of excretion of metabolites from the central nervous system. The emergence of a new player in the arena of the immune and drainage mechanisms of the brain requires the development of a detailed description of the anatomy of the lymphatic vessels and their physiology. Here we present a 3D atlas of the lymphatic system of the brain and its membranes in humans and mice, including interactive technologies for demonstrating the functions of cerebral and meningeal lymphatic vessels (https://lymphasleep.com/atlas). The 3D atlas is the world's first systematized scientific resource on the lymphatic network in CNS, which be prepared using digital and interactive technologies for creation of multimedia objects, virtual reality, 3D computer graphics and machine learning.

Keywords: lymphatic system of the brain, 3D computer graphics, machine learning.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 23-75-30001)

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-6

Effects of anesthesia in rat electrocorticograms

German Alexandrovich Guyo, Alexey Nikolaevich Pavlov✉

Saratov State University, Institute of Physics, Physics of Open Systems Department
(Saratov, Russia)
✉pavlov.lesha@gmail.com

Using rat electrocorticograms (ECoG), we discuss how detrended fluctuation analysis (DFA) and its recently proposed extension characterize anesthesia effects in the electrical activity of the brain. Two groups of animals with injection and inhalation anesthesia are considered to reveal differences in ECoG depending on the type of anesthetic or the absence of differences, and also to demonstrate how the distribution of local fluctuations of signal profiles from the trend makes it possible to obtain additional information about the complex organization of ECoG signals. Based on this information, the analysis of physiological experiments can be performed more thoroughly than using only one diagnostic marker, such as the DFA scaling exponent. The practical importance of such thorough signal processing is the possibility of better control of the depth of anesthesia in long-term physiological experiments, when sensitive diagnostic markers become high relevance.

Keywords: electrocorticograms, detrended fluctuation analysis, anesthesia.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 24-22-00015).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-7

An automated tracking system for analysis of mouse memory and locomotor activity

Anastasiia Igorevna Semiachkina-Glushkovskaia✉, Daria Andreevna Zlatogorskaya, Viktoria Vyacheslavovna Adushkina

Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
✉ nastya.glushkovskaya04@mail.ru

Assessing animal behavior is an important task in the development of new technologies for treating brain diseases, including traumatic brain injury. One of the important conditions for effective data analysis is to bring the experimental conditions closer to natural ones, i.e. in a home cage and in the absence of an experimenter. For this purpose, video recordings are used for a certain time (sometimes throughout the entire day or even several days) during the animal's stay in the experiment. After completing the experiment, a large amount of data requires careful analysis, which requires the development of automated tracking systems that allow data to be assessed in a short time based on computer vision and learning methods.

In this study, we developed an automated tracking system for analyzing data obtained in the experiments on mice during tests: (1) Y-shaped maze, (2) open field and (3) 2-object novel object recognition using cv2, numpy, datetime. An automated tracking system was used for automatic assessment of the following parameters: in the open field test - distance moved and time spent in pre-defined zones; in the Y-shaped maze test - the number of arm entries and the number of triads in the percentage of alternation; in the 2-object novel object recognition – the time spent exploring each object and the discrimination index in percentage.

This new tracking system can be easily implemented in any laboratory for fast and effective automatic assessment of memory and locomotor activity as well as the impact of therapeutic interventions in large groups of rodents with various models of brain pathologies, including genetically modified animals.

Key words: automated tracking systems, brain injuries, Y-maze test, open field test, new object recognition test.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 24-45-00010).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-8

Testing a method for detection of synchronization between the low-frequency oscillations in the cardiovascular signals on the model dataset

Aleksandr Vasilievich Kurbako[1,2], Yurii Mikhailovich Ishbulatov [1,2,3]✉, Anna Mikhailovna Vahlaeva[1], Mikhail Dmitrievich Prokhorov[1,2], Vladimir Ivanovich Gridnev[1,3], Boris Petrovich Bezruchko [1,2], Anatoly Sergeevich Karavaev[1,2,3]

[1] Saratov State University, Institute of Physics (Saratov, Russia)
[2]Saratov Branch of Kotelnikov Institute of Radio Engineering and Electronics of Russian Academy of Sciences (Saratov, Russia)
[3]Saratov State Medical University, Institute of Cardiology (Saratov, Russia)
✉ishbulatov95@mail.ru

The autonomic control of circulation, attributed to the sympathetic and parasympathetic branches of the autonomic nervous systems, is important for maintaining homeostasis. Dysfunction of the autonomic control could lead to the development of various cardiovascular and other diseases, including myocardial infarction and arterial hypertension, therefore diagnostics of the autonomic control is important for prevention and therapy of cardiovascular diseases.

The ~0.1 Hz oscillations in the RR-intervalogram and photoplethysmogram are coupled and exhibit intervals of phase synchronization, which can last up to hundreds of seconds and alternate with the intervals of asynchronous behavior. Relative duration of the synchronous intervals is smaller in people with impaired autonomic control and is perspective for medical diagnostics and therapy of myocardial infarction and arterial hypertension.

We proposed mathematical models for the electrocardiogram and photoplethysmogram signals with functionality to preset the pattern of synchronization between the phases of the ~0.1 Hz oscillations. The simulated phase difference reproduce the statistical and spectral characteristics of the experimental data, including the alternating horizontal and sloped sections, corresponding to the intervals of synchronous and asynchronous behavior. The developed models were used to generate the testing dataset.

The previously proposed method for detection of phase synchronization between the abovementioned ~0.1 Hz oscillations was tested against the model dataset. The parameters of the method were refined to achieve better accuracy. The refined method reached the sensitivity of 0.69, specificity of 0.60, and AUC of 0.75. The performance improved, since the unmodified approach reached the sensitivity of 0.64, specificity of 0.63, and AUC of 0.71.

The results suggest that accuracy of the method is lower, than previously assumed, but we consider this estimation to be more credible, due to a more accurate simulation of the real data processing routine, including filtration of the broadband experimental signals and introduction of the phases using the Hilbert Transform.

Key words: cardiovascular system, medicine, mathematical modeling, phase coupling.

Acknowledgments: This work was supported by the Russian Science Foundation (project No. 23-12-00241).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-9

Photobiomodulation of lymphatic removal of toxins from the mouse brain during deep sleep

Inna Andreevna Blokhina✉, **Egor Vladislavovich Ilyukov,**
Alexander Vladimirovich Dmitrenko

Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
✉inna-474@yandex.ru

Meningeal lymphatic vessels (MLV) play an important role in brain's drainage and clearance of toxins from the central nervous system through the flow of brain fluids. The development of innovative technologies for stimulation of the MLV function is a promising direction in the progress of treatment of various brain diseases associated with MLV anomalies, including Alzheimer's and Parkinson's diseases, brain tumors, traumatic brain injuries and intracranial hemorrhages. Sleep is a natural state when brain's drainage is most active. Therefore, stimulation of brain's drainage and the MLV function during sleep may have the most pronounced therapeutic effect. However, such commercial technologies do not currently exist.

This study presents a novel, portable electroencephalography (EEG)-guided transcranial photobiomodulation (tPBM) technology for photoactivation of lymphatic clearance of soluble beta-amyloid from the brains of aged mice and compares the effectiveness of different optical light sources. This technology can be used in the natural conditions of a home cage without anesthesia and while maintaining the natural motor activity of mice. The technology opens up new prospects for the development of non-invasive and clinical methods for photo-correction of age-related changes in the functions of the MLVs and drainage processes of the brain for the effective cleansing of its tissues from metabolites and toxins.

Key words: meningeal lymphatic vessels; photobiomodulation; sleep; removal of toxins; amyloid-beta.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 23-75-30001).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-10

Photobiomodulation of the brain during sleep to improve neurocognitive abilities of mice

Darya Andreevna Zlatogorskaya✉, Victoria Vyacheslavovna Adushkina, Dmitry Andreevich Myagkov, Dmitry Viktorovich Tuktarov, Egor Vladislavovich Ilyukov

Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
✉eloveda@mail.ru

Photobiomodulation (PBM) is a promising technology for improving the functions of meningeal lymphatic vessels (MLVs). Recently, it was discovered that PBM effectively stimulates the functions of the MLVs, promoting the elimination of toxins and metabolites from brain tissue in rodents maintaining optimal synaptogenesis. Sleep is a natural factor for improving MLS function. During the deep sleep stage, the perivascular spaces increase, facilitating the movement of interstitial fluid and thereby increasing metabolic processes between brain tissue and blood. Recently, it was discovered that MLVs play an important role in the development of diseases associated with memory impairment, such as various types of dementia and Alzheimer's disease. Based on these data, this study tested the hypothesis that PBM can enhance cognitive performance in male mice, more effectively during sleep than during wakefulness.

To test this hypothesis, we studied the effects of a 10-day course of PBM on learning and memory in healthy male mice using a specially designed EEG-guided PBM system as described in our previous study (Biomed Opt Express, 2024, 15(1), 44–58).

The results of the study showed that PBM significantly increased the neurocognitive abilities of mice. Indeed, regardless of the use of FBM in sleep or wakefulness, performing a test for recognizing a new location of an object and developing a conditioned instrumental reflex according to I.P. Pavlova using the example of reinforcement after a combination of sounds preceding pressing a lever that gives reinforcement. However, a course of FBM during sleep allowed animals to perform these tests faster compared to individuals receiving FBM while awake.

Overall, the results indicate that PBM during sleep, compared to wakefulness, promotes a more effective improvement in memory and learning in mice, which may be due to the creation of more optimal conditions for synaptogenesis due to photo- stimulation of drainage of brain tissue, as we have shown previously.

Key words: photobiomodulation, meningeal lymphatic system, neurocognitive functions.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 23-75-30001).

Night photostimulation of clearance of beta-amyloid from the brain of mice with alzheimer's disease

Arina Sergeevna Evsyukova✉, Andrey Vitalievich Terskov, Inna Andreevna Blokhina, Victoria Vyacheslavovna Adushkina, Daria Andreevna Zlatogorskaya

[1]Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
✉arina-evsyukova@mail.ru

Alzheimer's disease (AD) is one cause of dementia associated with progressive associated with damages of neurons responsible for memory, language and thinking. With the increase in the aging population worldwide, AD has become a rapidly increasing public health concern. However, pharmacological therapies for AD have failed to show effectiveness and safety. Therefore, the search for non-pharmacological strategies for therapy of AD is an urgent problem in medicine. The meningeal lymphatic vessels (MLVs) plays an important role in resistance to the progression of AD. The development of methods for augmentation of functions of MLVs may contribute to progress in AD therapy. There is evidence that beta-amyloid (Aß) is excreted from brain tissues through the meningeal lymphatic vessels, which are activated during sleep. Photobiomodulation (PBM) is considered to be a non-pharmacological and safe approach for AD therapy. Based on these facts, we assume that PBM-stimulation of lymphatic removal of Aß during sleep may increase resistance to AD in mice.

The results showed a significant suppression of Aβ clearance from the brain into the deep cervical lymph nodes in mice with AD compared with healthy animals. A single dose of PBM significantly increased lymphatic clearance of Aβ, more pronounced during sleep compared to wakefulness. Mice with AD had impaired memory for recognizing new objects compared to healthy individuals, which significantly improved after a 7-day course of FBM. Moreover, the effects of FBM were more significant in individuals receiving phototherapy during sleep than during wakefulness.

Overall, the results revealed that a course of FBM during sleep compared to wakefulness has a more pronounced therapeutic effect in AD, providing better lymphatic clearance of Aβ from the brain, which is associated with effective memory recovery in mice with AD. These groundbreaking data shed light on the restorative mechanism of sleep and provide an important information platform for the development of innovative smart technologies for the treatment of AD during sleep.

Key words: neurotechnology, medicine, photostimulation, Alzheimer's disease.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 23-75-30001)

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-12

System for photobiomodulation under EEG control

Sergey Valeryevich Popov✉, **Egor Vladislavovich Ilukov**

Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
✉richardclarksp@icloud.com

The objective of this study was to develop a fully autonomous photobiomodulation (PBM) system for the mouse brain during deep sleep. This is due to the fact that PBM is a promising method for the treatment of brain diseases, in particular Alzheimer's disease. Recent discoveries have shown that PBM should be administered during deep sleep to enhance therapeutic effects. However, there are no commercial solutions for sleep PBM. Therefore, the goal was set to develop a technology for portable PBM under electroencephalographic (EEG) control of the delivery of photo-exposure to the deep sleep stage.

The PBM device consists of commercially available hardware modules. The EEG signal is recorded using an integrated circuit for digital measurement of biopotentials ADS1293 (Texas Instruments, USA). The ADS1293 chip is a single module that contains three independent channels for EEG recording. Each EEG channel contains an input low-noise instrumental amplifier with a programmable gain, a delta-sigma analog-to-digital converter with a capacity of 24 bits. The sampling frequency of the analog-to-digital converter is 2.4 kHz. Input range – 1mV. The channel bandwidth is 250 Hz. The integrated circuit for digital measurement of biopotentials is connected to the Atmega328 microcontroller via the SPI (Serial Peripheral Interface) interface. Attmega 328, in turn, connects to the ESP-01 WI-FI module. Information packets between the microcontroller and the WI-FI module are transmitted using the UART interface. The device's power subsystem consists of a Li-ion battery; step-up voltage stabilizer; step-down voltage stabilizer. The boost stabilizer converts 3.4 - 3.7V (depending on the battery charge) into 5V to power the microcontroller. The step-down stabilizer converts 3.4 - 3.7V to 3.3V to power the WI-FI module and the integrated circuit for digital measurement of biopotentials. The FBM uses an LED with a wavelength of 1050 nm and an output power of 50 mW in a 2853 SMD package. The LED driver was controlled using pulse width modulation of a microcontroller. The LED is connected to the device using a flexible two-wire cable 0.3 m long and mounted in a miniature 3D-printed frame with a pair of cylindrical magnets with a diameter of 3 mm and a height of 3 mm each.

Key words: photobiomodulation, electroencephalogram.

Acknowledgements: The research was supported by the Russian Science Foundation (project No. 23-75-30001).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-13

Non-invasive way to identify dynamics of blood microcirculation oscillations and oxidative metabolism in the peripheral link across sleep stages

Maria Olegovna Tsoy[1]✉, Ekaterina Igorevna Borovkova[1], Viktor Vasilievich Sidorov[2], Oxana Semyachkina-Glushkovskaya[1]

[1]Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
[2]Limited Liability Company Scientific and Production Enterprise "Lazma" (Moscow, Russia)
✉dethaos@bk.ru

The influence of higher nervous activity on the processes of the cardiovascular system is of considerable interest both for understanding the fundamental regularities of human body functioning and for developing methods of diagnostics and therapy of various pathologies. However, the complexity of the analyzed systems limits the research possibilities in this field, requiring the development of new research tools.

The work is aimed at studying the tone-forming mechanisms of regulation of microhemodynamics, as well as the state of oxidative metabolism, which determines the restoration of the basic functions of the body, with sequential changes in sleep phases. By combining the methods of polysomnography and laser Doppler flowmetry, a technique for non-invasive monitoring of the dynamics of parameters of the peripheral microvasculature during sleep was developed.

As part of the study, a time-frequency analysis of the microcirculation signal was carried out using an approach based on continuous wavelet transform with the selection of the optimal frequency-time resolution ratio. The non-stationary distribution of the average power of wavelet coefficients in the frequency ranges of the activity of sympathetic, sensory-peptidergic and myogenic regulation of vascular tone was revealed, which is hypothetically determined by the duration of sleep phases, transition processes between phases and the individual nature of regulatory mechanisms and requires additional research on an expanded sample.

A significant change in signal amplitude was detected at the fluorescence wavelength of reduced form of nicotinamide-adenine-dinucleotide (the coenzyme NADH). A decrease in the biomarker of oxidative metabolism was shown during the transition to the deep delta-wave sleep stage (NREM3) relative to the NREM2 phase.

The work was carried out as an important step towards identifying reliable bio-markers of human conditions during periods of sleep and wakefulness.

Key words: neurotechnology, cardiovascular system, wavelet analysis, medicine.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 22-15-00143).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-14

The mathematical model: Local sleep vs power naps

Ksenia Olegova Merkulova✉, **Dmitry Engelevich Postnov**

Saratov State University, Department of Optics and Biophotonics, (Saratov, Russia)
✉merksenia@gmail.com

In the usual understanding, sleep is a global phenomenon of the brain, characterized by a reduced response to the outside world and specific brain activity. However, more and more research suggests that our brain can sleep in parts - this is called local sleep. That is, during a general state of wakefulness, certain areas of the brain may exhibit sleep-like states. Cognitive and behavioral performance deteriorates with prolonged wakefulness that can be explained sleep-like states occur in some small brain networks. This is especially evident when the brain is loaded with a specific task. Interestingly, during subsequent night sleep (restorative sleep), it is in these areas of the brain that increased slow-wave activity is observed. Thus, during wakefulness, local sleep may occur in some likely overloaded areas of the brain.

On the other hand, there is such a unique phenomenon as power naps. This is a short sleep without a slow wave stage, which reduces drowsiness, restores alertness and improves a person's cognitive functions for some time. A number of studies demonstrate the benefits of short daytime sleep episodes lasting 5-15 minutes. In the modern world, the positive effect of napping is used by some large corporations around the world to organize the work of employees.

The important aspects of sleep described above are currently not yet sufficiently understood both in terms of the general sleep paradigm and in mathematical models of sleep-wake dynamics. In this paper, we propose a variant of a mathematical model in which the power naps is associated with the phenomenon of local sleep. This model is based on the interaction of functional neuro-glial-vascular units, taking into account the influence of various external and internal factors on them. We test the created model using two important special cases. The first demonstrates the overload of a small area of the brain responsible for the visual and auditory perception of information new to a person (drowsiness on a lecture), and in the second case, a general low level of exogenous stimuli is considered.

Key words: local sleep, power naps, psycho-sensory drive, mathematical model.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 22-15-00143).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-15

Lymphatic clearance of red blood cells from human and mouse brain tissue following intraventricular hemorrhage

Andrey Vitalievich Terskov[1]✉, Arina Sergeevna Evsyukova[1], Maria Bahodyrovna Manzhaeva[1], Alexander Alexandrovich Shirokov[1,2], Ivan Vladlenovich Fedosov[1]

[1]Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
[2]Institute of Biochemistry and Physiology of Plants and Microorganisms, Russian Academy of Sciences (Saratov, Russia)
✉terskow.andrey@gmail.com

Intraventricular hemorrhage is one of the most fatal forms of traumatic brain injury. However, therapy for this type of hemorrhage is limited and new strategies are needed to reduce hematoma proliferation. This study demonstrates that the meningeal lymphatic vessels (MLVs) serve as "tunnels" for the clearance of red blood cells from the ventricular system of the brain in male and adult rodents.

To confirm the important role of the MLS in the removal of red blood cells from the ventricles of the brain, the effectiveness of this process was studied under conditions of damage to the MLS. For this purpose, the photoablation method was used. This method involves the introduction of a photosensitizer, visudin, into the large cistern of the brain and its excitation with a laser with a wavelength of 689 nm. The photodynamic reaction leads to damage to the meningeal network.

The results found that MLVs transported red blood cells from the right lateral ventricle to the deep cervical lymph nodes. Using the membranes of the brain of people who died from intraventricular hemorrhage, red blood cells were found in MLVs. Our results in animals and humans convincingly indicate that MLVs play an important role in the evacuation of red blood cells from the brain during the development of intracranial hemorrhages.

Key words: intraventricular hemorrhage, meningeal lymphatic vessels, photoablation, photosensitizer.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 23-75-30001).

Complex system and future technologies in neuroscience – CSFTN'24
CSFTN-24-16

New automated operant wall technology for measuring social motivation in mice

Dmitry Andreevich Myagkov✉, Dmitry Viktorovich Tuktarov,
Daria Andreevna Zlatogorskaya, Victoria Vyacheslavovna Adushkina

Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
✉dmyagk0v@yandex.ru

In recent years, the need to study various neurodegenerative diseases, such as Alzheimer's disease, has led to the creation of mouse models for the study of mechanisms of these diseases, including social behavior. Due to this, the new techniques were created for analysis the relationship between the social behavior of mice and neurodegenerative diseases.

There are several established techniques that can be used to study social motivation in mice, but all have serious limitations in their ability to quantify the strength of motivated behavior. For example, some of the earliest behavioral assessments involve simply observing social interactions between two rodents that have never met. Several behaviors are often measured, including approaching, following, sniffing, and grooming, which can serve as indicators of social motivation. These studies were originally conducted in rats and later adapted for use in mice.

To overcome these limitations, an automated operant wall was developed to study the social behavior of mice in a natural cage environment. The device is designed to monitor the formation of conditioned instrumental reflexes during sequential learning of combinations of unconditioned and conditioned stimuli, as well as complex social behavior based on the transfer of experience between individuals. The technology allows simultaneous analysis of a large number of physiological parameters on an unlimited number of individuals, which significantly improves the quality of experimental data.

Keywords: Alzheimer's disease, neurodegenerative disease, mice.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 23-75-30001).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-17

Non-invasive technology for increasing the permeability of the blood-brain barrier

Arina Sergeevna Evsukova[1]✉, Andrey Vitalievich Terskov[1], Ivan Vladlenovich Fedosov[1], Alexander Alexandrovich Shirokov[1,2]

[1]Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
[2]Saratov Scientific Centre of the Russian Academy of Sciences (IBPPM RAS),
Institute of Biochemistry and Physiology of Plants and Microorganisms, (Saratov, Russia)
✉arina-evsyukova@mail.ru

Glioblastoma (GBM) is the most common tumor of the central nervous system (CNS). The first step in treating GBM in adults and children is surgical removal of the tumor tissue. However, in most cases, GBM recurs. There is no standard treatment for relapses. Typically, patients undergoing surgery receive chemotherapy, which is often combined with radiation. In neonates, radiation therapy can cause severe impairment of brain development, growth, and cognitive abilities due to direct ionization of DNA, causing not only DNA degradation in the nuclei of GBM cells, but also DNA mutations in healthy neuronal cells surrounding the GBM.

The blood-brain barrier (BBB) limits the delivery of the vast majority of anticancer drugs, which poses a challenge for pharmacological therapy of GBM, especially the treatment of satellite tumor regions that grow along healthy brain vessels with an intact BBB. Therefore, effective therapy for recurrent GBM depends on the development of a strategy to bypass the intact BBB at the GBM border to prevent tumor migration and progression.

This study found that infrared laser (1268 nm) induces the opening of the blood-brain barrier (OBBB) in the local cortex, which is accompanied by activation of the brain drainage system. These data indicate that OBBB stimulates interstitial fluid drainage, which is an important pathway for drug delivery to the brain. The OBBB-mediated increase in interstitial fluid movement may lead to the greater accumulation of liposomes in GBM tissues that we observed in mice treated with the 1268 nm laser compared to intact animals. In addition, the 1268 nm OBBB laser may be a new strategy for drug delivery to sites of GBM growth, preventing its recurence.

Key words: neurotechnology, medicine, photodynamic therapy, glioblastoma, blood-brain barrier.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 23-25-00296).

Complex system and future technologies in neuroscience –CSFTN'24

CSFTN-24-18

Molecular mechanisms of phototherapy of glioblastoma in rats

Inna Andreevna Blokhina✉, **Andrey Vitalievich Terskov,**
Alexander Alexandrovich Shirokov

Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
✉inna-474@yandex.ru

One of the most common oncological diseases is brain tumors, in particular glioblatoma (GBM). Despite the recent improvement of surgical treatment techniques, it has not been possible to improve the results of treatment of GBM, as evidenced by the fact that the life expectancy, for example, of patients with GBM remains on average at 8–12 months. The main challenge in the treatment of GBM is that it is characterized by a striking invasive phenotype, lack of clear boundaries of distribution, and the ability to continue to grow after surgical removal.

Thus, the problem of increasing the effectiveness of treatment for GBM is relevant at the moment. The search for new methods of treating this disease remains one of the main tasks of modern oncology.

Currently, photodynamic therapy has become a promising treatment method for GBM. This method involves the introduction of a photosensitizer (PS) followed by laser excitation. PS 5-ALA is used in medicine to treat GBM in patients; it has the ability to selectively accumulate in brain tumor cells and, when exposed to a laser with a wavelength of 635 nm, singlet oxygen is generated, which triggers mitochondrial apoptosis in cancer cells, which leads to the death of GBM.

However, the use of PS has a number of limitations; it cannot be administered to newborns and small children, as well as patients with allergic reactions and sensitive skin, since in addition to the tumor, PS can accumulate in other cells. In this regard, a new breakthrough photobiomodulation (PBM) technology with a wavelength of 1267 nm was developed, which promotes the generation of singlet oxygen without introducing PS into the body and effectively suppresses the growth of GBM in male rats.

This study investigated the molecular mechanisms of the therapeutic effects of FBM in GBM rats. The research results showed that a course of PBM for 4 weeks suppresses the process of autophagy in tumor cells, increases the activity of apoptosis by increasing the expression of Bax and fas, but not P53, as well as reducing proliferation by suppressing the expression of Ki57. Thus, it was found that FBM is able to enhance the protective processes of the brain, increasing its resistance to the progression of GBM due to the sustained suppression of its growth.

Key words: glioblastoma, photodynamic therapy, photosensitizers, laser therapy.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 23-75-00296).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-19

Phototherapy of intraventricular hemorrhages in mice

Anastasia Alexandrovna Lysenko, Elena Ivanovna Sarantseva✉

[1]Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
✉sophora68@mail.ru

Intraventricular hemorrhage (IVH) is one of the most dangerous forms of brain injury. Blood is toxic and therefore, the faster it is removed, the higher the chances of restoring normal brain functions. However, there are no current non-invasive methods to effectively remove blood from the brain. Therefore, the processes of blood excretion in mice with cerebral hemorrhages were studied using photostimulation in vivo and in vitro. Photobiomodulation (PBM) is the use of visible and near-infrared radiation to stimulate cellular processes of biochemical activity of mitochondrial components at non-thermal and low-level doses. Currently, PBM has gained significant credibility and is becoming one of the most common physical treatment methods. PBM may serve as a non-invasive neuroprotective strategy for the effective removal of toxins, including blood, since PBM has been shown to have stimulating effects on meningeal lymphatic vessels (MLVs), which play a key role in the clearance of metabolites through both the cerebrospinal fluid and interstitial fluid from the central nervous system into cervical lymph nodes.

This study examined the effects of PBM on the processes of lymphatic clearance of red blood cells from the brain tissue of mice with IVH. It was found that PBM significantly increases the number of red blood cells removed from the ventricular system into the peripheral lymphatic system. This is accompanied by faster recovery processes from the development of perivascular edema, which also helps to effectively reduce intracranial pressure and reduce the volume of the hematoma. A course of PBM for 10 days significantly improves the recovery of neurological parameters in mice compared to individuals not receiving phototherapy. These results indicate that PBM is a promising method for the treatment of IVH by stimulating the lymphatic processes of removing blood products from the brain that are toxic to its tissues.

Key words: intraventricular hemorrhages, photobiomodulation.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 23-75-00296).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-20

Using a phenotyping system to identify Alzheimer's disease and the effectiveness of its treatment

Dmitry Viktorovich Tuktarov✉, **Dmitry Andreevich Myagkov**

Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
✉ivanov.ivao@yandex.ru

Phenotyping is a procedure for the comprehensive assessment of the behavioral characteristics of laboratory animals, developed in order to standardize the collection and interpretation of behavioral data to identify disorders of the central nervous system in laboratory animals. The processes of memory and learning ability are closely related; it is believed that memory determines from 1/3 to 1/2 of a person's intelligence quotient (IQ), determining the amount of information that an individual can simultaneously operate with (Conway et al., 2003). There are several classifications of memory types. One of the most used and valid is the division of memory into two large groups: explicit (declarative, event memory) and implicit (procedural, action memory). These types of memory reflect anatomically different neural networks, mechanisms for encoding, storing, consolidating and reproducing information. Human declarative memory has parallels with the spatial memory of rodents (and this is what makes it possible to model it on animals). They have representation in the hippocampus and are associated with such a neutral process as long-term potentiation (Voikar, 2006). Alzheimer's disease, which affects people in old age, is associated with disorders of this type of memory.

We have developed a system for phenotyping small laboratory animals, which has a flexible real-time experimental setup, allowing scientists to conduct various studies related to the learning and memory of laboratory animals. With its help, you can evaluate the speed of learning and memory of the test subject, as well as the ability to adapt to new experimental conditions. Since impairment of these functions is one of the main effects of Alzheimer's disease, the data obtained can enable an automated phenotyping system to quickly and efficiently diagnose the severity of the disease and the effectiveness of treatment. The technology can also be used to conduct pharmacological and toxicological studies.

Keywords: behavior, phenotyping, laboratory animals, experimental models, Alzheimer's disease.

Acknowledgements: The research was supported by the Russian Science Foundation (project No. 23-75-30001).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-21

Mechanisms of phototherapy for Alzheimer's disease during sleep and wakefulness: The role of meningeal lymphatics in removing beta-amyloid from the brain of 5xFAD male mice

Alexander Shirokov[1,2], Inna Blokhina[2], Andrey Terskov[2], Arina Evsyukova[2], Ivan Fedosov[2], Oxana Semyachkina-Glushkovskaya[2]

[1]Institute of Biochemistry and Physiology of Plants and Microorganisms, Saratov Scientific Centre of the Russian Academy of Sciences (Saratov, Russia)
[2]Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
✉shirokov_a@ibppm.ru

The number of people with Alzheimer's disease (AD) is increasing worldwide. However, there is no effective pharmacological therapy for AD. Photobiomodulation (PBM), based on non-invasive transcranial infrared radiation, may be a promising technology for the treatment of AD. The mechanisms of therapeutic effects of PBM in AD remain poorly understood. This study shows an important role of meningeal lymphatic vessels (MLVs) in the clearance of beta-amyloid from the brain of adult 5xFAD male mice, which can be modulated by PBM. Indeed, PBM improves the MLV function after photodamage to the meningeal lymphatic network.

The results of an enzyme immunoassay for the determination of beta-amyloid 1-42 in lysates of 5xFAD mouse brain tissue demonstrate that the use of PBM during sleep compared to wakefulness has more significant effects on reducing the content of beta-amyloid in brain tissue and improving the neurocognitive status of 5xFAD mice with AD. The results obtained shed light on the mechanism of PBM and show the stimulating effect of PBM on lymphatic drainage of the brain, which promotes the removal of beta-amyloid from its tissues through the lymphatic route. PBM, as a non-invasive and safe approach, has high prospects for implementation in clinical practice for the treatment of brain diseases associated with lymphatic disorders, such as AD, Parkinson's disease, glioma, traumatic brain injury, and intracranial hemorrhage.

Keywords: Alzheimer's disease, photobiomodulation, brain lymphatics, sleep, mechanisms.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 23-75-30001).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-22

Mechanisms of phototherapy for Alzheimer's disease in mice during sleep and wakefulness

Matvey Alekseevich Tuzhilkin✉, Inna Andreevna Blokhina, Victoria Vyacheslavovna Adushkina, Daria Andreevna Zlatogorskaya, Mariya Bahodyrovna Manzhaeva, Valeria Vasilievna Krupnova, Alexander Vladimirovich Dmitrenko, Andrey Vitalievich Terskov, Arina Sergeevna Evsyukova

Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
✉TuzhilkinMA@yandex.ru

Although scientific data on the existence of meningeal lymphatic vessels (MLV) have been available for a long time, the scientific community has only recently taken them seriously. Studying the anatomy and physiology of MLV is one of the frontiers of modern neurobiology. Over the past eight years, there has been an unprecedented increase in the number of publications covering various aspects of this topic, which underscores its relevance and incredible research interest. Considering the key role of meningeal lymphatic pathways in lymphatic drainage and brain tissue cleansing from toxins and metabolites, one can confidently speak of the prospect of developing technologies to enhance the lymphatic drainage activity of MLV. For example, for the prevention and treatment of neurodegenerative diseases.

One of our studies aimed at developing an optical technology for the therapy of Alzheimer's disease in mice during deep sleep. Through numerous experiments on animal models, we found that photoablation to MLV in mice is accompanied by suppression of lymphatic drainage and brain lymphatic clearance functions, a course of photobiomodulation (PBM) for 7 days is an effective method for restoring these functions, with PBM applied during sleep demonstrating more pronounced therapeutic effects than during wakefulness. Our results unequivocally demonstrate that MLV are pathways for the removal of β-amyloid in mice and therapeutic targets for PBM. This indicates the effectiveness of non-invasive, physiotherapeutic methods of stimulating lymphatic flow, such as photobiomodulation, in the prevention and treatment of neurodegenerative diseases.

Key words: neurobiology, medicine, meningeal lymphatic vessels, photobiomodulation, photoablation, Alzheimer's disease.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 23-75-30001).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-23

Intranasal delivery of liposomes to the brain

Alexander Vladimirovich Dmitrenko✉, **Inna Andreevna Blokhina**

[1]Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
✉admitrenko2001@mail.ru

The increasing incidence of neurodegenerative diseases is a serious problem worldwide. The global statistics of Alzheimer's disease for 2024 was more than 50 million people, and by 2050 it is predicted to increase to 150 million people. The low effectiveness of pharmacological drugs in the fight against this disease, as well as the tendency to increase the incidence of neurodegenerative diseases, which requires the creation of a new, more effective system for delivering drugs to the brain.

This study presents a new method for intranasal delivery of liposomal drugs to the brain of mice. The method is based on photostimulation of the transport of drugs along the lymphatic pathways to targets in brain tissue. This method is non-invasive and reduces the overall toxic effect on the body. It is possible to develop sprays and ointments based on this method of delivering drugs to the brain.

Key words: liposomes, Alzheimer's disease, drug delivery.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 23-75-30001).

The study of fluorescent dye diffusion in murine brain tissue using confocal microscopy-based fluorescence recovery after photobleaching

Alexander Ilyich Dubrovskiy✉, Alexander Vladimirovich Dmitrenko, Ivan Fladlenovich Fedosov

Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
✉paskalkamal@mail.ru

Proper understanding of brain tissue characteristics and functions plays an important role in modern day biomedical and biophysical fields. Creating a mathematical model for interactions of liquids with brain intercellular space, blood vessel and lymphatic vessel networks can further the studies related to curing neuro-degenerative diseases, such as Alzheimer's disease, as well as other brain-related disorders.

This study describes a potential method for calculating brain tissue diffusion coefficient. We performed an imaging of fluorescein isothiocyanate-dextran fluorescence recovery after photobleaching utilizing a laser scanning confocal microscopy system. Implementing z-stack scanning alongside the imaging time-lapse partially offsets the micro-movements of the specimen during a potential *in vivo* experiment. The diffusion coefficient of the brain tissue can be calculated based on the changes in fluorescence intensity over time in a predetermined area of the sample.

Key words: fluorescent dye diffusion, fluorescent microscopy, photobleaching.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 23-75-30001).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-25

Technology of concussive brain injury in laboratory animals

Dmitry Andreevich Myagkov ✉, Dmitry Viktorovich Tuktarov, Daria Andreevna Zlatogorskaya, Victoria Vyacheslavovna Adushkina

Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
✉ dmyagk0v@yandex.ru

Traumatic brain injury (TBI) has the highest incidence of any common neurological disorder and represents a significant public health burden. TBI is increasingly being documented not only as an acute condition, but also as a chronic disease with long-term consequences, including an increased risk of late neurodegeneration. The use of mouse models for TBI has several advantages over other animal models, including low cost of rodents, ease of maintenance, and innovative technologies for creating genetically modified strains. TBI can be caused by direct trauma resulting in a concussion or contusion of the brain.

Contusion-controlled brain injury (CBBI) technology was originally developed to study TBI in ferrets, and its desirable properties (reproducibility, control of injury parameters) have led researchers to apply it on a larger scale. The original design uses a pneumatic piston, which causes TBI. However, a newer alternative uses a linear actuator that is more portable by using an electromagnetically driven piston, which is lighter in weight. Because of this, there is no need for a compressed gas cylinder. Although there are other models of TBI, such as weight drop and fluid percussion, CBBI is more precise, easier to control, and most importantly, produces traumatic brain injuries similar to those seen in humans. However, no model is currently capable of reproducing pathological changes identical to those observed in humans. This study introduces our new CBBI technology, which allows us to investigate the short- and long-term effects of TBI, such as neuronal death, memory impairment, and brain swelling, as well as potential treatments for traumatic brain injury.

Keywords: traumatic brain injury, mice, electromagnet, pneumatic, controlled brain injury.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 24-45-00010).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-26

Transcranial photosensitizer-free laser treatment of glioblastoma in rat brain

Andrey Vitalievich Terskov[1]✉, Alexander Alexandrovich Shirokov[1,2], Ivan Vladlenovich Fedosov[1]

[1]Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
[2]Institute of Biochemistry and Physiology of Plants and Microorganisms, Russian Academy of Sciences (Saratov, Russia)
✉terskow.andrey@gmail.com

Glioblastoma is the most lethal form of brain cancer with very limited treatment options and a poor prognosis. In this rat study, we have shown that glioblastoma (GBM) growth can be suppressed by photosensitizer-free laser therapy using a 1267 nm quantum dot laser diode. This wavelength, which is strongly absorbed by oxygen, is capable of converting triplet oxygen into singlet oxygen. Application of 1267 nm laser irradiation over a 4-week course with a total dose of 12.7 kJ/cm^2 reliably suppresses GBM growth and increases survival from 34 to 64%.

In this in vivo and ex vivo study in rats and on C6 glioma cells in in vitro experiments, we demonstrated that a course of non-invasive transcranial laser therapy without photosensitizer can significantly suppress GBM growth in the rat brain and positively affect survival through laser-induced oxidative stress, induction of cancer cell apoptosis, reduction of GBM cell proliferation and reduction of intracranial pressure by stimulating lymphatic drainage and cleansing functions.

Key words: glioblastoma, phototherapy, lymphatic system.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 23-75-00296).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-27

Device for creating concussive brain injury in rodents

Dmitry Viktorovich Tuktarov✉, **Dmitry Andreevich Myagkov**

Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
✉ivanov.ivao@yandex.ru

Traumatic brain and spinal cord injury (TBI/SCI) is a change or dysfunction of brain function, or brain pathology, that occurs as a result of external trauma. TBI/SCI are serious diseases due to its complexity and far-reaching consequences, including damage, necrosis, and axonal degeneration. Controlled concussion (CC) is a model of neurotrauma that uses an impact system to produce graded, reproducible damage to the subject's dural mater that mimics the physiological, histological, and behavioral aspects of closed TBI/SCI. This results in mild to severe forms of TBI/SCI similar to those seen in humans. The CC uses an electronic pneumatic piston. Our laboratory has developed a device based on an electromagnet. This allows you to more accurately set the impact force and delay time, and the device is much safer, easier to operate and maintain. It is a simple and accurate model for studying the effects and possible treatments of TBI/SCI. The CC device makes it possible to create TBI/SCI to study the mechanisms of development of acute and chronic post-traumatic periods, as well as to develop effective therapeutic strategies. This contusion TBI/SCI technology is useful for studies of neuronal death, cerebral edema, vascular injury, morphological changes in central nervous system tissue, and memory impairment.

Keywords: traumatic brain injury, spinal cord injury, controlled concussion.

Acknowledgements: The research was supported by the Russian Science Foundation (project No. 24-45-00010).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-28

EEG markers activation of the lymphatic drainage system of the brain

Maria Bahodyrovna Manzhaeva✉, Inna Andreevna Blokhina, Andrey Vitalievich Terskov, Daria Andreevna Zlatogorskaya, Victoria Vyacheslavovna Adushkina, Arina Sergeevna Evsyukova

[1]Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
✉mariamang1412@gmail.com

The lymphatic drainage of the brain (LDSB) is the removal of metabolites and toxins from its tissues. Disruption of LDSB function is an important sign of aging, brain oncology, Alzheimer's and Parkinson's diseases. The development of new strategies to diagnose LDSB damage may improve the prevention of age-related cerebral amyloid angiopathy, neurodegenerative and cerebrovascular diseases. There are two conditions, such as deep sleep and opening of the blood-brain barrier (OBBB), associated with LDSB activation. Electroencephalography (EEG) may be a promising candidate to measure LDSB during sleep and OBBB. Indeed, both deep sleep and OBBB are characterized by similar and distinct changes in brain electrical activity in the form of low frequency EEG dynamics. It is hypothesized that the low frequency EEG pattern may be a biomarker of LDSB activation. Slow cortical oscillations (delta waves) may contribute to the efficiency of fluid flow to the brain parenchyma and excretion of waste products from the brain. Decreased low sleep activity is one of the important diagnostic symptoms of altered cerebral clearance in neurodegenerative diseases due to accumulation of toxins in the brain.

The aim of this study is to investigate the activation of the lymphatic drainage system of the brain and to compare EEG indices in sleep and at an open blood-brain barrier in rats.

Studies were performed on male rats in which sleep was detected by EEG parameters, and real-time activation of LDSB during sleep and wakefulness was studied.

Using functional models of in vivo studies of LDSB activation, we compared EEG dynamics in sleep, OBBB, and wake groups using spectral analysis, coherence estimation. We used the coherence function to analyze the EEG dynamics in the three mentioned conditions. The coherence function was calculated between a pair of EEG leads for each animal.

Our studies on healthy rats show for the first time that sleep and OBBB are an important informative platform to efficiently extract EEG markers of LDSB activity. Using wavelets and power spectra analysis of EEG dynamics combined with a coherence function, we found that LDSB activation during OBBB and sleep is associated with similar changes in θ EEG activity.

Thus, sleep and OBBB, two unique conditions associated with LDSB activation, are characterized by similar changes in θ-activity of the EEG, whereas more pronounced LDSB activation during OBBB compared to sleep is accompanied by specific EEG pattern changes in the form of low-frequency EEG dynamics.

Key words: lymphatic drainage of the brain, blood-brain barrier, electroencephalography.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 23-75-30001).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-29

Different effects of phototherapy of rat glioma during sleep and awake

Alexander Alexandrovich Shirokov[1,2]✉, Inna Andreevna Blokhina[2], Andrey Vitalievich Terskov[2], Evsyukova Arina Sergeevna[2], Nikita Aleksandrovich Navolokin[3], Ivan Vladlenovich Fedosov[2], Oxana Valerievna Semyachkina-Glushkovskaya[2]

[1]Institute of Biochemistry and Physiology of Plants and Microorganisms, Saratov Scientific Centre of the Russian Academy of Sciences (Saratov, Russia)
[2]Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
[3]Saratov State Medical University, Department of Pathological Anatomy (Saratov, Russia)
✉shirokov_a@ibppm.ru

There is a connection between sleep quality and the severity of glioma development. The important role of sleep in these processes may be due to the suppression of cerebral drainage (CD), the activity of which depends on deep sleep. There is evidence that photobiomodulation (PBM) is an effective technology for both stimulation of CD and adjunctive therapy of glioma. Recently, it was discovered that PBM stimulates CD more strongly during deep sleep than during wakefulness. In this study on male Wistar rats, it was shown that a course of PBM during deep sleep, compared to the wake group, more effectively suppressed glioma growth and increased survival compared to controls. The study of the mechanisms of this phenomenon revealed a more pronounced effect of a course of PBM in sleeping rats compared to awake ones on the stimulation of the CD and on the immune response against glioma, including an increase in the number of CD8+ in tumor cells, activation of apoptosis and suppression of proliferation of glioma cells. New sleep phototherapy technology opens a new strategy for improving the quality of care for patients with brain cancer using promising "smart sleep" and non-invasive approaches to treat glioma.

Keywords: glioma, photobiomodulation, brain's drainage, CD8+ cells, immune response.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 23-25-00296).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-30

Lymphatic structure in the human brain

Inna Vladimirovna Elizarova[1] ✉, Nikita Aleksandrovich Navolokin[1,2], Alexander Aleksandrovich Shirokov[1,3], Ivan Vladlenovich Fedosov[1], Oxana Valerievna Semyachkina-Glushkovskaya[1]

[1]Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
[2]Saratov State Medical University, Department of Pathological Anatomy (Saratov, Russia)
[3]Institute of Biochemistry and Physiology of Plants and Microorganisms, Saratov Scientific Centre of the RAS, Saratov, Russia
✉inna.elizarowa7@yandex.ru

The lymphatic system performs the important function of tissue drainage, transporting metabolites, unnecessary compounds and toxins that need to be eliminated from the body, as well as immune cells. In the central nervous system, drainage processes proceed as intensively as in peripheral tissues. The brain actively exchanges nutritional compounds with the blood and secretes unnecessary metabolites using drainage pathways that are closely connected to the peripheral lymphatic system. However, lymphatic vessels have not yet been discovered in the tissues of the brain and spinal cord.

The discovery of the meningeal lymphatic system is a great event in neuroscience. They were discovered in the 17th century by the Italian anatomist Paulo Mascagni. New knowledge about the lymphatic system was a real breakthrough in science and the master's works became a striking masterpiece of anatomy. However, after Mascagni, no one was able to repeat his research and therefore a dogma developed among scientists that there is no lymphatic system in the brain. Only in 2015, using modern technologies for imaging rodent and human brain tissue, as well as markers of the lymphatic endothelium, Mascagni's discovery was confirmed. However, this rediscovery did not allow progress in the search for lymphatic vessels in the brain, since the membranes do not belong to its tissues. Therefore, the scientific community did not recognize the "forgotten" meningeal lymphatics as a new discovery.

In laboratory «Smart Sleep», the existence of lymphatic structures expressing LYVE-1 and PROX-1, which are markers of the lymphatic endothelium, was established. Lymphatic cells, such as macrophages expressing CD68, were found within lymphatic structures. These structures are located in the perivascular spaces of the human brain. The successful solution of this problem radically changes scientific ideas about the mechanisms of drainage and cleansing of brain tissue, which is also a springboard for the development of breakthrough technologies for managing the restorative properties of the brain. This is an important information platform both for fundamentally new fundamental knowledge about the lymphatic system of the meninges, and for the development of innovative technologies for neurorehabilitation based on the management of lymphatic drainage processes of removing toxins and unnecessary molecules from the central nervous system.

Key words: lymphatic structures, human brain.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 23-75-30001).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-31

Activation of the brain's lymphatic drainage system during sleep in rats

Valeria Vasilievna Krupnova✉, Inna Andreevna Blokhina, Alexander Vladimirovich Dmitrenko, Andrey Vitalievich Terskov, Arina Sergeevna Evsyukova, Victoria Vyacheslavovna Adushkina, Daria Andreevna Zlatogorskaya, Alexander Ilyich Dubrovsky, Maria Olegovna Tsoi

Saratov State University, Scientific Medical Center, laboratory "Smart Sleep", (Saratov, Russia)
✉krupnova_0110@mail.ru

The lymphatic drainage system of the brain (LDSBM) performs the important function of removing metabolites and toxins from its tissues, ensuring homeostasis in the central nervous system. Dysfunction of the LDSHM underlies the development of a large number of diseases, such as Alzheimer's disease, brain tumors, and intracranial hemorrhages. However, despite the important role of LDSGM, little is known about the nature and mechanisms of LDSGM. It is believed that sleep is the natural state in which the LDSHM is activated. The purpose of this study was to study the activation of LDSGM by optical visualization of tracer movement in brain tissue in rats.

The studies were carried out on male rats, in which the activation of LDSGM during sleep was studied in real time using confocal monitoring of the diffusion of the tracer - fluorescein isothiocyanate (FITC)-dextran 70 kDa (FITCD) in brain tissue. Sleep stages were detected using electroencephalographic (EEG) recordings.

The results revealed that active diffusion of FITCD in brain tissue is observed with the appearance of a delta rhythm in the EEG pattern, which indicates activation of LDSGM in a state of deep sleep. During wakefulness, as well as in a state of drowsiness, the spread of the dye throughout the brain tissue is minimal. Activation of LDSGM is accompanied by the release of FITCD from brain tissue into the deep cervical lymph nodes, which was also most pronounced in the state of deep sleep compared to wakefulness.

Thus, the research results indicate activation of LDSGM in a state of deep sleep, which can be studied using in vivo confocal microscopy. The results obtained are an important informative platform for further study of the mechanisms of activation of the LDSGM during sleep and the development of methods for diagnosing the functions of the LDSGM, as well as their disorders in order to predict brain diseases associated with pathological changes in the LDSGM.

Key words: lymphatic drainage system of the brain, sleep, electroencephalography.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 23-75-30001).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-32

Photostimulation of neonatal and adult rodent brain lymphatic vessels for therapy of intraventricular hemorrhage

Maria Bahodyrovna Manzhaeva✉, Inna Andreevna Blokhina, Andrey Vitalievich Terskov, Alexander Ilyich Dubrovsky

Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
✉mariamang1412@gmail.com

Intraventricular hemorrhage (IVH) is one of the most common types of traumatic brain injury in premature infants born before the 30th week of gestation. IVH leads to irreversible dysfunction of the child's brain. However, despite the serious problem of IVH, there is no effective treatment. Recent discoveries have found that photobiomodulation (PBM) stimulates clearance of blood from rodent brain through the meningeal lymphatic vessels (MLVs). This fact opens up great prospects for the use of PBM as a promising technology for the treatment of neonatal IVH. The purpose of this study was to develop PBM technology to effectively remove blood from the brain of newborn male rats. For PBM, a laser with a wavelength of 1267 nm (dose 4 J/cm^2) was used.

The research results revealed that red blood cells are transported through MLVs from the right lateral ventricle to the deep cervical lymph nodes. In this case, damage to MLVs significantly reduces the lymphatic clearance of erythrocytes, which indicates that MLVs are an important route for the evacuation of erythrocytes from the brain. A seven-day course of PBM contributed to a more rapid reduction of hematoma in the ventricle, a decrease in perivascular edema, and restoration of BBB permeability, which was accompanied by better recovery of neurocognitive functions and increased survival of newborn rats compared to individuals with IVH and without PBM.

Thus, the results of the study showed that PBM is an effective method of stimulating the functions of the MLS for the removal of red blood cells from the brain of newborn rats, which has pronounced therapeutic effects in them, contributing to increased survival and rapid recovery after IVH. These results may be clinically significant for the treatment of cerebral hemorrhages in premature newborns who are at high risk of IVH and in whom PBM can be used through the fontanel.Thus, the results of the study have shown that PS is an effective method of stimulation of the MLV functions on erythrocyte excretion from the brain of newborn rats, which has a pronounced therapeutic effect on them, contributing to increased survival and rapid recovery after IVH. These results may be clinically relevant for the therapy of cerebral hemorrhage in premature neonates, who are at high risk of cerebral hemorrhage and in whom PS through the fontanel can be used.

Key words: intraventricular hemorrhage, meningeal lymphatic vessels, photostimulation.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 24-45-00010).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-33

Mathematical modeling of diffusion in the lymphatic system of the brain

Timofey Sergeevich Inozemtsev✉, Alexander Ilyich Dubrovsky, Alexander Vladimirovich Dmitrienko, Ivan Vladlenovich Fedosov

Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
✉inoztim@gmail.com

Research in the field of neurobiology is by far the most promising in medicine. First of all, of greatest interest is the lymphatic system of the brain, which performs an important function in removing toxins. An important factor in the study of the lymphatic system of the brain is the diffusion of fluids flowing through them. A distinctive difficulty in research is the structure of the lymphatic system, and as a result, the difficulty in understanding the transport of substances through it. The structure of the lymphatic vessels is significantly different from the structure of the circulatory system. The diameter of lymphatic capillaries is several times greater than the diameter of blood capillaries. When lymphatic capillaries merge, lymphatic vessels are formed, which are characterized by the presence of valves that ensure lymph flow in one direction. At the locations of the valves, narrowings are formed, and therefore the vessels have a distinct shape. Lymphatic vessels form wide-loop plexuses in the walls of organs. The movement of lymph is an active process. The propulsive driving force in the lymphatic system is created by the so-called internal and external factors, designated by the term "lymphatic pump." For a more complete understanding of the process of diffusion through the lymphatic system in the brain, a mathematical model of the diffusion of brain fluids (intrestial and spinal cord), as well as the ability to predict behavior, can help systems.

In this study, a mathematical model of fluid diffusion in the lymphatic system of the mouse brain was developed based on COMSOL Multiphysics. This software allows you to solve partial differential equations using the finite element method, which allows you to take into account many variables when calculating a mathematical model. COMSOL also works great with graphics and visualization, so you can visually track changes. The most interesting thing from the point of view of mathematical modeling is taking into account the heating of biological tissue by a laser (in the case of studying the lymphatic system of the brain - the membrane of the brain) during confocal microscopy, which makes it possible to more accurately determine the data needed for the study.

Keywords: diffusion, mathematical model, software model, visualization, COMSOL.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 23-75-30001).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-34

Technology of lymphatic delivery of liposomes to brain tissue and study of carrier accumulation in mouse glioma tissues

Victoria Nikolaevna Daniltseva ✉, **Elena Ivanovna Sarantseva**

Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
✉daniltseva.v22@bk.ru

The lymphatic system of the brain plays an important role in maintaining brain homeostasis. Dysfunction of the lymphatic system is an important mechanism in the development of a number of diseases, such as Alzheimer's disease, Parkinson's disease, tumors and brain injury. The development of technologies to improve the functions of the lymphatic system of the brain is a priority direction in medicine. However, there are no commercially accepted methods for stimulating brain tissue drainage and lymphatic elimination of toxins.

In this work, a method has been developed for activating lymphatic drainage processes in the brain through combined photoexposure and needle stimulation of the GB20 acupuncture zones in mice. The technical problem of the invention is solved by the fact that the method of stimulating the lymphatic drainage function of the mouse brain, according to the solution, is carried out through needle exposure in acupuncture zones GB20 once on the right and left sides at the depth of the occipital lymph nodes of the mouse (200 μm) for 10 minutes and subsequent photoexposure for a length of waves of 1267 nm of this acupuncture zone for 10 minutes, which stimulates the lymphatic function of the brain and is accompanied by the cleansing of its tissues from unnecessary compounds.

The development of methods for stimulating the lymphatic system of the brain is a priority in modern medicine, which will create new brands for medical technologies of the future and increase the competitiveness of Russian business in the international arena, as well as the quality of medical services for patients in need of neurorehabilitation with neurodegenerative diseases and brain injuries. Since the proposed method is safe, easy to implement, cost-effective, does not require pharmacological intervention, and has a history of use in medicine, it can be quickly introduced into clinical practice as a technology for stimulating the removal of toxins, blood, and other unnecessary compounds from brain tissue.

Key words: acupuncture, phototherapy, lymphatic system of the brain.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 23-75-30001).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-35

Maturation of venous and lymphatic processes of cerebrospinal fluid removal from the mouse brain at different stages of ontogenesis

Arina Vadimovna Yakunina ✉, **Tatiana Dmitrievna Iskra**

Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
✉arinaakunina683@gmail.com

This study addressed the problem of studying age-related changes in the drainage of brain tissue, which is important in the effective removal of toxins from the central nervous system. The problem was solved by monitoring the diffusion of the FITC-dextran dye (1% solution, Sigma Aldrich) through the brain tissues of young (1 month, n=10) and old (16 months, n=10) mice in real time using multiphoton microscopy and subsequent qualitative and quantitative analysis of dye accumulation in deep cervical lymph nodes using confocal microscopy.

The research results revealed that the introduction of the dye into the brain parenchyma is accompanied by its distribution throughout the perivascular spaces of the brain with subsequent excretion and accumulation in the deep cervical lymph nodes of mice of both ages. However, the intensity of distribution of the dye throughout the brain tissue during 4 hours of observation and its lymphatic excretion into the deep cervical lymph nodes was more effective in young animals compared to old animals. The deep cervical lymph nodes are the first anatomical station, collecting together with brain fluids the compounds removed from it. The more intensely the studied dye accumulates in the deep cervical lymph nodes, the more efficiently the drainage system of the brain works. Based on the results obtained, it was concluded that in old animals the lymphatic drainage function decreases compared to young mice.

Key words: drainage of brain tissue, age-related changes.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 23-75-30001).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-36

Technology for preserving brain function in conditions of sleep deficiency and aging

Zhanna Aramaisovna Manysheva[1]✉, Nikita Aleksandrovich Navolokin[2]

[1]Saratov State University, Scientific Medical Center, laboratory "Smart Sleep" (Saratov, Russia)
[2]Saratov State Medical University, Department of Pathological Anatomy (Saratov, Russia)

✉manischewa@mail.ru

Research is devoted to the development of technology for photobiomodulation of the removal of metabolites and toxins from the brain tissue of healthy people experiencing sleep deficiency due to intense work or associated with jet lag during long flights, as well as in elderly people with age-related changes in sleep structure. This study discusses the development of a portable head unit (5 x 8 cm) for non-invasive transcranial photobiomodulation in the form of a flexible and soft plate with LEDs in the infrared range, which can be installed in a comfortable design (bandanas, hats, scarves, nets, etc.) and is intended for individual use to stimulate the lymphatic removal of metabolites and toxins from human brain tissue. Photo-effects on the drainage system of the brain will be controlled using developed software via Bluetooth via a fitness bracelet.

Key words: photobiomodulation, metabolites, sleep deficiency, brain tissue drainage, age-related changes.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 23-75-30001).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-37

Photobiomodulation of brain waste removal system

Constance Sonina✉

Boarding -Lyceum 64 (Saratov, Russia)

✉wellimconstance@gmail.com

Meningeal lymphatic vessels (MLV) are an important part of the brain waste removal system (BWRS). Decreased MLV function is associated with various brain diseases, including Alzheimer's and Parkinson's diseases, brain tumors and injuries. Activation of BWRS can become an innovative and promising strategy for neurorehabilitation medicine.

At this stage of the development of ideas about the functioning of MLV, it is indicated that transcranial photobiomodulation (PBM) of MLV may be a new non-drug activation technology for BWRS. In our groundbreaking study, we found that the use of PBM during sleep stimulates the excretion of Aß from the mouse brain more effectively than PBM used during wakefulness.

PBM causes dilation of meningial and mesenteric lymphatic vessels. PBM-induced dilation of lymphatic vessels(LV) is associated with an increase in the permeability of the lymphatic endothelium and a decrease in the expression of tight junction proteins (TJ). TJ proteins are the main components of the lymphatic endothelium and play a crucial role in regulating the movement of lymph in the lymphatic network. Changes in the permeability of the lymphatic endothelium allow metabolites and immune cells to be transported with lymph into LV. It has been established that the transport of antigens, immune and dendritic cells through LV is associated with the flow of water and depends on the permeability of LV. These effects of PBM may be related to PBM-induced nitric oxide (NO) production in the lymphatic endothelium. NO dilates blood and lymphatic vessels by activating soluble guanylate cyclase and protein kinase G, which stimulates the opening of calcium (Ca2+)-activated potassium channels. A decrease in intracellular Ca2+ levels blocks phosphorylation of myosin light chain kinase, leading to vascular relaxation. Recent studies show that PBM increases the contractility of lymph and that PBM stimulates the synthesis of NO in isolated cells of the lymphatic endothelium. The contractility of lymph is important for the movement of cells and molecules in LV and is regulated by NO. These facts suggest that PBM-induced lymph contractility may be a possible mechanism responsible for a PBM-mediated increase in the excretion of metabolites from the brain, therefore, the use of PBM based on light-emitting diodes (LED) may become one of the most promising therapeutic noninvasive technologies for cleansing the brain of toxins.

Key words: meningeal lymphatic vessels, brain waste removal system, photobiomodulation.

Acknowledgments: The research was supported by the Russian Science Foundation (project No. 23-75-30001).

Functional brain networks for diagnosis of mental disorders: A perspective from complex network theory and machine learning

Hramov Alexander✉
Baltic Center for Neurotechnology and Artificial Intelligence, Immanuel Kant Baltic Federal University (Kaliningrad, Russia)
✉aekhramov@kantiana.ru

Abstract: The lecture will focus on the diagnosis of neural diseases using functional brain networks reconstructed from fMRI and EEG data. To analyze functional networks, mathematical approaches based on the calculation of various metrics of network topology organization, as well as machine learning methods - LDA, graph neural networks and contrastive learning - are considered. The results of classification accuracy of patients with MDD and children with ASD using the above approaches are presented.

Speaker: Alexander E. Hramov was born on September 20, 1974, in Saratov, Russia. He received the specialist degree in Electronic Engineering from Saratov State University, Russia in 1996, and the Ph.D. degree in Electronic Engineering from Saratov State University, Russia in 1999. In 2005, he defended his doctoral dissertation in Mathematics and Physics.

From 1999 to 2014, he held positions as a Researcher, Associate Professor, and Full Professor at Saratov State University, Russia. From 2014 to 2018, he served as a Leading Researcher in the Science and Educational Center of Artificial Intelligence Systems and Neurotechnology and as the Head of the Department of Automation, Control, and Mechatronics at Saratov State Technical University, Russia.

From 2019 to 2021, he was a Professor and Head of the Laboratory of Neuroscience and Cognitive Technology at Innopolis University, Kazan, Russia. Currently, he holds the position of Head of the Baltic Center for Neurotechnology and Artificial Intelligence at Immanuel Kant Baltic Federal University, Kaliningrad, Russia.

His research interests include complex network theory, methods of brain diagnostics, development of AI methods for neuroimaging data processing, and applied research in digital medicine, neurotechnologies and education.

Tissue optical clearing for whole-organ imaging in neuroscience

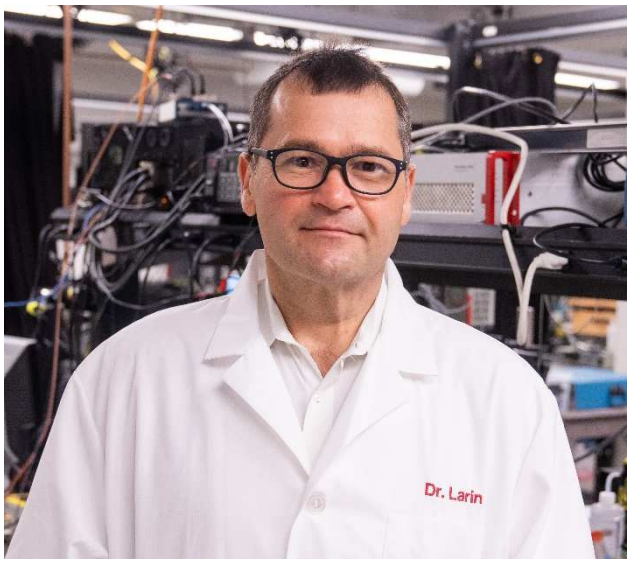
Tingting Yu✉
Britton Chance Center for Biomedical Photonics, Wuhan National Laboratory for Optoelectronics, Huazhong University of Science and Technology (HUST, Wuhan, China)
✉yutingting@hust.edu.cn

Abstract: Acquiring the three-dimensional (3D) structure of biological tissues is essential for research in life sciences. Modern optical imaging techniques and fluorescent labeling technologies have provided vital tools for obtaining high-resolution information on the 3D structures of biological tissues. However, the turbid nature of biological tissues limits the depth of light penetration, leading to restricted applications for large tissues or whole organs. Tissue optical clearing technology takes a different approach by making the tissues transparent using various physical and chemical strategies to reduce the attenuation of light in tissues, and providing a new approach for the 3D imaging of whole tissue organs. Here, we will introduce our progress in the research of ex vivo tissue optical clearing methods and applications, covering the fluorescence labeling, tissue clearing, and imaging of whole organs.

Speaker: Tingting Yu is an Associate Researcher at the Wuhan National Laboratory for Optoelectronics, Huazhong University of Science and Technology. She is mainly engaged in research on tissue optical clearing methods and applications, focusing on the development of optical imaging techniques based on tissue clearing for obtaining and reconstructing three-dimensional structure information of the central nervous system, peripheral nervous system, and other biological tissues. She has published over 30 SCI papers in journals such as Science Advances, Nature Communications, and Theranostics, and has contributed to the compilation of four Chinese and English monographs, with five authorized patents. She has led projects including the General Project, Young Scientists Fund from NSFC, International Cooperation and Exchanges Projects from NSFC, and Hubei Province's Key R&D Program, as well as participating in Key R&D projects of the Ministry of Science and Technology and the Key International Cooperation Research Projects of NSFC. She is a Young Committee Member of the Biomedical Optics Division of the Chinese Society of Biomedical Engineering and a Young Committee Member of the Biomedical Optics Professional Committee of the Chinese Optical Society.

Recent advances in optical coherence elastography

Kirill V. Larin✉
University of Houston, (Houston, USA)
✉klarin@uh.edu



Abstract: Several optical methods are emerging as a powerful tool for the noninvasive quantification of viscoelastic properties of several tissues, such as the eye, skin, and even whole embryos. In this presentation, I'll overview recent progress made in the development and application of Optical Coherence Elastography (OCE) for quantification of mechanical properties of various tissues and how we use these data for health diagnostics, such as early detection of keratoconus (structural degeneration of the cornea), quantitative assessment of systemic sclerosis (an autoimmune disease that involves the hardening and tightening of the skin), and whole embryos.

Speaker: Kirill Larin is a Cullen College of Engineering Endowed Professor of Biomedical Engineering at the University of Houston. He also holds joint appointments at the College of Optometry and the Department of Physiology and Biophysics at Baylor College of Medicine. Larin received his first M.S. in Laser Physics and Mathematics from the Saratov State University, Russia, in 1995, his second M.S. in Cellular Physiology and Molecular Biophysics in 2001, and his Ph.D. in Biomedical Engineering in 2002 from the University of Texas Medical Branch. His research contributions are in Biomedical Optics and Biophotonics and the development and application of various optical methods for noninvasive and nondestructive imaging and diagnostics of tissues and cells. Larin has authored more than 200 peer-reviewed publications and chapters in ten textbooks on Biomedical Optics. He is the recipient of the prestigious Presidential Award from Russian President Boris Yeltsin. Larin currently serves as an Instructor for short courses on Tissue Optics at SPIE, Optica, and IEEE conferences. He was inducted as a Fellow of SPIE in 2015, a Fellow of Optica in 2016, and a Fellow of AIMBE in 2020.

Therapeutic potential of photobiomodulation therapy for neurological and neuropsychiatric disorders: A glymphatic perspective

Joe DiDuro✉

ProNeuroalLIGHT LLC. Phenix AZ USA Chief Executive Officer (CEO), (Arizona, USA)

✉drjoe@proneurolight.com; https://proneurolight.myshopify.com

Abstract: The glymphatic system is a glial-dependent waste clearance pathway in the central nervous system, devoted to drain away waste metabolic products and soluble proteins such as amyloid-beta. An impaired brain glymphatic system can increase the incidence of neurovascular, neuroinflammatory, and neurodegenerative diseases. Photobiomodulation (PBM) therapy can serve as a non-invasive neuroprotective strategy for maintaining and optimizing effective brain waste clearance. In this review, we discuss the crucial role of the glymphatic drainage system in removing toxins and waste metabolites from the brain.

Speaker: His passion is to help people by teaching them how they can create neuroregeneration and healing in their own lives. In his 40 years of clinical experience, Dr. DiDuro has come to understand the very low quality of life that people affected by neurodegenerative diseases experience and that their disability touches every aspect of a person's existence; personal, social and family. Dr DiDuro has made it his life's work to help end this suffering, initiate their recovery and restore their humanity. Dr. DiDuro earned his Bachelor of Arts degree from the State University of New York at Buffalo 1983 He received his Doctor of Chiropractic Degree from Palmer College of Chiropractic in Davenport, Iowa 1986. Dr. DiDuro lived and practiced in Vicenza Italy for 10 years and also completed further specialized training in Amsterdam, The Netherlands for the American Chiropractic Associations' American Board of Chiropractic Neurology and has Diplomate Status in Chiropractic Neurology 2000. Upon moving back to America, Dr. DiDuro was accepted to Palmer Center for Chiropractic Research and completed an NIH funded program for a Master's Degree in Clinical Research 2006. He has been dedicating himself to research and unlocking the keys for new technology to help create More Brain Power and combating the huge wave of neurodegenerative brain conditions. He is the HOST of the BRAIN +tPBMT Virtual SUmmit, an ONLINE forum where 40 of the world's leading scientist share their personal stories and research on the use of transcranial photobiomodulation therapy as an effective therapy for neurodegenerative conditions. He is the PRESIDENT and CEO of ProNeuroLIGHT LLC. a Medical device company that brings a suite of tPBMT products directly to the public that so desperately are looking for rapid reversal of cognitive decline in themselves and their loved ones. While leaving practice to care for his mother with dementia, he realized the personal challenges involved in primary caregiving for people with neurodegenerative diseases. He focused all his clinical, professional and scientific knowledge to develop a FAMILY CENTERED approach to NeuroCognitive rehab. He is currently

Moderator of the tPBMT - Brain Research Consortium (transcranial Photobiomodulation Therapy) and a highly sought after Cognitive Neurotherapist and Brain Fitness Coach. He is the Developer and Author of My Brain Matters - the NeuroMetabolic Solution: How to Increase Brain Power for Your Loved Ones and Yourself.

Studying electrocorticograms based on the concept of rhythms coordination

Alexey N. Pavlov✉
[1]Saratov State University, Institute of Physics, Chair of Open Systems Physics (Saratov, Russia)
✉pavlov.alexeyn@gmail.com

Abstract: Rhythms are known in the nervous system for a long time, but there are still open questions concerning functions they serve. Recently, a new paradigm of network interactions of physiologically significant cortical rhythms has been proposed and various classes of coupling forms have been discovered that coexist during a certain physiological state and reorganize during transitions between physiological states. In particular, it has been demonstrated that physiological states cannot be fully described by focusing only on individual rhythms. In this study, cross-correlations of cortical rhythms are considered for different physiological states with a modified version of fluctuation analysis. Distinctions in the cross-correlations of pairs of rhythms are reported caused by sleep deprivation in mice.

Speaker: Alexey Pavlov is a Professor of the Department of Open Systems Physics at the Saratov State University. He received M.S. in Radiophysics in 1995, Ph.D. in 1998, and D.Sc. in 2009 also in Radiophysics from the Saratov State University, Russia. His research interests are in signal processing, dynamics of living systems, theory of oscillations, neuroscience, nonlinear dynamics and its applications in biology and medicine. A. Pavlov is a co-author of more than 250 peer-reviewed publications, including the book "Wavelets in Neuroscience", Springer 2015 (1-st ed.) and 2021 (2-nd ed.). He was supervisor of 9 PhD-students.

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-L6

The role of the cerebellum in spatial navigation

Tatyana Yakusheva✉
Washington University in St. Louis, Department of Potolaryngology, (St. Louis, USA)
✉tanya.yakusheva@gmail.com

Abstract: Our laboratory studies the role of the vestibulocerebellum (Nodulus/Uvula and Flocculus) in visual-vestibular signal processing and spatial navigation. Dysfunction in the vestibulocerebellum has been linked to a range of clinical conditions, such as ataxia, vertigo, and other balance disorders associated with neurogenerative deceases. By studying the neural mechanisms that underlie the function of the vestibulocerebellum, our research could provide new insights into the causes and treatment of these conditions.

We use various experimental techniques, including single-unit recordings, pharmacology, behavioral neuroscience, neurogenetics, immunohistochemistry, and computational neuroscience. Here, I will present the results of our landmark studies in rhesus monkeys, where we showed that cerebellar nodulus and uvula performs a key computation for spatial navigation. They transform an idiothetic motion reference frame into an earth-bounded, allothetic, motion (translation and tilt) reference frame. We found that the cerebellar Purkinje cells, the sole output of cerebellum, carry transformed vestibular information from semicircular canals and otolith organs. Furthermore, using minute injections of GABA-A receptor antagonist to disrupt local cerebellar processing in the macaque monkey, we found that all canal-related information is removed from Purkinje cell responses, indicating that the canal signal transformations happen locally within the cerebellar nodulus and uvula. The implications of these findings extend beyond basic neuroscience, offering valuable insights into the neural basis of spatial cognition in primates, including humans.

Speaker: Tatyana Yakusheva is a Assistant Professor of Department of Otolaryngology at the Washington University School of Medicine in St. Louis. Dr. Yakusheva received M.S. in Biology and Physiology from the Saratov State University, Russia, in 1997. She received her Ph.D. in Physiology in 2003 from the Saratov State University and Peoples' Friendship University of Russia. Dr. Tatyana Yakusheva's major contribution lies in her groundbreaking research on the vestibulocerebellum, particularly focusing on the cerebellar nodulus and uvula. Her work has significantly advanced our understanding of how these brain regions contribute to spatial navigation, motor control, and vestibular processing.

CSFTN-24-L7

Photonics technologies for biomedical applications: Imaging, diagnostics and treatments

Edik U. Rafailov✉
Aston University, (Birmingham, UK)
✉e.rafailov@aston.ac.uk

Abstract: S In recent years, there has been a growing interest in the development of compact and low-cost, versatile, broadly tunable CW and ultra-short pulse laser sources generating light across the near-infrared and visible spectral ranges. In this talk we are presenting the recent progress on the development of novel compact laser sources generating light across broad spectral ranges in CW and ultra-short pulse regimes. We also will demonstrate applicability of such lasers in Biomedical Photonics.

Speaker: Prof. Edik U. Rafailov received the Ph.D. degree from Ioffe Institute, Saint Petersburg, Russia, in 1992. In 1997, he moved to St. Andrews University, Scotland, UK and in 2005, he established a new group in Dundee University, Scotland. In 2014, he and his Optoelectronics and Biomedical Photonics Group moved to Aston University, Birmingham, UK. He has authored and coauthored more than 550 articles in refereed journals and conference proceedings, including three books, ten invited chapters and numerous plenary/invited talks. His current research interests include high-power CW and ultra-short pulsed lasers, generation of UV/visible/IR/MIR and THz radiation, nanostructures and biomedical photonics. He coordinated the €14.7M FP7 FAST-DOT project development of new ultrafast lasers for biophotonics applications and the €12.5M NEWLED project which aims to develop a new generation of LEDs. He also coordinated the H2020 FET projects: Mesa-Brain (€3.3M, aims to develop 3D nano-printing technology for functional three-dimensional human stem cell derived neural networks), and NEUROPA (€3.6M, aims to develop novel non-invasive brain theragnostic approaches), and PLATFORMA. Recently he as a Coordinator was awarded HE Pathfinder GlioLight project (€3.2M, aims to develop novel laser treatment of cancer). He also leads a few other projects funded by EU FP7, H2020 and EPSRC. In 2014 he has been awarded the Lebedev Medal of the Russian Optical Society. In 2022 he was elected as a Fellow of Optica (former OSA) and in 2023 elected as a Fellow SPIE.

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-L8

Changes in the regulation of cutaneous blood microcirculation during sequential changes in sleep phases (pilot study)

Viktor V. Sidorov✉
SPE "LAZMA" Ltd, (Moscow, Russia)
✉victor.v.sidorov@mail.ru

Abstract: A distributed system of wearable laser flowmeters (DSF) of blood microcirculation with two non-invasive diagnostic methods was developed: laser Doppler flowmetry of blood microcirculation and a fluorescent method for assessing oxidative metabolism in skin tissue "LAZMA PF". The application of DSF allows you to move from the traditional assessment of the tissue system in the local area to the definition of systemic changes in humans. The presentation will discuss the use of DSF for sequential changes in sleep phases. The criterion for selection of sleep phase and time interval with the greatest activity of microcirculation regulation mechanisms will be proposed for effective therapeutic action in a therapeutic procedure. From the obtained data, it follows that the highest microcirculation activity occurs in the fourth phase, REM 4 fast sleep, after the third phase of NREM 3 slow sleep.

Speaker: Viktor Sidorov is a CEO of Scientific Production Enterprise "LAZMA" Ltd (Moscow), PhD in Optical Engineering in 1990 from SPO "Astrophysics" (Moscow). His area of research interests is development of a new types of medical laser diagnostic equipment. Sidorov has authored more than 50 publications and he is a coauthor of three textbooks at various laser methods for noninvasive diagnostics of tissues and also a developer of medical devices.

Objective sleep estimation by polysomnography - from speculations to clinical implication

Mikhail Poluektov✉
Chair of Neurvous Diseases and Neurosurgery of Sechenov University, (Moscow, Russia)
✉poluektov_m_g@staff.sechenov.ru

Abstract: The state of sleep is a difficult subject to study. The fact of observation and the environment by itself lead to a disruption of its natural progression. Some pathological phenomena, such as seizures, do not occur every night, which also limits the implication of the objective sleep data in clinical practice. However, for certain disorders, such as obstructive sleep apnea, REM sleep behavior disorder, bruxism, overnight polysomnography supports the diagnosis with high confidence. This is also true for some phenotypes of insomnia. The report presents examples of identification and confirmation of some pathological conditions in humans, in which the ability to objectively verify different features of sleep plays a key role.

Speaker: Mikhail Poluektov works as an associate professor at the Department of Nervous Diseases at Sechenov University in Moscow. He is also the head of the sleep medicine department at the same institution and the acting president of the Russian Society of Somnologists. In 1993 he graduated from the Medical University by I.M. Sechenov, then specialized in neurology. His PhD, received in 1998, was devoted to studying the effect of autonomic neuropathy on sleep-disordered breathing. As an associate professor, Mikhail Poluektov teaches sleep medicine in neurology and general medicine, organizes conferences on somnology, and publishes regular issues on sleep disorders in «S.S. Korsakov Journal of Neurology and Psychiatry» and «Effective pharmacotherapy». Serves as a reviewer editor in «Frontiers in Psychiatry», «Frontiers in Neurology». Author of more than 250 publications in Russian and foreign journals, 5 monographs in Russian, 3 popular books about sleep.

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-L10

Neurotechnologies for the nonpharmacological treatment of sleep disorders

Vladimir B. Dorokhov✉
Institute of Higher Nervous Activity & Neurophysiology RAS, (Moscow, Russia)
✉vbdorokhov@mail.ru

Abstract: The mechanisms of homeostatic regulation of sleep is the presentation of stimuli of different modality with a frequency of about 1 Hz, that is, close to the frequency of delta waves, the basic rhythm of slow-wave sleep. Will be considered of nonpharmacological treatment of sleep disorders. Different types of audio effects, temperature treatment, vestibular stimulation, olfactory stimulation, phototherapy, electrocutaneous stimulation, audio-visual stimulation, transcranial electrical and magnetic stimulation, non-contact ultraweak electromagnetic stimulation. Alternative medicine is generally defined as a set of methods for healing, prevention, diagnosis, and treatment based on the experience of many generations of people.

We will consider data on the possible use of these approaches for improving sleep quality using the three most widely employed methods as examples: deep breathing, aromatherapy, and reflex therapy (acupressure). Sleep hygiene: include the formation of a regular sleep schedule, careful use of daytime sleep, refusal of physical or mental exercises before bedtime, restriction of stress stimuli, restriction of light effects before bedtime, refusal to use beds for anything other than sleep and sex.

Speaker: Vladimir Dorokhov works as the head of the laboratory of neurobiology of sleep and wakefulness in Institute of Higher Nervous Activity & Neurophysiology RAS, Moscow. He also holds joint appointments at the Peoples' Friendship University of Russia and Higher School of Economics. Dorokhov received his first Ph.D. in the Institute of higher nervous activity of the RAS in 1981, his second Dr. of Physiology in the Institute of Higher Nervous Activity of the RAS in 2006. His research contributions are head of the Laboratory of sleep/wake neurobilogy in the Institute of higher nervous activity of the RAS in 2007. Member of dissertation committee of 1) Institute of Higher Nervous Activity & Neurophysiology of the RAS and 2) Cognitive Science of the Higher School of Economics. Currently, the laboratory is engaged in research on neurophysiological correlates of consciousness during the sleep-wake protocol, cardio-respiratory respiration processes during falling asleep and chronotypes. The proposed Abstract will be made according to the article V.B. Dorokhov and A.N. Puchkova. Neuroscience and Behavioral Physiology, 2022. Vol.52, No.7, http://sleep.ru/lib/Dorokhov_Puchkova_2022_en.pdf.

Spatiotemporal sleep dynamics and neurogliavascular unit signaling: Recent evidence calls for a new paradigm

Dmitry E. Postnov✉
[1]Saratov State University, Institute of Physics, Chair of Optics and Biophotonics (Saratov, Russia)
✉postnov@info.sgu.ru

Abstract: Over the last decade, important data have been obtained in the field of sleep physiology, new functions of astrocytes and pathways of interaction in the neuro-glia-vascular unit have been discovered, and the main patterns of the removal of harmful metabolites from the brain parenchyma have been identified. All together, this makes it possible to take a fresh look at the listed processes as a single global-local brain circuit that provides important functions for the organism as a whole. In particular, the phenomenon of local sleep, now proven by a number of experiments, requires a revision of the paradigm according to which sleep is a whole-brain state and thus opens the way to the concept of spatial-temporal dynamics of sleep. In turn, this raises the question of the presence and characteristics of a minimal "sleep unit" to which a group of neurovascular units corresponds. Further, this approach leads to the possibility of a local and time-unsynchronized process of cleaning the parenchyma from harmful metabolites. In my report, I provide an overview of specific data supporting the above assumptions and discuss a hypothesis that combines them into a consistent system. The work was supported by a grant from the Russian Science Foundation, #22-15-00143.

Speaker: Dmitry Postnov—chief researcher at the Department of Optics and Biophotonics, Saratov State University (SSU). In 1983, he graduated from the Department of Radiophysics at SSU, qualifying as an engineer. Over the next 17 years, he was engaged in research in the field of deterministic chaos and synchronization of non-periodic oscillations. Received a Candidate of Science degree in 1990 and a Doctor of Science degree in 2000. In 1997-1998. worked at Chungbuk University (South Korea), where he became interested in modeling processes in living systems. In subsequent years, he carried out a number of model and theoretical studies in the field of neuroscience, including neuro-glial ensembles, hemodynamics and filtration processes in the kidneys, vasomotor activity of vascular networks, etc. Since 2016, he has been focusing on mathematical modeling of processes in the brain parenchyma: cortical spreading depression, migraine waves, autoregulation of cerebral blood flow. Project leader for a number of grants from the RF Ministry of Education and Science and the Russian Science Foundation. In recent years, the focus has been on studying the relationships between the sleep-wake cycle, the activity of astrocytes and the process of removing harmful metabolites from the brain parenchyma.

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-L12

Therapeutic monoclonal antibodies for the treatment of neurodegenerative diseases. Modern approaches, challenges and prospects

Sergey V. Diduk✉
LEENERS LLC, (Moscow, Russia)
✉diduk.sv@leeners.pro

Abstract: The creation of highly effective biotech products based on therapeutic monoclonal antibodies for the treatment of neurodegenerative diseases is a major issue of modern biopharmaceutics. The study will present various approaches used in development of therapeutic monoclonal antibodies products and challenges of a mAb-based drug generation. The topic also addresses the problems of genetic stability and clonality of production cell lines, alongside with perspectives of creating new molecules and their application in treating neurodegenerative diseases.

Speaker: Sergey Diduk, CEO of LEENERS LLC, PhD in Oncology of N.N. Blokhin National Medical Research Center of Oncology, Ministry of Health of Russia (2008). From 2012 till 2019 a Director of Biotechnology Department in CJSC BIOCAD, coordinating works on obtaining therapeutic monoclonal antibodies and gene therapy products development. From 2019 till 2022 Head of Laboratory of Pharmaceutical Biotechnology and Vice-Principal of Research Pushchino State Institute of Natural Science. Author of over 40 peer-reviewed publications and patents.

Photobiomodulation in the treatment of traumatic brain injury

Denis E. Bragin✉
Lovelace Biomedical Research Institute, (Albuquerque, USA)
✉dbragin@salud.unm.edu

Abstract: Traumatic brain injury (TBI) is a major health problem that results in long-term brain damage and cognitive dysfunctions, leading to neurodegenerative diseases. Pharmacological therapeutics that demonstrated efficacy for TBI treatment in animal research have failed to demonstrate benefits in human TBI. Photobiomodulation (PBM) is a non-invasive, nonpharmacological method of therapy that has gained interest in preclinical and clinical scientists and has been shown to be a promising approach for the treatment of TBI. In this presentation, I'll overview recent progress made in the research and development of PBM in TBI, including novel mechanisms and applications.

Speaker: Denis E. Bragin is an Associate Professor of Translational Neuroscience at Lovelace Biomedical Research Institute, Albuquerque, New Mexico, USA. He also holds joint appointments at the Department of Neurology, University of New Mexico School of Medicine, and New York Medical College. Dr. Bragin received his M.S. in Biology/Biochemistry from the Southern Federal University (former Rostov State University), Russia, in 1999 and his Ph.D. in Biophysics in 2004 from the Voronezh State University, Russia. His research focuses on the development of novel methods of treatment and diagnostics for cerebral circulation and metabolism after brain injury, stroke, and other cerebrovascular and metabolic diseases and their comorbidities, including hemorrhagic and septic shock and intracranial hypertension. Dr. Bragin has authored over 150 peer-reviewed publications and book chapters and has been granted six patents for novel treatment strategies for brain and related diseases. He was elected a Fellow of the American Heart Association (Stroke Council) in 2015 and nominated as a Fellow of Critical Care Medicine in 2024.

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-L14

The role of synaptic homeostasis in the sleep-wake cycle

Eugene V. Verbitsky✉
Southern Scientific Center of the Russian Academy of Sciences, (Rostov on Don, Russia)
✉e_verbitsky@mail.ru

Abstract: In recent decades many mysteries of the sleep-wake cycle have been solved. The use of data-loggers has clarified the influence of habitat factors on the diversity of animal sleep. Ways of studying similar patterns in humans have been outlined. The theory of synaptic homeostasis of the active environment of the brain in the sleep-wake cycle has gained special importance. Its further development leads somnologists to the understanding of sleep individuality as the organism's reaction to wakefulness preceding sleep. This approach opens new horizons for the study of sleep and wakefulness by introducing computer technologies in the development of personalized clinical somnology.

Speaker: The interest in the study of sleep-wakefulness was formed in the speaker by his teacher Prof. Alexander B. Kogan from Rostov University (Rostov on Don). This scientist, for his method of chronic implantation of electrodes in the brain, was honored by the Russian Academy of Sciences with two awards in Physiology: the I.P. Pavlov Prize and the I.M. Sechenov Prize. The speaker is currently working as a chief researcher at the Ecosystems Laboratory of the Southern Scientific Center of the Russian Academy of Sciences (Rostov on Don). He is the Chairman of the Rostov Branch of the I.P. Pavlov Physiological Society of the Russian Academy of Sciences, as well as the Chairman of the Rostov Regional Branch of the Russian Society of Somnologists. Evgeny V. Verbitsky is the author of articles and monographs on sleep and anxiety, a specialist in experimental and clinical somnology. His followers continue to study sleep and participate in the training of future doctors at Rostov State Medical University.

Technologies of the future in neuroscience

Oxana Semyachkina-Glushkovskaya✉
Saratov State University, Scientific Medical Center, Laboratory «Smart Sleep»,
(Saratov,Russia)
✉glushkovskaya@mail.ru

Abstract: Looking into the future, neurotechnology is expected to be the most promising field in medicine. Just yesterday, it seemed fantastic to create technologies that could be controlled only by thought. But today, a number of companies Synchron Switch, Neuralink and Blackrock Neurotech have created a brain-computer interface that, using the power of thought and neurochips, makes it possible to restore movement, communication and reading in people with disabilities.

For the first time in the world, in 2023, a Russian breakthrough non-invasive technology was developed for cleansing brain tissue of toxins during sleep. This innovative direction opens a new page in the history of the development of neuroscience, when brain diseases will be treated in sleep. The technology is a portable flexible plate of LEDs that, in the infrared range, act on the meningeal lymphatic vessels, stimulating the removal of toxins (beta-amyloid and blood products) from the brain through them. Light exposure is supplied through a smart bracelet, which performs the function of monitoring sleep stages and sends a signal to photo elements via Bluetooth technology. Clinical trials of the technology will take place in 2025 on 30 patients with Alzheimer's disease and in 2026 on 30 patients with brain injuries. It is known that even one night without sleep leads to the accumulation of toxic molecules in the brain in healthy people, and in conditions of its chronic deficiency over 25 years, dementia develops. The technology is also intended to prevent dementia in healthy people who experience sleep deficiency due to overwork or in older people who experience age-related sleep disturbances. The portable size of the technology, safety and ease of use allow it to be used in a car, airplane, office and at home. The development of smart sleep technology has no analogues in the world, which contributes to the emergence of its own highly competitive niche for Russian technologies in the international arena and increases the prestige of Russian science. This will also help preserve the health of the nation, improve the quality of medical services and reduce the economic costs of treating patients with brain diseases.

Keywords: neurotechnology, medicine, photobiomodulation, Alzheimer's disease, brain injury.

Acknowledgments: The research was supported by the Russian Science Foundation grant No. 23-75-30001.

The observer effect for MRI experiments

Pavel Rudych✉
International Tomography Center and Novosibirsk State University, (Novosibirsk, Russia)
✉Pavel.Rudych@gmail.com

Abstract: MRI is a powerful method for neurophysiological studies, but the MRI experimental environment required to measure the data has a major impact on the conduct of the experiment and dramatically alters the physiology and behaviour of the participant. The closed loop, loud high frequency noise, fixed head, minimal body movement requirements, relaxed lying position and high-tech environment all put a lot of stress on the participant, but we expect them to ignore this and engage in the experiment.
I'll give an overview of the MRI-induced changes in participants' perception, the processes of adaptation in the MRI and the physiological markers of good adaptation. We will review the samples of data recorded, reject the MRI induced artefacts and compare the results with the data recorded outside the MRI.

Speaker: Pavel Rudych is an engineer and project manager at Novosibirsk State University and the International Tomography Centre of Novosibirsk. Pavel received his M.S. in Physics from Novosibirsk State University, Russia, in 2005 and his second B.S. in Clinical Psychology in 2021. His research interests are in functional MRI and coregistered EEG experiments, experiment stimulus gamification and environmental transparency based on web, EEG/MRI data aggregation and automated processing, machine learning analysis. Pavel is the author of more than 30 peer-reviewed publications.

Pattern of "sleep spindles" in obstructive sleep apnea patients

Irina Madaeva I.[1]✉

[1]Scientific Centre for Family Health and Human Reproduction Problems (Irkutsk, Russia)

✉ nightchild@mail.ru

Abstract: Obstructive sleep apnea (OSA) is very serious and multifactorial sleep disorder which closely related with disruption of sleep homeostasis. It is known that such sleep encephalographic (EEG) phenomenon as sleep spindles (SSs) support sleep stability and may display a sleep protective function. Thus, it is of particular interest to assess the SSs pattern in OSA patient that was the aim of the present research. We investigated whether SS activity could be altered in patient with moderate degree of OSA compared with non-OSA subjects. 35 middle-aged OSA patients and 30 controls underwent full-night polysomnography (PSG). SSs were automatically detected during stage 2 (N2) of non-rapid eye movements. The SSs activity characteristics involved: total number, mean density, mean maximum amplitude and mean frequency. All differences were considered statistically significant at $p < 0.05$. We noted a significant decrease in the density and number of central SSs in patients with OSA compared to controls, however, the amplitude is significantly higher in OSA subjects. To summarize, our results show that OSA lead to significant disruption of SSs density, reduction of their number and frequency in N2 sleep stages. These findings can be evidence of the extinction of a brain protective mechanism against exciting stimuli during apnea episodes in OSA patients with a long duration of sleep disturbances.

Keywords: polysomnography, EEG -pattern, sleep spindle, obstructive sleep apnea.

Speaker: Irina M. Madaeva , MD, PhD, is a Head of Irkutsk Somnological center, chief researcher of somnological and neurophysiological department of Federal State Public «Scientific Center for Family Health and Human Reproduction Problems», Irkutsk , Russia. She obtained her Ph.D. (1994) and D.Sc. (2009) in sleep medicine. Research interests include relationship between aging and sleep, modifying factors of sleep disorders, molecular mechanisms of sleep disorders, melatonin circadian rhythms, ethnic aspects of sleep disorders .

Madaeva I.M. is scientific supervision of 7 scientific theses. She is member of World Association of Sleep Medicine. She is the Heard of Scientific Committee of Russian Society of Sleep Medicine . She is author more than 200 scientific papers in peer-reviewed journals, from them 162 publications in bases Web of Sciences and Scopus, Q 1-2.

Sleep medicine of the future

Alexander Kalinkin✉
Sleep Medicine Centre of Moscow State University (Moscow, Russia)
✉akalinkin@sleeplab.ru

Abstract: Over the last decades, accumulating evidence has documented the burden of sleep disorders on individuals and society. Sleep disorders are highly prevalent in children and adults, resulting in compromised wake functioning and behavioral dysregulation. Iron deficiency (ID) has received increasing attention in disorders affecting sleep. Proposed mechanisms are derived from iron's central role in the brain as a co-factor in neurotransmitter synthesis, as well as in myelination and oxygen delivery. ID in humans and animals can lead to damage of diffuse brain structures, including the hippocampus, basal ganglia, and cerebellum. Emerging and evolving technologies that impact the practice of sleep medicine will be discovered.

Speaker: Alexander Kalinkin, Head of Sleep Medicine Centre of Moscow State University (www.sleeplab.ru). A graduate of Sechenov University (Moscow), certified as a cardiologist, and received his MD in Medical Centre of presidential affairs department. A board member of Russian Sleep Research Society, Russian Neuro-Muscular Diseases Society, member of American Academy of Sleep Medicine, European Sleep Research Society (ESRS). Alexander Kalinkin is first expert of ESRS in Russia. The main research activities are related to sleep breathing disorders, insomnia, RLS, arterial hypertension, iron metabolism. He has authored more than 100 peer-reviewed publications and chapters in textbooks on sleep medicine. Alexander Kalinkin is a Head of sleep medicine course and mentor of scientific work on sleep medicine in Moscow State University. Alexander Kalinkin is a founder of International Sleep Forum (www.sleepforum.ru).

Complex system and future technologies in neuroscience – CSFTN'24

CSFTN-24-L19

Analysis of Medical Data with Synolitic Networks

Alexey Zaikin✉
University College London, University Higher School of Economics
✉alexey.zaikin@ucl.ac.uk

Abstract: Recently we observe merging Nonlinear Dynamics, Graph Theory and Artificial Intelligence research directions. Representing high-dimensional biological data in the form of a graph and linking features by biological and thermodynamic laws seems to be a very promising approach to deal with overwhelming complexity of biological systems. However, one can utilise this approach only if we have information about how features and attributes are connected biologically. Here we would like to draw attention to alternative methods to represent high dimensional data in the form of the graph if a-priori we do not have established connections. There is an algorithm, first described by Zanin and Bocaletti, able to establish links between parameters/nodes without any a-priori knowledge of their interactions using residual distances from linear regression models constructed between every pair of analytes to construct a graph. They termed this approach a "parenclitic" network representation, from the Greek term for "deviation". On our turn, we have introduced a variation of parenclitic networks, that can be called "synolitic" from the Greek word for "ensemble". In principle, these networks can be considered an ensemble of classifiers in a graph form and thus are a kind of correlation network where the correlation is in the changes between two classes (e.g., disease and non-disease). These networks have been successfully used to detect age related trajectories in Down's syndrome and for prediction of survival for severely ill Covid-19 patients. Especially important is that Synolitic graphs enable us to use Graph Neural Networks for analysis of the data.

Speaker: Prof Alexey Zaikin (AZ) holds a Chair in Systems Medicine joint between Institute for Women's Health(IfWH) and Applied Mathematics at University College London (UCL). AZ studied physics at Moscow State University, and received an MS in Physics with distinction and the Khoklov Award for Excellence in Research. AZ got his PhD in 1998 in Moscow and Habilitation in 2003 in Potsdam, Germany. AZ published 175 papers in multi-disciplinary areas including Stochastic Processes, Nonlinear Dynamics, Data Analysis, Statistics, Systems Biology and Systems Medicine. AZ and the team developed and licensed new methods to analyse trends in longitudinal oncomarkers (Clinical Cancer Research 2018, British J of Cancer 2020). These works confirmed the power of longitudinal algorithms over the analysis of single time points. In the frame of MRC funded grant AZ suggested synolitic network analysis methodology to identify biomarkers (PLOS One 2017, Frontiers in Genetics 2021) and applied it for survival prediction of COVID-10 patients (PLOS Digital Health 2022, Cell Systems 2021). AZ contributed to the application of AI methods to the prediction of prostate cancer progressors (European Urology Open Science 2023, European Radiology 2023).

Научное издание

КОМПЛЕКСНЫЕ СИСТЕМЫ И БУДУЩИЕ ТЕХНОЛОГИИ В НЕЙРОНАУКЕ

Сборник тезисов докладов

Выпуск 1
Материалы Международной летней школы «Комплексные системы и будущие технологии в нейронауке – CSFTN’24»
Санкт-Петербург, 29–30июня 2024 г.

При оформлении обложки была использована фотография с сайта www.arina-tour.ru

Ответственный за выпуск: О. *В. Семячкина-Глушковская*
Компьютерная верстка и подготовка оригинал-макета: Э. *И. Кайбелева, В. А. Халова*

Подписано к использованию 22.05.2024. Размещено на сайте 24.05.2024.
Формат 60x84 1/16. Усл. печ. л. 3,95 (4,25). Объем данных 16.6 Мб. Заказ 5-у.

Управление по издательской деятельности Саратовского университета
410012, Саратов, Астраханская, 83
https://www.sgu.ru/structure/uprid

For notes