VISUAL NEUROPROSTHESIS – STIMULATION OF VISUAL CORTICAL CENTERS IN THE BRAIN. DESIGN OF NON-INVASIVE TRANSCRANIAL STIMULATION OF FUNCTIONAL NEURONS

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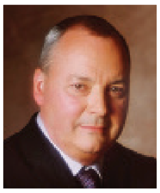

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SUMMARY

Purpose: The purpose of the article is to present the history and current status of visual cortical neuroprostheses, and to present a new method of stimulating intact visual cortex cells.

Methods: This paper contains an overview of the history and current status of visual cortex stimu-lation in severe visual impairment, but also highlights its shortcomings. These include mainly the stimulation of currently damaged cortical cells over a small area and, from a morphological point of view, possible damage to the stimulated neurons by the elec-trodes and their encapsulation by gliotic tissue.

Results: The paper also presents a proposal for a new technology of image processing and its transformation into a form of non-invasive transcranial stimulation of undamaged parts of the brain, which is protected by a national and international patent.

Conclusion: The paper presents a comprehensive review of the current options for compensating for lost vision at the level of the cerebral cortex and a proposal for a new non-invasive method of stimulating the functional neurons of the visual cortex.

Key words: visual neuroprosthesis, cortical visual centers, transcranial stimulation

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INTRODUCTION

Retinal abnormalities (dystrophy, retinal degeneration, glaucoma and others) leading to severe disorder of visual functions are not localized only in their primarily damaged cellular structures, but also cause damage to other structures, including the visual pathway and the cortical visual center in the brain. For this reason, attempts to restore visual functions by neuroprosthesis on the level of the eye (epiretinal, subretinal, suprachoroidal or intrascleral) cannot have the desired effect [1,2].

HISTORY

This has led a series of researchers to seek other structures for stimulation of the visual analyzer.

The visual cortex was one of the first locations where visual prostheses were considered.

The first studies by the German ophthalmologist Foerster in the 1930s confirmed that direct electrical stimulation of the visual cortex enabled a completely blind person to perceive spots of light [3].

A subsequent study by Kraus and Schum then demonstrated that light bursts (phosphenes) could be generated also in people with long-term loss of sight. It was important that phosphenes from a fixed point in the visual cortex were localized to a corresponding point in the visual field [4].

Thirty years later, Brindley and Lewi used a system of radio receivers connected via an interface to electrodes, which were in contact with the occipital pole of the right brain hemisphere on a 52-year-old blind patient. By sending appropriate radio signals, phosphenes were generated in the left half of the visual field. One electrode triggered a very small spot of white light in a constant location in the visual field. When multiple electrodes were applied, this generated two or several such spots, or a small cloud.

Upon the use of stronger stimuli, further phosphenes appeared, which could be differentiated from each other upon stimulation with electrodes at a distance of 2.4 mm apart. The flashes usually ceased immediately after the cessation of stimulation, but after strong stimulation they sometimes persisted for up to 2 minutes [5]. Similar findings were also recorded by Dobelle and Mladejovsky. Phosphenes appeared immediately after the commencement of stimulation and disappeared immediately after cessation [6]. Schmidt et al. described in detail the results of an investigation of intracortical micro-stimulation of the visual cortex in a 42-year-old woman, who had been completely blind for 22 years as a consequence of glaucoma. A total of 38 micro-electrodes were implanted in the right visual cortex in close proximity to the occipital pole for a period of four months. The size of the phosphenes usually reduced with increasing stimulating current. At levels of stimulation close to the threshold value, the phosphenes were often colored. With an increasing level of stimulation the phosphenes usually remained white, grayish or yellowish. With only a few exceptions, the phosphenes rapidly disappeared after the termination of stimulation. When the period of stimulation was extended to more than one second, the phosphenes usually disappeared before the termination of the stimulation training [7].

As a result, electrical stimulation of the visual cortex has long been recognized for its potential in the development of visual cortical prosthetic devices for use by blind persons [8].

PRESENT DAY

Technological advances have enabled electrical stimulation with the aid of electrode grids with high density placed on the surface of the cortex [9] or penetrating into the cortex of the brain [10]. A visual cortical prosthesis composed of a micro-camera placed in sunglasses, a computer and electrodes implanted in the visual center was introduced by Dobelle in the year 2000 [11]. A blind volunteer was capable of orienting himself among a "family" of three mannequins (a standing adult man, seated adult woman and standing three-year-old child) randomly placed within a large room, without colliding with any of them. He was then able to walk to the wall and pick up a hat which had been placed at a random point on the wall. When he returned in the direction from which he had come, he was able to locate any of the three mannequins and place the hat on the head of the selected mannequins [11].

Fernandes et al. implanted micro-electrodes (total 96) in the visual cortex of a 57-year-old individual with total blindness for a period of six months. The implantation and subsequent explantation of the micro-electrodes took place without complications. Simultaneous stimulation by means of multiple electrodes was associated with a pronounced lowering of the threshold values and triggered distinguishable phosphene perceptions, which enabled the blind subject to identify certain letters and distinguish the boundaries of objects [12].

Worthy of attention are cortical neuroprostheses manufactured by Piedade et al., who developed a wireless connection between an external camera, a processor and an intracranial unit in order to stimulate cortical cells implanted as electrodes in the visual cortex. The entire system was composed of a primary unit placed outside the body and a secondary unit implanted intracranially. The power supply and information about the stimuli were transmitted with the aid of a low-frequency transformer, which created a wireless induction connection between both units. The secondary unit was composed of a receiver, stimulation circuits of micro-electrodes and a return transmitter, which served for monitoring of the implant [13].

In 2020, the American neurosurgeon Pouratian published his first experiences with the implantation of the wireless cortical prosthesis Orion (Second Sight Medical Products). Neurological problems appeared in three out of six patients during an examination of the stimulation parameters. Over the course of a one-year observation period, no system failure occurred. All the subjects perceived phosphenes, and during this period they stated an improvement of visual functions. Despite the fact that this study incorporated only a small number of patients, according to the author the results are encouraging. As the author himself states, "the prosthesis provides artificial vision, but does not restore vision" [14].

Similarly, Beauchamp et al. also published results of the Orion system. According to expectations, electrical stimulation of the individual electrodes generated phosphenes in the locations that corresponded to a retinotopic map in the visual cortex. However, if multiple electrodes were stimulated simultaneously, the perceptions usually merged into larger phosphenes, which made it practically impossible to distinguish shapes. In order to avoid these limitations, they developed procedures for controlling the flow and rapid sequence stimulation of electrodes in order to create a sequence of phosphenes which follows the shape of the intended pattern. This enabled them to generate phosphenes of various geometric shapes (letters M, N, U, W etc.) [15].

Although flow control and sequence stimulation may help improve the effectiveness of cortical visual prosthesis with surface electrodes, a range of problems persist, which it is necessary to overcome [16].

For example, each chain of impulses on the electrode in question had to be completed before a chain of impulses could be commenced on the next electrode. As a result, dynamic stimulation was limited only to one phosphene at the given moment, and it remains unclear as to whether it is possible to present multiple phosphenes simultaneously. Another limitation is the difficulty of mediating information about visual objects which move or change shape, because the delineation of a single shape takes a long time [12].

A disadvantage of the Orion prosthesis and others is that they stimulate only a small part of the visual cortex (V1, V2). The main visual decoding processes take place in the "higher areas" (V4 and V5) [17–19]. Connection with the V5 system is directly with the lateral geniculate nucleus [20,21]. This means that the fibers avoid the V1 area.

The currents that were recorded for generating perception were within the range of several miliamperes [15]. Such substantial currents could cause damage to the brain cortex and potentially lead to seizures, especially when it is necessary to stimulate a group of electrodes simultaneously in order to create useful phosphene perceptions [12].

With regard to the fact that the visual cortex is an extensive area, it is ideal for implantation of a large number of electrodes which could ensure higher visual resolution and potentially the restoration of a larger number of visual functions [22]. Each hemisphere of the primary visual cortex in humans measures 25 to 30 square centimeters, and future implants should cover a sufficiently large area of the visual field with a sufficient density of phosphenes in order to enable the interpretation of perceptions. In addition to this, it is necessary to create wireless technologies with a large number of channels, and to develop resistant, biocompatible electrodes which minimize the risk of gliosis, damage to tissue and encapsulation of the electrodes [23].

Stimulation of the V1 area in order to restore sight has a range of advantages, but the technical limitations of implants indicate that stimulation of the V1 area is not sufficient to restore visual perception with such a resolution that would enable blind individuals to live a full-value daily life. A promising strategy for increasing resolution is a combination of temporally and spatially coherent electrical stimulation targeted at different areas. Implants in the V1, V2 and V3 areas increase visual resolution by creating more phosphenes throughout the entire visual field, enable safe distances of implantation and ensure that intracortical electrodes are targeted at foveal localizations [24].

Simultaneous stimulation with a pair of electrodes at a distance of more than 4 mm apart had a tendency to generate an impression of two different phosphenes. However, stimulation with multiple electrodes did not lead to a perception of distinguishable forms [25].

Besides cortex stimulation, de Ruyter van Steveninck et al. attempted to pre-process the image by selective filtering of the visual environment in order to maximize its usefulness for the interpretability of phosphene representation. The selection of filtering is not trivial, and therefore the implementation and optimization of image pre-processing techniques remain an active subject of scientific investigation for prosthetic vision [26].

Systems using the installation of electrodes in the brain and its stimulation with electrical signals are based on the principle of analogy with cochlear endoprosthesis. However, there is a fundamental problem here, in that the transmission of data replacing sound (from a technical perspective) requires a relatively small quantity of data (typically single figures to tens of kB/s). Stimulation of the brain is only on the level of one defined location in the auditory cortex, and the quantity of electrodes is small. With regard to the processing of the image, the envisaged number of electrodes is logically several times higher. In combination with the necessity of a surgical procedure, this entails unacceptable health risks, and furthermore, as stated above, the result is uncertain.

Further valuable information for cortical stimulation consists in the fact that processing of image information does not take place only in a single, precisely delineated area of the brain, but according to the nature of the image occurs in various different parts of the visual cortex.

For the sake of completeness, we also present the non-invasive possibility of stimulating the visual cortex with the aid of focused ultrasound [27–29]. The disadvantage of these systems is the size of the modulation area and the temperature during focusing on the given area. A similar situation applies also to transcranial stimulation using a magnetic field (which is performed as a method of treating epilepsy, Parkinson's disease, recurrent vascular events etc.) [30,31] and stimulation with alternating electric current [32] or transcranial stimulation by means of direct current [33–35].

From the overview presented above, it is evident that the existing electronic systems attempting to compensate for lost sight are implemented in the brain's visual centers with the aid of electrodes, and stimulated by an electrical current. Most of them stimulate only the primary (V1) or associated visual centers (V2, V3). Based on our experiences, it is precisely these centers that are damaged by anterograde retinal processes [1,2,36–41].

Another important finding from our studies on functional magnetic resonance in the visual paradigm is that during the stimulation of healthy individuals, not all areas of the visual cortex are displayed. We assume that it is precisely these areas that shall be functional also in the case of severe disorders of vision.

Proposal for a new method – stimulation of the brain cortex with the aid of radio waves

However, another option exists, namely the application of electromagnetic signals without surgical intervention. Approximately since 1969, attempts have been ongoing to create a neural interface with the aim of linking the brain to a computer and thereby enabling it to control other devices (e.g. an artificial limb). In principle, this concerns an electroencephelogram with signals Alfa (8–13 Hz), Beta (14–30 Hz), Theta (4–7.5 Hz) and Delta (0.5–4 Hz). Nevertheless, it is also possible to reverse this process. Electromagnetic waves on an extremely low energy level can trigger electrochemical changes in the stimulated neurons. They do not have damaging effects on DNA, cell membranes, enzymes or other parts of the cells [42].

In hygiene norms, the gauge is usually the density of the incident wattage p [W/m^2], actual wattage v (specific absorption rate) [W/kg] or absorbed energy per kg of tissue ARD (Absorption Rate Density) [W/m^3] and the intensity of the electrical field E [V/m], as well as the power of the magnetic field H [A/m] and several other parameters [43].

It is possible to assume that this stimulation will lead to neuroplasticity of the visual centers and open up a new chapter in the approach of possibilities for stimulating the brain.

The use of this technology raises a series of questions:

- What radio frequencies can be used for stimulation of the brain cortex?
- Is it appropriate to use some type of modulation, and if so, what kind (analogue, digital, amplitude, frequency)?
- How are we to designate the areas in the brain to be stimulated, selected and demarcated?
- Is stimulation in point or blanket form? Is it 2D or 3D?
- Is one area to be stimulated, or are multiple areas of the cortex to be stimulated simultaneously?
- How is the area to be stimulated to be determined (in dependency on the image)?

On the other hand, certain parameters of stimulation are now clearly defined – the quantity of stimulation energy must not exceed the value defined by the healthcare norm [44, 45].

For this reason, we have designed and developed an entirely new type of stimulation, referred to as the "Unit for non-invasive stimulation of cells of the visual cortex in severe disorders of vision."

In principle this concerns a camera whose signal is processed (video-chip controlled by a microprocessor, potentially supported by artificial intelligence detecting the character of the image), and transmitted in the form of radio frequency to the brain. The configuration is placed in a stabilized position in relation to the brain. This position is defined and calibrated with the aid of magnetic resonance and therapeutic markers in order to determine the position where stimulation shall take place.

For each potential patient it is first of all necessary to identify undamaged areas of the visual cortex, through the use of functional magnetic residence (fMRI) [39] in the visual paradigm or positron emission tomography (PET). In the case of PET we determine the non-functional areas of the visual cortex. It is possible that we will not be able to verify the functional areas of the visual cortex with the aid of fMRI. However, this does not mean that the suprastriatic areas V4 and V5 shall be non-functional in this case. In both cases the most fundamental step is the direct transcranial transmission of image information to the brain (without implanted electrodes), with the use of appropriate frequencies and appropriate stimulation modulations of neurons. The combination of signals is from the entire electromagnetic spectrum. In the first phase, frequencies are used from single figures to hundreds of GHz. Finding the correct range and modulation is the priority part of the realization. The stimulation itself will be targeted in

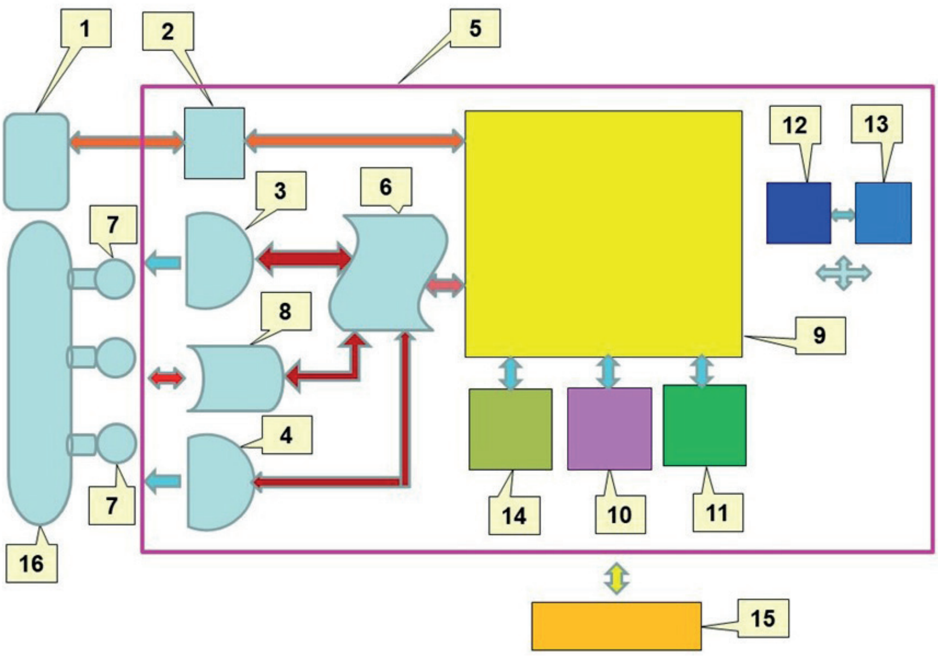

Figure 1. Block diagram "Units for stimulating cells of the visual cortex of the brain in severe visual impairment"
1. *image sensor (camera),* ***2.*** *video chip,* ***3.*** *transmitting sensor A (antennas), self-stimulation,* ***4.*** *transmitting sensor B (position stabilization),* ***5.*** *unit supporting structure,* ***6.*** *position stabilization unit (gyroscopic and/or floating),* ***7.*** *position stabilization feedback sensors - passive/active (transmitting),* ***8.*** *position stabilization feedback sensors (receiving),* ***9.*** *processor,* ***10.*** *LAN communication module,* ***11.*** *WAN communication module,* ***12.*** *power supply unit (battery),* ***13.*** *Rechargeable battery module,* ***14*** *GNSS unit (Galileo, GLONASS, GPS,...),* ***15.*** *mobile unit (phone, tablet, ...) to control and set the function,* ***16.*** *active/passive positioning sensor carrier fixed/implanted on the subject's head*

points by the antenna configuration of the transmission unit, which will thus enable its shaping, area sweeping and focusing on the target surface, both in 2D and 3D. On this basis, it shall be possible to identify further potential parallel or superordinate relationships between the areas of the visual cortex, and also to stimulate them or use even more complex images. Corresponding stimulations will be transmitted by the antennas. Phase-controlled antenna modules will be used here, which together with gyroscopic stabilization of position also enable precise direction of the signal. Stabilization of the position also has a series of active and passive sensors, which enable maintenance of emission of the antennas, also upon movement of the head in space.

An important component is the possibility of communication of the LAN and WAN modules with the controlling device (tablet or mobile telephone), and especially with the transmission of image information to the remote center with high-performance computer technology, which enables determination of the character of the scanned image and thus targeting of stimulation to the correct area of the brain. It is possible to assume that in the near future, parts of the process of determining the character of the scanned scene will probably be taken over by elements of artificial intelligence directly inside the camera. Figure.

The new method of stimulation is protected by the valid national patent no. 309083 (Unit for non-invasive stimulation of cells of the visual cortex in severe disorders of vision) and utility model no. 34195. In 2023 international patent no. EP4051195 was also granted for this type of stimulation.

CONCLUSION

Restoration of sight is a difficult but essential goal. It would lead to a dramatic improvement of the quality of life of the blind, as well as a pronounced alleviation of both the physical problems and financial burdens associated with loss of sight [24]. At the present time, the surgical risks outweigh the minimal benefits of invasive prostheses. By their very nature, large-scale neurosurgical procedures are dangerous and can lead to severe complications such as infection, inflammation, neurodegeneration and further neurological problems [46]. The presented patent for non-invasive transcranial stimulation of preserved cortical cells may contribute to a partial adjustment of the sight of blind or severely visually impaired persons.

REFERENCES

1. Lešták J. Neurotransmission in Visual Analyzer and Bionic Eye. A Review. Cesk Slov Oftalmol. 2021;77:55-59.
2. Lestak J, Chod J, Rosina J, Hana K. Visual neuroprosthesis: present and future perspectives. Biomed Pap Med Fac Univ Palacky Olomouc Czech Repub. 2022;166:251-257.
3. Foerster O. Contributions to the pathophysiology of the visual pathway and visual sphere. J Psychol Neurol. 1929;39:435-463.
4. Krause F, Schum H. Neue deutsche Chirurgie. Stuttgart, Germany: Enke.1931
5. Brindley GS, Lewin WS. The sensations produced by electrical stimulation of the visual cortex. J Physiol. 1968;196:479-493.
6. Dobelle WH, Mladejovsky MG. Phosphenes produced by electrical stimulation of human occipital cortex, and their application to the development of a prosthesis for the blind. J Physiol. 1974;243:553-557.
7. Schmidt EM, Bak MJ, Hambrecht FT, Kufta CV, O'Rourke DK, Vallabhanath P. Feasibility of a visual prosthesis for the blind based on intracortical microstimulation of the visual cortex. Brain. 1996;119:507-522.
8. Lewis PM, Rosenfeld JV. 2016. Electrical stimulation of the brain and the development of cortical visual prostheses: an historical perspective. Brain Res. 2016;1630:208-212.
9. Khodagholy D, Gelinas JN, Thesen T, et al. NeuroGrid: recording action potentials from the surface of the brain. Nat Neurosci. 2015;18:310-315.
10. Rousche PJ, and Normann RA. Chronic recording capability of the Utah Intracortical Electrode Array in cat sensory cortex. J Neurosci Methods. 1998;82:1-15.
11. Dobelle WH. Artificial vision for the blind by connecting a television camera to the visual cortex. ASAIO J. 2000;46:3-9.
12. Fernández E, Alfaro A, Soto-Sánchez C, et al. Visual percepts evoked with an intracortical 96-channel microelectrode array inserted in human occipital cortex. J Clin Invest. 2021;131(23):e151331. doi: 10.1172/JCI151331
13. Piedade M, Gerald J, Sousa LA, Tavares G, Tomas P. Visual neuroprosthesis: a non invasive system for stimulating the cortex. IEEE Transactions on Circuits and Systems I: Regular Papers. 2005;52:2648-2662.
14. Pouratian N. The visual cortical prosthesis system provided some functional vision to blind patients in a 12-month assessment of the device. Ophthalmology Times 2020;23, Available from: https://www. ophthalmologytimes.com/retina/prosthesis-system-may-help-blind-patients-see-again). [cited 2022 Apr]
15. Beauchamp MS, Oswalt D, Sun P, et al. D. Dynamic Stimulation of Visual Cortex Produces Form Vision in Sighted and Blind Humans. Cell. 2020;181:774-783.
16. Fernandez E, Alfaro A, and Gonzalez-Lopez P. Toward Long-Term Communication With the Brain in the Blind by Intracortical Stimulation: Challenges and Future Prospects. Front Neurosci. 2020;14:681. https://doi.org/10.3389/fnins.2020.00681
17. Strong SL, Silson EH, Gouws AD, Morland AB, McKeefry DJ. A Direct Demonstration of Functional Differences between Subdivisions of Human V5/MT. Cereb Cortex. 2017;27:1-10.
18. Sanada TM, Namima T, Komatsu H. Comparison of the color selectivity of macaque V4 neurons in different color spaces. J Neurophysiol. 2016;116:2163-2172.
19. Conway BR. The Organization and Operation of Inferior Tempora l Cortex. Annu Rev Vis Sci. 2018;15:381-402.
20. Gaglianese A, Costagli M, Bernardi G, RicciardiE., Pietrini P. Evidence of a direct influence between the thalamus and h.MT+ independent of V1 in the human brain as measured by fMRI. Neuroimage. 2012;60:1440-1447.
21. Ajina S, Bridge H. Subcortical pathways to extrastriate visual cortex underlie residual vision following bilateral damage to V1. Neuropsychologia. 2019;128:140-149.
22. Pezaris JS, Eskandar E. Getting signals into the brain: Visual prosthetics through thalamic microstimulation. Neurosurg Focus. 2009;27(1): E6.
23. Chen SC, Suaning GJ, Morley JW, et al. Simulating prosthetic vision: II. Measuring functional capacity. Vision Res. 2009;49:2329-2343.
24. Liu X, Chen P, Ding X, et al. A narrative review of cortical visual prosthesis systems: the latest progress and significance of nanotechnology for the future. Ann Transl Med. 2022 Jun;10(12):716. doi: 10.21037/atm-22-2858.
25. Bosking WH, Oswalt DN, Foster BL, Sun P, Beauchamp MS, Yoshor D. Percepts evoked by multi-electrode stimulation of human visual cortex. Brain Stimul. 2022;15:1163-1177.
26. de Ruyter van Steveninck J, Güçlü U, van Wezel R, van Gerven M. End-to-end optimization of prosthetic vision. J Vis. 2022;22:20. doi: 10.1167/jov.22.2.20
27. Legon W, Sato TF, Opitz A, et al. Transcranial focused ultrasound

modulates the activity of primary somatosensory cortex in humans. Nat Neurosci. 2014;17:322-329.
28. Lee W, Kim HC, Jung Y, et al. Transcranial focused ultrasound stimulation of human primary visual cortex. Sci Rep. 2016;6:34026. doi: 10.1038/srep34026
28. Lu G, Qian X, Castillo J, et al. Transcranial Focused Ultrasound for Noninvasive Neuromodulation of the Visual Cortex. IEEE Trans Ultrason Ferroelectr Freq Control. 2021;68:21-28.
30. Fregni F, Pascual-Leone A. Technology insight: noninvasive brain stimulation in neurology-perspectives on the therapeutic potential of rTMS and tDCS. Nat Clin Pract Neurol. 2007;3:383-393.
31. Williams JA, Imamura M, Fregni,F. Updates on the use of non-invasive brain stimulation in physical and rehabilitation medicine. J Rehabil Med. 2009;41:305-311.
32. Sabel BA, Cárdenas-Morales L, Gao Y. Vision Restoration in Glaucoma by Activating Residual Vision with a Holistic, Clinical Approach: A Review. J Curr Glaucoma Pract. 2018;12:1-9.
33. Cicmil N, Krug K. Playing the electric light orchestra-how electrical stimulation of visual cortex elucidates the neural basis of perception. Philos Trans R Soc Lond B Biol Sci. 2015;370:20140206.
34. Cohen MR, Newsome WT. What electrical microstimulation has revealed about the neural basis of cognition. Curr Opin Neurobiol. 2004;14:169-177.
35. Histed MH, Ni AM, Maunsell JH. Insights into cortical mechanisms of behavior from microstimulation experiments. Prog. Neurobiol. 2013;103:115-130.
36. Lešták J, Tintěra J, Kynčl M, Svatá Z, Obenberger J, Saifrtová A. Changes in the Visual Cortex in Patients with High-Tension Glaucoma. J Clinic Exp Ophthalmol. 2011; S4 doi: 10.4172/2155-9570.S4-002
37. Saifrtová A, Lešták J, Tintěra J, et al. Colour vision defect in patients with high-tension glaucoma. J Clin Exp Ophthalmol. 2012;3:9 http://dx.doi.org/10.4172/2155-9570.1000252
38. Lestak J, Tintera J, Karel I, Svata Z, Rozsival P. FMRI in Patients with Wet Form of Age-Related Macular Degeneration. Neuro-Ophthalmology. 2013;37:192-197.
39. Lešták J, Tintěra J. Funkční magnetická rezonance u vybraných očních onemocnění [Functional Magnetic Resonance Imaging in Selected Eye Diseases]. Cesk Slov Oftalmol. 2015;71:127-133. Czech.
40. Lestak J, Kyncl M, Tintera J. Bionic Eye and Retinitis Pigmentosa. Biomed J Sci & Tech Res. 2019;19:14347-14348.
41. Lestak J, Fus M. Neuroprotection in glaucoma – a review of electrophysiologist. Exp Ther Med. 2020;19:2401-2405.
42. Luan S, Williams I, Nikolic K, Constandinou TG. Neuromodulation: present and emerging methods. Front Neuroeng 2014;7:27. doi: 10.3389/fneng.2014.00027
43. Vrba J. Lékařské aplikace mikrovlnné techniky. Vyd. 1. V Praze: Nakladatelství ČVUT, 2007, dotisk. 168 s. ISBN 978-80-01-02705-9 ú.
44. Boonzaier J, van Tilborg GAF, Neggers SFW, Dijkhuizen RM. Noninvasive Brain Stimulation to Enhance Functional Recovery After Stroke: Studies in Animal Models. Neurorehabil Neural Repair 2018;32:927-940. doi: 10.1177/1545968318804425
45. Zheng KY, Da GY, Lan Y, Wang XQ. Trends of Repetitive Transcranial Magnetic Stimulation From 2009 to 2018: A Bibliometric Analysis. Front Neurosci 2020;14:106. doi: 10.3389/fnins.202
46. Ortiz-Rios M, Agayby B, Balezeau F, et al. Optogenetic stimulation of primate V1 reveals local laminar and large-scale cortical networks related to perceptual phosphenes. bioRxiv. 2021. doi:10.1101/2021.06.01.446505