Neuromodulation techniques: A synoptic overview

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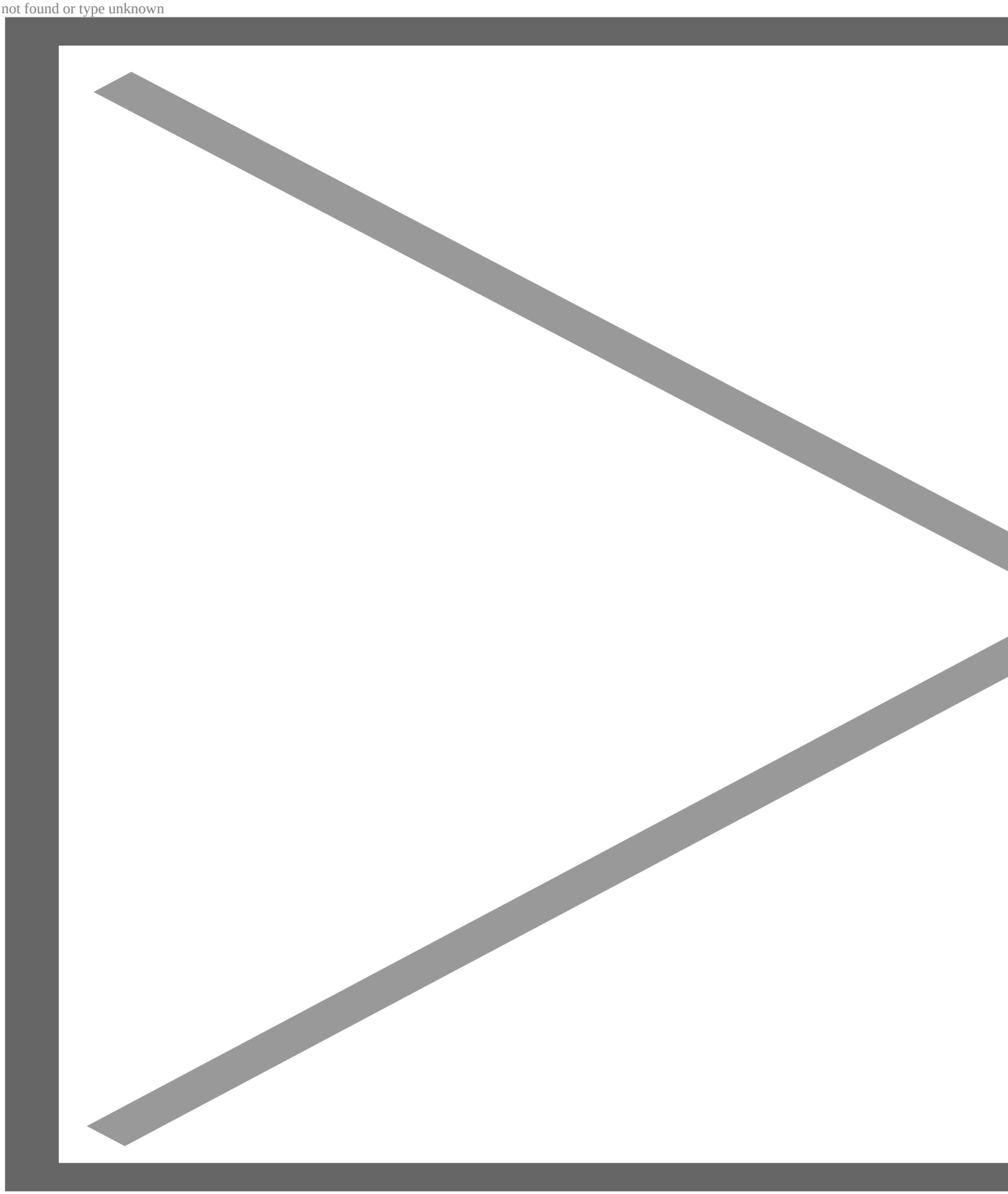

Peter, N., & Kleinjung, T.. (2019). Neuromodulation for tinnitus treatment: an overview of invasive and non-invasive techniques. Journal of Zhejiang University: Science B

Plain numerical DOI: 10.1631/jzus.B1700117
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“Tinnitus is defined as a perception of sound without any external sound source. chronic tinnitus is a frequent condition that can affect the quality of life. so far, no causal cure for tinnitus has been documented, and most pharmacologic and psychosomatic treatment modalities aim to diminish tinnitus’ impact on the quality of life. neuromodulation, a novel therapeutic modality, which aims at alternating nerve activity through a targeted delivery of a stimulus, has emerged as a potential option in tinnitus treatment. this review provides a brief overview of the current neuromodulation techniques as tinnitus treatment options. the main intention is to provide updated knowledge especially for medical professionals counselling tinnitus patients in this emerging field of medicine. non-invasive methods such as repetitive transcranial magnetic stimulation, transcranial electrical stimulation, neurofeedback, and transcutaneous vagus nerve stimulation were included, as well as invasive methods such as implanted vagus nerve stimulation and invasive brain stimulation. some of these neuromodulation techniques revealed promising results; nevertheless, further research is needed, especially regarding the pathophysiological principle as to how these neuromodulation techniques work and what neuronal change they induce. various studies suggest that individually different brain states and networks are involved in the generation and perception of tinnitus. therefore, in the future, individually tailored neuromodulation strategies could be a promising approach in tinnitus treatment for achieving a more substantial and longer lasting improvement of complaints.”

Fomenko, A., Neudorfer, C., Dallapiazza, R. F., Kalia, S. K., & Lozano, A. M.. (2018). Low-intensity ultrasound neuromodulation: An overview of mechanisms and emerging human applications. Brain Stimulation

Plain numerical DOI: 10.1016/j.brs.2018.08.013
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“Background: there is an emerging need for noninvasive neuromodulation techniques to improve patient outcomes while minimizing adverse events and morbidity. low-intensity focused ultrasound (lifus) is gaining traction as a non-surgical experimental approach of modulating brain activity. several lifus sonication parameters have been found to potentiate neural firing, suppress cortical and epileptic discharges, and alter behavior when delivered to cortical and subcortical mammalian brain regions. objective: this review introduces the elements of an effective sonication protocol and summarizes key preclinical studies on lifus as a neuromodulation modality. the state of the art in human ultrasound neuromodulation is then comprehensively summarized, and current hypotheses regarding the underlying mechanism of action on neural activity are presented. methods: peer-reviewed literature on human ultrasound neuromodulation was obtained by searching several electronic databases. the abstracts of all reports were read and publications which examined low-intensity transcranial

ultrasound applied to human subjects were selected for review. results: lifus can noninvasively influence human brain activity by suppressing cortical evoked potentials, influencing cortical oscillatory dynamics, and altering outcomes of sensory/motor tasks compared to sham sonication. proposed mechanisms include cavitation, direct effects on neural ion channels, and plasma membrane deformation. conclusions: though optimal sonication paradigms and transcranial delivery methods are still being established, future applications may include non-invasive human brain mapping experiments, and nonsurgical treatments for functional neurological disorders."
Brock, D. G., & Demitrack, M. A.. (2014). Therapeutic neuromodulation: Overview of a novel treatment platform. Psychiatric Annals

Plain numerical DOI: 10.3928/00485713-20140609-04
DOI URL
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"There is an increasing interest in the development of novel nonpharmacological options for the treatment of major psychiatric illnesses, especially major depressive disorder. this is understandable, given that a majority of patients with major depression experience difficulty achieving disease remission with currently available treatments. therapeutic neuromodulation defnes a group of technologies that effect changes in the brain by exploiting both (1) the electrochemical nature of neurons, and (2) that the pathophysiology of psychiatric diseases, including depression, can be described as a disruption in the functional connections of neuronal networks. these emerging treatment options include technologies cleared by the u.s. food and drug administration-electroconvulsive therapy (ect), transcranial magnetic stimulation (tms), and vagus nerve stimulation (vns)-as well several experimental methods. this article provides a general overview for understanding these various technologies and places them within a framework to help differentiate the mechanisms by which they influence the behavior of neurons. © slack incorporated."
Gunduz, A., & Ruffini, G.. (2018). Editorial overview: Neuromodulation. Current Opinion in Biomedical Engineering

Plain numerical DOI: 10.1016/j.cobme.2018.12.001
DOI URL
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Pathak, Y. J., Greenleaf, W., Verhagen Metman, L., Kubben, P., Sarma, S., Pepin, B., … Ross, E.. (2021). Digital Health Integration With Neuromodulation Therapies: The Future of Patient-Centric Innovation in Neuromodulation. Frontiers in Digital Health

Plain numerical DOI: 10.3389/fdgth.2021.618959
DOI URL
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"Digital health can drive patient-centric innovation in neuromodulation by leveraging current tools to identify response predictors and digital biomarkers. iterative technological evolution has led us to an

ideal point to integrate digital health with neuromodulation. here, we provide an overview of the digital health building-blocks, the status of advanced neuromodulation technologies, and future applications for neuromodulation with digital health integration."
Velasco, F.. (2000). Neuromodulation: An overview. Archives of Medical Research

Plain numerical DOI: 10.1016/S0188-4409(00)00063-1
DOI URL
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"For over two centuries, electricity has been known to induce modification of neural and nerve fiber activity and has been proposed to be used to treat some neurological dysfunctions. the new era of the use of electrical current in the treatment of neurological symptoms began in 1967 with the use of totally implanted devices that deliver a controlled amount of electricity on a precise structure within the nervous systems and was first used to control pain. extensive research has been carried out ever since to elucidate the mechanism of action of this treatment and extend its indication for the treatment of the other neurological symptoms. so far, there is evidence that the treatment is safe and efficient for long periods of time, as it does not induce permanent damage to the stimulated structure. most likely, electrical current at the parameters used for therapeutic purpose induces an inhibition of the structure on which it is applied. however, this may be accompanied by either inhibition or excitation of anatomically related structures. for this reason, it seems more convenient to refer to this type of therapy as neuromodulation.a review of the historical development of this fascinating area is presented, with special attention to the evidence derived from experimental work on the parameters that electrical current must maintain to avoid damage to the underlying tissue. copyright (c) 2000 imss."
Tanagho, E. A.. (2012). Neuromodulation and neurostimulation: Overview and future potential. Translational Andrology and Urology

Plain numerical DOI: 10.3978/j.issn.2223-4683.2012.01.01
DOI URL
directSciHub download

Kulkarni, S., & Kothari, S.. (2020). Pediatric Movement Disorders and Neuromodulation: An Overview. In Neurology India

Plain numerical DOI: 10.4103/0028-3886.302474
DOI URL
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"Pediatric movement disorders are heterogeneous and complex disorders with various aetiologies. these are broadly classified as hypo and hyperkinetic disorders. genetic causes of basal ganglia dysfunction or direct injuries to the basal ganglia mark the genesis of these abnormal movements. the management of pediatric movement disorders is multidisciplinary with pharmacotherapy as the first line of management along with physical therapy. patients resistant to medications are candidates for invasive neuromodulation which is an upcoming treatment modality in pediatric movement disorders.

deep brain stimulation of basal ganglia and thalamic nuclei are associated with promising symptomatic benefit with reduction in disability and improvement in quality of life of these children. in this article, we have reviewed the management of pediatric movement disorders with emphasis on neuromodulation i.e., deep brain stimulation."
Roy, H., Offiah, I., & Dua, A.. (2018). Neuromodulation for pelvic and urogenital pain. Brain Sciences

Plain numerical DOI: 10.3390/brainsci8100180
DOI URL
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"Chronic pain affecting the pelvic and urogenital area is a major clinical problem with heterogeneous etiology, affecting both male and female patients and severely compromising quality of life. in cases where pharmacotherapy is ineffective, neuromodulation is proving to be a potential avenue to enhance analgesic outcomes. however, clinicians who frequently see patients with pelvic pain are not traditionally trained in a range of neuromodulation techniques. the aim of this overview is to describe major types of pelvic and urogenital pain syndromes and the neuromodulation approaches that have been trialed, including peripheral nerve stimulation, dorsal root ganglion stimulation, spinal cord stimulation, and brain stimulation techniques. our conclusion is that neuromodulation, particularly of the peripheral nerves, may provide benefits for patients with pelvic pain. however, larger prospective randomized studies with carefully selected patient groups are required to establish efficacy and determine which patients are likely to achieve the best outcomes."
N., P., & T., K.. (2019). Neuromodulation for tinnitus treatment: an overview of invasive and non-invasive techniques. Journal of Zhejiang University: Science B

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"Tinnitus is defined as a perception of sound without any external sound source. chronic tinnitus is a frequent condition that can affect the quality of life. so far, no causal cure for tinnitus has been documented, and most pharmacologic and psychosomatic treatment modalities aim to diminish tinnitus' impact on the quality of life. neuromodulation, a novel therapeutic modality, which aims at alternating nerve activity through a targeted delivery of a stimulus, has emerged as a potential option in tinnitus treatment. this review provides a brief overview of the current neuromodulation techniques as tinnitus treatment options. the main intention is to provide updated knowledge especially for medical professionals counselling tinnitus patients in this emerging field of medicine. non-invasive methods such as repetitive transcranial magnetic stimulation, transcranial electrical stimulation, neurofeedback, and transcutaneous vagus nerve stimulation were included, as well as invasive methods such as implanted vagus nerve stimulation and invasive brain stimulation. some of these neuromodulation techniques revealed promising results; nevertheless, further research is needed, especially regarding the pathophysiological principle as to how these neuromodulation techniques work and what neuronal change they induce. various studies suggest that individually different brain states and networks are involved in the generation and perception of tinnitus. therefore, in the future, individually tailored neuromodulation strategies could be a promising approach in tinnitus treatment for achieving a more substantial and longer lasting improvement of complaints."
McCormick, D. A., & Nusbaum, M. P.. (2014). Editorial overview: Neuromodulation: Tuning the properties of neurons, networks and behavior

. Current Opinion in Neurobiology

Plain numerical DOI: 10.1016/j.conb.2014.10.010
DOI URL
directSciHub download

Yu, K., Niu, X., & He, B.. (2020). Neuromodulation Management of Chronic Neuropathic Pain in the Central Nervous System. Advanced Functional Materials

Plain numerical DOI: 10.1002/adfm.201908999
DOI URL
directSciHub download

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“Neuromodulation is a clinical tool used for treating chronic neuropathic pain by transmitting controlled physical energy to the pre-identified neural targets in the central nervous system. its drug-free, nonaddictive, and improved targeting characteristics have attracted increasing attention among neuroscience research and clinical practices. this article provides a brief overview of the neuropathic pain and pharmacological routines for treatment, summarizes both the invasive and noninvasive neuromodulation modalities for pain management, and highlights an emerging brain stimulation technology, transcranial focused ultrasound (tfus), with a focus on ultrasound transducer devices and the achieved neuromodulation effects and applications on pain management. practical considerations of spatial guidance for tfus are discussed for clinical applications. the safety of transcranial ultrasound neuromodulation and its future prospectives on pain management are also discussed.”
(2019). An overview on Neuromodulation. Case Medical Research

Plain numerical DOI: 10.31525/cmr-fbd972
DOI URL
directSciHub download

Vanneste, S., & De Ridder, D.. (2012). Noninvasive and invasive neuromodulation for the treatment of tinnitus: An overview. Neuromodulation

Plain numerical DOI: 10.1111/j.1525-1403.2012.00447.x
DOI URL
directSciHub download

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“Objective: nonpulsatile tinnitus is an auditory phantom percept characterized as a tone, or a noise-like sound such as a hissing or buzzing sound or polyphonic, in the absence of any objective physical sound source. although advances have been made in symptomatic pharmacologic and nonpharmacologic treatments, these treatments are unable to eliminate the tinnitus sensation in most patients. a novel approach using noninvasive and invasive neuromodulation has emerged as an interesting and promising modality for tinnitus relief. methodology: we review noninvasive neuromodulation techniques including transcranial magnetic stimulation, transcranial direct current

stimulation, transcutaneous electrical nerve stimulation, and cortical neurofeedback, as well as invasive neuromodulation techniques including auditory cortex stimulation, dorsolateral prefrontal cortex stimulation, subcutaneous occipital nerve stimulation, and deep brain stimulation, as potential treatments of tinnitus. conclusion: although the different techniques introduced revealed promising results, further research is needed to better understand how these techniques work and how the brain responds to neuromodulation. more sophisticated stimulation regimens and parameters should be developed to dynamically stimulate various regions at different frequencies and intensities, physiologically tailored to the patient's brain state in an attempt to maximize efficacy. © 2012 international neuromodulation society."
Waldron, N. H., Fudim, M., Mathew, J. P., & Piccini, J. P.. (2019). Neuromodulation for the Treatment of Heart Rhythm Disorders. JACC: Basic to Translational Science

Plain numerical DOI: 10.1016/j.jacbts.2019.02.009
DOI URL
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"There is an increasing recognition of the importance of interactions between the heart and the autonomic nervous system in the pathophysiology of arrhythmias. these interactions play a role in both the initiation and maintenance of arrhythmias and are important in both atrial and ventricular arrhythmia. given the importance of the autonomic nervous system in the pathophysiology of arrhythmias, there has been notable effort in the field to improve existing therapies and pioneer additional interventions directed at cardiac-autonomic targets. the interventions are targeted to multiple and different anatomic targets across the neurocardiac axis. the purpose of this review is to provide an overview of the rationale for neuromodulation in the treatment of arrhythmias and to review the specific treatments under evaluation and development for the treatment of both atrial fibrillation and ventricular arrhythmias."
Luigjes, J., Breteler, R., Vanneste, S., & de Ridder, D.. (2013). [Neuromodulation as an intervention for addiction: overview and future prospects].. Tijdschrift Voor Psychiatrie

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"BACKGROUND in recent years several neuromodulation techniques have been introduced as interventions for addiction. aim to review and discuss studies that have investigated the effects of treating addiction by means of electroencephalography (eeg) neurofeedback, real-time functional magnetic resonance imaging (rt-fmri) neurofeedback, transcranial magnetic stimulation/transcranial direct current stimulation (tms/tdcs) and deep brain stimulation (dbs). method we reviewed the literature, focusing on dutch studies in particular. results studies using eeg neurofeedback were shown to have positive effects on drug use, treatment compliance, and cue reactivity in patients with cocaine and alcohol dependence. a pilot study investigating the effects of rt-fmri neurofeedback on nicotine dependent patients showed that modulation of the anterior cingulate cortex can decrease smokers' craving for nicotine. in several studies decreased craving was found in alcohol dependent patients after tms or tdcs stimulation of the anterior cingulate cortex or the dorsolateral prefrontal cortex. the first dbs pilot studies suggest that the nucleus accumbens is a promising target region for the treatment of alcohol and heroin dependence. conclusion neuromodulation provides us with a unique opportunity to directly apply neuroscientific knowledge to the treatment of addiction. however, more research is

needed to ensure the efficacy, safety and feasibility of the various neuromodulation techniques that are now available."
Brunoni, A. R., Teng, C. T., Correa, C., Imamura, M., Brasil-Neto, J. P., Boechat, R., … Fregni, F.. (2010). Neuromodulation approaches for the treatment of major depression: Challenges and recommendations from a working group meeting. Arquivos de Neuro-Psiquiatria

Plain numerical DOI: 10.1590/s0004-282×2010000300021
DOI URL
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"The use of neuromodulation as a treatment for major depressive disorder (mdd) has recently attracted renewed interest due to development of other non-pharmacological therapies besides electroconvulsive therapy (ect) such as transcranial magnetic stimulation (tms), transcranial direct current stimulation (tdcs), deep brain stimulation (dbs), and vagus nerve stimulation (vns). method: we convened a working group of researchers to discuss the updates and key challenges of neuromodulation use for the treatment of mdd. results: the state-of-art of neuromodulation techniques was reviewed and discussed in four sections: [1] epidemiology and pathophysiology of mdd; [2] a comprehensive overview of the neuromodulation techniques; [3] using neuromodulation techniques in mdd associated with non-psychiatric conditions; [4] the main challenges of neuromodulation research and alternatives to overcome them. discussion: ect is the first-line treatment for severe depression. tms and tdcs are strategies with a relative benign profile of side effects; however, while tms effects are comparable to antidepressant drugs for treating mdd; further research is needed to establish the role of tdcs. dbs and vns are invasive strategies with a possible role in treatment-resistant depression. in summary, mdd is a chronic and incapacitating condition with a high prevalence; therefore clinicians should consider all the treatment options including invasive and non-invasive neuromodulation approaches."
Antony, A. B., Mazzola, A. J., Dhaliwal, G. S., & Hunter, C. W.. (2019). Neurostimulation for the treatment of chronic head and facial pain: A literature review. Pain Physician

Plain numerical DOI: 10.36076/ppj/2019.22.447
DOI URL
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"Background: head and facial pain is a common and often difficult to treat disorder. routine treatments sometimes fail to provide acceptable relief, leaving the patient searching for something else, including narcotics and surgery. recently, neuromodulation has been expanding to provide another option. secondary to its potentially temporary nature and relatively manageable risk profile, several reviews have suggested trialing neuromodulation prior to starting narcotics or invasive permanent surgeries. there is evidence that neuromodulation can make a difference in those patients with intractable severe craniofacial pain. objectives: to provide a basic overview of the anatomy, epidemiology, pathophysiology and common treatments of several common head and facial disorders. furthermore, to demonstrate the suggested mechanisms of neuromodulation and the evidence currently existing for the use of neuromodulation. methods: a comprehensive review was performed regarding the available

literature through targeting articles reporting on the use of neuromodulation to treat pain of the head and face. results: we compiled and discuss the current evidence available in treating head and facial pain. the strongest evidence currently for neuromodulation is for occipital nerve stimulation for migraine, transcutaneous vagal nerve stimulation for migraine and cluster headache, sphenopalatine ganglion microstimulation for cluster headache, and transcutaneous supraorbital and supratrochlear nerve stimulation for migraine. in addition, there is moderate evidence for occipital nerve stimulation in treating occipital neuralgia. limitations: neuromodulation has been trialed and is promising in several craniofacial pain disorders; however, there remains a need for large-scale, randomized, placebo-controlled clinical trials to further evaluate the efficacy and safety of most treatments. much of the current data relies on case reports without randomization or placebo controls. conclusions: with advancing techniques and technology, neuromodulation can be promising in treating intractable pain of the head and face. although more randomized controlled trials are warranted, the current literature supports the use of neuromodulation in intractable craniofacial pain."
Schluter, R. S., Daams, J. G., Van Holst, R. J., & Goudriaan, A. E.. (2018). Effects of non-invasive neuromodulation on executive and other cognitive functions in addictive disorders: A systematic review . Frontiers in Neuroscience

Plain numerical DOI: 10.3389/fnins.2018.00642
DOI URL
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"Background: in order to improve the current treatment of addictive disorders non-invasive neuromodulation over the dorsolateral prefrontal cortex (dlpfc) has gained attention. the dlpfc is crucially involved in executive functioning, functions which are related to the course of addictive disorders. non-invasive stimulation of the dlpfc may lead to changes in executive functioning. currently an overview of effects of neuromodulation on these functions is lacking. therefore, this systematic review addresses the effects of non-invasive neuromodulation on executive functioning in addictive disorders. methods: the current review is conducted and reported in accordance with the preferred reporting items for systematic reviews and meta-analyses for protocols 2015 (prisma-p 2015) guidelines and has been registered in prospero international prospective register of systematic reviews (www.crd.york.ac.uk/prospero/, registration number: crd42018084157). original articles were searched using the ovid medline, embase and psycinfo database. results: the systematic search resulted in 1,228 unique studies, of which sixteen were included in the current review. some of these studies do not address the classic definition of executive functions, but another cognitive function. however, they were included in this review since the field is small and still under development and we aim to give an inclusive overview in its broadest sense. the following executive and other cognitive functioning domains were assessed: attention, cognitive flexibility, response inhibition, memory and learning, problem solving, social cognition, risk taking, cognitive bias modification and overall executive functioning. the executive function domain most positively affected was social cognition followed by memory & learning, response inhibition, cognitive flexibility and attention. conclusions: the studies addressed in the current review used a large variability of stimulation protocols and study designs which complicates comparability of the results. nevertheless, the results of these studies are promising in light of improvement of current treatment. therefore, we recommend future studies that compare the effect of different types of stimulation, stimulation sides and number of stimulation sessions in larger clinical trials. this will significantly increase the comparability of the studies and thereby accelerate and

clarify the conclusion on whether non-invasive neuromodulation is an effec…"
Hunter, C. W., Stovall, B., Chen, G., Carlson, J., & Levy, R.. (2018). Anatomy, pathophysiology and interventional therapies for chronic pelvic pain: A review. Pain Physician

Plain numerical DOI: 10.36076/ppj.2018.2.147
DOI URL
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"Background: chronic pelvic pain (cpp) represents a group of poorly understood disorders that are often refractory to conventional treatment. referral to pain management typically occurs later in the continuum of care; as such, many of the injections and nerve blocks commonly prescribed for such patients are potentially limited in efficacy. while neuromodulation is conventionally considered the next algorithmic step in the treatment of chronic pain after injections fail, there is a common perception that neuromodulation is largely ineffective for cpp conditions. however, there is evidence that suggests neuromodulation may in fact be a viable treatment option for this particular patient population when utilized properly. objectives: to provide a basic overview of the pathophysiology of cpp and the relevant neuroanatomy as it pertains to various available treatment options, as well as the techniques and potential targets for neuromodulation. study design: literature review. setting: private practice, academic and hospital setting. methods: a comprehensive review of the available literature was performed targeting publications focused on cpp and various techniques for utilizing neuromodulation to treat it. results: neuromodulation is an established treatment modalities, however its usefulness as it relates to treating cpp has typically been drawn into question. in this literature review, we discuss the efficacy of various techniques for treating cpp with neuromodulation. limitations: evidence to support the various treatments, while encouraging, is based on small studies and case series. large-scale randomized, placebo-controlled clinical trials are warranted to evaluate the clinical efficacy and safety of the different treatments described, particularly neuromodulation. conclusions: in addition to the percutaneous, injection-based treatments described herein, neuromodulation remains a plausible option for recalcitrant cases that fail to respond to more conventional means."
Powell, K., Shah, K., Hao, C., Wu, Y.-C., John, A., Narayan, R. K., & Li, C.. (2019). Neuromodulation as a new avenue for resuscitation in hemorrhagic shock. Bioelectronic Medicine

Plain numerical DOI: 10.1186/s42234-019-0033-z
DOI URL
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"Hemorrhagic shock (hs), a major cause of early death from trauma, accounts for around 40% of mortality, with 33–56% of these deaths occurring before the patient reaches a medical facility. intravenous fluid therapy and blood transfusions are the cornerstone of treating hs. however, these options may not be available soon after the injury, resulting in death or a poorer quality of survival. therefore, new strategies are needed to manage hs patients before they can receive definitive care. recently, various forms of neuromodulation have been investigated as possible supplementary treatments for hs in the prehospital phase of care. here, we provide an overview of neuromodulation methods that show promise to treat hs, such as vagus nerve stimulation, electroacupuncture,

trigeminal nerve stimulation, and phrenic nerve stimulation and outline their possible mechanisms in the treatment of hs. although all of these approaches are only validated in the preclinical models of hs and are yet to be translated to clinical settings, they clearly represent a paradigm shift in the way that this deadly condition is managed in the future."
Fletcher, N.. (2020). An overview of sacral neuromodulation: A treatment for patients with symptoms of lower urinary tract dysfunction. British Journal of Nursing

Plain numerical DOI: 10.12968/bjon.2020.29.15.848
DOI URL
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"This article provides an introduction to patient selection for, and the processes involved in, sacral neuromodulation (snm) device implantation as a treatment for urinary symptoms. snm has been an option to treat lower urinary tract dysfunction for more than 20 years and is a treatment for both overactive bladder syndrome (oab) and female non obstructed chronic urinary retention (fcur). it is recognised by the national institute for health and care excellence as a therapeutic option for oab and fcur. snm has its place in the pathway for the treatment of both conditions and, in the correctly assessed patient, can be the last option before considering major surgical intervention."
Shin, S. S., & Pelled, G.. (2017). Novel neuromodulation techniques to assess interhemispheric communication in neural injury and neurodegenerative diseases. Frontiers in Neural Circuits

Plain numerical DOI: 10.3389/fncir.2017.00015
DOI URL
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"Interhemispheric interaction has a major role in various neurobehavioral functions. its disruption is a major contributor to the pathological changes in the setting of brain injury such as traumatic brain injury, peripheral nerve injury, and stroke, as well as neurodegenerative diseases. because interhemispheric interaction has a crucial role in functional consequence in these neuropathological states, a review of noninvasive and state-of-the-art molecular based neuromodulation methods that focus on or have the potential to elucidate interhemispheric interaction have been performed. this yielded approximately 170 relevant articles on human subjects or animal models. there has been a recent surge of reports on noninvasive methods such as transcranial magnetic stimulation and transcranial direct current stimulation. since these are noninvasive techniques with little to no side effects, their widespread use in clinical studies can be easily justified. the overview of novel neuromodulation methods and how they can be applied to study the role of interhemispheric communication in neural injury and neurodegenerative disease is provided. additionally, the potential of each method in therapeutic use as well as investigating the pathophysiology of interhemispheric interaction in neurodegenerative diseases and brain injury is discussed. new technologies such as transcranial magnetic stimulation or transcranial direct current stimulation could have a great impact in understanding interhemispheric pathophysiology associated with acquired injury and neurodegenerative diseases, as well as designing improved rehabilitation therapies. also, advances in molecular based neuromodulation techniques such as optogenetics and other chemical, thermal, and

magnetic based methods provide new capabilities to stimulate or inhibit a specific brain location and a specific neuronal population."
Abboud, H., Hill, E., Siddiqui, J., Serra, A., & Walter, B.. (2017). Neuromodulation in multiple sclerosis. Multiple Sclerosis

Plain numerical DOI: 10.1177/1352458517736150
DOI URL
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"Neuromodulation, or the utilization of advanced technology for targeted electrical or chemical neuronal stimulation or inhibition, has been expanding in several neurological subspecialties. in the past decades, immune-modulating therapy has been the main focus of multiple sclerosis (ms) research with little attention to neuromodulation. however, with the recent advances in disease-modifying therapies, it is time to shift the focus of ms research to neuromodulation and restoration of function as with other neurological subspecialties. preliminary research supports the value of intrathecal baclofen pump and functional electrical stimulation in improving spasticity and motor function in ms patients. deep brain stimulation can improve ms-related tremor and trigeminal neuralgia. spinal cord stimulation has been shown to be effective against ms-related pain and bladder dysfunction. bladder overactivity also responds to sacral neuromodulation and posterior tibial nerve stimulation. despite limited data in ms, transcranial magnetic stimulation and brain–computer interface are promising neuromodulatory techniques for symptom mitigation and neurorehabilitation of ms patients. in this review, we provide an overview of the available neuromodulatory techniques and the evidence for their use in ms."
Tohyama, S., Walker, M. R., Sammartino, F., Krishna, V., & Hodaie, M.. (2020). The Utility of Diffusion Tensor Imaging in Neuromodulation: Moving Beyond Conventional Magnetic Resonance Imaging. Neuromodulation

Plain numerical DOI: 10.1111/ner.13107
DOI URL
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"Objectives: conventional targeting methods for neuromodulation therapies are insufficient for visualizing targets along white matter pathways and localizing targets in patient-specific space. diffusion tensor imaging (dti) holds promise for enhancing neuromodulation targeting by allowing detailed visualization of white matter tracts and their connections on an individual level. material and methods: we review the literature on dti and neuromodulation, focusing on clinical studies that have utilized dti tractography for surgical neuromodulation planning. this primarily includes the growing number of studies on tractography-guided targeting in deep brain stimulation as well as magnetic resonance-guided focused ultrasound. results: in this review, we discuss three main topics: 1) an overview of the basic principles of dti, its metrics, and tractography, 2) the evolution and utility of dti to better guide neuromodulation targets, and 3) the ability of dti to investigate structural connectivity and brain networks, and how such a network perspective may be an integral part of identifying new or optimal neuromodulation targets. conclusion: there is increasing evidence that dti is superior to conventional targeting methods with respect to improving brain stimulation therapies. dti has the ability

to better define anatomical targets by allowing detailed visualization of white matter tracts and localizing targets based on individual anatomy. network analyses can lead to the identification of new or optimal stimulation targets based on understanding how target regions are connected. the integration of dti as part of routine mri and surgical planning offers a more personalized approach to therapy and may be an important path for the future of neuromodulation."
Lakatos, P., Gross, J., & Thut, G.. (2019). A New Unifying Account of the Roles of Neuronal Entrainment. Current Biology

Plain numerical DOI: 10.1016/j.cub.2019.07.075
DOI URL
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"Rhythms are a fundamental and defining feature of neuronal activity in animals including humans. this rhythmic brain activity interacts in complex ways with rhythms in the internal and external environment through the phenomenon of 'neuronal entrainment', which is attracting increasing attention due to its suggested role in a multitude of sensory and cognitive processes. some senses, such as touch and vision, sample the environment rhythmically, while others, like audition, are faced with mostly rhythmic inputs. entrainment couples rhythmic brain activity to external and internal rhythmic events, serving fine-grained routing and modulation of external and internal signals across multiple spatial and temporal hierarchies. this interaction between a brain and its environment can be experimentally investigated and even modified by rhythmic sensory stimuli or invasive and non-invasive neuromodulation techniques. we provide a comprehensive overview of the topic and propose a theoretical framework of how neuronal entrainment dynamically structures information from incoming neuronal, bodily and environmental sources. we discuss the different types of neuronal entrainment, the conceptual advances in the field, and converging evidence for general principles. lakatos, gross, and thut review the evidence for neuronal entrainment by environmental, self-produced, and neuromodulatory rhythms, which leads them to propose a new, unifying account of the role of neuronal entrainment in the selection and structuring of information – taking into account the brain in a wider context."
Vlaicu, A., & Bustuchina Vlaicu, M.. (2020). New neuromodulation techniques for treatment resistant depression. International Journal of Psychiatry in Clinical Practice

Plain numerical DOI: 10.1080/13651501.2020.1728340
DOI URL
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"In the treatment of depression, when pharmacotherapy, psychotherapy and the oldest brain stimulation techniques are deadlocked, the emergence of new therapies is a necessary development. the field of neuromodulation is very broad and controversial. this article provides an overview of current progress in the technological advances in neuromodulation and neurostimulation treatments for treatment-resistant depression: magnetic seizure therapy; focal electrically administered seizure therapy; low field magnetic stimulation; transcranial pulsed electromagnetic fields; transcranial direct current stimulation; epidural cortical stimulation; trigeminal nerve stimulation; transcutaneous vagus nerve stimulation; transcranial focussed ultrasound; near infra-red transcranial radiation; closed loop

stimulation. the role of new interventions is expanding, probably with more efficacy. nowadays, still under experimentation, neuromodulation will probably revolutionise the field of neuroscience. at present, major efforts are still necessary before that these therapies are likely to become widespread.key points there is a critical need for new therapies for treatment resistant depression. newer therapies are expanding. in the future, these therapies, as an evidence-based adjunctive treatments, could offer a good therapeutic choice for the patients with a trd. the current trend in the new neuromodulation therapies is to apply a personalised treatment. these news therapies can be complementary. that treatment approaches can provide clinically significant benefits."
Yang, X., McGlynn, E., Das, R., Pa?ca, S. P., Cui, B., & Heidari, H.. (2021). Nanotechnology Enables Novel Modalities for Neuromodulation. Advanced Materials

Plain numerical DOI: 10.1002/adma.202103208
DOI URL
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"Neuromodulation is of great importance both as a fundamental neuroscience research tool for analyzing and understanding the brain function, and as a therapeutic avenue for treating brain disorders. here, an overview of conceptual and technical progress in developing neuromodulation strategies is provided, and it is suggested that recent advances in nanotechnology are enabling novel neuromodulation modalities with less invasiveness, improved biointerfaces, deeper penetration, and higher spatiotemporal precision. the use of nanotechnology and the employment of versatile nanomaterials and nanoscale devices with tailored physical properties have led to considerable research progress. to conclude, an outlook discussing current challenges and future directions for next-generation neuromodulation modalities is presented."
Ramirez-Zamora, A., Giordano, J. J., Gunduz, A., Brown, P., Sanchez, J. C., Foote, K. D., … Okun, M. S.. (2018). Evolving applications, technological challenges and future opportunities in neuromodulation: Proceedings of the fifth annual deep brain stimulation think tank. Frontiers in Neuroscience

Plain numerical DOI: 10.3389/fnins.2017.00734
DOI URL
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"The annual deep brain stimulation (dbs) think tank provides a focal opportunity for a multidisciplinary ensemble of experts in the field of neuromodulation to discuss advancements and forthcoming opportunities and challenges in the field. the proceedings of the fifth think tank summarize progress in neuromodulation neurotechnology and techniques for the treatment of a range of neuropsychiatric conditions including parkinson's disease, dystonia, essential tremor, tourette syndrome, obsessive compulsive disorder, epilepsy and cognitive, and motor disorders. each section of this overview of the meeting provides insight to the critical elements of discussion, current challenges, and identified future directions of scientific and technological development and application. the report addresses key issues in developing, and emphasizes major innovations that have occurred during the past year. specifically, this year's meeting focused on technical developments in dbs, design considerations for dbs electrodes, improved sensors, neuronal signal processing, advancements in development and uses of

responsive dbs (closed-loop systems), updates on national institutes of health and darpa dbs programs of the brain initiative, and neuroethical and policy issues arising in and from dbs research and applications in practice."
Goudriaan, A. E., & Schluter, R. S.. (2019). Non-invasive Neuromodulation in Problem Gambling: What Are the Odds?. Current Addiction Reports

Plain numerical DOI: 10.1007/s40429-019-00266-y
DOI URL
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"Purpose of review: non-invasive neuromodulation as a potential therapeutic target in addiction treatment is a fast-growing, but nascent research field. with gambling disorder as the first behavioral addiction, the goal of this review is to provide an overview of the current state-of-the-art of neuromodulation in substance use disorders and gambling disorder. recent findings: only a few neuromodulation studies in gambling disorder are present, most of these are single-session studies. effects of rtms on craving have been described, but large placebo effects are also present, indicating a need for larger, blinded, multiple-session neuromodulation trials. summary: the field of neuromodulation in gambling is in its infancy, given the limited number of studies, with small sample sizes. the effects that neuromodulation can have on diminishing craving and improving cognitive functions in substance use disorders are promising. as these factors also play a role in relapse in gambling disorder, these findings in suds indicate that investment in larger studies in gambling disorder, focusing on both clinically relevant outcome measures and on intermediate working mechanisms like craving and cognitive functions, is warranted."
Elias, G. J. B., Boutet, A., Parmar, R., Wong, E. H. Y., Germann, J., Loh, A., … Bhat, V.. (2021). Neuromodulatory treatments for psychiatric disease: A comprehensive survey of the clinical trial landscape. Brain Stimulation

Plain numerical DOI: 10.1016/j.brs.2021.08.021
DOI URL
directSciHub download

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"Background: numerous neuromodulatory therapies are currently under investigation or in clinical use for the treatment of psychiatric conditions. objective/hypothesis: we sought to catalogue past and present human research studies on psychiatric neuromodulation and identify relevant trends in this field. methods: clinicaltrials.gov (www.clinicaltrials.gov/) and the international clinical trials registry platform (www.who.int/ictrp/en/) were queried in march 2020 for trials assessing the outcome of neuromodulation for psychiatric disorders. relevant trials were categorized by variables such as neuromodulation modality, country, brain target, publication status, design, and funding source. results: from 72,086 initial search results, 1252 unique trials were identified. the number of trials registered annually has consistently increased. half of all trials were active and a quarter have translated to publications. the largest proportion of trials involved depression (45%), schizophrenia (18%), and substance use disorders (14%). trials spanned 37 countries; china, the second largest contributor (13%) after the united states (28%), has increased its output substantially in recent years. over 75% of

trials involved non-convulsive non-invasive modalities (e.g., transcranial magnetic stimulation), while convulsive (e.g., electroconvulsive therapy) and invasive modalities (e.g., deep brain stimulation) were less represented. 72% of trials featured approved or cleared interventions. characteristic inter-modality differences were observed with respect to enrollment size, trial design/phase, and funding. dorsolateral prefrontal cortex accounted for over half of focal neuromodulation trial targets. the proportion of trials examining biological correlates of neuromodulation has increased. conclusion(s): these results provide a comprehensive overview of the state of psychiatric neuromodulation research, revealing the growing scope and internationalism of this field."
Doshi, P. P., Russo, M., & Doshi, P. K.. (2021). Practice Trends of Neuromodulation Therapies for Pain and Spasticity in India. Neuromodulation

Plain numerical DOI: 10.1111/ner.13393
DOI URL
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"Background: neuromodulation has been successfully used globally to address severe refractory chronic pain for over five decades. compared to the wide acceptance that it enjoys in united states and europe, it is fairly underutilized in asia, including india. objectives: we conducted the first systematic nationwide survey to provide an overview of neuromodulation in the past 20 years to investigate the practice trends for severe refractory chronic pain and barriers for the uptake of neuromodulation therapies for pain in india. design: a 20-point detailed questionnaire survey was sent out for online completion in august 2020 to practitioners in india involved in interventions for pain. the survey was completed by 112 practitioners (10% return rate). the response data collected were analyzed, tabulated, and presented as percentages. results: the average duration of pain practice in india for the majority of respondents was less than a decade. about 70% of practitioners expressed that they manage severe refractory pain without neuromodulation. this survey confirms that neuromodulation is grossly underutilized for pain, comprising only 10% of total neuromodulation implants performed per annum in india. the most common indications were neuropathic pain (45%) and failed back surgery syndrome (42%). the respondents expressed the main barriers to be related to the cost (85%); lack of awareness (68%) and lack of good training (59%). more than 50% of respondents also expressed difficulty of access to neuromodulation therapies for pain and acceptance by patients. conclusion: the younger generation of pain practitioners in india is becoming more aware and convinced about the role of neuromodulation to alleviate severe pain and suffering. an all-round approach combining improved training, awareness at various levels, more flexible options of newer technology and reimbursement approval can positively influence its use. this can be achieved with the collective efforts of physicians, insurers, industry, and focused academic activities of clinical societies."
Ward, M., Doran, J., Paskhover, B., & Mammis, A.. (2018). The 50 Most Cited Articles in Invasive Neuromodulation. World Neurosurgery

Plain numerical DOI: 10.1016/j.wneu.2018.02.170
DOI URL
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“Objective: bibliometric analysis is a commonly used analytic tool for objective determination of the most influential and peer-recognized articles within a given field. this study is the first bibliometric analysis of the literature in the field of invasive neuromodulation, excluding deep brain stimulation. the objectives of this study are to identify the 50 most cited articles in invasive neuromodulation, provide an overview of the literature to assist in clinical education, and evaluate the effect of impact factor on manuscript recognition. methods: bibliometric analysis was performed using the science citation index from the institute for scientific information, accessed through the web of science. search terms relevant to the field of invasive neuromodulation were used to identify the 50 most cited journal articles between 1900 and 2016. results: the median number of citations was 236 (range, 173–578). the most common topics among the articles were vagus nerve stimulation (n = 24), spinal cord stimulation (n = 9), and motor cortex stimulation (n = 6). median journal impact factor was 5.57. most of these articles (n = 19) contained level i, ii, or iii evidence. conclusions: this analysis provides a brief look into the most cited articles within the field, many of which evaluated innovated procedures and therapies that helped to drive surgical neuromodulation forward. these landmark articles contain vital clinical and educational information that remains relevant to clinicians and students within the field and provide insight into areas of expanding research. journal impact factor may play a significant role in determining the literary relevance and general awareness of invasive neuromodulation studies.”
Starling, A.. (2018). Noninvasive neuromodulation in migraine and cluster headache. Current Opinion in Neurology

Plain numerical DOI: 10.1097/WCO.0000000000000557
DOI URL
directSciHub download

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“Purpose of review the purpose of this narrative review is to provide an overview of the currently available noninvasive neuromodulation devices for the treatment of migraine and cluster headache. recent findings over the last decade, several noninvasive devices have undergone development and clinical trials to evaluate efficacy and safety. based on this body of work, single-pulse transcranial magnetic stimulation, transcutaneous supraorbital neurostimulation, and noninvasive vagal nerve stimulation devices have been cleared by the united states food and drug administration and are available for clinical use for the treatment of primary headache disorders. summary overall, these novel noninvasive devices appear to be safe, well tolerated, and have demonstrated promising results in clinical trials in both migraine and cluster headache. this narrative review will provide a summary and update of the proposed mechanisms of action, evidence, safety, and future directions of various currently available modalities of noninvasive neuromodulation for the treatment of migraine and cluster headache.”
Senova, S., Fomenko, A., Gondard, E., & Lozano, A. M.. (2020). Anatomy and function of the fornix in the context of its potential as a therapeutic target. Journal of Neurology, Neurosurgery and Psychiatry

Plain numerical DOI: 10.1136/jnnp-2019-322375
DOI URL

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“The fornix is a white matter bundle located in the mesial aspect of the cerebral hemispheres, which connects various nodes of a limbic circuitry and is believed to play a key role in cognition and episodic memory recall. as the most prevalent cause of dementia, alzheimer’s disease (ad) dramatically impairs the quality of life of patients and imposes a significant societal burden on the healthcare system. as an established treatment for movement disorders, deep brain stimulation (dbs) is currently being investigated in preclinical and clinical studies for treatment of memory impairment in ad by modulating fornix activity. optimal target and stimulation parameters to potentially rescue memory deficits have yet to be determined. the aim of this review is to consolidate the structural and functional aspects of the fornix in the context of neuromodulation for memory deficits. we first present an anatomical and functional overview of the fibres and structures interconnected by the fornix. recent evidence from preclinical models suggests that the fornix is subdivided into two distinct functional axes: a septohippocampal pathway and a subiculothalamic pathway. each pathway’s target and origin structures are presented, followed by a discussion of their oscillatory dynamics and functional connectivity. overall, neuromodulation of each pathway of the fornix is discussed in the context of evidence-based forniceal dbs strategies. it is not yet known whether driving fornix activity can enhance cognition-optimal target and stimulation parameters to rescue memory deficits have yet to be determined.”
Doesborg, P., & Haan, J.. (2018). Cluster headache: New targets and options for treatment. F1000Research

Plain numerical DOI: 10.12688/f1000research.13380.1
DOI URL
directSciHub download

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“Cluster headache is a severe headache disorder with considerable impact on quality of life. the pathophysiology of the disease remains poorly understood. with few specific targets for treatment, current guidelines mainly include off-label treatment with medication. however, new targets for possible treatment options are emerging. calcitonin gene-related peptide (cgrp)-targeted medication could become the first (cluster) headache-specific treatment option. other exciting new treatment options include invasive and non-invasive neuromodulation techniques. here, we provide a short overview of new targets and treatment options that are being investigated for cluster headache.”
Gardner, J.. (2017). Securing a future for responsible neuromodulation in children: The importance of maintaining a broad clinical gaze. European Journal of Paediatric Neurology

Plain numerical DOI: 10.1016/j.ejpn.2016.04.019
DOI URL
directSciHub download

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“Aim this perspective paper provides an overview of several key tensions and challenges within the social context of neuromodulation, and it suggests a means of securing the future of paediatric neuromodulation in light of these. results tensions and challenges relate to: the considerable clinical and economic need for new therapies to manage neurological diseases; significant commercial involvement in the field; funding pressures; public perceptions (particularly unrealistic expectations); and the emerging responsible research and innovation initiative. this paper argues that managing these challenges and tensions requires that clinicians working within the field adopt what could be called a broad clinical gaze. this paper will define the broad clinical gaze, and it will propose several ways in which a broad clinical gaze can be – and indeed is being – operationalised in recent advances in neuromodulation in children. these include the use of multidisciplinary and interdisciplinary clinical team structures, the adoption of clinical assessment tools that capture day-to-day functionality, and the use of patient registries. conclusion by adopting a broad clinical gaze, clinicians and investigators can ensure that the field as a whole can responsibly and ethically deliver on its significant clinical potential.”
Crockett, M. J., & Fehr, E.. (2014). Social brains on drugs: Tools for neuromodulation in social neuroscience. Social Cognitive and Affective Neuroscience

Plain numerical DOI: 10.1093/scan/nst113
DOI URL
directSciHub download

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“Neuromodulators such as serotonin, oxytocin and testosterone play an important role in social behavior. studies examining the effects of these neuromodulators and others on social cognition and behavior (and their neural underpinnings) are becoming increasingly common. here, we provide an overview of methodological considerations for those wishing to evaluate or conduct empirical studies of neuromodulation in social neuroscience. © the author (2013).”
Edwards, C. A., Kouzani, A., Lee, K. H., & Ross, E. K.. (2017). Neurostimulation Devices for the Treatment of Neurologic Disorders. Mayo Clinic Proceedings

Plain numerical DOI: 10.1016/j.mayocp.2017.05.005
DOI URL
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“Rapid advancements in neurostimulation technologies are providing relief to an unprecedented number of patients affected by debilitating neurologic and psychiatric disorders. neurostimulation therapies include invasive and noninvasive approaches that involve the application of electrical stimulation to drive neural function within a circuit. this review focuses on established invasive electrical stimulation systems used clinically to induce therapeutic neuromodulation of dysfunctional neural circuitry. these implantable neurostimulation systems target specific deep subcortical, cortical, spinal, cranial, and peripheral nerve structures to modulate neuronal activity, providing therapeutic effects for a myriad of neuropsychiatric disorders. recent advances in neurotechnologies and neuroimaging, along

with an increased understanding of neurocircuitry, are factors contributing to the rapid rise in the use of neurostimulation therapies to treat an increasingly wide range of neurologic and psychiatric disorders. electrical stimulation technologies are evolving after remaining fairly stagnant for the past 30 years, moving toward potential closed-loop therapeutic control systems with the ability to deliver stimulation with higher spatial resolution to provide continuous customized neuromodulation for optimal clinical outcomes. even so, there is still much to be learned about disease pathogenesis of these neurodegenerative and psychiatric disorders and the latent mechanisms of neurostimulation that provide therapeutic relief. this review provides an overview of the increasingly common stimulation systems, their clinical indications, and enabling technologies."
Rimmele, F., & Jürgens, T. P.. (2020). Neuromodulation in primary headaches: current evidence and integration into clinical practice. Current Opinion in Neurology

Plain numerical DOI: 10.1097/WCO.0000000000000820
DOI URL
directSciHub download

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"PURPOSE of review: neuromodulatory approaches add to our armamentarium of therapeutic tools for the treatment of primary headaches. this review provides a comprehensive overview of current controlled studies on the different neuromodulation techniques and recommendations for clinical practice. recent findings: evidence for efficacy of transcutaneous vagal nerve stimulation (tvns) is limited to acute use in migraine with ambiguous results and episodic cluster headache as well as chronic cluster headache if applied in addition to conventional treatment. transcutaneous stimulation of the supraorbital and supratrochlear nerve was effective in both acute and preventive stimulation (the latter with ambiguous results) in episodic migraines. thus, invasive procedures should be reserved for severe and refractory cases only. occipital nerve stimulation for chronic refractory cluster headache is the only available invasive approach with a conformité européenne mark. summary: neuromodulation can complement conventional therapy, with noninvasive procedures being used preferably. given the limited number of studies for each modality and the lack of head-to-head studies, it is difficult to place neuromodulation techniques in a conventional treatment algorithm."
La Rosa, V. L., Platania, A., Ciebiera, M., Garzon, S., J?dra, R., Ponta, M., & Buttice, S.. (2019). A comparison of sacral neuromodulation vs. transvaginal electrical stimulation for the treatment of refractory overactive bladder: The impact on quality of life, body image, sexual function, and emotional well-being. Przeglad Menopauzalny

Plain numerical DOI: 10.5114/pm.2019.86834
DOI URL
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"Overactive bladder syndrome (oab) is defined by the presence of urinary urgency, with or without urge incontinence, usually accompanied by an increase in urinary frequency and nocturia in the absence of urinary tract infections (uti) or other diseases. the overall prevalence of oab symptoms in the female population is reported to be 16.6% and increases with advancing age and menopause. the aetiology of oab is not fully understood and is likely to affect a heterogeneous population of patients due to

changes to their central and peripheral nervous systems. although oab is frequently associated with female sexual dysfunction (fsd), its real impact on sexual function in women has been evaluated only in a few studies. the first line of treatment for oab includes behavioural modification and physical therapy, either as monotherapies or in combination. many patients who have not had success in managing their symptoms with more conservative therapies may decide to resort to third-line treatments for refractory oab. these treatments include neuromodulation therapies, particularly transvaginal electrical stimulation (tes) and sacral neuromodulation (sn). the aim of this short commentary is to provide an overview of the effectiveness of these treatments and of their impact on quality of life, body image, sexual function, and emotional well-being."
Pericolini, M., Miget, G., Hentzen, C., Finazzi Agrò, E., Chesnel, C., Lagnau, P., … Amarenco, G.. (2021). Cortical, Spinal, Sacral, and Peripheral Neuromodulations as Therapeutic Approaches for the Treatment of Lower Urinary Tract Symptoms in Multiple Sclerosis Patients: A Review. Neuromodulation

Plain numerical DOI: 10.1111/ner.13525
DOI URL
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"Introduction: multiple sclerosis (ms) is often associated with urological disorders, mainly urinary incontinence and retention, the management of which being necessary to improve patient's quality of life (qol) and to reduce potential urological complications. besides the classical treatments based mainly on anticholinergics and/or self-catheterization, several neuromodulation techniques have been tried in recent years to improve these urinary disorders. by this review, we aim at providing an overview of neuromodulation and electrostimulation approaches to manage urinary symptoms in ms patients. materials and methods: a literature search using medline was performed. only papers in english, and describing the effects of neuromodulation in ms patients, were considered. results: a total of 18 studies met inclusion criteria and were reviewed. of them, four related to sacral neuromodulation (snm), seven to percutaneous tibial nerve stimulation (ptns), six to spinal cord stimulation (scs), and one to transcranial magnetic stimulation (tms). discussion: ptns and snm seem to be effective and safe therapeutic options for treating lower urinary tract symptoms in ms patients principally in case of overactive bladder (oab) symptoms. similarly, also scs and tms have been shown to be effective, despite the very limited number of patients and the small number of studies found in the literature. interestingly, these techniques are effective even in patients who do not respond well to conservative therapies, such as anticholinergics. furthermore, given their safety and efficacy, stimulations such as ptns could be considered as a first-line treatment for oab in ms patients, also considering that they are often preferred by patients to other commonly used treatments."
Pauwels, N., Willemse, C., Hellemans, S., Komen, N., Van den Broeck, S., Roenen, J., … De Schepper, H.. (2021). The role of neuromodulation in chronic functional constipation: A systematic review. Acta Gastro-Enterologica Belgica

Plain numerical DOI: 10.51821/84.3.012
DOI URL
directSciHub download

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“Background: chronic functional constipation is a highly prevalent disorder in which, when conservative measures fail to relieve symptoms, surgical interventions are sometimes indicated. in recent years, neuromodulation for the treatment of functional constipation has gained interest but its role and effectiveness are still unclear. the purpose of this review is to provide a systematic overview on the current literature on the different modalities of neurostimulation and their effect on chronic functional constipation in adults as reported in the literature. methods: a search in the literature for articles concerning the effect of different types of neuromodulation on constipation was performed in pubmed using extensive search terms for the different modalities of neuromodulation. studies and trials were checked for eligibility. for all types of neuromodulation together, 27 articles were included. results: 17 studies were included on snm (sacral nerve modulation). although multiple studies show positive results on the effect of snm in constipation, double-blind crossover rct’s (randomised controlled trials) showed no significant effect. 3 studies were included for tsns (transcutaneous sacral nerve stimulation), 2 for ptns (percutaneous tibial nerve stimulation) and 2 for ttns (transcutaneous tibial nerve stimulation). studies and trials on these modalities of neuromodulation reported ambiguous results on statistical significance of the effect. for transcutaneous ifc (interferential current therapy) 2 studies were included, which both reported a statistically significant effect on all outcomes. conclusion: the beneficial effect of neuromodulation in chronic functional constipation remains questionable. however, neuro-modulation might be worth considering in patients refractory to treatment before turning to more invasive measures. future research should shed more light on the effects of neuromodulation in constipation. (acta gastroenterol. belg., 2021, 84, 467-476).”
Azad, T. D., Veeravagu, A., & Steinberg, G. K.. (2016). Neurorestoration after stroke. Neurosurgical Focus

Plain numerical DOI: 10.3171/2016.2.FOCUS15637
DOI URL
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“Recent advancements in stem cell biology and neuromodulation have ushered in a battery of new neurorestorative therapies for ischemic stroke. while the understanding of stroke pathophysiology has matured, the ability to restore patients’ quality of life remains inadequate. new therapeutic approaches, including cell transplantation and neurostimulation, focus on reestablishing the circuits disrupted by ischemia through multidimensional mechanisms to improve neuroplasticity and remodeling. the authors provide a broad overview of stroke pathophysiology and existing therapies to highlight the scientific and clinical implications of neurorestorative therapies for stroke.”
de Wall, L. L., & Heesakkers, J. P. F. A.. (2017). Effectiveness of percutaneous tibial nerve stimulation in the treatment of overactive bladder syndrome. Research and Reports in Urology

Plain numerical DOI: 10.2147/RRU.S124981
DOI URL
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“Overactive bladder syndrome (oab) is a common condition affecting adults and children worldwide, resulting in a substantial economic and psychological burden. percutaneous tibial nerve stimulation (ptns) is derived from acupuncture used in chinese traditional medicine and was first described in the early 1980s. it is a neuromodulation technique used to modulate bladder function and facilitate storage. being a minimally invasive, easily applicable, but time-consuming treatment, future developments with implantable devices might be the solution for the logistical problems and economic burden associated with ptns on the long term. this nonsystematic review provides a current overview on ptns and its effectiveness in the treatment of oab for both adults and children.”
Ramirez-Zamora, A., Giordano, J., Boyden, E. S., Gradinaru, V., Gunduz, A., Starr, P. A., … Okun, M. S.. (2019). Proceedings of the Sixth Deep Brain Stimulation Think Tank Modulation of Brain Networks and Application of Advanced Neuroimaging, Neurophysiology, and Optogenetics. In Frontiers in Neuroscience

Plain numerical DOI: 10.3389/fnins.2019.00936
DOI URL
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“The annual deep brain stimulation (dbs) think tank aims to create an opportunity for a multidisciplinary discussion in the field of neuromodulation to examine developments, opportunities and challenges in the field. the proceedings of the sixth annual think tank recapitulate progress in applications of neurotechnology, neurophysiology, and emerging techniques for the treatment of a range of psychiatric and neurological conditions including parkinson’s disease, essential tremor, tourette syndrome, epilepsy, cognitive disorders, and addiction. each section of this overview provides insight about the understanding of neuromodulation for specific disease and discusses current challenges and future directions. this year’s report addresses key issues in implementing advanced neurophysiological techniques, evolving use of novel modulation techniques to deliver dbs, ans improved neuroimaging techniques. the proceedings also offer insights into the new era of brain network neuromodulation and connectomic dbs to define and target dysfunctional brain networks. the proceedings also focused on innovations in applications and understanding of adaptive dbs (closed-loop systems), the use and applications of optogenetics in the field of neurostimulation and the need to develop databases for dbs indications. finally, updates on neuroethical, legal, social, and policy issues relevant to dbs research are discussed.”
Klooster, D. C. W., de Louw, A. J. A., Aldenkamp, A. P., Besseling, R. M. H., Mestrom, R. M. C., Carrette, S., … Boon, P.. (2016). Technical aspects of neurostimulation: Focus on equipment, electric field modeling, and stimulation protocols. Neuroscience and Biobehavioral Reviews

Plain numerical DOI: 10.1016/j.neubiorev.2016.02.016
DOI URL
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“Neuromodulation is a field of science, medicine, and bioengineering that encompasses implantable and non-implantable technologies for the purpose of improving quality of life and functioning of humans. brain neuromodulation involves different neurostimulation techniques: transcranial magnetic stimulation (tms), transcranial direct current stimulation (tdcs), vagus nerve stimulation (vns), and deep brain stimulation (dbs), which are being used both to study their effects on cognitive brain functions and to treat neuropsychiatric disorders. the mechanisms of action of neurostimulation remain incompletely understood. insight into the technical basis of neurostimulation might be a first step towards a more profound understanding of these mechanisms, which might lead to improved clinical outcome and therapeutic potential. this review provides an overview of the technical basis of neurostimulation focusing on the equipment, the present understanding of induced electric fields, and the stimulation protocols. the review is written from a technical perspective aimed at supporting the use of neurostimulation in clinical practice.”
De Ridder, D., Manning, P., Cape, G., Vanneste, S., Langguth, B., & Glue, P.. (2016). Pathophysiology-Based Neuromodulation for Addictions: An Overview. In Neuropathology of Drug Addictions and Substance Misuse

Plain numerical DOI: 10.1016/B978-0-12-800213-1.00002-X
DOI URL
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“Treatments for addiction are of limited effectivity and characterized by high relapse rates, requiring the development of novel pathophysiology-based treatment approaches. one such option is to use neuromodulation. neuromodulation can be defined as the use of techniques to focally induce directed neuroplasticity. both nonsurgical and surgical neuromodulation have been experimentally used for the suppression of craving. noninvasive techniques used include transcranial magnetic stimulation, transcranial electrical stimulation, and neurofeedback. surgical neuromodulation techniques involve lesioning and electrical stimulation via implanted electrodes. most studies using noninvasive stimulation have investigated the dorsolateral prefrontal cortex as the target. the two brain areas most commonly used as targets for lesioning are the anterior cingulate and nucleus accumbens. for implanted electrodes the nucleus accumbens and subthalamic nucleus have been investigated. the targets used can be linked to brain circuits involved in craving or withdrawal. for noninvasive neuromodulation no long-term studies have been performed and for implanted electrodes only small case series have been reported. thus even if results seem to be promising, they still have to be considered preliminary.”
Lo, P. A., Huang, K., Zhou, Q., Humayun, M. S., & Yue, L.. (2020). Ultrasonic retinal neuromodulation and acoustic retinal prosthesis. Micromachines

Plain numerical DOI: 10.3390/mi11100929
DOI URL
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“Ultrasound is an emerging method for non-invasive neuromodulation. studies in the past have demonstrated that ultrasound can reversibly activate and inhibit neural activities in the brain. recent research shows the possibility of using ultrasound ranging from 0.5 to 43 mhz in acoustic frequency to activate the retinal neurons without causing detectable damages to the cells. this review recapitulates pilot studies that explored retinal responses to the ultrasound exposure, discusses the advantages and limitations of the ultrasonic stimulation, and offers an overview of engineering perspectives in developing an acoustic retinal prosthesis. for comparison, this article also presents studies in the ultrasonic stimulation of the visual cortex. despite that, the summarized research is still in an early stage; ultrasonic retinal stimulation appears to be a viable technology that exhibits enormous therapeutic potential for non-invasive vision restoration.”
Krauss, J. K., Lipsman, N., Aziz, T., Boutet, A., Brown, P., Chang, J. W., … Lozano, A. M.. (2021). Technology of deep brain stimulation: current status and future directions. Nature Reviews Neurology

Plain numerical DOI: 10.1038/s41582-020-00426-z
DOI URL
directSciHub download

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“Deep brain stimulation (dbs) is a neurosurgical procedure that allows targeted circuit-based neuromodulation. dbs is a standard of care in parkinson disease, essential tremor and dystonia, and is also under active investigation for other conditions linked to pathological circuitry, including major depressive disorder and alzheimer disease. modern dbs systems, borrowed from the cardiac field, consist of an intracranial electrode, an extension wire and a pulse generator, and have evolved slowly over the past two decades. advances in engineering and imaging along with an improved understanding of brain disorders are poised to reshape how dbs is viewed and delivered to patients. breakthroughs in electrode and battery designs, stimulation paradigms, closed-loop and on-demand stimulation, and sensing technologies are expected to enhance the efficacy and tolerability of dbs. in this review, we provide a comprehensive overview of the technical development of dbs, from its origins to its future. understanding the evolution of dbs technology helps put the currently available systems in perspective and allows us to predict the next major technological advances and hurdles in the field.”
S., V., & D., D. R.. (2012). Noninvasive and invasive neuromodulation for the treatment of tinnitus: An overview. Neuromodulation

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“Objective: nonpulsatile tinnitus is an auditory phantom percept characterized as a tone, or a noise-like sound such as a hissing or buzzing sound or polyphonic, in the absence of any objective physical sound source. although advances have been made in symptomatic pharmacologic and nonpharmacologic treatments, these treatments are unable to eliminate the tinnitus sensation in most patients. a novel approach using noninvasive and invasive neuromodulation has emerged as an interesting and promising modality for tinnitus relief. methodology: we review noninvasive neuromodulation techniques including transcranial magnetic stimulation, transcranial direct current stimulation, transcutaneous electrical nerve stimulation, and cortical neurofeedback, as well as

invasive neuromodulation techniques including auditory cortex stimulation, dorsolateral prefrontal cortex stimulation, subcutaneous occipital nerve stimulation, and deep brain stimulation, as potential treatments of tinnitus. conclusion: although the different techniques introduced revealed promising results, further research is needed to better understand how these techniques work and how the brain responds to neuromodulation. more sophisticated stimulation regimens and parameters should be developed to dynamically stimulate various regions at different frequencies and intensities, physiologically tailored to the patient's brain state in an attempt to maximize efficacy. (copyright) 2012 international neuromodulation society."
Kaczmarek, K. A.. (2017). The Portable Neuromodulation Stimulator (PoNS) for neurorehabilitation. Scientia Iranica

Plain numerical DOI: 10.24200/sci.2017.4489
DOI URL
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"The portable neuromodulation stimulator (pons) is a compact, self-contained device that delivers a fixed sequence of dc-balanced voltage pulses to the anterior-dorsal tongue through a matrix of 143 gold-plated electrodes. this form of stimulation is being investigated as a possible aid to rehabilitation of motor, cognitive, and emotional symptoms resulting from a range of neurological disorders of traumatic, degenerative, or developmental origin. this article provides a technical overview of the pons device as well as a summary of applications research to date."
Somani, A., & Kar, S. K.. (2019). Efficacy of repetitive transcranial magnetic stimulation in treatment-resistant depression: The evidence thus far. General Psychiatry

Plain numerical DOI: 10.1136/gpsych-2019-100074
DOI URL
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"Depression is a common mental disorder, which attributes to significant morbidity, disability and burden of care. a significant number of patients with depression still remain symptomatic after adequate trials of antidepressant treatment as well as psychotherapy, which is often referred to as treatment-resistant depression. neuromodulation techniques-like electroconvulsive therapy, vagus nerve stimulation, transcranial magnetic stimulation (tms) and transcranial direct current stimulation, may be useful augmenting techniques in depression, mostly recommended for treatment-resistant cases. robust evidence exists regarding the efficacy of electroconvulsive therapy in the management of treatment-resistant depression; however, other techniques are understudied. tms has been increasingly studied in various psychiatric disorders including depression. it has been approved by the us food and drug administration for use in major depressive disorder. over the past two decades, tms has been studied in diverse groups of the population with depression using several research designs. this article gives an overview of the efficacy of repetitive tms in treatment-resistant depression with the recent evidence."
Meng, Y., Hynynen, K., & Lipsman, N.. (2021). Applications of focused ultrasound in the brain: from thermoablation to drug delivery

. Nature Reviews Neurology

Plain numerical DOI: 10.1038/s41582-020-00418-z
DOI URL
directSciHub download

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“Focused ultrasound (fus) is a disruptive medical technology, and its implementation in the clinic represents the culmination of decades of research. lying at the convergence of physics, engineering, imaging, biology and neuroscience, fus offers the ability to non-invasively and precisely intervene in key circuits that drive common and challenging brain conditions. the actions of fus in the brain take many forms, ranging from transient blood–brain barrier opening and neuromodulation to permanent thermoablation. over the past 5 years, we have seen a dramatic expansion of indications for and experience with fus in humans, with a resultant exponential increase in academic and public interest in the technology. applications now span the clinical spectrum in neurological and psychiatric diseases, with insights still emerging from preclinical models and human trials. in this review, we provide a comprehensive overview of therapeutic ultrasound and its current and emerging indications in the brain. we examine the potential impact of fus on the landscape of brain therapies as well as the challenges facing further advancement and broader adoption of this promising minimally invasive therapeutic alternative.”
Coman, A., Skårderud, F., Reas, D. L., & Hofmann, B. M.. (2014). The ethics of neuromodulation for anorexia nervosa: A focus on rTMS. Journal of Eating Disorders

Plain numerical DOI: 10.1186/2050-2974-2-10
DOI URL
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“Objective: recently there has been emerging clinical and research interest in the application of deep brain stimulation (dbs) and repetitive transcranial magnetic stimulation (rtms) to the treatment of anorexia nervosa (an). to our knowledge, few studies have discussed ethical aspects associated with the increased use of neuromodulation in an, some of which are quite specific to an, despite the rapid development and dissemination of these new technologies.method: we provide a brief overview of three published rtms studies for an and discuss ethical issues involved in the use of neuromodulation for an.results: in contrast to neurosurgery or dbs, rtms is a less invasive technique, with less associated risk, and thus has greater potential to become a more widespread augmentation or add-on therapy for an. new therapeutic procedures are promising, yet they raise ethical questions regarding informed consent and patient selection. illness-specific issues surrounding authenticity and autonomy are important to consider, ensuring an ethical approach to treatment for patients with an.discussion: we argue that ethical investigations for neuromodulation techniques are timely and important, and discussions should go beyond the immediate goals of patient safety, consent, and risk and benefit, to consider broader ethical concepts such as authenticity and autonomy.”
Herremans, S. C., & Baeken, C.. (2017). Clinical effects of non-invasive neuromodulation techniques in substance use disorder: An overview. Tijdschrift Voor Psychiatrie

Show/hide publication abstract

“BACKGROUND substance dependence is a chronic disorder that is difficult to treat. non-invasive stimulation techniques may have beneficial effects on the course of the illness. aim to provide an overview of studies that evaluate the clinical effects that transcranial magnetic stimulation (tms) and transcranial direct current stimulation (tdcs) have on patients with substance use disorders. method we performed an extensive search of the literature, using pubmed. results most studies showed that both tms and tdcshavea beneficial effect on clinical outcomes. however, the effects seemed to wear off over time, even if tms and tdcs had been administered to patients over several sessions. conclusion in terms of efficacy, we award a level b qualification to both tms and tdcs, which means that we regard both techniques as’very probably efficient’.”
Tyler, W. J.. (2011). Noninvasive neuromodulation with ultrasound? A continuum mechanics hypothesis . Neuroscientist

Plain numerical DOI: 10.1177/1073858409348066
DOI URL
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“Deep brain stimulation and vagal nerve stimulation are therapeutically effective in treating some neurological diseases and psychiatric disorders. optogenetic-based neurostimulation approaches are capable of activating individual synapses and yield the highest spatial control over brain circuit activity. both electrical and light-based neurostimulation methods require intrusive procedures such as surgical implantation of electrodes or photon-emitting devices. transcranial magnetic stimulation has also shown therapeutic effectiveness and represents a recent paradigm shift towards implementing less invasive brain stimulation methods. magnetic-based stimulation, however, has a limited focusing capacity and lacks brain penetration power. because ultrasound can be noninvasively transmitted through the skull to targeted deep brain circuits, it may offer alternative approaches to currently employed neuromodulation techniques. encouraging this idea, literature spanning more than half a century indicates that ultrasound can modulate neuronal activity. in order to provide a comprehensive overview of potential mechanisms underlying the actions of ultrasound on neuronal excitability, here, i propose the continuum mechanics hypothesis of ultrasonic neuromodulation in which ultrasound produces effects on viscoelastic neurons and their surrounding fluid environments to alter membrane conductance. while further studies are required to test this hypothesis, experimental data indicate ultrasound represents a promising platform for developing future therapeutic neuromodulation approaches. © the author(s) 2011.”
Yamamoto, K., Elias, G. J. B., Beyn, M. E., Zemmar, A., Loh, A., Sarica, C., … Lozano, A. M.. (2021). Neuromodulation for Pain: A Comprehensive Survey and Systematic Review of Clinical Trials and Connectomic Analysis of Brain Targets. Stereotactic and Functional Neurosurgery

Plain numerical DOI: 10.1159/000517873
DOI URL
directSciHub download

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“Background: chronic pain is a debilitating condition that imposes a tremendous burden on health-care systems around the world. while frontline treatments for chronic pain involve pharmacological and psychological approaches, neuromodulation can be considered for treatment-resistant cases. neuromodulatory approaches for pain are diverse in both modality and target and their mechanism of action is incompletely understood. objectives: the objectives of this study were to (i) understand the current landscape of pain neuromodulation research through a comprehensive survey of past and current registered clinical trials (ii) investigate the network underpinnings of these neuromodulatory treatments by performing a connectomic mapping analysis of cortical and subcortical brain targets that have been stimulated for pain relief. methods: a search for clinical trials involving pain neuromodulation was conducted using 2 major trial databases (clinicaltrials.gov and the international clinical trials registry platform). trials were categorized by variables and analyzed to gain an overview of the contemporary research landscape. additionally, a connectomic mapping analysis was performed to investigate the network connectivity patterns of analgesic brain stimulation targets using a normative connectome based on a functional magnetic resonance imaging dataset. results: in total, 487 relevant clinical trials were identified. noninvasive cortical stimulation and spinal cord stimulation trials represented 49.3 and 43.7% of this count, respectively, while deep brain stimulation trials accounted for
Hennessey, D. B., Hoag, N., & Gani, J.. (2017). Impact of bladder dysfunction in the management of post radical prostatectomy stress urinary incontinence-a review. Translational Andrology and Urology

Plain numerical DOI: 10.21037/tau.2017.04.14
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“Bladder dysfunction is a relatively common urodynamic finding post radical prostatectomy (rp). it can be the sole cause of post prostatectomy incontinence (ppi) or may be found in association with stress urinary incontinence (sui). the aim of this review is to provide a comprehensive review of the diagnosis and different treatments of post rp bladder dysfunction. a comprehensive literature review using medical search engines was performed. the search included a combination of the following terms, ppi, detrusor overactivity (do), detrusor underactivity (du), impaired compliance, anticholinergic, onabotulinumtoxina (botox®) and sacral neuromodulation (snm). definitions, general overview and management options were extracted from the relevant medical literature. do, du and impaired compliance are common and may occur alone or in combination with sui. in some patients the conditions exist pre rp, in others they arise due to denervation and surgical changes. do can be treated with anticholinergics, botox® and snm. do may need to be treated before sui surgery. du may be a contraindication to male sling surgery as some patients may go into urinary retention. severely impaired bladder compliance may be a contraindication to sui surgery as the upper tracts may be at risk. each individual dysfunction may affect the outcome of ppi treatments and clinicians should be alert to managing bladder dysfunction in ppi patients.”

Urits, I., Schwartz, R., Smoots, D., Koop, L., Veeravelli, S., Orhurhu, V., … Viswanath, O.. (2020). Peripheral neuromodulation for the management of headache. Anesthesiology and Pain Medicine

Plain numerical DOI: 10.5812/aapm.110515
DOI URL
directSciHub download

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“Context: neuromodulation is an expanding field of study for headache treatment to reduce pain by targeting structures within the nervous system that are commonly involved in headache pathophysiology, such as the vagus nerve (vns), occipital nerves, or sphenopalatine ganglion (spg) for stimulation. pharmaceutical medical therapies for abortive and prophylactic treatment, such as triptans, nsaids, beta-blockers, tcas, and antiepileptics, are effective for some individuals, but the role that technology plays in investigating other therapeutic modalities is essential. peripheral neuromodulation has gained popularity and fda approval for use in treating certain headaches and migraine headache conditions, particularly in those who are refractory to treatment. early trials found fda approved neurostimulatory implant devices, including cephaly and springtms, improved patient-oriented outcomes with reductions in headaches per month (frequency) and severity. evidence acquisition: this was a narrative review. the sources for this review are as follows: searching on pubmed, google scholar, medline, and sciencedirect from 1990 – 2019 using keywords: peripheral neuromodulation, headache, vagus nerve, occipital nerves, sphenopalatine ganglion. results: the first noninvasive neurostimulator device approved for migraine treatment was the cefaly device, an external trigeminal nerve stimulation device (e-tns) that transcutaneously excites the supratrochlear and supraorbital branches of the ophthalmic nerve. the second noninvasive neurostimulation device receiving fda approval was the single-pulse transcranial magnetic stimulator, springtms, positioned at the occiput to treat migraine with aura. gammacore is a handheld transcutaneous vagal nerve stimulator applied directly to the neck at home by the patient for treatment of cluster headache (ch) and migraine. several other devices are in development for the treatment of headaches and target headache evolution at different levels and inputs. the scion device is a caloric vestibular stimulator (cvs) which interfaces with the user through a set of small cones resting in the ear canal on either side and held in place by modified over-ear headphones. the pulsante spg microstimulator is a patient-controlled device implanted in the patient’s upper jaw via an hour-long oral procedure to target the sphenopalatine ganglion. the occipital nerve stimulator (ons) is an invasive neuromodulation device for headache treatment that consist…”
Robbins, M. S., & Burch, R.. (2021). Preventive Migraine Treatment. CONTINUUM Lifelong Learning in Neurology

Plain numerical DOI: 10.1212/CON.0000000000000957
DOI URL
directSciHub download

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“PURPOSE of review this article provides an overview of preventive interventions for migraine, including when to start and how to choose a treatment, pharmacologic options (both older oral treatments and new monoclonal antibodies to calcitonin gene-related peptide [cgrp] or its receptor),

nonpharmacologic treatment such as neuromodulation, and preventive treatment of refractory migraine. recent findings the migraine preventive treatment landscape has been transformed by the development of monoclonal antibodies targeting cgrp or its receptor. these treatments, which are given subcutaneously or intravenously monthly or quarterly, have high efficacy and were well tolerated in clinical trials. emerging real-world studies have found higher rates of adverse events than were seen in clinical trials. they are currently recommended for use if two traditional preventive therapies have proven inadequate. since the commonly cited 2012 american headache society/american academy of neurology migraine prevention guidelines were released, clinical trials supporting the preventive use of lisinopril, candesartan, and memantine have been published. neuromodulation devices, including external trigeminal nerve stimulation and single-pulse transcranial magnetic stimulation devices, have modest evidence to support preventive use. the american headache society/american academy of neurology guidelines for the preventive treatment of migraine are currently being updated. a new class of oral cgrp receptor antagonists (gepants) is being tested for migraine prevention. summary successful preventive treatment of migraine reduces disease burden and improves quality of life. many pharmacologic and nonpharmacologic treatment options are available for the prevention of migraine, including newer therapies aimed at the cgrp pathway as well as older treatments with good evidence for efficacy. multiple treatment trials may be required to find the best preventive for an individual patient."
Ahmed, A. I., & Lucas, J. D.. (2020). Spinal cord injury: pathophysiology and strategies for regeneration . Orthopaedics and Trauma

Plain numerical DOI: 10.1016/j.mporth.2020.06.003
DOI URL
directSciHub download

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"Spinal cord injury (sci) is regarded as a devastating irreversible process leading to high morbidity and dependence. the pathophysiology is complex resulting in changes in the spinal cord in the acute phase, followed by sub-acute and chronic changes. this leads to cell death, glial scar formation and the inability to regenerate. nevertheless, many strategies for regeneration are being actively pursued, including cell therapy, drug delivery and neuromodulation. several of these strategies are in current clinical trials. this review aims to give an overview of the current understanding of the injury process and the potential treatment strategies for sci."
Argiolas, A., & Melis, M. R.. (1995). Neuromodulation of penile erection: an overview of the role of neurotransmitters and neuropeptides. Progress in Neurobiology

Plain numerical DOI: 10.1016/0301-0082(95)80003-Q
DOI URL
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"Penile erection is regulated by several neurotransmitters and neuropeptides at penile tissue and central nervous system levels. at penile level, the key event is the relaxation of corpora cavernosa smooth muscles. here, three kinds of neural autonomic control have been characterized in detail, one adrenergic stimulatory, that under normal conditions maintains the corpora cavernosa contracted (that

is a flaccid penis), a second cholinergic inhibitory that is believed to cooperate with a third, nonadrenergic-noncholinergic control also inhibitory, possibly mediated by nitric oxide (no), to reduce the adrenergic tone favouring the relaxation of corpora cavernosa, as during a sexual stimulus. however, the complex interactions between these neurotransmitters that determine the final condition of the corpora cavernosa, e.g. the presence or the absence of penile erection, are still a matter of controversy. this is further complicated by the presence of several neuropeptides in nervous penile vascular and smooth muscle tissues such as vasoactive intestinal polypeptide, peptide histidine-isoleucine, peptide histidine-methionine, neuropeptide y and endothelins, that often exert very potent (relaxant or contractant) effects in penile tissues. also at the central level, several neurotransmitters and neuropeptides that influence penile erection have been identified. among neurotransmitters, the most studied are dopamine (da), serotonin (5ht), acetylcholine (ach), glutamic acid and no. da, ach, glutamic acid and no seem to have a facilitatory role, while 5ht may be either facilitatory or inhibitory, depending on the receptor subtype involved. among neuropeptides, the best known are oxytocin, adrenocorticotropin (acth)-?-melanocyte stimulating hormone (?-msh)-related peptides and opioid peptides. interestingly da, glutamic acid and no seem to facilitate while opioid peptides inhibit penile erection by increasing and decreasing, respectively, central oxytocinergic transmission by acting in the paraventricular nucleus of the hypothalamus. acth-msh peptides also facilitate penile erection, although with a mechanism(s) different from those recalled above. despite some recent progress, more has still to be done to clarify the role played by neurotransmitters and neuropeptides at peripheral and central levels in the control of this primary sexual function. © 1995."
Mohammad, S. S., Paget, S. P., & Dale, R. C.. (2019). Current therapies and therapeutic decision making for childhood-onset movement disorders. Movement Disorders

Plain numerical DOI: 10.1002/mds.27661
DOI URL
directSciHub download

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"Movement disorders differ in children to adults. first, neurodevelopmental movement disorders such as tics and stereotypies are more prevalent than parkinsonism, and second, there is a genomic revolution which is now explaining many early-onset dystonic syndromes. we outline an approach to children with movement disorders starting with defining the movement phenomenology, determining the level of functional impairment due to abnormal movements, and screening for comorbid psychiatric conditions and cognitive impairments which often contribute more to disability than the movements themselves. the rapid improvement in our understanding of the etiology of movement disorders has resulted in an increasing focus on precision medicine, targeting treatable conditions and defining modifiable disease processes. we profile some of the key disease-modifying therapies in metabolic, neurotransmitter, inflammatory, and autoimmune conditions and the increasing focus on gene or cellular therapies. when no disease-modifying therapies are possible, symptomatic therapies are often all that is available. these classically target dopaminergic, cholinergic, alpha-adrenergic, or gabaergic neurochemistry. increasing interest in neuromodulation has highlighted that some clinical syndromes respond better to dbs, and further highlights the importance of 'disease-specific' therapies with a future focus on individualized therapies according to the genomic findings or disease pathways that are disrupted. we summarize some pragmatic applications of symptomatic therapies, neuromodulation techniques, and some rehabilitative interventions and provide a contemporary overview of treatment in

childhood-onset movement disorders. © 2019 international parkinson and movement disorder society.” Rajan, R., Skorvanek, M., Magocova, V., Siddiqui, J., Alsinaidi, O., Shinawi, H., … Bajwa, J.. (2020). Neuromodulation Options and Patient Selection for Parkinson’s Disease. In Neurology India

Plain numerical DOI: 10.4103/0028-3886.302473
DOI URL
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“Neuromodulation therapies, including deep brain stimulation (dbs) and pump therapies, are currently the standard of care for pd patients with advanced disease and motor complications that are difficult to control with medical management alone. the quest for alternate lesser invasive approaches led to the development of several novel therapies like intrajejunal levodopa infusions (ijli), continuous subcutaneous apomorphine infusions (csai) and magnetic resonance guided focused ultrasound (mrgfus) in recent years. to achieve good outcomes with any of these therapeutic modalities, careful patient selection, multidisciplinary evaluation and technical expertise are equally important. in this review, we will provide an overview of the neuromodulation strategies currently available for pd, emphasizing on patient selection and choosing among the various strategies.”
Dean, O. M., Gliddon, E., Van Rheenen, T. E., Giorlando, F., Davidson, S. K., Kaur, M., … Williams, L. J.. (2018). An update on adjunctive treatment options for bipolar disorder. Bipolar Disorders

Plain numerical DOI: 10.1111/bdi.12601
DOI URL
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“Objectives: bipolar disorder is a complex illness often requiring combinations of therapies to successfully treat symptoms. in recent years, there have been significant advancements in a number of therapies for bipolar disorder. it is therefore timely to provide an overview of current adjunctive therapeutic options to help treating clinicians to inform their patients and work towards optimal outcomes. methods: publications were identified from pubmed searches on bipolar disorder and pharmacotherapy, nutraceuticals, hormone therapy, psychoeducation, interpersonal and social rhythm therapy, cognitive remediation, mindfulness, e-health and brain stimulation techniques. relevant articles in these areas were selected for further review. this paper provides a narrative review of adjunctive treatment options and is not a systematic review of the literature. results: a number of pharmacotherapeutic, psychological and neuromodulation treatment options are available. these have varying efficacy but all have shown benefit to people with bipolar disorder. due to the complex nature of treating the disorder, combination treatments are often required. adjunctive treatments to traditional pharmacological and psychological therapies are proving useful in closing the gap between initial symptom remission and full functional recovery. conclusions: given that response to monotherapy is often inadequate, combination regimens for bipolar disorder are typical. correspondingly, psychiatric research is working towards a better understanding of the disorder’s underlying biology. therefore, treatment options are changing and adjunctive therapies are being increasingly recognized as providing significant tools to improve patient outcomes. towards this end, this paper provides an

overview of novel treatments that may improve clinical outcomes for people with bipolar disorder." Moisset, X., Lanteri-Minet, M., & Fontaine, D.. (2020). Neurostimulation methods in the treatment of chronic pain. Journal of Neural Transmission

Plain numerical DOI: 10.1007/s00702-019-02092-y
DOI URL
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"The goal of this narrative review was to give an up-to-date overview of the peripheral and central neurostimulation methods that can be used to treat chronic pain. special focus has been given to three pain conditions: neuropathic pain, nociplastic pain and primary headaches. both non-invasive and invasive techniques are briefly presented together with their pain relief potentials. for non-invasive stimulation techniques, data concerning transcutaneous electrical nerve stimulation (tens), transcranial direct current stimulation (tdcs), repetitive transcranial magnetic stimulation (rtms), remote electrical neuromodulation (ren) and vagus nerve stimulation (vns) are provided. concerning invasive stimulation techniques, occipital nerve stimulation (ons), vagus nerve stimulation (vns), epidural motor cortex stimulation (emcs), spinal cord stimulation (scs) and deep brain stimulation (dbs) are presented. the action mode of all these techniques is only partly understood but can be very different from one technique to the other. patients' selection is still a challenge. recent consensus-based guidelines for clinical practice are presented when available. the development of closed-loop devices could be of interest in the future, although the clinical benefit over open loop is not proven yet."
Er?ss, L., Entz, L., & Fabó, D.. (2015). Invasive neuromodulation in the treatment of drug-resistant epilepsies. Orvosi Hetilap

Plain numerical DOI: 10.1556/650.2015.30319
DOI URL
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"Neuromodulation is one of the most developing new disciplines of medical science, which examines how electrical, chemical and mechanical interventions can modulate or change the functioning of the central and peripheral nervous system. neuromodulation is a reversible form of therapy which uses electrical or mechanical stimulation or centrallydelivered drugs to modulate the abnormal function of the central nervous system in pain, spasticity, epilepsy, movement and psychiatric disorders, and certain cardiac, incontinency, visual and auditory diseases. neuromodulation therapy has two major branches. non-invasive neuromodulation includes transcranial magnetic simulation, direct current stimulation and transcutaneous electric nerve stimulation. invasive neuromodulation includes deep brain stimulation, cortical stimulation, spinal cord stimulation, peripheral nerve stimulation, sacral nerve simulation, and subcutan stimulation. in this article the authors overview the apparently available neural interface technologies in epilepsy surgery."
Ashina, M., Buse, D. C., Ashina, H., Pozo-Rosich, P., Peres, M. F. P., Lee, M. J., … Dodick, D. W.. (2021). Migraine: integrated approaches to clinical management and emerging treatments. The Lancet

Plain numerical DOI: 10.1016/S0140-6736(20)32342-4

DOI URL
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“Migraine is a highly disabling neurological disorder that directly affects more than 1 billion individuals worldwide. available treatment options differ between countries and include acute, preventive, and non-pharmacological therapies. because of major progress in the understanding of migraine pathogenesis, novel mechanism-based medications have emerged and expanded the armamentarium of treatments. we provide a comprehensive overview of the current standard of care that will enable informed clinical management. first, we discuss the efficacy, tolerability, and safety profile of various pharmacological therapies for acute and preventive treatment of migraine. second, we review the current knowledge on non-pharmacological therapies, such as neuromodulation and biobehavioural approaches, which can be used for a multidisciplinary approach to clinical management. third, we emphasise that any effective treatment strategy starts with building a therapeutic plan tailored to individual clinical characteristics, preferences, and needs. finally, we explore the outlook of emerging mechanism-based treatments that could address unmet challenges in clinical management of migraine.”
All, A. H., Zeng, X., Teh, D. B. L., Yi, Z., Prasad, A., Ishizuka, T., … Liu, X.. (2019). Expanding the Toolbox of Upconversion Nanoparticles for In Vivo Optogenetics and Neuromodulation. Advanced Materials

Plain numerical DOI: 10.1002/adma.201803474
DOI URL
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“Optogenetics is an optical technique that exploits visible light for selective neuromodulation with spatio-temporal precision. despite enormous effort, the effective stimulation of targeted neurons, which are located in deeper structures of the nervous system, by visible light, remains a technical challenge. compared to visible light, near-infrared illumination offers a higher depth of tissue penetration owing to a lower degree of light attenuation. herein, an overview of advances in developing new modalities for neural circuitry modulation utilizing upconversion-nanoparticle-mediated optogenetics is presented. these developments have led to minimally invasive optical stimulation and inhibition of neurons with substantially improved selectivity, sensitivity, and spatial resolution. the focus is to provide a comprehensive review of the mechanistic basis for evaluating upconversion parameters, which will be useful in designing, executing, and reporting optogenetic experiments.”
Fandel, T., & Tanagho, E. A.. (2005). Neuromodulation in voiding dysfunction: A historical overview of neurostimulation and its application. Urologic Clinics of North America

Plain numerical DOI: 10.1016/j.ucl.2004.09.006
DOI URL
directSciHub download

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“This article presents a historical overview of neurostimulation and its application in voiding dysfunction.”
Zbar, A. P.. (2014). Sacral neuromodulation and peripheral nerve stimulation in patients with anal incontinence: An overview of techniques, complications and troubleshooting. Gastroenterology Report

Plain numerical DOI: 10.1093/gastro/gou015
DOI URL
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“4 sacral neuromodulation (snm) therapy has revolutionized the management of many forms of anal incontinence, with an expanded use and a medium-term efficacy of 75% overall. this review discusses the technique of snm therapy, along with its complications and troubleshooting and a discussion of the early data pertaining to peripheral posterior tibial nerve stimulation in incontinent patients. future work needs to define the predictive factors for neurostimulatory success, along with the likely mechanisms of action of their therapeutic action.”
Karri, J., Singh, M., Orhurhu, V., Joshi, M., & Abd-Elsayed, A.. (2020). Pain Syndromes Secondary to Cluneal Nerve Entrapment. Current Pain and Headache Reports

Plain numerical DOI: 10.1007/s11916-020-00891-7
DOI URL
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“Purpose of review: the purpose of this review is to provide an overview of the cluneal nerves, present a summary of pain syndromes secondary to clunealgia, and evaluate current literature for diagnostic and treatment modalities. recent findings: multiple trials and studies have reported success with numerous modalities ranging from nerve blocks, neuroablation, and even peripheral neuromodulation with varying degrees of clinical benefit. summary: cluneal nerve entrapment or chronic impingement can cause buttock pain or referred pain to nearby areas including the lower back, pelvic area, or even the lower extremities. clunealgias and associated pain syndromes can often be challenging to diagnose and differentiate. an appreciation of the pathophysiology of clunealgias can assist with patient selection for interventional pain strategies targeted towards the cluneal nerves, including nerve blocks, neuroablation, and peripheral neuromodulation. more research is needed to better delineate the efficacy of these procedures for clunealgias.”
Fekete, Z., Horváth, C., & Zátonyi, A.. (2020). Infrared neuromodulation:A neuroengineering perspective. Journal of Neural Engineering

Plain numerical DOI: 10.1088/1741-2552/abb3b2
DOI URL

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“Infrared neuromodulation (inm) is a branch of photobiomodulation that offers direct or indirect control of cellular activity through elevation of temperature in a spatially confined region of the target tissue. research on inm started about 15 ago and is gradually attracting the attention of the neuroscience community, as numerous experimental studies have provided firm evidence on the safe and reproducible excitation and inhibition of neuronal firing in both in vitro and in vivo conditions. however, its biophysical mechanism is not fully understood and several engineered interfaces have been created to investigate infrared stimulation in both the peripheral and central nervous system. in this review, recent applications and present knowledge on the effects of inm on cellular activity are summarized, and an overview of the technical approaches to deliver infrared light to cells and to interrogate the optically evoked response is provided. the micro- and nanoengineered interfaces used to investigate the influence of inm are described in detail.”
Zhu, A., Qureshi, A. A., Kozin, E. D., & Lee, D. J.. (2020). Concepts in Neural Stimulation: Electrical and Optical Modulation of the Auditory Pathways. Otolaryngologic Clinics of North America

Plain numerical DOI: 10.1016/j.otc.2019.09.002
DOI URL
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“Understanding the mechanisms of neural stimulation is necessary to improve the management of sensory disorders. neurons can be artificially stimulated using electrical current, or with newer stimulation modalities, including optogenetics. electrical stimulation forms the basis for all neuroprosthetic devices that are used clinically. off-target stimulation and poor implant performance remain concerns for patients with electrically based neuroprosthetic devices. optogenetic techniques may improve cranial nerve stimulation strategies used by various neuroprostheses and result in better patient outcomes. this article reviews the fundamentals of neural stimulation and provides an overview of recent major advancements in light-based neuromodulation.””
LeBeau, F. E. N., El Manira, A., & Griller, S.. (2005). Tuning the network: Modulation of neuronal microcircuits in the spinal cord and hippocampus. Trends in Neurosciences

Plain numerical DOI: 10.1016/j.tins.2005.08.005
DOI URL
directSciHub download

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“Adaptation of an organism to its changing environment ultimately depends on the modification of neuronal activity. the dynamic interaction between cellular components within neuronal networks relies on fast synaptic interaction via ionotropic receptors. however, neuronal networks are also subject to modulation mediated by various metabotropic g-protein-coupled receptors that modify synaptic and neuronal function. modulation increases the functional complexity of a network, because the same

cellular components can produce different outputs depending on the behavioural state of the animal. this review, which is part of the tins microcircuits special feature, provides an overview of neuromodulation in two neuronal circuits that both produce oscillatory activity but differ fundamentally in function. hippocampal circuits are compared with the spinal networks generating locomotion, with a view to exploring common principles of neuromodulatory activity. © 2005 elsevier ltd. all rights reserved."
Cha, K. S., Yeo, D., & Kim, K. H.. (2016). Neural signal processing for closed-loop neuromodulation. Biomedical Engineering Letters

Plain numerical DOI: 10.1007/s13534-016-0231-5
DOI URL
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"Purpose: the purpose of this article is to provide an overview of the current status of neural signal processing techniques for closed-loop neuromodulation. methods: first we described overall structure of closed-loop neuromodulation systems. then, the techniques for the stimulus artifact removal were explained, and the methods for neural state monitoring and biomarker extraction were described. finally, the current status of neuromodulation based on neural signal processing was provided in detail. results: closed-loop neuromodulation system automatically adjusts stimulation parameters based on the brain response in real time. adequate tools for signal sensing and signal processing can be used to obtain meaningful biomarkers reflecting the state of neural systems. especially, an appropriate neural signal processing technique can optimize the details of stimulation for effective treatment of target disease. conclusions: neural signal-based biomarkers reflecting the pathophysiological statuses of patients are essential for closedloop neuromodulation, and they should be developed from an understanding of the relationship between clinical states and neural signals."
Hoffmann, J., & May, A.. (2019). Neuromodulation for the treatment of primary headache syndromes. Expert Review of Neurotherapeutics

Plain numerical DOI: 10.1080/14737175.2019.1585243
DOI URL
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"Introduction: neuromodulation techniques play an increasing role in the treatment of primary headaches. while initially reserved for refractory cases they are now increasingly taken into consideration in earlier treatment phases and in non-refractory situations. one of the main reasons for this paradigm shift is that most neuromodulation techniques are better tolerated as compared to the majority of pharmacological approaches. however, these techniques have their limitations that should be considered. areas covered: the review provides an overview of the available techniques and their therapeutic rationale as well as on the evidence for their efficacy and their limitations. the review covers these aspects for non-invasive vagal nerve stimulation, sphenopalatine ganglion stimulation, external trigeminal nerve stimulation, occipital nerve stimulation as well as single-pulse and repetitive-pulse transcranial magnetic stimulation. expert commentary: most of the evidence is based on open-label studies. sham devices used in controlled studies remain problematic as they either do not

produce the paresthesias perceived during stimulation or induce some degree of stimulation. invasive techniques require a surgical intervention with all the potential complications that may arise. in summary, some of the techniques provide an effective expansion of available treatment options but their indication should be thoroughly evaluated before treatment is considered."
Martens, F. M. J., & Sievert, K. D.. (2020). Neurostimulation in neurogenic patients. Current Opinion in Urology

Plain numerical DOI: 10.1097/MOU.0000000000000773
DOI URL
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"Purpose of reviewto provide an overview of available electrical stimulation devices in neurogenic patients with lower urinary tract disease.recent findingsit is advocated to do more studies in neurogenic patients as results seem promising and useful but most studies did not include neurogenic patients or neurogenic patients were not analyzed or reported separately. most studies included a small heterogenous neurogenic group with multiple pathophysiologic origin focusing on effect of a treatment instead of results of a treatment in a specific neurogenic group. neuromodulation or stimulation has the advantage that it acts on different organs, like bladder and bowel, so can treat neurogenic patients, who mostly suffer from multiple organ failure.summarybrindley procedure, sacral neuromodulation (snm) and posterior tibial nerve stimulation (ptns) are available for a while already. the brindley procedure (including sacral anterior root stimulation in combination with a rhizotomy of posterior sacral roots) is developed for selected spinal cord injury patient with a complete spinal injury, and has shown results for many years in neurogenic patients. an alternative to the rhizotomy is not established yet. snm and ptns are other modalities that are used in nonneurogenic patients, but are not yet indicated and much studied in neurogenic patients."
Harmsen, I. E., Elias, G. J. B., Beyn, M. E., Boutet, A., Pancholi, A., Germann, J., … Lozano, A. M.. (2020). Clinical trials for deep brain stimulation: Current state of affairs. Brain Stimulation

Plain numerical DOI: 10.1016/j.brs.2019.11.008
DOI URL
directSciHub download

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"Background: deep brain stimulation (dbs) is a surgical neuromodulation procedure with a historically wide range of possible therapeutic indications, including movement disorders, neuropsychiatric conditions, and cognitive disorders. ongoing research in this field is critical to gain further insights into the mechanisms of dbs, to discover novel brain targets for new and existing indications, and to refine targeting and post-operative programming techniques for the optimization of therapeutic outcomes. objective: to update on the state of dbs-related clinical human research by cataloging and summarizing clinical trials that have been completed or are currently ongoing in this field worldwide. methods: a search was conducted for clinical trials pertaining to dbs, currently listed on the clinicaltrials.gov database. trials were analyzed to generate a detailed overview of ongoing dbs-related research. specifically, trials were categorized by trial start date, study completion status, clinical phase, projected subject enrollment, disorder, brain target, country of origin, device manufacturer, funding source, and

study topic. results: in total, 384 relevant clinical trials were identified. the trials spanned 28 different disorders across 26 distinct brain targets, with almost 40% of trials being for conditions other than movement disorders. the majority of dbs trials have been us-based (41.9% of studies) but many countries are becoming increasingly active. the ratio of investigator-sponsored to industry-sponsored trials was 3:1. emphasizing the need to better understand the mechanism of action of dbs, one-third of the studies predominantly focus on imaging or electrophysiological changes associated with dbs. conclusions: this overview of current dbs-related clinical trials provides insight into the status of dbs research and what we can anticipate in the future concerning new brain targets, indications, techniques, and developing a better understanding of the mechanisms of action of dbs."
Chen, Y., Tang, T., & Erdek, M. A.. (2019). Advanced Image-Guided Procedures for Painful Spine. Neuroimaging Clinics of North America

Plain numerical DOI: 10.1016/j.nic.2019.07.005
DOI URL
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"In addition to basic image-guided injections, there are many advanced procedures to address the challenges of spine pain. patients with debilitating symptoms are offered relief, a shorter recovery period, and fewer potential complications. pain arises from numerous sites along the spine, presenting as spine pain or radiculopathy. this article is an overview of advanced techniques in this rapidly progressing field, including neuromodulation, radiofrequency thermocoagulation, discography, intradiscal thermocoagulation, and percutaneous image-guided lumbar decompression; and it highlights etiologic factors and their relationship to therapeutic technique and clinical evidence."
Mishra, S., Kumar, A., Padmanabhan, P., & Gulyás, B.. (2021). Neurophysiological correlates of cognition as revealed by virtual reality: Delving the brain with a synergistic approach. Brain Sciences

Plain numerical DOI: 10.3390/brainsci11010051
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"The synergy of perceptual psychology, technology, and neuroscience can be used to comprehend how virtual reality affects cognition of human brain. numerous studies have used neuroimaging modalities to assess the cognitive state and response of the brain with various external stimulations. the virtual reality-based devices are well known to incur visual, auditory, and haptic induced perceptions. neurophysiological recordings together with virtual stimulations can assist in correlating humans' physiological perception with response in the environment designed virtually. the effective combination of these two has been utilized to study human behavior, spatial navigation performance, and spatial presence, to name a few. moreover, virtual reality-based devices can be evaluated for the neurophysiological correlates of cognition through neurophysiological recordings. challenges exist in the integration of real-time neuronal signals with virtual reality-based devices, and enhancing the experience together with real-time feedback and control through neuronal sig-nals. this article provides an overview of neurophysiological correlates of cognition as revealed by virtual reality experience, together with a description of perception and virtual reality-based neuromodulation, various

applications, and existing challenges in this field of research."
Christen, M., & Müller, S.. (2017). Editorial: The Clinical and Ethical Practice of Neuromodulation – Deep Brain Stimulation and Beyond. Frontiers in Integrative Neuroscience

Plain numerical DOI: 10.3389/fnint.2017.00032
DOI URL
directSciHub download

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"Neuromodulation is among the fastest-growing areas of medicine, involving many diverse specialties and affecting hundreds of thousands of patients with numerous disorders worldwide. it can briefly be described as the science of how electrical, chemical, and mechanical interventions can modulate the nervous system function. a prominent example of neuromodulation is deep brain stimulation (dbs), an intervention that reflects a fundamental shift in the understanding of neurological and psychiatric diseases: namely as resulting from a dysfunctional activity pattern in a defined neuronal network that can be normalized by targeted stimulation. the application of dbs has grown remarkably and more than 130,000 patients worldwide have obtained a dbs intervention in the past 30 years—most of them for treating movement disorders. these numbers will grow further for several reasons. first, dbs is investigated for various novel neurological and psychiatric indications. second, current research suggests that stimulation may be more beneficial if it is applied earlier in the course of the disease, especially for parkinsonian patients. third, the number of countries, centers, and companies that get involved in this field is steadily increasing. this frontiers research topics provides an overview on the current discussion beyond basic research in dbs and other brain stimulation technologies. researchers from clinical disciplines (e.g., neurology, neurosurgery, and psychiatry), neuroethics, social science, law, and economics who are working on broader clinical and social issues related to dbs and related neuromodulation technologies have contributed to this research topic. in the following, we provide a brief overview on the content of the e-book on " the clinical and ethical practice of neuromodulation – deep brain stimulation and beyond. " the paper from ineichen and christen exemplifies the impressive publication activity in the field. they analyzed more than 7,000 papers published between 1991 and 2014 on dbs using quantitative methods. the study confirms known trends within the field such as the emergence of psychiatric indications with a particular focus on depression and the increasing discussion of complex side-effects such as personality changes. other findings are more surprising, e.g., that hardware-related issues are far more robustly connected to ethical issues compared to impulsivity, concrete side-effects or death/suicide. this indicates that the bioethica…"
Stakenborg, N., & Boeckxstaens, G. E.. (2021). Bioelectronics in the brain-gut axis: Focus on inflammatory bowel disease (IBD). International Immunology

Plain numerical DOI: 10.1093/intimm/dxab014
DOI URL
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"Accumulating evidence shows that intestinal homeostasis is mediated by cross-talk between the nervous system, enteric neurons and immune cells, together forming specialized neuroimmune units at distinct anatomical locations within the gut. in this review, we will particularly discuss how the intrinsic

and extrinsic neuronal circuitry regulates macrophage function and phenotype in the gut during homeostasis and aberrant inflammation, such as observed in inflammatory bowel disease (ibd). furthermore, we will provide an overview of basic and translational ibd research using these neuronal circuits as a novel therapeutic tool. finally, we will highlight the different challenges ahead to make bioelectronic neuromodulation a standard treatment for intestinal immune-mediated diseases." Serrano-Munoz, D., Taylor, J., Megia-Garcia, A., & Gomez-Soriano, J.. (2019). Neuromodulation for neurorehabilitation of motor disorders for stroke and spinal cord injury: An overview. Neuromodulation

Show/hide publication abstract

"The international neuromodulation society has defined therapeutic neuromodulation as 'the alteration of nerve activity through targeted delivery of a stimulus, such as electrical stimulation or chemical agents, to specific neurological sites in the body' (1). therapeutic neuromodulation can improve functional recovery and relieve neurological symptoms associated with stroke and spinal cord injury (sci), which has been highlighted by a tenfold increase in the number of studies cited in this field (institute for scientific information, january 2019). however, the overall quality of these studies needs to be assessed to facilitate better evidence-based choices about health interventions, especially as recent advances in this field has attracted intense online media attention (altmetric. bodleian oxford library, january 2019). in this workshop leading international researchers in the field of therapeutic neuromodulation for sci and stroke will present their latest results for improving motor system neurorehabilitation using both invasive and non-invasive neuromodulation techniques, ranging from repetitive magnetic motor cortex, transcutaneous spinal and deep brain cerebellum stimulation. each speaker will highlight the clinical impact of their research line and the priority areas that need to be addressed for further technical development. results from a systematic review of non-invasive transcutaneous spinal cord stimulation for sci motor neurorehabilitation will be presented, with a special emphasis on stimulation parameters, clinical trial design and outcome measures. finally, two ongoing research projects at the hospital nacional de paraplejicos and the universidad castilla-la mancha will be introduced to the audience. the neurotrain project will apply lumbosacral transcutaneous electrical spinal stimulation in combination with intensive cycling, with the aim of potentiating gait function and controlling spasticity for patients with incomplete sci. in parallel the recode project will assess how non-invasive transcutaneous spinal and transcortical direct current stimulation, synchronized with robotic exoskeletons, can potentiate gait rehabilitation after sci." Civelli, O.. (2012). Orphan GPCRs and Neuromodulation. Neuron

Plain numerical DOI: 10.1016/j.neuron.2012.09.009
DOI URL
directSciHub download

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"Most g protein-coupled receptors (gpcrs) started as orphan gpcrs. matching them to known neuromodulators led to the elucidation of the broad diversity of the neuroreceptor families. moreover, orphan gpcrs have also been used as targets to discover novel neuromodulators. these discoveries have had profound impact on our understanding of brain function. here, i present an overview of how some of the novel neuropeptides have enlarged our comprehension of responses that direct sleep/wakefulness, the onset of obesity and the feeding response. i also discuss other advances gained from orphan gpcr studies such as the concept of specificity in neuromodulation or of receptors

acting as sensors instead of synaptic transmitters. finally, i suggest that the recently discovered neuromodulators may hold the keys to our understanding of higher brain functions and psychiatric disorders."
Wagner, T., Valero-Cabre, A., & Pascual-Leone, A.. (2007). Noninvasive human brain stimulation. Annual Review of Biomedical Engineering

Plain numerical DOI: 10.1146/annurev.bioeng.9.061206.133100
DOI URL
directSciHub download

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"Noninvasive brain stimulation with transcranial magnetic stimulation (tms) or transcranial direct current stimulation (tdcs) is valuable in research and has potential therapeutic applications in cognitive neuroscience, neurophysiology, psychiatry, and neurology. tms allows neurostimulation and neuromodulation, while tdcs is a purely neuromodulatory application. tms and tdcs allow diagnostic and interventional neurophysiology applications, and focal neuropharmacology delivery. however, the physics and basic mechanisms of action remain incompletely explored. following an overview of the history and current applications of noninvasive brain stimulation, we review stimulation device design principles, the electromagnetic and physical foundations of the techniques, and the current knowledge about the electrophysiologic basis of the effects. finally, we discuss potential biomedical and electrical engineering developments that could lead to more effective stimulation devices, better suited for the specific applications. copyright © 2007 by annual reviews. all rights reserved."
Cho, Y., Park, J., Lee, C., & Lee, S.. (2020). Recent progress on peripheral neural interface technology towards bioelectronic medicine. Bioelectronic Medicine

Plain numerical DOI: 10.1186/s42234-020-00059-z
DOI URL
directSciHub download

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"Modulation of the peripheral nervous system (pns) has a great potential for therapeutic intervention as well as restore bodily functions. recent interest has focused on autonomic nerves, as they regulate extensive functions implicated in organ physiology, chronic disease state and appear tractable to targeted modulation of discrete nerve units. therapeutic interventions based on specific bioelectronic neuromodulation depend on reliable neural interface to stimulate and record autonomic nerves. furthermore, the function of stimulation and recording requires energy which should be delivered to the interface. due to the physiological and anatomical challenges of autonomic nerves, various forms of this active neural interface need to be developed to achieve next generation of neural interface for bioelectronic medicine. in this article, we present an overview of the state-of-the-art for peripheral neural interface technology in relation to autonomic nerves. also, we reveal the current status of wireless neural interface for peripheral nerve applications. recent studies of a novel concept of self-sustainable neural interface without battery and electronic components are presented. finally, the recent results of non-invasive stimulation such as ultrasound and magnetic stimulation are covered and the perspective of the future research direction is provided."

Linster, C.. (2014). Neuromodulation: Overview. In Encyclopedia of Computational Neuroscience

Plain numerical DOI: 10.1007/978-1-4614-7320-6_787-1
DOI URL
directSciHub download

Lakatos, P., Gross, J., & Thut, G.. (2019). Review A New Unifying Account of the Roles of Neuronal. Current Biology

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“Rhythms are a fundamental and defining feature of neuronal activity in animals including humans. this rhyth- mic brain activity interacts in complex ways with rhythms in the internal and external environment through the phenomenon of ‘neuronal entrainment’, which is attracting increasing attention due to its suggested role in a multitude of sensory and cognitive processes. some senses, such as touch and vision, sample the environ- ment rhythmically, while others, like audition, are faced with mostly rhythmic inputs. entrainment couples rhythmic brain activity to external and internal rhythmic events, serving fine-grained routing and modulation of external and internal signals across multiple spatial and temporal hierarchies. this interaction between a brain and its environment can be experimentally investigated and even modified by rhythmic sensory stimuli or invasive and non-invasive neuromodulation techniques. we provide a comprehensive overview of the topic and propose a theoretical framework of how neuronal entrainment dynamically structures information from incoming neuronal, bodily and environmental sources. we discuss the different types of neuronal entrainment, the conceptual advances in the field, and converging evidence for general principles.”
Bartoli, F., Burnstock, G., Crocamo, C., & Carrà, G.. (2020). Purinergic signaling and related biomarkers in depression. Brain Sciences

Plain numerical DOI: 10.3390/brainsci10030160
DOI URL
directSciHub download

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“It is established that purinergic signaling can shape a wide range of physiological functions, including neurotransmission and neuromodulation. the purinergic system may play a role in the pathophysiology of mood disorders, influencing neurotransmitter systems and hormonal pathways of the hypothalamic-pituitary-adrenal axis. treatment with mood stabilizers and antidepressants can lead to changes in purinergic signaling. in this overview, we describe the biological background on the possible link between the purinergic system and depression, possibly involving changes in adenosine-and atp-mediated signaling at p1 and p2 receptors, respectively. furthermore, evidence on the possible antidepressive effects of non-selective adenosine antagonist caffeine and other purinergic modulators is reviewed. in particular, a2a and p2x7 receptors have been identified as potential targets for depression treatment. preclinical studies highlight that both selective a2a and p2x7 antagonists may have antidepressant effects and potentiate responses to antidepressant treatments. consistently, recent studies feature the possible role of the purinergic system peripheral metabolites as possible biomarkers of depression. in particular, variations of serum uric acid, as the end product of purinergic metabolism, have been found in depression. although several open questions remain, the purinergic

system represents a promising research area for insights into the molecular basis of depression."
Fellous, J. M., & Linster, C.. (1998). Computational Models of Neuromodulation. Neural Computation

Plain numerical DOI: 10.1162/089976698300017476
DOI URL
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"Computational modeling of neural substrates provides an excellent theoretical framework for the understanding of the computational roles of neuromodulation. in this review, we illustrate, with a large number of modeling studies, the specific computations performed by neuromodulation in the context of various neural models of invertebrate and vertebrate preparations. we base our characterization of neuromodulations on their computational and functional roles rather than on anatomical or chemical criteria. we review the main framework in which neuromodulation has been studied theoretically (central pattern generation and oscillations, sensory processing, memory and information integration). finally, we present a detailed mathematical overview of how neuromodulation has been implemented at the single cell and network levels in modeling studies. overall, neuromodulation is found to increase and control computational complexity."
Chaudhry, S. R., Stadlbauer, A., Buchfelder, M., & Kinfe, T. M.. (2021). Melatonin moderates the triangle of chronic pain, sleep architecture and immunometabolic traffic. Biomedicines

Plain numerical DOI: 10.3390/biomedicines9080984
DOI URL
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"Preclinical as well as human studies indicate that melatonin is essential for a physiological sleep state, promotes analgesia and is involved in immunometabolic signaling by regulating neuroin-flammatory pathways. experimental and clinical neuromodulation studies for chronic pain treatment suggest that neurostimulation therapies such as spinal cord stimulation, vagus nerve stimulation and dorsal root ganglion stimulation have an impact on circulating inflammatory mediators in blood, cerebrospinal fluid and saliva. herein, we provide an overview of current literature relevant for the shared pathways of sleep, pain and immunometabolism and elaborate the impact of melatonin on the crossroad of sleep, chronic pain and immunometabolism. furthermore, we discuss the potential of melatonin as an adjunct to neurostimulation therapies. in this narrative review, we addressed these questions using the following search terms: melatonin, sleep, immunometabolism, obesity, chronic pain, neuromodulation, neurostimulation, neuroinflammation, molecular inflammatory phenotyping. so far, the majority of the published literature is derived from experimental studies and studies specifically assessing these relationships in context to neurostimulation are sparse. thus, the adjunct potential of melatonin in clinical neurostimulation has not been evaluated under the umbrella of randomized-controlled trials and deserves increased attention as melatonin interacts and shares pathways relevant for noninvasive and invasive neurostimulation therapies."

Konofagou, E.. (2018). Focused ultrasound for modulation of the central and peripheral nervous system . The Journal of the Acoustical Society of America

Plain numerical DOI: 10.1121/1.5035647
DOI URL
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“Noninvasive neuromodulation has been the preferred option of neurological treatment but noninvasive approaches fall short when it comes to depth penetration. ultrasound modulation has been shown feasible in several species including humans both in vitro and in vivo. in this paper, an overview of our group’s ultrasound neuromodulation in both the central (cns) and the peripheral (pns) nervous systems will be provided. in cns, both motor- and sensory-related responses have been elicited in mice in vivo both in ipsilateral and contralateral limbs and pupils, respectively. the success are was highly correlated with the applied intensity and pressure in both the limb movement and ocular changes. the brain regions targeted were the somatosensory and visual cortex for the limb movement and the superior colliculus and locus coeruleus for the pupil dilation. in pns, stimulation and inhibition of the sciatic nerve with fus was elicited at different ultrasound parameters in vivo. displacement of the nerve highly cor…”
Byron, N., Semenova, A., & Sakata, S.. (2021). Mutual interactions between brain states and Alzheimer’s disease pathology: A focus on gamma and slow oscillations. Biology

Plain numerical DOI: 10.3390/biology10080707
DOI URL
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“Brain state varies from moment to moment. while brain state can be defined by ongoing neuronal population activity, such as neuronal oscillations, this is tightly coupled with certain behavioural or vigilant states. in recent decades, abnormalities in brain state have been recognised as biomarkers of various brain diseases and disorders. intriguingly, accumulating evidence also demonstrates mutual interactions between brain states and disease pathologies: while abnormalities in brain state arise during disease progression, manipulations of brain state can modify disease pathology, suggesting a therapeutic potential. in this review, by focusing on alzheimer’s disease (ad), the most common form of dementia, we provide an overview of how brain states change in ad patients and mouse models, and how controlling brain states can modify ad pathology. specifically, we summarise the relationship between ad and changes in gamma and slow oscillations. as pathological changes in these oscillations correlate with ad pathology, manipulations of either gamma or slow oscillations can modify ad pathology in mouse models. we argue that neuromodulation approaches to target brain states are a promising non-pharmacological intervention for neurodegenerative diseases.”
Kohan, L., McKenna, C., & Irwin, A.. (2020). Ilioinguinal Neuropathy. Current Pain and Headache Reports

Plain numerical DOI: 10.1007/s11916-020-0833-6
DOI URL

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“Purpose of review: the purpose of this review is to present an overview of ilioinguinal (il) neuralgia and evaluate the current literature. recent findings: treatment of il neuralgia includes pharmacotherapies, perineural injections, radiofrequency ablation, cryoablation, neuromodulation, and neurectomy. the efficacy of these therapies varies considerably. summary: il neuralgia is a common pain disorder characterized by pain in the lower abdomen and upper thigh. while various modalities can be used in the treatment of il neuralgia, the efficacy of these modalities is at times limited. dorsal root ganglion stimulation exhibits promise in the treatment of il neuralgia. more research is needed to better address the needs of patients suffering from this disorder.”
Chen, S. P., & Ayata, C.. (2017). Novel Therapeutic Targets Against Spreading Depression. Headache

Plain numerical DOI: 10.1111/head.13154
DOI URL
directSciHub download

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“Migraine is among the most prevalent and disabling neurological diseases in the world. cortical spreading depression (sd) is an intense wave of neuronal and glial depolarization underlying migraine aura, and a headache trigger, which has been used as an experimental platform for drug screening in migraine. here, we provide an overview of novel therapeutic targets that show promise to suppress sd, such as acid-sensing ion channels, casein kinase i?, p2x7-pannexin 1 complex, and neuromodulation, and outline the experimental models and essential quality measures for rigorous and reproducible efficacy testing.”
Ekhtiari, H., Tavakoli, H., Addolorato, G., Baeken, C., Bonci, A., Campanella, S., … Hanlon, C. A.. (2019). Transcranial electrical and magnetic stimulation (tES and TMS) for addiction medicine: A consensus paper on the present state of the science and the road ahead. Neuroscience and Biobehavioral Reviews

Plain numerical DOI: 10.1016/j.neubiorev.2019.06.007
DOI URL
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“There is growing interest in non-invasive brain stimulation (nibs) as a novel treatment option for substance-use disorders (suds). recent momentum stems from a foundation of preclinical neuroscience demonstrating links between neural circuits and drug consuming behavior, as well as recent fda-approval of nibs treatments for mental health disorders that share overlapping pathology with suds. as with any emerging field, enthusiasm must be tempered by reason; lessons learned from the past should be prudently applied to future therapies. here, an international ensemble of experts provides an overview of the state of transcranial-electrical (tes) and transcranial-magnetic (tms) stimulation applied in suds. this consensus paper provides a systematic literature review on published

data – emphasizing the heterogeneity of methods and outcome measures while suggesting strategies to help bridge knowledge gaps. the goal of this effort is to provide the community with guidelines for best practices in tes/tms sud research. we hope this will accelerate the speed at which the community translates basic neuroscience into advanced neuromodulation tools for clinical practice in addiction medicine."
Fridén, J., House, J., Keith, M., Schibli, S., & van Zyl, N.. (2021). Improving hand function after spinal cord injury. Journal of Hand Surgery: European Volume

Plain numerical DOI: 10.1177/17531934211027460
DOI URL
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"Nerve transfer surgery has expanded reconstructive options for restoring upper extremity function following spinal cord injury. by adding new motor donors to the pool already available through tendon transfers, the effectiveness of treatment should improve. planning which procedures and in which order to perform, along with their details must be delineated. to meet these demands, refined diagnostics are needed, along with awareness of the remaining challenges to restore intrinsic muscle function and to address spasticity and its consequences. this article summaries recent advances in surgical reanimation of upper extremity motor control, together with an overview of the development of neuro-prosthetic and neuromodulation techniques to modify recovery or substitute for functional losses after spinal cord injuries."
Anderson, N. D., & Craik, F. I. M.. (2017). 50 years of cognitive aging theory. Journals of Gerontology – Series B Psychological Sciences and Social Sciences

Plain numerical DOI: 10.1093/geronb/gbw108
DOI URL
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"Objectives: the objectives of this introduction to the journal of gerontology: psychological sciences special issue on '50 years of cognitive aging theory' are to provide a brief overview of cognitive aging research prior to 1965 and to highlight significant developments in cognitive aging theory over the last 50 years. method: historical and recent theories of cognitive aging were reviewed, with a particular focus on those not directly covered by the articles included in this special issue. results: prior to 1965, cognitive aging research was predominantly descriptive, identifying what aspects of intellectual functioning are affected in older compared with younger adults. since the mid-1960s, there has been an increasing interest in how and why specific components of cognitive domains are differentially affected in aging and a growing focus on cognitive aging neuroscience. discussion: significant advances have taken place in our theoretical understanding of how and why certain components of cognitive functioning are or are not affected by aging. we also know much more now than we did 50 years ago about the underlying neural mechanisms of these changes. the next 50 years undoubtedly will bring new theories, as well as new tools (e.g., neuroimaging advances, neuromodulation, and technology), that will further our understanding of cognitive aging."

Category

1. Cognitive science
2. Education
3. General
4. General psychology
5. Neuropolitics
6. Neuroscience

Tags

1. deep brain stimulation
2. neuromodulation
3. tms
4. transcranial magnetic stimulation
5. transcranial ultrasound stimulation
6. tus

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