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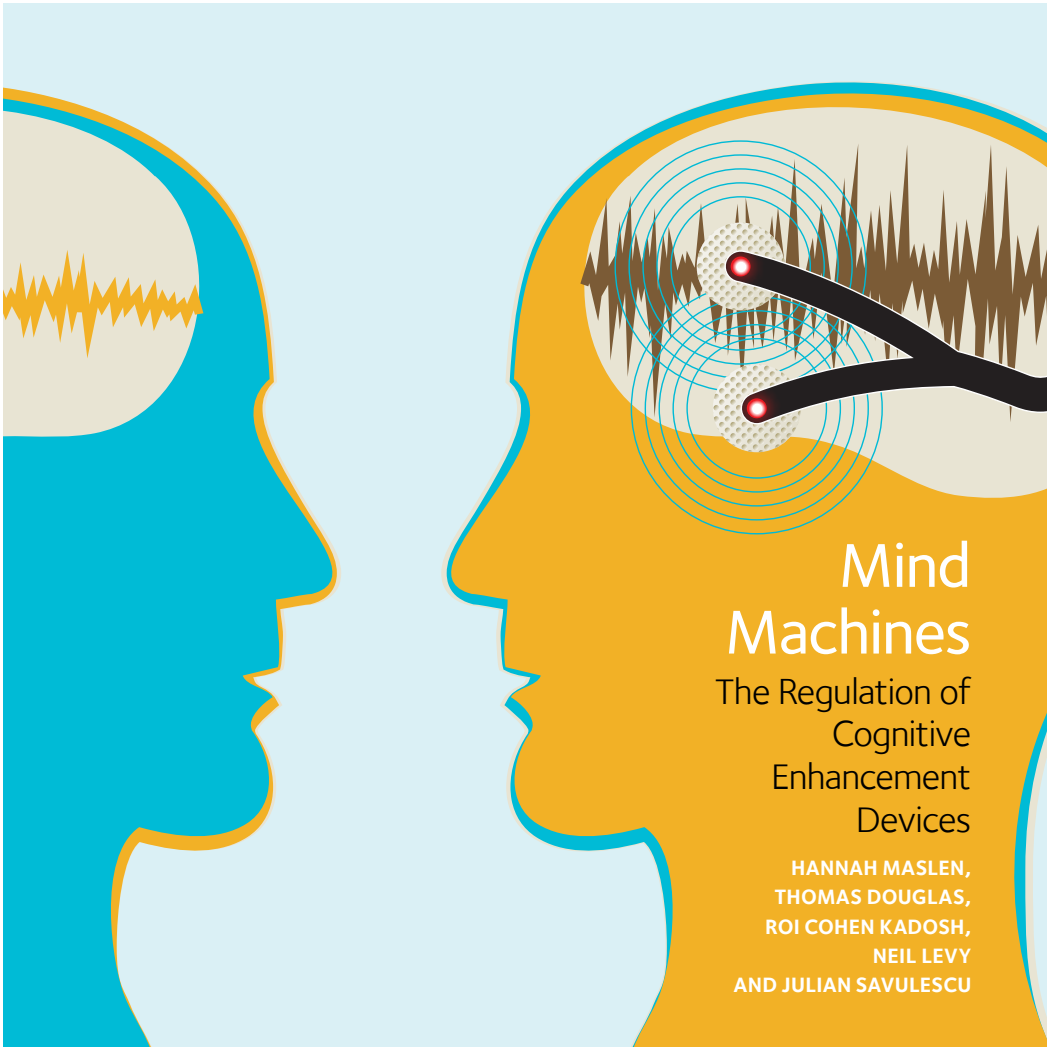

Mind Machines

The Regulation of Cognitive Enhancement Devices

HANNAH MASLEN,
THOMAS DOUGLAS,
ROI COHEN KADOSH,
NEIL LEVY
AND JULIAN SAVULESCU

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For comprehensive discussion of the detail of relevant legislation and the challenges it presents for implementing our model, please see our companion academic paper: Maslen, H., Douglas, T., Cohen Kadosh, R., Levy, N., and Savulescu, J. (2014). The regulation of cognitive enhancement devices: extending the medical model. *Journal of Law and the Biosciences*, 1(1), 68-93.
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Executive Summary

The aims of the paper

It is becoming increasingly easy for individuals to buy brain-modulating devices online that promise to make the user's brain work faster, or more effectively, or more creatively. Such devices can involve passing electrical currents through one's brain or using electromagnetic fields to penetrate the scalp and skull to make neurons fire. Yet, when purchased outside clinical settings, these devices are unregulated, with no system in place to ensure their safety. With the market for enhancement technologies expanding, and with devices already crossing international borders, controlling which products are approved for sale is a global issue, potentially requiring international regulatory harmonisation.

It is a confused situation given that the same kinds of devices are being trialled by scientists in clinical settings to potentially alleviate the symptoms of conditions such as depression or Parkinson's disease. Others are being developed to improve the concentration of people suffering with attention deficit hyperactivity disorder, or as a cure for insomnia. However, when no claim to therapeutic effect - either treatment or diagnosis - is made by the manufacturer, these devices can be considered to be cognitive enhancement devices (CEDs). As the market for CEDs grows, it is timely to ensure that the correct regulatory mechanisms are in place to oversee this expanding industry. This paper provides a comprehensive overview of the types of CEDs available; assesses the regulatory weaknesses as they relate to CEDs; and provides a practical path forward in designing an appropriate regulatory model for CEDs.

What are CEDs?

A CED is a piece of equipment or combination of pieces of equipment that affects the functioning of a healthy brain such that it performs better in at least one cognitive domain (e.g. memory, attention, learning, facial recognition). Possible examples include:

- ***Transcranial direct current stimulators***: the most widely-marketed CED, which involves sending a small direct current between two or more electrodes to facilitate or inhibit spontaneous neuronal activity. They have been shown to enhance working memory, attention, language and mathematics skills.
- ***Transcranial magnetic stimulation***: a neurostimulation and neuromodulation technique that uses electromagnetic åelds to penetrate the scalp and skull. It has been shown to improve working memory and performance of complex motor learning tasks.
- ***Cranial electrotherapy stimulator***: a non-traditional therapeutic device that applies pulsed, alternating microcurrent transcutaneously to the head via electrodes placed on the earlobes. There is evidence that CES is effective for anxiety, headaches, åbromyalgia, smoking cessation, drug withdrawal symptoms, and pain.
- ***Neurofeedback equipment***: uses real-time displays of electrical patterns from brainwave activity to regulate or suppress different patterns of activity. In the clinical domain, neurofeedback has helped patients with epilepsy, autism and insomnia.

Why are CEDs currently not regulated?

CEDs, despite often raising safety and effectiveness concerns comparable to those raised by medical devices, are not covered by the EU Medical Devices Directive (MDD). The current definition of a medical device specifies that the device must be intended by the manufacturer to be used for diagnostic and/or therapeutic purposes. Since CEDs are neither diagnostic nor therapeutic, they are not identified as devices for medical regulation. In our paper we present a summary of the scientific literature on CEDs, but it is beyond the scope of this paper to comprehensively assess how effective these devices are. We then explore a number of regulatory options for CEDs, including the possible use of new and/or existing instruments. We also consider the conceptual and practical issues which will influence the different approaches, and argue that the MDD should be amended to ensure appropriate safety and regulatory oversight of CEDs.

Our recommendations in summary:

Recommendations for regulators in the EU

- ***Regulate CEDs within the Medical Devices Directive***: CEDs have similar mechanisms and risk-proåles to some medical devices and are often essentially the same device; parsimony in legislation is desirable; and the proposed inclusion of some non-medical (cosmetic) implantable and invasive devices sets a precedent for broadening the remit of the directive in this way.
- ***Develop a 'positive list' of 'cognition improving or facilitating devices (without a medical purpose)'***: Although this means that the legislation has to react to the emergence of hitherto unregulated devices as they come on to the market, the extension of the directive to all cognition improving or facilitating devices would generate huge difåculties for regulators in keeping the purview of the directive appropriately narrow.

To be included on the list, it must be the case that the manufacturer makes cognitive enhancement claims about the device. There should be a strong presumption for inclusion of all active devices. Devices used widely in quasi-clinical settings should also be considered for inclusion.

- ***Develop a graded system of regulation***: Low, moderate and high-risk devices will undergo different assessment procedures designed to optimise consumer choice and maximise efâciency of the system.
- ***Prohibit high-risk CEDs from the market***: Where particular models of devices are likely to cause harm (e.g. some TMS-type devices may be likely to cause seizures), they should be prohibited.
- ***Err on the side of consumer choice for moderate-risk devices***: Given that there may be differences in opinion concerning how valuable enhancement is, and given that consumer decisions are not made amidst the vulnerabilities of the clinical context, an estimation of the beneâts of a moderate-risk CED should not be restricted to a narrow measure of effectiveness. The assessment should therefore err towards consumer freedom. Comprehensive, objective information from the manufacturers about mechanisms, safe use and risks and beneâts should be required under the MDD to allow consumers to make informed decisions and to use devices safely.
- ***Ensure regulatory efæciency by incorporating a low-risk exemption***: Where CEDs are deemed to be low risk and are unlikely to generate large indirect costs to the healthcare system, there would be a case for exempting them from continued regulatory evaluation and the need to demonstrate objective beneât. Neurofeedback devices would be an example of a low-risk CED unlikely to require ongoing evaluation.

Recommendations for protecting children

- ***Require a higher level of safety***: The exception to our proposal is where devices of any level of risk are intended for use on/by non-competent third parties such as children. These devices should be regulated to the same standard as medical devices, requiring effectiveness to justify risk.
- ***Introduce criminal sanctions***: Due to the possibility that CEDs that are intended for adults could be used on children, by individuals lacking adequate training, we propose that such use should attract criminal sanctions in the same way as supplying children with alcohol attracts criminal sanctions.

Recommendations for regulators in the US and elsewhere

- ***Address global gaps***: The same regulatory gap exists in the US and other jurisdictions, so our model could be adopted elsewhere. It is conceivable that a global response to the emerging CED market could involve a coordinated approach to amend analogous pieces of medical device legislation in recognition that most CEDs will be marketed and purchased across borders.

Recommendations for manufacturers of CEDs

- ***Exercise best practice***: In anticipation of regulatory oversight, manufacturers should begin to adhere to good practice in manufacturing consistent with the sorts of requirements that the MDD would be likely to impose. This could involve drawing up technical documentation (including clinical evaluation); setting up an internal quality management system; establishing a follow-up system to respond to incidents arising from consumer usage or from the internal testing process; and ensuring devices are sold with comprehensive, objective information about safe use, risks and effectiveness.

Benefits of our proposed regulatory model

The outcome of our model would be to filter the most dangerous enhancement technologies out of the market, leaving individuals free to choose which small-to-moderate risks they are willing to take in pursuit of their wellbeing. It also imposes requirements on manufacturers to provide enough detailed, honest information about the product to enable individuals to use the devices in the safest way possible, in full knowledge of all known risks and side effects.

Introduction

Devices such as brain stimulators are being marketed to the general public for the purpose of cognitive enhancement. Such devices directly modify the electrical activity of the brain, with some effects persisting beyond the stimulation session. As scientific research into cognitive enhancement burgeons, it is likely that public interest will increase, generating a market for more – and more powerful – devices.

This emerging market presents a challenge for regulatory bodies around the world. In many jurisdictions, such as the EU and the US, if the manufacturer of a device makes medical claims – indicating that the device can be used to treat or diagnose a particular condition – then that device is subject to regulatory requirements. These requirements often involve the manufacturer having to prove a certain level of safety and effectiveness for the device. However, devices about which enhancement claims are made are not currently subject to anything more than basic product safety requirements. Despite often being the same type of device as those manufactured for research or medical purposes, versions of these devices can be made and sold without regulation, as long as the manufacturer avoids making treatment claims. For example, transcranial direct current stimulation (tDCS) is a technique used in clinical research. Amongst other things, scientists are investigating its potential to treat depression and Parkinson's disease. However, the very same sort of device is now being marketed online as a device that can improve focus and reaction speed in healthy individuals. Whilst the devices manufactured for research and clinical use will have been assessed by governmental agencies for safety and effectiveness, the devices marketed for enhancement have undergone no comparable assessment.

In the EU context, there have been a number of calls from groups such as the British Medical Association (2007)[1] for more policy debate on enhancement technologies. However, very few specific recommendations have been made about how regulators should create or amend legislation to react to the sale of devices intended for enhancement. Indeed, the debate that has taken place has focused predominantly on pharmaceutical cognitive enhancers; drugs developed for medical conditions that are being used off-label to improve things like concentration, impulse control and memory in healthy individuals.

Through exploring the regulatory options, this policy paper argues that the existing medical device legislation should be amended so that it also regulates which cognitive enhancement devices (CEDs) are placed on the market. In arguing for this regulatory model, the paper highlights potential challenges to its implementation, and suggests solutions. Although we focus on the European regulatory context, we note that the same regulatory gap exists in the US and elsewhere, and that our model might also provide a solution in these jurisdictions.

1. What are cognitive enhancement devices?

A cognitive enhancement device is a piece of equipment or combination of pieces of equipment that affects the functioning of a healthy brain such that it performs better in at least one cognitive domain (e.g. memory, attention, learning, impulse control, facial recognition). Although conclusive scientific evidence on the existence and strength of enhancement effects of potential CEDs is still to be gathered, existing studies indicate some efficacy. Sometimes a device might at the same time be a CED and a medical device, where the device also has therapeutic applications. It is important to note, however, that in regulatory contexts, it is often what the manufacturer claims the device is to be used for that denotes its purpose, and not a broader consideration of all of the possible uses for the device (see section 3.2).

Providing a definition of what constitutes a CED is a different task from deciding which CEDs should be regulated, and to what level of stringency. Under our definition, a DVD that the manufacturer claims has cognition-enhancing effects might plausibly be considered a CED. That DVDs and other innocuous devices might be captured by a general definition does not mean that any proposal for the regulation of CEDs is doomed to overreach. Instead, it highlights the importance of proposing a regulatory model that captures only the devices that warrant at least some monitoring. Further, if a device were to come within the purview of a regulatory body, this does not necessarily mean that it will automatically trigger an arduous process of investigation and testing in order to meet the regulator's approval. Distinctions can be made between devices that warrant very rigorous assessment procedures; devices that warrant some assessment of key aspects of their design and functioning; and other devices, the manufacturers of which perhaps simply need to register their conformity with basic safety requirements. Such stratification occurs for medical devices: [2]

'It is not feasible economically nor justifiable in practice to subject all medical devices to the most rigorous conformity assessment procedures available. A graduated system of control is more appropriate. In such a system, the level of control corresponds to the level of potential hazard inherent in the type of device concerned. A medical device classification system is therefore needed, in order to apply to medical devices an appropriate conformity assessment procedure.'

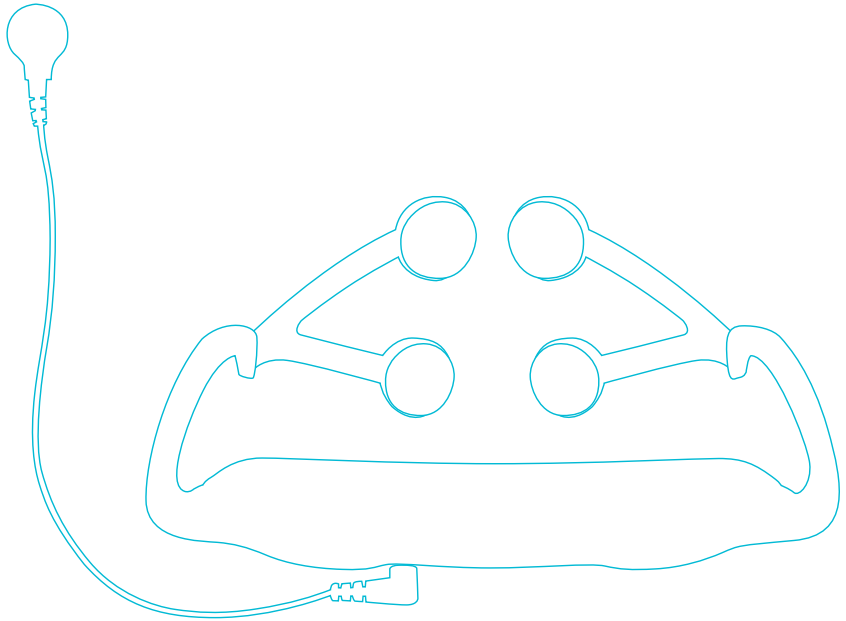
If a device were to be identified by a regulatory instrument, only to be cleared as not needing ongoing assessment, this does not mean that it was a mistake for the device to have received regulatory attention. A decision that reflects that a device is not in need of further control can be as important as a decision about a device's need for control. This is because 1) it allows consumers to know and be reassured that the device they are considering purchasing poses low or no risk and 2) it cannot always be known pre-consideration that the decision will be made to subject the device to no further assessment. Further, we later suggest that the manufacturers of low-risk devices be required to satisfy regulators that they provide with their device sufficient information on safe use (see section 3.4). Regulation is not just about safety; it also prevents manufacturers from making erroneous or exaggerated claims. This allows consumers to make informed choices. In what is proposed below we take care to consider the regulatory model that best avoids overreach (see section 3.1) and that does not impose inappropriate burdens on the manufacturers of low risk devices (see section 3.4).

Examples of CEDs are presently not numerous. However, this does not obviate the need to make a proposal now about how they should be regulated: the current emergence of a market for tDCS for enhancement is enough to demonstrate a regulatory gap, and the likelihood that new devices will be developed and placed on the market is not at all far-fetched. Further, some devices (such as Transcranial Magnetic Stimulators (TMS)) that are currently sold for clinical research are beginning to show potential as devices which could also be used for enhancement.[3] That there is currently no obvious enhancement market for these devices does not mean that manufacturers could not begin to market the same or similar devices whilst making enhancement, rather than treatment, claims.

The devices we now describe are plausible examples of CEDs. Some are already being sold without regulation. In presenting potential therapeutic and enhancement effects of these devices, we summarise and report studies from the scientific literature, but do not claim to have undertaken an independent meta-analysis of all published research. It is beyond the scope of this paper to determine how effective these devices are.

It is worth emphasising that proposing that CEDs be regulated is not an exercise in scaremongering: it might be that some of the devices we describe pose little or no risk, and should only have to meet basic requirements. It was argued above that these possibilities do not make regulatory attention pointless. Moreover, there will be some types of device that do pose moderate risks and that should therefore undergo more rigorous assessment procedures. Further still, even when a type of intervention is considered safe enough in general, this does not mean that all devices sold for this purpose will be similarly safe.

1.1 Transcranial direct current stimulation (tDCS)



1.1.1 What is tDCS?

Transcranial direct current stimulation is the most widely publically-marketed kind of brain stimulation device for cognitive enhancement. It involves sending a small direct current between two or more electrodes to facilitate or inhibit spontaneous neuronal activity. tDCS is usually described as a non-invasive technique as no part of the device breaches the skin. However, the fact that electrical currents go through the

brain makes the distinction between invasive and truly non-invasive devices blurry, and this should not elude regulators.

Weak electrical currents, usually in the order of 1-2 mA, are applied to the head via electrodes. The electrodes, most frequently at the size of 25-35cm^2, are placed on the scalp above the area that the experimenter is interested in affecting. When the current is applied constantly over a short duration (10-20 minutes) it passes painlessly through the scalp and skull and alters spontaneous neuronal activity.

The neurological effects of tDCS depend on whether the stimulation is anodal or cathodal: anodal stimulation increases cortical excitability whilst cathodal stimulation decreases cortical excitability.[4]

1.1.2 Therapeutic applications

To date, a number of clinical studies have reported some promising effects of tDCS when treating patients with depression, chronic pain, schizophrenia, dementia, Parkinson's disease and cerebral stroke.[5]

1.1.3 Enhancement in healthy individuals

tDCS has also been used in healthy individuals with studies showing the potential of tDCS to improve abilities including working memory, attention, language, mathematics, and decision-making.[6]

1.1.4 Accessibility

Individuals can buy tDCS devices online. The most recent addition to the market is the foc.us device.[7] The manufacturers claim that the foc.us device can 'increase the plasticity of your brain' and 'make your synapses fire faster'. The manufacturers are careful to note that the device has not received FDA approval and has no medical purpose.

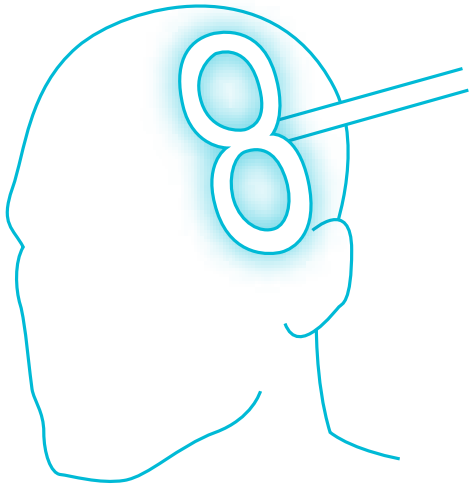
1.1.5 Risks and safety concerns (related to the structure and functioning of a tDCS device)[8]

The position of the electrodes is crucial to obtaining reliable effects. Devices must be constructed so that the electrodes can be positioned correctly. Ensuring the correct placement of electrodes is made more difficult when the user is left handed, as the brains of left-handed people may be organised differently from right-handed people. Devices that enable reversing the polarity pose risks as this can impair brain function: reversing the polarity of the electrodes may be ineffective in producing enhancement and may also result in impairment. The strength and duration of stimulation the device delivers will affect how safe it is to use and can also reverse the obtained results.[9] Stimulation that is too strong or stimulation that exceeds the optimum duration may be damaging.

1.1.6 Risks and safety concerns (related to how the tDCS device is used) [10]

Stimulation can interact with other treatment; the pharmacological status of the brain can have an effect on the outcome of tDCS, and there is a great variety of psychoactive agents that home users may use. Effects may be unintended and long lasting; some studies have reported effects lasting for months. Users may cause long-lasting effects in their underlying neurobiology, including unintended and undesirable effects, which may be difficult to reverse. An example of this phenomenon can be seen in studies in which tDCS stimulation of the posterior parietal cortex enhanced numerical competence but impaired automaticity.[11] Finally, use of the device on a developing brain might lead to atypical brain development in children and young adults: like other types of atypical experience during sensitive periods, the stimulation of the wrong brain area might induce abnormal patterns of brain activity in this brain region and interconnected areas, and increase metabolic consumption in brain areas that are irrelevant to the specific psychological function.[12]

1.2 Transcranial magnetic stimulation (TMS)



1.2.1 What is TMS?

Transcranial magnetic stimulation (TMS) is a neurostimulation and neuromodulation technique, based on the principle of electromagnetic induction of an electric field in the brain. TMS involves the generation of a magnetic field in a coil of wire. When this coil is held to the head of a subject, the magnetic field penetrates the scalp and skull inducing a small current in the brain parallel to the plane of the coil. This current is sufficient to depolarise neuronal membranes and generate action potentials (neuronal 'firing'). Again, although this technique is usually referred to as non-invasive, this label has the potential to mask the fact that TMS has direct effects on the activity of neurons.[13]

TMS can be applied repetitively in pulses (rTMS). This technique has been shown to change cortical excitability even beyond the stimulation event. Evidence suggests that rTMS delivered at a low frequency (0.5–2 Hz) tends to decrease cortical excitability, whereas higher frequencies (faster than 5 Hz) tend to increase excitability.[14] Other applications of TMS, for example those using theta burst stimulation, have also been shown to lead to effects beyond the stimulation period.[15]

1.2.2 Therapeutic applications

Therapeutic utility of TMS has been claimed in the literature for psychiatric disorders, such as depression, acute mania, bipolar disorders, panic, hallucinations, obsessions/compulsions, schizophrenia, catatonia, post-traumatic stress disorder, or drug craving; neurologic diseases such as Parkinson's disease, dystonia, tics, stuttering, tinnitus, spasticity, or epilepsy; rehabilitation of aphasia or of hand function after stroke; and pain syndromes, such as neuropathic pain, visceral pain or migraine.[16]

1.2.3 Enhancement in healthy individuals

TMS has, amongst other things, been shown to improve working memory, performance on various complex motor learning tasks, induce faster object naming, and improve visuospatial processing.[17] There is also some evidence to suggest that TMS can unmask so-called 'savant-like' abilities.[18] Suppressing the left anterior temporal lobe (involved in semantic memory – our knowledge of objects, people, words, and facts) is thought to increase access to less-processed information, improving performance in perceptual abilities on tasks such as drawing, proof-reading, numerosity judgment, and other cognitive processes in which conceptual knowledge biases performance.[19]

1.2.4 Accessibility

Unlike tDCS, there is limited access to TMS devices equivalent to those used in clinical research at present, and this might in part be due to their expense. However, with more research showing enhancement effects, public interest could increase as it did for tDCS. There are some unregulated devices available that use the same principles as TMS but are not chiefly marketed for cognitive enhancement (although their appearance on websites with names such as www.braintuner.com implies such a potential use).[20] The 'strength' of the device seems to be a key marketing point although, again, cognitive

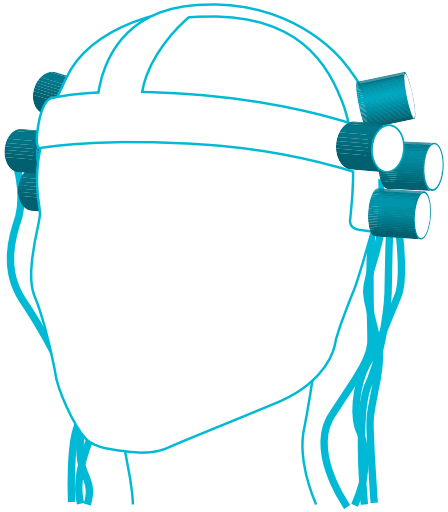
enhancement uses are not yet being explicitly claimed for these devices.[21] The manufacturers note that the 'use, safety and effectiveness of [the device] has not been approved by any government agency'.

There are also devices using alternative methods of magnetic stimulation, which are not clearly understood. For example, the 8 Coil Shakti headset claims to produce weak and complex magnetic fields that alter neurobiological processes.[22] The manufacturers claim that 'Meditation Enhancement, Out Of Body Experiences, Visions, Altered States, Lucid Dreaming, Visual Enhancements, and other effects have been reported from this technology'.

1.2.5 Risks and safety concerns

The risks of TMS are similar to those of tDCS, particularly relating to overstimulation or to unintended impairments.[23] However, with TMS, due to the intensity of the stimulation and its ability to induce action potential, there is an additional concern about seizures. In a 2010 review, it was reported that 'there have been less than 20 reported seizures induced with TMS, with a sample size of several thousand. The risk is less than one half of 1%.'[24] However, it should be noted that these seizures occurred within a laboratory setting where guidelines were being followed and certain populations had been excluded due to safety criteria (e.g. people with a first-degree relative with epilepsy). Unregulated devices might deliver too much stimulation, or instructions included with the device may not explain how to (or who can) use the device safely. A lack of instruction is particularly likely where a manufacturer only implies the possibility of using the device to stimulate the brain.

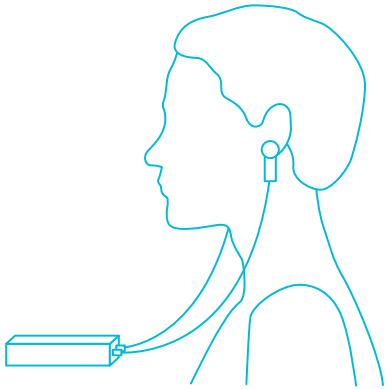
The safety of devices such as the 8 Coil Shakti has not been studied.



1.3 Cranial electrotherapy stimulation (CES)

1.3.1 What is CES?

Cranial electrotherapy stimulation (CES) is a non-traditional therapeutic device that applies pulsed, alternating microcurrent (<4 mA) transcutaneously to the head via electrodes placed on the earlobes. The mechanism of action has not been extensively researched and it remains unclear how the electrical current from CES alters brain activity. The results of a recent study were thought to suggest that CES stimulation might result in cortical deactivation, as well as altering brain connectivity in the default mode network (the network of brain regions that are active when the individual is not focused on the outside world and the brain is at wakeful rest). The authors suggested that relatively small perturbations in brain oscillation patterns might cause significant changes in brain activity and within intrinsic connectivity networks.[25]



1.3.2 Therapeutic applications

Controlled studies provide evidence that CES is effective for anxiety, headaches, fibromyalgia, smoking cessation, drug withdrawal symptoms, and (in some but not all studies) pain.[26]

1.3.3 Enhancement in healthy individuals

There has been no clinical research into the enhancement effects of CES although anecdotal reports of reduced anxiety and general improvements to mood have been recorded. Manufacturers have made a variety of enhancement claims, however (see below).

1.3.4 Accessibility

CES devices are available to purchase online. It is important to note that CES devices are available commercially as medical devices but, where medical claims are being made, the device must have been approved by a regulator. For example, the Alpha-Stim® AID Cranial Electrotherapy Stimulation (CES) Device has been classed as a Class IIa Medical Device and declares its conformity with all the relevant essential requirements and provisions of the Medical Devices Directive.[27] The manufacturer legitimately makes treatment claims, listing it as 'a medical device intended to deliver controlled microcurrents using a method called cranial electrotherapy stimulation (CES), for the treatment of anxiety, depression and insomnia'.

Other CES devices available, however, have not been assessed and have not received approval. These evade regulation because they make enhancement claims instead of treatment claims. For example, the manufacturers of the Bio-Tuner CES device are careful to state that it is not approved as a medical device, yet they also report that 'Some research suggests that these subtle energies may be linked to improved memory, creativity, learning, and intelligence'.[28]

1.3.5 Risks and safety concerns

For approved CES devices, the reported side effects are minimal. Adverse effects of CES in humans occur in less than 1% of cases and they are usually mild and self-limiting. These adverse effects include vertigo, skin irritation at electrode sites, and headaches.[29] A recent review of CES reports that headaches and vertigo are usually associated with the current being set too high for the individual and that the effects resolve when the current is reduced or within minutes to hours following treatment. The authors also explain that irritation at the electrode site can be avoided by moving electrodes around slightly during treatments and that no serious adverse effect has ever been reported from using CES.[30] Whilst these side effects are not serious, it must be remembered that unregulated devices may not be designed in the same way, with the same parameters.

1.4 Neurofeedback

1.4.1 What is neurofeedback?

Neurofeedback is a type of feedback that uses realtime displays of electroencephalography (and recently, but not commercially, other neuroimaging techniques such as functional MRI) to illustrate brain activity, often with the goal of enabling the person to regulate his or her brainwave activity. This is achieved through a process of operant conditioning. Neurofeedback training involves placing electrodes on the person's scalp to measure the electrical patterns emanating from his or her brain. Connected to a computer, the person receives instantaneous auditory and visual feedback about his or her brainwave activity. Having awareness of his or her brainwave patterns enables the person to learn to reinforce or suppress different patterns of activity. Particular patterns are associated with inwardly-

focused attention, others with outwardly-focused alertness and others still with relaxation, daydreaming and sleep. Depending on the desired state, neurofeedback can be used to cultivate different patterns. With repeated feedback training and practice, desirable brainwave patterns can usually be retrained in most people.

1.4.2 Therapeutic applications

In the clinical domain, neurofeedback has been used to help patients with attention deficit hyperactivity disorder, epilepsy, autism, and insomnia.[31]

1.4.3 Enhancement in healthy individuals

Neurofeedback has also been used in healthy individuals to enhance attention, memory, microsurgical skills, intelligence and wellbeing. Further studies have shown that musical creativity can be enhanced in elite performers and that such results extend to competitive ballroom dancing.[32]

1.4.4 Accessibility

Individuals can buy equipment online and some devices are not regulated. The manufacturer of the NeuroBit Lite claims that their neurofeedback equipment 'teaches better concentration, attention and creativity, raises immunity to stress and helps to develop many other psychological functions'. They also emphasise that 'this product is not intended for medical or therapeutic purposes. It is manufactured for personal use'.[33]

1.4.5 Risks and safety concerns

Mild side effects such as fatigue, anxiety and irritability can sometimes occur during neurofeedback training. Neurofeedback training can also cause headaches and lead to difficulties falling asleep. It is thought that sometimes the side effects occur because the training session is too long.[34] Unless the training is tailored to the individual, there will be a risk that it will be ineffective or even produce an adverse reaction: due to the heterogeneity in the brainwave activity, training must be individualised, and research is increasingly showing that different treatment protocols have differential effects on the brain.[35] Crucially, the software that comes with the device must be able to correctly identify and give feedback about the user's brain activity. Incorrect feedback would result in the training being ineffective or producing changes that were unintended.

2. Addressing the regulatory gap

2.1 Why is there a regulatory gap for CEDs?

Whether or not a technology (or an instance of that technology) is identified for regulation by a regulatory body will depend on the definitions and criteria set out in the various directives. If subject to regulation at all, the standards the technology is required to meet will depend on which directive(s) it falls under. In the EU, CEDs only fall under the General Product Safety Directive (GPSD),[36] as they are not identified by the definitions employed in any of the other existing directives. The GPSD, however, only sets general requirements and does not make provision for pre-market assessment.

CEDs, despite often raising safety and effectiveness concerns comparable to those raised by medical devices, are not covered by the Medical Devices Directive (MDD)[37] because the definition the directive employs excludes them. The current definition of a medical device specifies that the device must be intended by the manufacturer to be used for diagnostic and/or therapeutic purposes. Since CEDs are neither diagnostic nor therapeutic, they are not identified as devices for medical regulation.

2.2 Previous discussion of CED regulation

The emergence of technologies for enhancement has motivated a variety of working groups to think about the social, ethical and regulatory challenges they raise. For example, the British Medical Association published a report in 2007 on the ethical aspects of cognitive enhancement; the European Commission funded a 7th framework programme on Ethics in Public Policy Making: The Case of Human Enhancement (EPOCH)[38]; and the Academy of Medical Sciences, in collaboration with the British Academy, the Royal Academy of Engineering and the Royal Society, published a report based on their workshop investigating Human Enhancement and the Future of Work.[39]

Notwithstanding the various important outputs of these and similar projects, there has been sparse overt guidance to lawmakers and regulatory bodies on the regulation of cognitive enhancement technologies. As summarised by Outram and Racine (2011),[40] the report published by the British Medical Association (BMA)[41] places emphasis on public debate in advance of making recommendations. Whilst it outlines the possible regulatory approaches and discusses their implications, it does not argue for the adoption of any particular course of action. The express aim of the BMA report is to facilitate informed debate amongst doctors, scientists, policymakers, and members of the public about the future development and use of cognitive enhancements. The BMA states that it 'does not have policy or recommendations to put forward on these issues but would welcome informed public debate about how, as a society, we should respond to these developments'.[42]

The aim of the EPOCH project was to broaden and deepen knowledge of the role of ethics in the governance of science and technology, focusing on ethical aspects of new and emerging bio-, neuro- and nano-technologies and specifically related to the topic of human enhancement. Although regulatory challenges were a focus of the project, the central aim was to generate new insights into the role of ethical expertise in European policy making on science and technology, coherent with national and other European projects. Overt recommendations to lawmakers were thus not the goal.

The recent report from the joint academies had a narrow focus on human enhancement in the workplace. The report suggests that the

greatest immediate challenges for regulators and other policymakers will arise from the use of drugs, brain stimulation, and digital devices that enhance cognition and concludes that dialogue with potential users and the wider stakeholder community, as well as studies and commissioned research, will be required to balance the risks and benefits of these technologies in the future workplace. The report does go some way towards suggesting particular regulatory approaches, but these recommendations are specific to employment contexts. As the report notes, 'in many ways, work represents a unique context, within which a cautionary regulatory approach is desirable, with the primary objective of protecting employees'.[43] We should not assume that the regulatory approach appropriate for work contexts will also be appropriate for other contexts.

More recently, attention has been paid in particular to the lack of regulation for tDCS devices used outside the clinical setting. Emphasising that tDCS is not without safety concerns, Fitz and Reiner[44] call on regulators, scientists and the tDCS DIY community to develop policy proposals that ensure public safety while supporting DIY innovation. To our knowledge, only the Nuffield Council on Bioethics[45] has outlined a model for the regulation of neurointerventions used for enhancement. In accordance with the model we develop, the Nuffield Council proposes that neurointerventions such as tDCS should be regulated in the same way as medical devices. However, an in-depth discussion of the existing legislation and exploration of how the medical model could be implemented have not yet been undertaken. The remainder of this paper will examine the possible regulatory options and argue that the best approach is one where CEDs are regulated in a similar way to medical devices, although we propose that there are good reasons to hold CEDs to less stringent requirements. We explore the implications of this model and make recommendations for how it should be implemented.

2.3 Two possible regulatory routes: new or existing regulatory instruments

The possibilities for the regulation of CEDs can be identified according to the regulatory instruments that could be employed. CEDs could 1) be regulated by a new regulatory body/under new legislation specifically for CEDs or 2) they could be regulated under the same legislation as medical devices (the Medical Devices Directive).

We argue that existing regulatory bodies, such as the Medical and Healthcare products Regulatory Agency (MHRA) in the UK, should pursue the latter course of action. We later comment on how our model could also be adopted in the US and elsewhere.

2.4 Amending the MDD to incorporate CEDs

There are two main arguments for regulating CEDs within the MDD. First, CEDs are not categorically different from medical devices; in fact, the very same device may be used both for therapeutic and enhancement purposes, in some cases using similar parameters.[46] CEDs, as devices that modify brain function to improve cognitive performance are, in important respects, the same sorts of devices that the MDD covers: they intervene to modify physiological processes and present varying degrees of physiological risks and side effects. Whilst in some cases there is no mechanical distinction to be made between CEDs and medical devices, it is true that the purpose of CEDs is enhancement and not therapy. However, the proposed revision of the MDD to cover (principally cosmetic) devices without a medical purpose sets a precedent for non-therapeutic devices to be regulated in the same way as medical devices.[47] If non-therapeutic cosmetic devices are not out of place within the MDD, then neither are CEDs.[48]

There is also a philosophical reason to place CEDs within current medical regulatory regimes. Many philosophers have denied that there is a morally relevant difference between treatment and enhancement, although this is not uncontested.[49] Whilst labelling devices or drugs as therapeutic has practical value in being shorthand for 'something which the healthcare system makes accessible', it is unclear that the distinction is particularly helpful in demarcating any important difference in the effect the device or drug has on an individual.[50] Both therapy and enhancement aim to improve a human being's biology and/or psychology. The two most important ethical considerations in regulating such interventions are the risks that are involved and considerations of distributive justice in cases where there may not be equality of access to an intervention. It is plausible that treatments raise these concerns in similar ways to enhancements. Thus, the critical issue in the evaluation of any new technology, whether for treatment or enhancement, is to ascertain the likely benefits and risks, both medical and social. Although the MDD will not be in a position to evaluate the socio-economic effects of restricting or permitting a CED – and so questions of distributive justice will not arise here – the MDD is, we argue, the most appropriate instrument for ensuring adequate levels of safety.[51]

To revise the MDD, two possibilities present themselves: either the core definition of a medical device might be revised so that the potential purposes attributed to them include (or do not exclude) enhancement, or an ancillary 'positive list' of CEDs might be drawn up to supplement the existing definition. This latter option has been proposed by the MHRA as the preferred method for extending the directive to cover some implantable or other invasive products used for a non-medical purpose and we suggest the same approach to CED regulation.

2.5 Conceptual and practical issues shaping the regulatory approach

To come to a conclusion about the optimal approach for CEDs, various conceptual and practical questions need to be considered. The first conceptual question is whether, by amending the legal definition of a medical device, legislation explicitly intends to alter how we understand the term 'medical device' outside of legal contexts, or whether amending the definition is based merely on the view that the same regulatory instruments should apply to both medical devices and CEDs. A second conceptual question is whether the set of devices the definition is extended to cover should be determined by the way in which the device interacts with the body or the purpose for which it is used. The existing core definition of a medical device focuses on purposes, and it might be difficult to amend it to accommodate an additional class of devices that are defined according to their mode of interaction with the body. On the other hand, an ancillary list could be generated based either on the type of interaction with the body – e.g. brain stimulation devices – or by identifying the particular purpose, e.g. cognitive enhancement. The MHRA's proposal for inclusion of a positive list of implantable or other invasive products without a medical purpose takes the ancillary list approach; in this case, the devices share the feature that they are implantable or invasive, and the designation that they are without a medical purpose indicates that their inclusion is not meant to modify the concept of a medical device.

The practical question to be considered alongside these conceptual issues is how the regulators are best able to 'keep control' of what the Medical Devices Directive applies to. Even if there were good reason to re-conceptualise medical devices

as devices that can sometimes be used for enhancement, ensuring that the directive would not extend to things such as educational training software would be critical. A positive list allows for better control. Of course, such a list would need to be regularly updated. A benefit of amending the core definition of a medical device would be that new CEDs would be held to the required standards from their emergence on the market (indeed, their emergence on the market would be dependent on meeting the standards). A positive list that was reactive to CEDs already in use creates the risk that untested devices might be used for some time before being subject to regulation. However, given the need to keep control of the devices that fall under the directive, we suggest that a positive list would be the best approach. Even though this will require a decision to be made for each included device, their small number means that this should not be an overwhelming task. We return to the problem of unreasonable broadening of the directive below (see section 3.1).

To summarise, we believe that an amendment of the MDD is needed with the principal justifications as follows:

- CEDs and MDs are similarly-acting technologies which can have similar risks; there is thus no relevant distinction between devices used for treatment and enhancement in terms of mechanism.
- There is no morally relevant distinction between the purposes of treatment and enhancement. Both therapy and enhancement aim to improve a human being's biology and/or psychology.
- Parsimony in regulation is always preferred where possible.
- The recently-proposed inclusion of implantable and other invasive products without a medical purpose sets a precedent for extending the remit of the MDD.

Amending the directive presents significant challenges that would need to be resolved. We now explore these challenges in turn.

3. Challenges involved in amending the Medical Devices Directive

3.1 Challenge one: preventing regulatory overreach

When discussing how to extend the MDD to cover some implantable or other invasive products without a medical purpose, the European Commission considered how to ensure that the remit of the MDD was not unreasonably broadened. If the directive were extended to cover all implantable and invasive products, then items such as earrings and other body piercings would fall within its remit.[52] Similarly, if the directive were extended to cover all 'cognition improving or facilitating devices without a medical purpose', it would be very difficult to justify the inclusion of tDCS devices but the exclusion of, for example, educational software. To avoid this unreasonable broadening, device-by-device decisions need to be made. For implantable and other invasive products, the European Commission proposed to solve this by generating a positive list of devices:[53]

'With the suggested two-step approach, the incorporation of a general provision regarding implantable or other invasive nonmedical products in the medical device legislation would not have any immediate impact on these products. Only the inclusion in a 'positive list' would trigger the application of the legal requirements regarding a given type of products. This would have the advantage that the concrete impacts on specified products could be assessed once a type of product should be added to the positive list.'

We believe that this 'two-step' approach should also be taken to regulate CEDs. We therefore propose that a positive list of 'cognition improving or facilitating devices without a medical purpose' be included in the MDD. It will be at the discretion of the regulators to decide which devices should be included. In the same way that it was decided to exclude earrings from the list of implantable non-medical devices, sensible decisions can be made about what to include on a list of cognition improving or facilitating devices for regulatory attention.

3.1.1 Tentative criteria for inclusion

As a rough guide, we suggest that any CED that would be classed as 'active' if it were a medical device should be automatically included.[54] All brain stimulation devices would therefore be included. In addition, we suggest that devices that are widely used in non-medical 'clinics' should at least be considered for inclusion. This is principally because of the increased confidence in the device that consumers might have when they perceive it in a quasi-medical setting. Neurofeedback equipment could plausibly be a candidate.

As explained in more detail below, devices that are assessed by the regulators as low risk may ultimately be exempted from further controls. The risks that attend neurofeedback are primarily associated with incorrect use; a 'faulty' device is unlikely to cause harm, although erroneous feedback could have unintended training effects. What regulating neurofeedback equipment would principally achieve under our model is to activate the requirement for manufacturers to provide comprehensive, objective information and instructions with a device. This information would have to be of a standard the regulators are satisfied is sufficient to enable users to utilise the device properly and safely.

3.2 Challenge two: identifying devices for cognitive enhancement

If the MDD were to be amended to include CEDs by way of a positive list, thought would have to be given to how regulators are to identify whether a particular device on sale is used for enhancement – is a CED - rather than a medical device (or neither). This will be especially important where the same type of device is also used as a medical device. Identifying the purpose will determine which regulatory route is activated. The current wording of the directive specifies that medical devices are devices intended by their manufacturer to be used for diagnostic and/or therapeutic purposes. In some cases, this means that the same type of device is identified for regulation as a medical device when marketed as such, but not when it is marketed 'off-label' as a cognitive enhancement device.

Crucially, the wording suggests that what currently comes to be regulated under the directive depends on the explicit claims manufacturers make (and do not make) about their products. A guidance document published by the European Commission elaborates on how this purpose is identified:[55]

'Medical devices are defined as articles which are intended to be used for a medical purpose. The medical purpose is assigned to a product by the manufacturer. The manufacturer determines through the label, the instruction for use and the promotional material related to a given device its specific medical purpose.'

Given that the medical purpose of a device is identified in this way, if the directive were to be extended to include CEDs on a positive list, enhancement purposes might similarly be derived from the manufacturer's labels and instructions, and so forth. For example, claims that a device improves memory, learning, intelligence or attention would all be claims of cognitive enhancement. However, there might be difficulty in identifying purpose when a particular device is marketed for both therapy and enhancement, generating a need to adjudicate between primary and secondary purposes. Currently, where a manufacturer makes treatment claims about its device, it is regulated as a medical device irrespective of whether the manufacturer also claims that it can be used for enhancement.

Adjudicating between purposes might be significant for determining the appropriate regulatory route and requirements: if the risks and benefits of enhancement devices are to be assessed differently from the risks and benefits of medical devices, identifying the principal purpose could be important. How to weigh risks against the benefits of enhancement is considered in the next sections (3.3, 3.4).[56] In general, we suggest that where a device makes both medical and enhancement claims, it should be regulated under the route that is the more stringent (in cases where one of the two routes would be more stringent). Under the model we propose, some devices would be regulated more stringently as medical devices (see 3.4).

3.3 Challenge three: assessing the benefits of CEDs

If CEDs were regulated in exactly the same way as medical devices, they would be subject to the general requirements emphasising safety and effectiveness, requiring risks to be weighed against benefits. However, whilst the risks and side effects of CEDs could be assessed in a similar way to the risks and side effects associated with medical devices, it is less clear how the benefits of CEDs should be measured. It could be argued that unlike medical devices – which either succeed or fail in improving or maintaining health to a measurable degree – CEDs confer benefits that are more subjective. Parallels might be drawn with the difficulty of assessing the benefits of non-therapeutic cosmetic enhancements; a nose might be made smaller or straighter in a way that we can measure, but how beneficial this is will vary from person to person.

It is certainly possible to measure the size of any improvement to cognitive performance. For example, improvements in the working memory of an individual using tDCS will be something determinable through laboratory tests. However, whilst we can measure the size of improvements to cognitive functions, it could be argued that the value of enhancement is something that varies between people to a greater extent than the value usually attached to health: most of the ailments and illnesses for which people seek medical remedy frustrate many commonly-shared life goals. Experiencing pain and discomfort, for example, is detrimental to the wellbeing of most individuals. Whilst effective medical remedies will therefore be widely valued, the effects of a CED on particular domains of cognition – for example, focus for gamers or creativity for artists – will be valued less uniformly.

Thus, a significant issue to resolve when extending the Medical Devices Directive to cover CEDs is how the benefits of the devices are to be estimated and weighed against any risks or side effects. It appears to be the view of the European Commission that, for medical devices, as measurable benefits fall, fewer (and only smaller) risks should be tolerated. We derive this understanding from the basic requirements pertaining to the safety and performance of medical devices:[57]

'Devices shall achieve the performance intended by the manufacturer and be designed and manufactured in such a way that, during normal conditions of use, they are suitable for their intended purpose, taking into account the generally acknowledged state of the art. They shall not compromise the clinical condition or the safety of patients, or the safety and health of users or, where applicable, other persons, provided that any risks which may be associated with their use constitute acceptable risks when weighed against the benefits to the patient and are compatible with a high level of protection of health and safety.'

Further, in proposing the amendments for the implantable and other invasive devices without a medical purpose, the European Commission seems to take the approach that as devices move further from treatment, the number and/or magnitude of the risks tolerated will decrease.[58] This has the result that devices without a medical purpose – even when they have the same risk profile as analogous devices with a medical purpose – will be held to more stringent standards than devices with a medical purpose; requiring zero or minimal risk is more cautious than requiring that risks are acceptable when weighed against the benefits to the patient. Further, the more stringent requirement makes no mention of weighing risks against benefits at all, possibly because it was considered that the devices for which no medical purpose is claimed do not confer (relevant, measurable) benefits on their users. The purposes of the devices included in the 'positive list' are principally cosmetic, and as suggested above, it might be thought that, as cosmetic benefits are subjective, they cannot be relevant to a risk/benefit assessment.

Contra the apparent position of the European Commission, we argue that it is not obvious that less objective or quantifiable benefits should be given less weight than more objective or quantifiable ones. Moreover, the benefits of cognitive enhancements are arguably more objective and more quantifiable than those of the non-therapeutic cosmetic interventions; improvements in cognitive performance can be measured, the benefits of non-corrective contact lenses cannot. Thus, even if the benefits of non-therapeutic cosmetic interventions should be given no or less weight, the same may not be true of the benefits produced by CEDs.

3.4 Challenge four: setting the regulatory standard for CEDs

In direct contrast to the European Commission's approach to non-therapeutic cosmetic devices, we suggest that, for CEDs, as medical need falls, consumer freedom-to-choose should rise, other things being equal. Although the informed consent of patients is routinely obtained before proceeding with any intervention, a patient's decline in health puts him or her in a vulnerable position where it is likely he or she will be inclined to accept the treatments on offer. This inclination may be bolstered by the perception that the intervention on offer is 'endorsed' by the medical profession, with its authority. This being the case, objective evidence of effectiveness (benefit) must be gathered before offering interventions posing any risks. However, decisions about the purchase and use of enhancement devices are made absent these vulnerabilities, which justifies giving individuals more choice about how to assess the risks and benefits of any particular device in the context of their own values, nature and life circumstances; an assessment they are best placed to make for themselves. This is not to say that experts are not required to identify and report the risks and benefits of devices, but rather that individuals are best placed to decide what sort of impact the risks and benefits would have on their lives. So, whilst there is a good case for imposing strict risk-based restrictions on therapeutic medical devices in order to protect vulnerable patients, for CEDs there may be an argument for placing decisions about the level of acceptable risk more in the hands of the consumers who will use them.

3.4.1 A graded system of regulation

This does not mean that we are ultimately adopting a laissez-faire approach. Rather, we are suggesting that CEDs should be regulated less stringently than medical devices. We envisage a grading system similar to that employed in the MDD: devices will first be classified based on risk as high-, moderate- or low-risk. An example of a high-risk device might be one that is very likely to induce seizures. A very strong (stronger than used in research) TMS device could pose such a risk. Where devices pose high risk they should not be approved. Devices posing moderate risks however, should not be assessed according to the same standards as moderately-risky medical devices. Whilst CEDs posing moderate risks should demonstrate some effectiveness, regulators should err on the side of approving a device if there is reasonable disagreement about whether the benefits justify the risks. Finally, given our preference for promoting consumers' freedom to choose, we suggest that consideration should also be given to incorporating a 'low-risk exemption', whereby any device that falls within the low-risk class would be eventually approved regardless of whether any objective benefit has been demonstrated. Being in no sense invasive, an obvious candidate for exemption would be neurofeedback equipment. Dependent on a closer consideration of the risks, CES might also be exempted from regulatory oversight under our model. This would allow consumers a degree of discretion to conduct their own assessments of risk and benefits.

Given this room for discretion, we suggest a stringent supplementary requirement for manufacturers to provide honest, transparent and detailed information pertaining to the mechanisms, risks and effects that might be construed as benefits of the devices. Providing such detailed information is currently not compulsory and will make unsupervised use as safe as possible.

It should be noted, however, that our argument for increasing consumer freedom would not apply to CEDs intended for use on children, who are arguably always a vulnerable group. For CEDs developed for children, stringent risk-based restrictions might still be appropriate: effectiveness would have to be shown to clearly justify the risks. Moreover, even CEDs not intended for use on children might in some cases be offered to children. If such devices are freely available, parents could use them on their children without the child's valid consent. So while respect for liberty speaks in favour of relaxed regulation of enhancement devices, we propose that criminal sanctions be considered for cases in which untrained adults use CEDs on children without suitable supervision. Similarly to the imposition of sanctions for giving children alcohol, (adults') freedom to purchase and use CEDs is preserved, whilst children are protected by placing legal restrictions on the freedom to use CEDs on them.

In addition to level of risk, there is a further factor that could moderate the degree of choice offered to consumers. Regulators should keep in mind how high the indirect costs to the healthcare system are likely to be if faulty devices are used or if devices are misused. These factors should be weighed against the resources that would be saved if low-risk devices were not subject to ongoing regulation under the Medical Devices Directive.

4. Limits and extensions to the model

4.1 Remaining regulatory issues

Whilst our proposed model would regulate the sale of CEDs, it would not prevent users constructing devices completely from scratch. Further, our proposal has made no recommendations pertaining to the regulation of (mis)use of these devices (other than the suggestion that untrained use on children should attract criminal sanctions). However, whilst the potential misuse of devices would remain a concern even if the devices themselves were regulated, the current lack of regulation is likely to give users the impression that there are no risks associated with using CEDs. Further, regulating CEDs may have the effect of encouraging people to purchase a regulated device, rather than build their own. The outcome of our regulatory model would therefore be to filter the most dangerous enhancement technologies out of the market, leaving individuals free to choose which small-to-moderate risks they are willing to take in pursuit of their wellbeing. It also imposes requirements on manufacturers to provide enough detailed, honest information about the product to enable individuals to use the devices in the safest way possible, in full knowledge of all known risks and side effects.

4.2 Applying our model to other jurisdictions

With the market for enhancement technologies expanding, and with products already crossing international borders, controlling which CEDs are approved for sale is a global issue, potentially requiring international regulatory harmonisation. Most jurisdictions have their own legislation controlling medical devices, but the provisions of separate jurisdictions often require overseas manufacturers intending to sell their products locally to go through the same or similar processes in order to gain approval. The legislation in some jurisdictions specifies that compliance with parts of the regulatory process in other jurisdictions is potentially a sufficient substitute to undergoing comparable local assessment. For example, the Australian Government, in its Regulatory Guidelines for Medical Devices (ARGMD), explains that "Despite the differences, and with the exception of some medical device manufacturers who require a [Therapeutic Goods Administration] Conformity Assessment Certificate, [European] CE Certificates can be submitted in support of an application to include medical devices in the [Australian Register of Therapeutic Goods]."[59] It is thus conceivable that a global response to the emerging CED market could involve a coordinated approach to amend analogous pieces of medical device legislation, in recognition that most CEDs will be marketed and purchased across borders.

Legislation from different jurisdictions suggests that the same regulatory gap currently exists around the world. The ARGMD defines medical devices in the same way as they are defined in the EU. It reiterates that medical devices are used for humans, have therapeutic benefits, and generally have a physical or mechanical effect on the body or are used to measure or monitor functions of the body.

The Federal Food, Drug, and Cosmetic Act of the United States[60] provides a definition of medical devices that is also similar to that employed in the MDD and ARGMD and, consequently, also does not capture devices making enhancement claims. Crucially, the various definitions indicate that it is the *claims made by the manufacturers* that are the key determinant of whether a device falls under regulatory purview in the EU, the US and Australia; a device is only a medical device if it has a therapeutic or diagnostic purpose, and regulators look to the words used in the manufacturer's labelling and advertising to assess whether a device is intended to be used for either purpose. This means that in these and other jurisdictions, the manufacturer can elude regulatory oversight by being careful to avoid making claims about their device's efficacy to treat or diagnose medically recognised conditions. Currently, indication that a device can be used to enhance cognitively healthy individuals does not trigger regulation.

This emphasis on the manufacturer's intentions for the device's use is seen elsewhere in the world. Chapter 1, Article 2 of the Japanese Pharmaceutical Affairs Law defines medical devices as:[61]

"Equipment/instruments intended for use in the diagnosis, treatment or prevention of disease in humans or animals, or intended to affect the bodily structure and functions of humans or animals."

However, from this definition alone, it is not clear whether devices which are intended to affect the bodily structure and functions of humans, but are not also intended for use in the diagnosis, treatment or prevention of disease, would fall under regulatory purview in Japan. Further research will be needed to explore all the definitions employed worldwide, but the recurrent theme appears to be a reliance on the claims and intentions of manufacturers in determining the purpose of a device, and the absence of regulation for devices without a diagnostic or therapeutic purpose.

In 2003, the World Health Organization (WHO) produced a guide entitled 'Medical Device Regulations: Global Overview and Guiding Principles'.[62] Its stated purpose was to provide guidance to member states wishing to create or modify their own regulatory systems for medical devices. Whilst the WHO acknowledged that there is no single template that will work for every country, the guide was intended to encourage governments to follow the growing movement towards harmonised regulatory systems. With the emergence of a market for CEDs, we suggest that it is now time to consider a harmonised global response. The recent consultation on extending the MDD in the EU provides an instructive case study, demonstrating the way that legislation can be adapted to cover new technologies (or new uses of existing technologies). Despite our focus on the EU as a catalyst for discussion, the regulatory model we have presented, and its supporting justification, should have much wider application. We suggest that regulatory bodies around the world should coordinate to incorporate into medical device legislation a unified positive list of cognition improving or facilitating devices without a medical purpose, which will then be subject to certain requirements as befits countries' respective systems. To the extent that the WHO's vision of more harmonious regulatory systems for medical devices is realised, the variation in jurisdictions' standards and procedures for regulating CEDs on the positive list should also be made to align.

5. Recommendations

Given the rapid emergence of a consumer market for CEDs, it is imperative that regulators reflect on the possible avenues to adequately protect those who use them. Regulating which devices manufacturers can place on the market, and with which conditions attached, will be the first step. Given the recent discussions that have taken place within the EU context about the regulation of other devices without a medical purpose, we believe that the EU will be well positioned to lead the way in both discussion and action.

Based on the above discussion, we recommend the following for the regulation of CEDs:

5.1 Recommendations for regulators in the EU

- ***Regulate CEDs within the Medical Devices Directive***: The justiåcations for this are that CEDs have similar mechanisms and risk-proåles to some medical devices and are often essentially the same device; parsimony in legislation is desirable; and the inclusion of some non-medical (cosmetic) implantable and invasive devices sets a precedent for broadening the remit of the directive in this way.

- ***Develop a 'positive list' of 'cognition improving or facilitating devices (without a medical purpose)'***: Although this means that the legislation has to react to the emergence of hitherto unregulated devices as they come on to the market, the extension of the directive to all cognition improving or facilitating devices would generate huge difåculties for regulators in keeping the purview of the directive appropriately narrow. To be included on the list, it must be the case that the manufacturer makes cognitive enhancement claims about the device. There should be a strong presumption for inclusion of all active devices. Devices used widely in quasi-clinical settings should also be considered for inclusion. The devices that should be included on the initial positive list are transcranial electrical stimulation (e.g. tDCS, transcranial random noise stimulation, transcranial alternating current stimulation); cranial electrotherapy stimulation; transcranial magnetic stimulation (including devices generating weak magnetic åelds); and neurofeedback equipment.

- ***Implement a graded system of regulation to optimise consumer freedom and maximise efæciency***:
  - Where CEDs are **high risk** (e.g. likely to cause seizures), they should be prohibited from the market. NB: this assessment, as for devices of all levels of risk, proceeds on a device-by-device basis, rather than for whole types of device. For example, some TMS devices may be higher risk than others.
  - Where CEDs pose **moderate risks**, the beneåts of CEDs should be identiåed in a similar way to the beneåts of medical devices – a measure of effectiveness - but the requirement for beneåts to clearly justify risks should be relaxed. Given that there may be differences in opinion concerning how valuable enhancement is, and given that consumer decisions are not made amidst the vulnerabilities of the clinical context, an estimation of the beneåts of a CED should not be restricted to the narrow measure of effectiveness. The assessment should therefore err towards consumer freedom.
  - Where CEDs are deemed to be **low risk** and are unlikely to generate large indirect costs to the healthcare system, there would be a case for exempting them from continued regulatory evaluation, thus further promoting consumer choice. Neurofeedback devices would be an example of a low-risk CED unlikely to require ongoing evaluation.

- ***Require manufacturers to provide adequate information for all devices***: Comprehensive, objective information from the manufacturers about the safe use, risks and effectiveness of all devices should be required under the MDD to allow consumers to make informed decisions and to use devices safely.

5.2 Recommendations for protecting children

- ***Require a higher level of safety***: The exception to our proposal is where devices of any level of risk are intended for use on/by non-competent third parties such as children. These devices should be regulated to the same standard as medical devices, requiring effectiveness to justify risk.

- ***Introduce criminal sanctions***: Due to the possibility that CEDs that are intended for adults could be used on children, by individuals lacking adequate training, we propose that such use should attract criminal sanctions in the same way as supplying children with alcohol attracts criminal sanctions.

5.3 Recommendations for regulators in the US and elsewhere

- ***Address global gaps***: The same regulatory gap exists in the US and other jurisdictions. Our model could be adopted elsewhere, although identifying the precise challenges involved in implementation and harmonisation is a task for future research. It is conceivable that a global response to the emerging CED market could involve a coordinated approach to amend analogous pieces of medical device legislation in recognition that most CEDs will be marketed and purchased across borders.

5.4 Recommendations for manufacturers of CEDs

- ***Exercise best practice***: In anticipation of regulatory oversight, manufacturers should begin to adhere to good practice in manufacturing consistent with the sorts of requirements that the MDD would be likely to impose. This could involve drawing up technical documentation (including clinical evaluation); setting up an internal quality management system; establishing a follow-up system to respond to incidents arising from consumer usage or from the internal testing process; and ensuring devices are sold with comprehensive, objective information about safe use, risks and effectiveness.

Notes

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47. The devices identified for inclusion are: contact lenses; implants for modification or fixation of body parts; facial or other dermal or mucous membrane fillers; equipment for liposuction; invasive laser equipment intended to be used on the human body; and intense pulsed light equipment.
48. It should be noted that cosmetic devices such as implants are sometimes used for treatment: cosmetic surgery that is reconstructive or authorised because of the psychological benefits that the patient is expected to receive is already regulated within the medical legislation. In contrast, the devices recently proposed for inclusion are expressly *non*-therapeutic devices. Thus, our aim is not to put much weight on the fact that some cosmetic procedures are sometimes therapeutic, rather to point to the extension of the MDD that would occur if some *explicitly non-medical* devices, most of which happen to be cosmetic, were to be included. Crucially, the extension of regulatory oversight is not necessarily about regulating new *types* of devices, it is about regulating a broader set of instances of a type of device. For example, by including implants without a medical purpose, the MHRA is neither claiming that all implants are non-medical, nor suggesting that the implants currently used within the health system are under-regulated. These implants *do* claim a medical purpose and so are already regulated. The point is that there will be implants on the market that are not regulated because they do not claim a medical purpose. They may or may not be as safe as those that have been approved but this cannot be known with much confidence until these particular products have been assessed.
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51. If it were to be the case, for example, that access to a very effective CED was prohibitively expensive, this could lead to those who already have an advantage in society acquiring further advantage. Hypothetically, if this were to happen, governmental agencies could either decide to restrict access to the device on these grounds or adopt a strategy whereby resources were spent to make the CED more accessible to those most in need, with less and less subsidisation as need reduces.
52. European Commission (2012). *Commission staff working document: Impact assessment on the revision of the regulatory framework for medical devices.*
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54. An active medical device is defined as: 'Any medical device operation of which depends on a source of electrical energy or any source of power other than that directly generated by the human body or gravity and which acts by converting this energy. Medical devices intended to transmit energy, substances or other elements between an active medical device and the patient, without any significant change, are not considered to be active medical devices.' http://ec.europa.eu/health/medical-devices/files/meddev/2_4_1_rev_9_classification_en.pdf page 10
55. European Commission (1994), *Medical Devices: Guidance* document - Guidelines relating to the application of: The council directive 90/385/EEC on active implantable medical devices; The council directive 93/42/EEC on medical devices, at 3.
56. Since we suggest that the assessment of CEDs should proceed differently from medical devices, this lends further support to the argument that a positive list should be drawn up.
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58. See: European Commission (2012). *Proposal for a Regulation of the European parliament and of the council on medical devices, and amending Directive 2001/83/EC, Regulation (EC) No 178/2002 and Regulation (EC) No 1223/2009*, at 102.
59. Australian Government (2011), *Australian Regulatory Guidelines for Medical Devices (ARGMD): Part 1 Introduction, Version 1*, at 149.
60. See http://www.fda.gov/MedicalDevices/DeviceRegulationandGuidance/Overview/ClassifyYourDevice/ucm051512.htm
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About the authors

Dr Hannah Maslen is a Research Fellow in Ethics on the Oxford Martin School Programme on Mind and Machine and a Junior Research Fellow at New College, University of Oxford. Her current research examines the ethical, legal and social implications of brain intervention technologies such as brain stimulation devices, brain-computer interfaces and optogenetics. For individuals, these technologies raise questions about authenticity and personal identity; for society, they present regulatory challenges, particularly in light of concerns about safety and distributive justice. In addition to her work in practical ethics, she also works on penal theory and sentencing, with a particular interest in retributive theories and aggravating and mitigating sentencing factors.

Dr Thomas Douglas is a Senior Research Fellow in the Oxford Uehiro Centre for Practical Ethics and a Golding Junior Fellow at Brasenose College, University of Oxford. He is Principal Investigator on the Wellcome Trust-funded project 'Neurointerventions in Crime Prevention: An Ethical Analysis'. His research lies mainly in practical and normative ethics. In practical ethics, his work focuses on the ethics of using medical technologies for 'non-medical' purposes, such as crime prevention and behaviour change; in normative ethics, he is primarily interested in the nature of moral improvement and in tensions between special obligations and requirements of fairness.

Dr Roi Cohen Kadosh is a Wellcome Trust Career Development Fellow, and a University Research Lecturer at the University of Oxford. He is a leading researcher in the field of numerical cognition and his research focuses on the neurocognitive mechanisms of numerical understanding and mathematics in people with all ability levels. He was the first to observe that combining numerical training with transcranial electrical stimulation (tES) - a non-invasive, painless, portable, and relatively cheap technique - can enhance numerical learning and mathematical abilities in adults with long-lasting effect. Since then, he has repeatedly drawn both scientific and public attention to the ethical implications of using tES for cognitive enhancement in healthy adults, the elderly, and children with learning disabilities, and has discussed the possible advantages and pitfalls of cognitive enhancement using tES.

Associate Professor Neil Levy is an Australian Research Council Future Fellow based at the Florey Institute of Neuroscience and Mental Health, Australia. He is also Director of Research at the Oxford Centre for Neuroethics. He is a philosopher with very wide-ranging interests, and has published more than 100 papers on applied ethics, free will, philosophy of mind and psychology as well as continental philosophy, political philosophy and other topics. He is the author of seven books, including *Neuroethics* (Cambridge University Press, 2007), *Hard Luck* (Oxford University Press, 2011) and *Consciousness and Moral Responsibility* (Oxford University Press, 2014). In 2009, he was awarded the Australia Museum Eureka Award for Research in Ethics.

Professor Julian Savulescu holds the Uehiro Chair in Practical Ethics at the University of Oxford. He is Director of the Institute for Science and Ethics within the Oxford Martin School. He is Director of the Oxford Uehiro Centre for Practical Ethics within the university's Faculty of Philosophy. He is Director of the Oxford Centre for Neuroethics, one of three strategic centres in biomedical ethics in the UK funded by the Wellcome Trust. Holding degrees in medicine, neuroscience and bioethics, he is a leader in medical and practical ethics. He is editor of the *Journal of Medical Ethics* and founding editor of the *Journal of Practical Ethics*, an open access journal in Practical Ethics. He is the Sir Louis Matheson Distinguished Professor at Monash University and an Honorary Professorial Fellow at the Florey Institute of Neuroscience and Mental Health.

As the market for cognitive enhancement devices (CEDs) grows, it is important to ensure that the correct regulatory mechanisms are in place to oversee this expanding industry. This paper provides a comprehensive overview of the types of cognitive enhancement devices available; assesses the regulatory weaknesses as they relate to CEDs; and provides a practical path forward in designing an appropriate regulatory model for CEDs.

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Oxford Martin School
University of Oxford
Old Indian Institute
34 Broad Street
Oxford OX1 3BD
United Kingdom

Tel: +44 (0)1865 287430
Fax: +44 (0)1865 287435
Email: info@oxfordmartin.ox.ac.uk
Web: http://www.oxfordmartin.ox.ac.uk/
Twitter: @oxmartinschool
Facebook: http://www.facebook.com/oxfordmartinschool

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