NEURAL INTERFACE SYSTEMS: A NEW LEGAL FRONTIER?

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Abstract

In an age where digital innovation knows no boundaries, research in the area of brain-computer interface and other neural interface devices go where none have gone before. The possibilities are endless and as dreams become reality, the implications of these amazing developments should be considered.

Some of these new devices have been created to correct or minimise the effects of disease or injury so the paper discusses some of the current research and development in the area, including neuroprosthetics.

To assist researchers and academics in identifying some of the legal and ethical issues that might arise as a result of research and development of neural interface devices, using both non-invasive techniques and invasive procedures, the paper discusses a number of recent observations of authors in the field.

The issue of enhancing human attributes by incorporating these new devices is also considered. Such enhancement may be regarded as freeing the mind from the constraints of the body, but there are legal and moral issues that researchers and academics would be well advised to contemplate as these new devices are developed and used.

While different fact situation surround each of these new devices, and those that are yet to come, consideration of the legal and ethical landscape may assist researchers and academics in dealing effectively with matters that arise in these times of transition. Lawyers could seek to facilitate the resolution of the legal disputes that arise in this area of research and development within the existing judicial and legislative frameworks. Whether these frameworks will suffice, or will need to change in order to enable effective resolution, is a broader question to be explored.

Keywords: Neural interface systems, brain-computer interface, brain-machine interface, research, ethics, legal issues, technological development, neurotechnology.

1 INTRODUCTION

Research in neural interface systems (NIs) is growing fast and provides incredible opportunities for technological advancement. What was thought to be simply science fiction is becoming a reality with outcomes ranging from "neurofeedback and neurostimulation to neurocontrol of actuators (e.g. for the purpose of communication and movement" [1, p.1352]. Some of these research outcomes include cars driven by brainwaves alone, brain controlled video games and operative systems, non-verbal human communication through synthetic telepathy and brain controlled artificial limbs [2]. The possibilities are infinite.

This paper provides an overview of NIs and some of the research, technological developments and ethical and legal issues that exist in the field. Despite the fact that this area of neurotechnological development is arguably going where no one has gone before, the question whether or not a new legal frontier will evolve as a result remains unanswered.

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2 BACKGROUND

The human senses of sight, sound and touch play an integral role in facilitating the interaction between people and electronic devices such as computers, scanners and multifarious mobile devices [3]. "But remove those senses from the equation, and electronic devices can become our eyes and ears and even our arms and legs, taking in the world around us and interacting with it through man-made software and hardware." [3, p. 1080]. Dr Jens Clausen assures us that this is already happening [3] and according to Emory University neuroscience Professor, Dr Michael Crutcher, "Anything can happen" [4]. Newspapers have caught on to the fact that "thought-controlled prosthetic arms could become the norm" [5].

The emerging field of neurotechnology in which NIs exist, is developing quickly [6]. The creation of "neurotechnologies to evaluate and treat nervous system disorders and to restore lost neural functions" is occurring "at the intersection of neuroscience, computer science, engineering and medicine" [6, p. 511]. This field of neurology is different from the advances in robotics where researchers strive to make robots more like human beings. Professor of Robotics at Carnegie Mellon University in Pittsburgh USA, Dr Reid Simmons, believes that "in five or ten years robots will routinely be functioning in human environments" [7, p. 72]. Commonly known as androids, these new generation robots are designed "to function not as programmed industrial machines but as increasingly autonomous agents capable of taking on roles in our homes, schools, and offices previously carried out only by humans." [7, p. 72]. Dr Siddhartha Srinivasa, the builder of Home Exploring Robotic Butler (HERB) and Professor at the Robotics Institute at Carnegie Mellon University in Pittsburgh, explains how HERB understands an object is a juice box. "This involves a great deal of mathematics and computer science, but it boils down to taking in information and processing it intelligently in the context of everything he already knows about what his world looks like." [7, p. 73].

In contrast, NIs include devices that sense brain signals, a signal processor and a device to effect action, in clinical terms an assistive technology [6]. One of the major goals of NIs is to work as "a kind of replacement part, or prosthesis, for the motor system" [6, p. 512]. Some human ailments limit the person's ability to move some or all of their limbs. "Concepts for NIs range from an externally driven, reliable, brain-activated switch for a person who is totally unable to move or speak, to an implanted system that provides direct brain-actuated dexterous limb movement for someone with limb paralysis." [6, p. 512].

3 HUMAN AILMENTS

There are many physical conditions including stroke, Alzheimers, tetraplegics and other spinal cord injuries, neurofibromatosis 2 and Parkinson's disease that provide an opportunity for hundreds of thousands of people to benefit from NIs [6].

> Many disorders leave the cerebral mechanisms for volitional movement intact, but disconnect motor signals from the muscles, preventing normal movement and, in the worst cases of complete 'locked in' paralysis, blocking all forms of communication as well. Paralysis originates in diverse ways that include: injury to descending motor pathways in the spinal cord, brainstem, or cerebrum through stroke or trauma (spinal cord injury [SCI], cerebral palsy); degenerative disorders that lead to the loss of motor neurons (such as amyotrophic lateral sclerosis [ALS]) or motor pathways (e.g., multiple sclerosis); degenerative disorders of the muscle (muscular dystrophy); or limb loss. An NI offers a physical means to reconnect action intentions to the world, as illustrated in Figure 1. [6, p. 512].

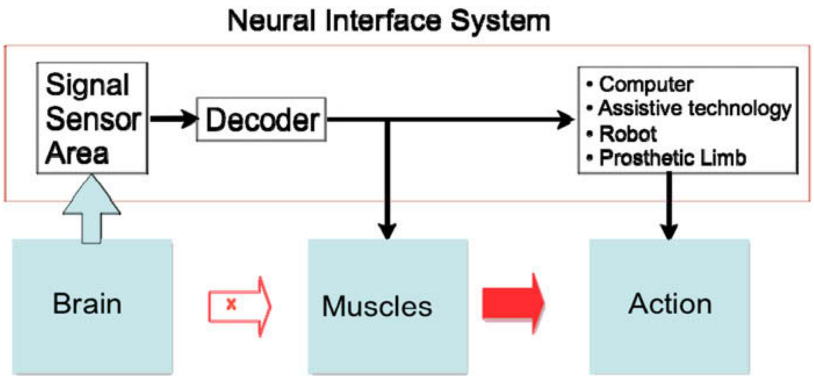

Figure 1. Design of a Neural Interface System. [6, p. 512].

4 THE TECHNOLOGY

Research in technology that enables the brain to communicate with external devices began in the 1970s under a National Science Foundation grant to the University of California Los Angeles (UCLA) [8]. This project "coined the term brain-computer interface" (BCI) [8]. Meel Velliste, Sagi Perel, M. Chance Spalding, Andrew S. Whitford and Andrew B. Schwartz have provided evidence of cortical control of a prosthetic arm by monkeys for self-feeding and this may "pave the way towards the development of dexterous prosthetic devices that could ultimately achieve arm and hand function at a near-natural level." [9, p. 1098].

In other research, the development of vision prosthesis using lasers is occurring [10]. Researchers at the Hawthorn campus of Swinburne University of Technology in Victoria, Australia are exploring the use of laser stimulation, rather than direct electrical stimulation [10].

> Electrodes need an electrical current so they consequently stimulate a group of nerves. Light, however, allows us to target individual nerves and this should mean more accurate communication of optical signals – an essential outcome if the information delivered to the brain via a prosthesis is to mean anything useful in terms of shapes, colours, dimensions. [10, p. 17].

Some of the research undertaken has lead to the development of NIs devices that have enabled incredible changes in the lives of many.

5 SOME NEURAL INTERFACE DEVICES

There are a number of neural interface devices that have been developed to assist those with particular ailments. "Brain-machine interfaces are clinically well established in restoring hearing perception through cochlear implants." [3, p. 1080].

Dr John P. Donoghue, director of the Brain Science Program at Brown University, Providence, Rhode Island USA, was awarded the K.J. Zülch Prize in 2007 'for pioneering BrainGate, the mind-to-movement device that allows people with paralysis to control assistive devices using thoughts alone [11]. His work has resulted in a new brain implant that has allowed people with paralysis to move a computer cursor, to read e-mail, control a television, play video games, control a wheelchair or operate a robotic arm – using thoughts alone [11].

> BrainGate consists of an implantable sensor and external processors that record and decode brain signals from the motor cortex, turning these signals into movement commands that can control assistive devices. [11].

Deep brain stimulation (DBS) is being used to treat people with end-stage Parkinson's disease [3]. "Worldwide, more than 30,000 implants have reportedly been made to control the severe motor symptoms of this disease." [3, p. 1080]. These implants are regarded as invasive NIs but electrocorticography (ECoG), that measures neural impulses from beneath the skull but above the cortex, is partially-invasive [4] while electroencephalography (EEG), that involves placement of electrodes on the scalp to measure neural activity, is non-invasive [12]. There are many other NI devices that are now being used and outcomes of research efforts may produce many more. NIs raise both ethical and legal issues that researchers and academics should consider.

6 ETHICAL ISSUES

Clausen believes that "brain–machine interfaces promise therapeutic benefit and should be pursued." [3, p.1081]. While Clausen admits that these new technologies may pose ethical challenges, he believes that "these are conceptually similar to those that bioethicists have addressed for other realms of therapy. Ethics is well prepared to deal with the questions in parallel to and in cooperation with the neuroscientific research." [3, p.1081].

Kevin Warwick leads into his discussion of the issues that might arise in the future relating to intelligent robots and human/machine mergers known as cyborgs by identifying science fiction movies such as The Terminator, The Matrix, Blade Runner and I, Robot [13]. Warwick believes that scientific developments are raising issues that were not only contemplated in science fiction but go far beyond these [13]. Discussing four different experiments, Warwick identifies some of these issues. The use of Radio Frequency Identification Device (RFID) implants to convey our personal identity raises ethical issues when used by children, the aged or prisoners [13]. As robots with biological brains, possibly developed using human neurons, continue to evolve, a range of social and ethical questions will arise, including the extent to which such a cyborg will be entitled to human rights [13]. With greater use of brain-computer interfaces, issues such as mental side effects, liability for unlawful actions of the human recipient exist and the debate over therapy versus enhancement arise [13].

However, Professor Ruth Chadwick questions whether the issues raised by Warwick are new questions or only old questions in a new guise [14]. Chadwick focuses on the issues of enhancement involving human thought transfer (synthetic telepathy), informed consent for DBS and brain-machine interface (BMI). In relation to enhancement, Chadwick stresses the need to distinguish between 'enhancement' (capabilities that humans do not have) and 'improvement', and concludes that despite the fact that the ability to transfer human thought is an enhancement, criteria are required, possibly moral judgement, to determine whether or not it is an improvement [14].

Where there has been a device developed to assist humans with a particular ailment, for example deafness, the community for which the device has been created might resist use of the device. An example of such resistance has occurred in the deaf community where many people regard the cochlear implants "as an enhancement beyond normal functioning" [3, p. 1081]. "What is enhancement and what is treatment depends on defining normality and disease, and this is notoriously difficult." [3, p. 1081]. Anita Silvers has described the use of the cochlear implant as a "tyranny of the normal" [15, p. 114] "designed to adjust people who are deaf to a world designed by the hearing, ultimately implying the inferiority of deafness" [3, p. 1081].

Chadwick considered BMI (used for DBS), drawing analogies with mind-altering drugs and transplantation of neural tissue [14]. The core issue, according to Chadwick, appears to be "the description of the machine's job as to 'out think the human brain'" but drugs and neural tissue transplants do not operate in this way, they are not intelligent [14]. "The fact that an intelligent machine is preventing my brain from doing what it 'wants' to do is something I may accept because my natural brain is not doing what 'I' want it to do". [14, p. 3]. This threat to the 'I', states Chadwick, "is certainly not a new philosophical puzzle." [14, p. 4]. Complications in legal responsibility, such as alteration of personality including mood, memory function and speech control, might arise where the machine changes the brain [3]. However, "side effects are common in most medical interventions" so "this does not illustrate a new ethical problem". [3, p. 1081].

Researchers proposing to engage in NIs research within, or in collaboration with, the higher education sector may need to convince the institution's ethics committee that these issues are addressed. From a wider perspective, legal issues that might arise during the research or flowing from the research outcomes should be considered.

7 LEGAL ISSUES

Some of the legal issues that might arise in connection with the research and use of NIs include informed consent, human free will, liability when biology and technology fail to work and misuse that results in injury to self or others.

7.1 Informed consent

For patients with Parkinson's disease, DBS can be used to limit the symptoms such as muscle tremor and/or rigidity [13]. Chadwick questions the possibility of the patient's informed consent because of the unforeseeability and unpredictability of the changes that might occur [14]. For example, a change of personality might occur, possibly to the extent of a change of personal identity [14]. However, Chadwick does not believe that informed consent constitutes an insuperable obstacle and that "The problems may be concerned with the post-intervention *experience*, rather than the consent prior to the event." [14, p. 3].

7.2 Human free will and responsibility

Clausen identifies some of the issues that might arise [3]. Brain-controlled prosthetic devices involve the decoding, by a computer within the device, of signals sent from the brain in order to predict what the person intends to do [3]. "Invariably, predictions will fail and this could lead to dangerous, or at the very least embarrassing, situations”. [3, p. 1080]. Where should liability for the involuntary acts fall? “Is it the fault of the computer or the user? Will a user need some kind of driver’s licence and obligatory insurance to operate a prosthesis?” [3, p. 1080].

Indeed, Clausen believes that “[m]elding brain and machine makes the latter an integral part of the individual. This could be seen to challenge our notions of personhood and moral agency.” [3, p. 1080]. Also, in relation to side effects, Clausen states that these “are common in most medical interventions, including treatment with psychoactive drugs.” [3, p. 1080]. “In the case of neuroprostheses, such potential safety issues should be identified and dealt with as soon as possible.” [3, p. 1080]. In relation to dealing with failure of the technology to work correctly, “there are precedents for dealing with liability. Increasing knowledge of human genetics, for example, led to attempts to reject criminal responsibility that were based on the inappropriate belief that genes predetermine actions.” [3, p. 1080].

> Moreover, humans are often in control of dangerous and unpredictable tools such as cars and guns. Brain–machine interfaces represent a highly sophisticated case of tool use, but they are still just that. In the eyes of the law, responsibility should not be much harder to disentangle. [3, p. 1080].

Professor Søren Holm and Teck Chuan Voo explored further the issue of personal responsibility and BMI in relation to the issues raised by Warwick [16].

Regarding BMI, Holm and Voo considered a brain-machine interfaced prosthetic arm represented a tool that individuals used making it possible to distinguish between actions initiated by the individual as opposed to the technology, enabling reliance on the existing ethical and legal frameworks [16]. The duty of care that normally exists would prevail so the responsibility for obtaining an operator’s licence or insurance may rest on the person with the BMI arm [16]. However, Holm and Voo believe that an issue arises if it becomes impossible to distinguish between the will of the person and the operation of the technology, where the natural neural system assimilates with the technology [16]. If this occurs, Holm and Voo question whether the person will be held liable or just simply culpable to an appropriate standard and whether the person could plead the defence that it was “the machine rather (or more) than I who did it” [16, pp. 2-3].

Holm and Voo consider responsibility in the form of attribution and accountability and then pose the question whether it might be justifiable to subject a person who chooses to replace their healthy arm for a “BMI-controlled, symbiotically assimilated artificial arm” to heavier sanctions than a fully paralysed person who needs the device to “realise the values of personal liberty...and well-being” [16, pp. 3-4]. They also consider manufacturer liability for faulty products and conclude that “the ‘changed nature of human action’ brought about by BMI technology does not quite change the very nature of responsibility for our actions” [16, p. 6].

It appears that the current legal framework is able to deal appropriately with these legal issues if they arise. However, there may well be other legal issues that have not yet been predicted and the uncertainty of the outcome of technological development provides an avenue for speculation.

7.3 The Singularity

In 1965, statistician I.J. Good described the following situation:

> Let an ultraintelligent machine be defined as a machine that can far surpass all the intellectual activities of any man however clever. Since the design of machines is one of these intellectual activities, an ultraintelligent machine could design even better machines; there would then unquestionably be an 'intelligence explosion', and the intelligence of man would be left far behind. Thus the first ultraintelligent machine is the last invention that man need ever make. [17, Ch. 2 [1]].

This event is now known as “the Singularity” which represents “an ‘event horizon’ in the predictability of human technological development past which present models of the future may cease to give reliable answers, following the creation of strong AI or the enhancement of human intelligence.” [18] The technological development most often referred to as heading in this direction is arguably Artificial Intelligence (AI), but there are others including direct BCI [19].

> All it takes is one technology – Artificial Intelligence, brain-computer interfaces, or perhaps something unforeseen – that advances to the point of creating smarter-than-human minds.

> That one technological advance is the equivalent of the first self-replicating chemical that gave rise to life on Earth. [19].

Should such an event occur, it is arguable that the existing legal system will be able to deal with any legal issue that might arise. However, during this time of technological development, technological embodiment of legal norms may present challenges for the law.

7.4 Privacy, equity, fairness, due process and the end of the law

As discussed above, Holm and Voo recognise that legal proceedings provide a mechanism to recompense for injury that might arise in the field. Kristrun Gunnarsdottir believes these legal proceedings involve negotiation "with reference to normative judgements, reasonable certainties and doubts about the ordinary behaviours of humans and things in particular circumstance." [20, p. 5]. This would appear to be no different from the present.

However, Dr Mireille Hildebrandt identifies the potential impact of these technological developments on privacy, equity, fairness and due process [21]. Hildebrandt states that "A viable democracy depends on the extent to which citizens have access to knowledge that informs the decision-making processes of those in power" [21, p. 449] and concludes that in circumstances where "others know facts about us which we do not know about ourselves can thus be a violation of our privacy caused by unequal access to knowledge and information" [21, p. 450]. The consequences may have an impact on criminal and civil procedure to the extent that automated profiling without our knowledge might be used against us [21]. Hildebrandt believes we are moving into a world where:

> technological embodiment of legal norms in the emerging technologies that will constitute and regulate our world, would mean the end of the rule of law, paving the way for an instrumentalist rule by means of legal and technological instruments. [21, p. 464].

To avoid these problems, lawyers, and arguably society at large, need to guard against such an erosion of the rule of law.

Timothy D Peters explored the limits of the law and argues that "in today's world of over-legislation and legal paranoia about technological development there has been a return" to the letter of a Christian-Hebrew scholar named Paul who wrote "to a small group of his protégés in Galatia declaring the demise of the Jewish law" [22, p. 78]. In contrast to the film, *I, Robot*, Peters examined the need for an event from which a truth proceeds that transcends law. Focussing on 'the event' that occurs at the end of *I, Robot* when Sonny "chooses to save the concrete individual in front of him and in the process, by passing the nanites to Spooner (who kills VIKI) is also able to save humanity" [22, p. 92], Peters concludes that "abandonment of the 'logic' of the abstract universalism is the recognition of love." [22, p. 92]. In the rapidly changing world where the end of the law might indeed be possible, finding such a truth may be integral to the survival of the legal system as we know it. This abandonment of the logic "deems the abstract as heartless and sees the love, passion and fidelity of the event as the truth that enables the break with the logic of the Law and the logic of universalism" [22, p. 92].

> Like St Paul, *I, Robot* calls us to recognise the heartlessness of the Law and step beyond its requirements into the realm of love. That is, *to love your robot as yourself*! [22, p. 92].

From the perspective of ensuring responsible and sustainable innovation in the convergence of the physical, mental and virtual, Gunnarsdottir believes that:

> Computationally inscribed laws make certain tasks possible and other tasks impossible. Laws as we ordinarily know them however, can always be broken and the court of law has always been an elbowroom for negotiation and mitigation. Legal proceedings and judgement are not an exact science but a space within which reasonable certainties and reasonable doubts are established. [20, p. 5].

The degree to which the existing legal framework will, or must, survive in its current form to ensure that legal issues arising in the field of NIs research and development are resolved appropriately is uncertain.

8 CONCLUSION

The extent to which the Singularity or technological advancement in NIs will impact on the law is unknown, but as Hildebrandt and Peters suggest, the impact may be substantial. From a practical perspective, as Clausen recommends, the safety issues in relation to research of NIs on human beings must be addressed [3]. NIs defects are dealt with in relation to product liability law and human will and responsibility issues that might arise appear to be well entrenched in the existing legal system. However, those unknown future legal issues that cannot be resolved within the existing legal framework as a result of the development of NI research provide an exciting voyage beyond science fiction to a place where anything can happen, a possible legal frontier where no one has gone before.

REFERENCES

[1] Haselager, P., Vlek, R., Hill, J. and Nijboer, F. (2009). A note on ethical aspects of BCI. *Neural Networks* 22, pp. 1352-1357.

[2] Anon. (2 March 2011). Four Brain Controlled Devices – The Coming Mind Power Wave). *Look Forward To* <http://www.ilookforwardto.com/2011/03/4-brain-controlled-devices-the-coming-mind-power-wave.html> at 18 July 2011.

[3] Clausen, J. (2009). Man, machine and in between. *Nature* 457, pp. 1080-1081.

[4] Hammock, A. (30 December 2009). The future of brain-controlled devices. *CNNTech* <http://articles.cnn.com/2009-12-30/tech/brain.controlled.computers_1_cochlear-implants-neural-activity-strokes-or-spinal-cord-injuries?_s=PM:TECH> at 24 December 2010.

[5] Anon. (14 February 2011). Prosthetics within reach. *MX,* Brisbane, 9.

[6] Donoghue, J.P. (2008). Bridging the Brain to the World: A Perspective on Neural Interface Systems. *Neuron* 60(3), pp. 511-521.

[7] Carroll, C. (2011). Us. And them. *National Geographic* August, pp. 66-84.

[8] Anon. (2011). Neuroelectronics. <http://moriarty.tech.dmu.ac.uk:8080/index.jsp?page=681504> at 13 July 2011.

[9] Velliste, M., Perel, S., Spalding, M.C., Whitford, A.S. and Schwarts, A.B. (2008). Cortical control of a prosthetic arm for self-feeding. *Nature* 453, pp. 1098-1101.

[10] Collis, B. (2011). Bionic eye hope from a touch of light. *Swinburne* July, pp. 16-17.

[11] Office of Media Relations, Brown University (2007). Brown Scientist John P. Donoghue Wins Major Neuroscience Award. Press Release 20 August, <http://news.brown.edu/pressreleases/2007/08/neuroscience-award> at 4 September 2011.

[12] Donoghue, J.P., Nurmikko, A., Black, M. and Hochberg, L.R. (2007). Assistive technology and robotic control using motor cortex ensemble-based neural interface systems in humans with tetraplegia. *The Journal of Physiology* 579(3), pp. 603-611.

[13] Warwick, K. (2010). Future Issues with Robots and Cyborgs. *Studies in Ethics, Law, and Technology* 4(3), Article 6.

[14] Chadwick, R. (2010). New Questions, or Only Old Questions in a New Guise. *Studies in Ethics, Law, and Technology* 4(3), Article 8.

[15] Silvers, A. (1998). A Fatal Attraction to Normalizing: Treating Disabilities as Deviations from Species-Typical Functioning. *Enhancing Human Traits: Ethical and Social Implications*, (ed Parens, E.) (Georgetown University Press, USA) pp. 95-123. <http://www.public.iastate.edu/~jwcwolf/Papers/Silvers.pdf> at 17 August 2011.

[16] Holm, S., and Voo, T.C. (2010). Brain-Machine Interfaces and Personal Responsibility for Action – Maybe Not As Complicated After All. *Studies in Ethics, Law, and Technology* 4(3), Article 7.

[17] Good, I.J. (1964). Speculations Concerning the First Ultraintelligent Machine Anon. <http://web.archive.org/web/20010527181244/http://www.aeiveos.com/~bradbury/Authors/Computing/Good-IJ/SCtFUM.html> at 15 September 2011.

[18] Anon. (2011). The Singularity Summit. <http://www.singularitysummit.com/summit/what_is_the_singularity> at 15 September 2011.

[19] Singularity Institute for Artificial Intelligence, Inc. (2011). What is Singularity? <http://singinst.org/overview/whatisthesingularity/> at 15 September 2011.

[20] Gunnarsdottir, K. (2010). The Convergence of the Physical, Mental and Virtual. *Studies in Ethics, Law, and Technology* 4(3), Article 1.

[21] Hildebrandt, M. (2009). Chapter 23 – Technology and the End of Law. Claes, E., Devroe, W. and Keirbilck, B. *Facing the Limits of the Law*, (Springer, USA), pp. 443-464.

[22] Peters, T.D. (2008). Allusions to theology: *I, Robot,* universalism and the limits of the law. *Media and Arts Law Review* 13, pp. 77-92.