THE BIODYNAMICS OF KNOWLEDGE CREATION
An Archaeological, Behavioural and Neurological account on the creation of human knowledge

Warren James Alexander Christie

Thesis submitted in partial fulfilment of the requirements for the degree

of

Master of Philosophy
(Information and Knowledge Management)

Stellenbosch University

Supervisor: Prof J Kinghorn

December 2008

Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the owner of the copyright thereof (unless to the extent explicitly or otherwise stated) and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Date: 21 November 2008

Summary

This thesis explores phenomena surrounding the creation of knowledge, employing a multidisciplinary approach.

To start with a view on the physical location of knowledge is discussed. This helps highlight the problem of defining knowledge and simultaneously introduces a set of fundamental and conceptual questions about the phenomena surrounding the creation of knowledge . The set of questions are then focussed on the process of knowledge creation.

The investigation starts in the field of archaeology, in particular at the dawn of modern civilisation, with views on the earliest forms of knowledge creation. From there the investigation moves on to aspects of contemporary neurology. This allows for a comparison between humans from the ancient past with humans of today thereby identifying a neurological link between these periods.

Based on current research within the field of behavioural neurology it is posed that knowledge creation is a process initiated by the impact of electromagnetic fields on the brain. A review of the medical research within the neurological sciences on the effects of electromagnetic field stimulation shows it to be effective as a treatment modality, a behavioural modifier, a suppressor and facilitator of cognition, as well as a sensory modulator.

The interaction of the brain with electromagnetic fields is shown as a form of transduction similar to that of regular sensory transduction. Since the transduction of electromagnetic stimuli can functionally modulate sensory reception, cognition, behaviour and some neurological conditions, the creation of sensory perception, cognition, behaviour and neurological conditions (all phenomena surrounding knowledge creation) can be shown as functionally dependant on the electro-chemical process of ferromagnetic transduction (magneto reception). The ferromagnetic transduction model may then be seen as the sensory mechanism that initiates and modulates the process of knowledge creation. The modulation of this process is revealed cognitively in savants, behaviourally in some of the greatest thinkers in history and on a planetary scale as a force of nature. The implications of these findings is that if the keys to the creation of knowledge have been found, great care needs to be taken when deciding to implement any type of artificial or natural modulation to neural firing rates not only because of the total effect modulation can have on the individual but also because of the social consequences resulting from those who wish to socially discriminate according to the ability of and beliefs arising from the knowledge creating process.

Opsomming

Die tesis ondersoek fenomene wat betrekking het op die skep van kennis deur van ‘n mulitidissiplinêre benadering gebruik te maak.

Om mee te begin, word ‘n beskouing oor die fisiese lokasie van kennis bespreek. Dit help om die probleem van die definisie van kennis te belig, en bring tegelyk ‘n stel fundamentele en konseptuele vrae ten opsigte van die fenomene rondom kennisskepping ter sprake. Hiedie stel vrae word dan toegepas op die proses van kennisskepping.

Die ondersoek begin by die gebied van die argeologie, in besonder by die aanvange van die moderne beskawing, met beskouings oor die vroegste vorme van kennisskepping. Dit word opgevolg met aspekte van kontemporêre neurologie. Dit maak ‘n vergelyking moontlik van mense van die vroegste tye met hedendaagse mense deurdat ‘n neurologiese verband gelê kan word.

Gebaseer op kontemporêre navorsing in neurologie word die standpunt ingeneem dat kennisskepping ‘n proses is wat geïnisieer word deur die impak van elektro-magnetiese velde op die brein. ‘n Oorsig van mediese navorsing binne die gebied van die neurologiese wetenskap oor die uitwerking van elektro-magnetiese veldstimulasie, toon dat dit effektief is as ‘n behandelingsmodaliteit, ‘n gedragswysiger, ‘n onderdrukker en fasiliteerder van kognisie, asook as ‘n sensoriese moduleerder.

Dit word getoon dat die interaksie van die elektro-magnetiese velde met die brein ‘n vorm van transduksie is, soortgelyk aan gewone sensoriese transduksie. Aangesien die transduksie van elektro-magnetiese stimuli die funksionering kan moduleer van sensoriese resepsie, kognisie, gedrag en sommige neurologiese kondisies, kan geargumenteer word dat die skepping van sensoriese persepsie, kognisie, gedrag en neurologiese kondisies (almal fenomene van kennisskepping) funksioneel afhanklik is van die elektro-chemiese proses van ferromagnetiese transduksie. Die ferromagnetiese transduksie model kan dus gesien word as die sensoriese meganisme wat die proses van kennisskepping inisïeer en moduleer.

Table of Contents

Prologue

1 Hypothesis

The creation of knowledge is a biological process defined by a transduction mechanism (sensory ability) in the brain that has effect on sensory perception, cognitive performance, behaviour and neurological condition.

2 Context

The hypothesis provides a conceptual root from which the entire thesis will be derived. The concept of knowledge and knowledge creation, the physiological process occurring during creation and how this affects sensory perception, cognitive performance, behaviour and neurological condition are the conceptual roots. As simple as it may sound, it seems identification of the relevant context per concept will explore a diverse range of disciplines beyond the field of knowledge management. It seems logical that not all the answers to the hypothesis would be found in one discipline.

The hypothesis attempts to bridge a variety of disciplines each of which require credible interpretation and for this an abundance of extracts have been used from reputable authors who have published their work in trustworthy publications. By using the words of those who have spent years researching and documenting it is hoped that a logical and valid chain of reasoning will be created that stands true beyond any personal extrapolations. Through the extensive use of extracts from each author an understanding of each extract will be explained and then linked to the original argument.

Consequently, one could see the concept/s proposed by each extract as one link is the chain of reasoning that constitutes the hypothetical argument. The successful progression of the argument is dependent on how well each conceptual link overlaps between extracts, between the authors and between disciplines.

However, the difficult part for the reader is not only familiarising oneself with the style of reasoning but also with the terminology used between the varying disciplines. In this regard the transitional links will be carefully identified to avoid confusion.

If the hypothesis is reasoned convincingly, what then remains to be discussed are the implications of the hypothesis. It is these implications which have formed an engaging commentary on the understanding of knowledge creation.

3 History

It is exactly this commentary which initially drew the argument in a historical direction. In particular, the notion first became an article written by a South African professor in Archaeology who has achieved international recognition for his theory on the cognitive origins of modern man. David Lewis-Williams' theory is well recognized as the most accurate explanation on why humans from the upper Palaeolithic (approximately 30 000 years ago) began to express themselves creatively (on rock face with paint) for the very first time.

For millions of years prior to this tipping point, there was absolutely no ritualised attempt at such a seemingly pointless activity. However, it marked a transition in the use of abstract thought and as it is understood today in the field of cognitive archaeology, it provides for the origin of art, religious thought, and scientific thinking.

So, this era in human history about 30 000 years ago, compared to the previous six millennia of human history, initiated a rapid transition in the development of language, technology, religion, science, politics and almost every other element of organised society associated with the humans of this era. The question that intrigues the cognitive archaeologist is why did humans gain this desire to create these rich symbolic images.

According to Lewis Williams, humans discovered the means to temporarily interfere with their nervous system and create altered states of consciousness. It is in these varying states of consciousness that 'visions' were experienced. These visions were extremely diverse in form and content and could range from a few simple zigzags to a fully immersive world with an unfolding plot and numerous characters. It is these 'magical' experiences that drove our ancient ancestors to trek deep into caves (just as their visions took them deep within their mind) and paint the astonishing visions they experienced.

Lewis Williams sees this procedure as the cognitive root of man's *imagination* (abstract thought) and they primary factor in the rapid increase in innovation throughout that era.

What interests me about this procedure is the induction of altered states of consciousness as the most successful means in human history to create the knowledge necessary for rapid

human advancement. The key here is clearly the recognition of abstract thought that gave rise to the multitude of symbolic systems now a requirement to survive in today's complex world.

4 Inducing Altered States of Consciousness

Regardless of the method employed by these ancient humans to enter altered states, their art remained categorically alike. Lewis Williams states that this is due to the fact that these early hominids were anatomically identical to each other (and also to the humans of today) since the last major biological change in humans was over 150 000 years ago. He goes further to say that the nervous system is 'hard wired' identically and therefore when temporarily stimulated/interfered with, the resulting 'visions' are almost identical to what can be experienced by humans today.

In this regard, the work of a Dr Michael Persinger came to my attention. He has been recreating 'visions' in his lab for the last 30 years using Transcranial Magnetic Stimulation (TMS). His testing apparatus basically consists of a series of four coils emitting a very low electromagnetic frequency (matching the frequencies the brain emits) placed on either side of the human cortex above temporal lobes. The result would show 80% of test subjects to experience a range of 'visions' from either a phosphene phenomenon (zigzag lines) towards the perception of 'a sensed presence' whose form and content would depend on each individual's culturally dependant view point, according to Dr Persinger.

So, these lab created 'visions' show remarkable similarity to the ones experienced by the ancient humans from the Upper Paleolithic. It's no surprise really when one considers that both are anatomically identical and, according to Dr Persinger, when entering an altered state of consciousness, neurons are being depolarised in certain parts of the brain, leading to changes in the patterns of neural activation. Essentially, the effect of altering one's state of consciousness is to change the information content in the neurons.

5 The Modulation of Knowledge Creation

The effects of changing patterns of neural activation through the use of TMS must then reveal the extent to which the brain is affected by electromagnetic fields. What the subsequent research exposed is that electromagnetic stimulation not only affected sensory perception but also cognition, behaviour and neurological condition; all of these human faculties evidently perform an integral function toward the creation of knowledge and can therefore be seen as the *faculties of knowledge creation*.

The process in which knowledge is created is therefore directly influenced by the reception of electromagnetic fields and so the biological mechanism which transduces electromagnetic potentials is key to understanding the process of knowledge creation. The *ferromagnetic transduction model*, as proposed by Joseph Kirschvink, is the most suitable biological explanation toward understanding the sensory mechanism that modulates the creation of knowledge.

The modulation of knowledge creation will be made evident by comparing the cognitive mastery of savants to similar effects that can be achieved with TMS. The behavioural phenomenon of hypnogogia will also be shown as a natural and widely accessible means to self induce an altered state of consciousness and modulate the knowledge creation process.

Introduction

Where is Knowledge?

1 The Mind of the Beholder

A matter of preliminary importance in this conceptual investigation is on the physical positioning of knowledge. Clarification of the physical position as within the biological anatomy of humans will allow for a more *physically definitive* understanding of the location of knowledge and its creation. Exclusivity of the definition will avoid confusion of the term as it is used throughout the document and ultimately enable coherency.

An article by Professor Thomas Wilson precisely delineates the whereabouts of knowledge. His view is not the only view but merely one of many, however, it is Wilson's view that seems to be widely supported by many scholars within the discipline of knowledge management.

Wilson's analysis begins by pointing out that knowledge is quite simply defined by "what we know: knowledge involves the mental processes of comprehension, understanding and learning that go on in the mind and only in the mind, however much they involve interaction with the world outside the mind, and interaction with others."

This point is pertinent to the current state of the 'Knowledge Management' discipline and the consequences on organizational consultancy based on Knowledge Management. Often consultants use the term to refer to information or data as Knowledge saying it is contained within computer databases, in books, on paper etc. However, as Wilson points out, knowledge is strictly within the *mind of the beholder*.

Professor Wilson emphasizes the confusion of the term knowledge (with information) by saying that whenever "we wish to express what we know, we can only do so by uttering messages of one kind or another - oral, written, graphic, gestural or even through 'body language'. Such messages do not carry 'knowledge', they constitute 'information', which a

knowing mind may assimilate, understand, comprehend and incorporate into its own knowledge structures."[1]

This is a very humanised (and ultimately biological) understanding of knowledge and currently makes the management of it extremely less predictable, which is of much less value to organisational consultants. In other words, since knowledge is only in the mind of the beholder, either the *beholder* can be managed and/or the beholders *access* to information can be managed. The concept of Human Resources or Information Management is nothing new to academics or consultants. Knowledge Management can therefore be seen as an attempt to manage the mind of the beholder which can prove a very complex and sometimes controversial endeavour indeed.

Wilson goes on to illustrate the complexity of knowledge management through the human structures that build and convey knowledge. "These structures are not identical for the person uttering the message and the receiver, because each person's knowledge structures are, as Shutz puts it, "biographically determined"[2]. Therefore, the knowledge built from the messages can never be exactly the same as the knowledge base from which the messages were uttered."[3] This is simply due to the fact that everyone's biographical constitution is unique to their particular cultural socialisation, individual experiences, emotional circumstance etc.

So, the current understanding of the physical location of *knowledge* to be within the mind of the beholder, leads academics and consultants to confuse the term with *information* sources external to the mind. In addition, the information which is conveyed can never exactly reflect the knowledge base from which it was sent and therefore never be recreated precisely because it is adapted by every individual's biographical constitution. The biographical constitution of every individual reinforces the *human nature* of knowledge.

The human nature of knowledge is a direct comment on the imperfect ability of every individual to accurately construct knowledge from information and subsequently disseminate knowledge into information. The biographical disposition of every individual prohibits the accurate exchange of knowledge through information. Therefore, to put it simply, the human nature of knowledge is the less than perfect ability to *'say what you know'* in conjunction with trying to *'know what has been said'*. Therefore the distinction of information from

---

[1] Wilson TD. October 2002. The nonsense of 'knowledge management'. *Information Research*. Vol 8 No 1.

[2] Schutz A. 1967. *The phenomenology of the social world*. Evanston, IL, Northwestern University Press

[3] Wilson TD. October 2002. The nonsense of 'knowledge management'. *Information Research*. Vol 8 No 1.

knowledge helps answer why knowledge management can be so complex; in organisational settings, perfect, machine driven information flows are disrupted by imperfect knowledge processes ultimately because knowledge remains in the exclusive physical domain of the human mind.

Final resolution on the disparaging whereabouts of ‘knowledge’ and ‘information’ and the resulting consequences is made clear by recognising “that everything outside the mind that can be manipulated in any way, can be defined as 'data', if it consists of simple facts, or as 'information', if the data are embedded in a context of relevance to the recipient. Collections of messages, composed in various ways, may be considered as 'information resources' of various kinds - collections of papers in a journal, e-mail messages in an electronic 'folder', manuscript letters in an archive, or whatever. Generally, these are regarded as 'information resources'. Thus, data and information may be managed, and information resources may be managed, but knowledge (i.e. what I know) can never be managed, except by the individual knower and, even then, only imperfectly. The fact is that we often do not know what we know: that we know something may only emerge when we need to employ the knowledge to accomplish something. Much of what we have learnt is apparently forgotten, but can emerge unexpectedly when needed, or even when not needed. In other words we seem to have very little control over 'what we know'.”[4]

It is intriguing to note that, according to Wilson (a consultant himself) ‘what we know’ is nearly impossible to control, let alone management. It makes the work of a knowledge management consultant very perplexing indeed. Wilson’s point of view on the topic is comparable to numerous other consultants who share a similar resolve.

Karl Erik Sveiby, who wrote one of the first books on the subject in 1990 entitled '*Kunskapledning*' and arguably one of the ‘founding fathers’ if not the founding father of knowledge management, provides extensive information on his approach to knowledge management on his website. In the Frequently Asked Questions section he is asked, “Why should knowledge be managed?” His reply was:

“I don't believe knowledge can be managed. Knowledge Management is a poor term, but we are stuck with it, I suppose. "Knowledge Focus" or "Knowledge Creation" (Nonaka) are

[4] Wilson TD. October 2002. The nonsense of 'knowledge management'. *Information Research,* Vol 8 No 1.

better terms, because they describe a mindset, which sees knowledge as activity not an object. It is a human vision, not a technological one."[5]

Sveiby is very clear at the end of his answer to define knowledge as a 'human vision' ie. Knowledge, as a concept, is strictly confined to be within every human and not within technological devices.

Another well known consultant on the topic, and probably the first person to write of the 'knowledge society' and the 'knowledge economy' in 1967, is Peter Drucker. In 2001 he attended the Delphi Group's Collaborative Commerce Summit to deliver a keynote address. When commenting on the subject of knowledge management Drucker "…scoffs at the notion of knowledge management...You can't manage knowledge... Knowledge is between two ears, and only between two ears."[6] Drucker is implying that "it's really about what individual workers do with the knowledge they have. When employees leave a company... their knowledge goes with them, no matter how much they've shared."[7]

In a very recent commentary, Wilson expressed in an editorial review for Chun Wei Choo's book[8] that "Overall, the book is a valuable contribution to the organization of ideas on 'the learning organization', but we have to bear in mind that the idea that *organizations* can learn and can acquire 'knowledge' is not tenable. Only humans, *working in organizations* are capable of learning and knowing... The managers of organization *can* establish systems for the collection and organization of information, which may be made accessible to other organizational members, and those members may, as a consequence, learn something from the record of past experience and, as a result, make more effective decisions. But the 'organization' is not capable of 'using' information, 'constructing meaning' or 'creating knowledge'."[9] Wilson's position on the subject seems to be clear and concurrent with some of the most respected authors on the subject.

---

[5] http://www.sveiby.com/TheLibrary/FAQs/tabid/85/Default.aspx#Whatis

[6] http://www.callcentermagazine.com/article/IWK20010604S0011

[7] http://www.callcentermagazine.com/article/IWK20010604S0011

[8] "The knowing organization: how organizations use information to construct meaning, create knowledge, and make decisions" published in 2007

[9] Wilson, TD. Review of: Choo, CW. 2007. *The knowing organization: how organizations use information to construct meaning, create knowledge, and make decisions.* 2nd. ed. New York, Oxford: Oxford University Press, 2006

Chapter 1

Defining Knowledge

1 What is Knowledge?

The question that now arises is 'What is Knowledge?' The answer according to Polyani should be quite simple. Knowledge is the "process of knowing"[10]. "Knowing involves a tacit connection between two entities— the distal, that entity toward which one attends, and the proximal, that from which one attends. To use an example, Polanyi refers to learning to play the piano. With learning to play the piano, the distal, that toward which one is attending, is the playing of music. The proximal, that from which one attends, is the sensations and feelings in one's fingers and body as they interact with the piano. Over time, the learner shifts his attention from the mechanical playing of the piano to the creation of ever more skilful and moving music. As the learning and knowing process continues, the learner no longer focuses on his fingers at the piano, becoming only subsidiarily aware of his fingers as he turns his focus to playing expressively."[11]

The sophistication of Polyani's definition provides a meaningful reflection on the purpose of the hypothesis. Consider the creation of music as comparable to the creation of knowledge then the hypothesis presents an eloquent adaptation of Polyani's definition.

The entity toward which it attends (distal) is the creation of knowledge, and the entity from which it attends (proximal) is the literal understanding of content. Over time, it is hoped the reader may be able to shift their attention from the literal understanding of knowledge to the creation of more skillful and moving knowledge. As the learning and knowing process continues, the reader no longer focuses on their literal understanding, becoming only subsidiarily aware of this understanding as the focus turns to creating knowledge expressively.

What follows then is a review of the process of knowledge creation as well as an opportunity to utilise the information resource to creatively expand what is known in the mind of the beholder.

---

[10] Palmer NA. 2001. Polanyi's Concept of Tacit Knowing. T-656 Inquiry: Tacit Knowledge and Intuition, Harvard Graduate School of Education (source: http://www.gse.harvard.edu/~t656_web/From_2000-2001_students/Polanyi_Nina.htm)

[11] Palmer NA. 2001. Polanyi's Concept of Tacit Knowing. T-656 Inquiry: Tacit Knowledge and Intuition, Harvard Graduate School of Education (source: http://www.gse.harvard.edu/~t656_web/From_2000-2001_students/Polanyi_Nina.htm)

2 A question of Methodology

With regard to the process of knowledge creation, understanding where the created knowledge is located has been shown clearly i.e. within the biological construct of every human being. This should be sufficient to understand the question of where knowledge is created.

Naturally, a logical assumption of the answer to that question (based on where it resides) is that it is created within every human being. If this is considered to be true then the human nature of knowledge presents a huge dilemma in accessing the true potential of our own creation.

As the human nature of knowledge points out, humans struggle to 'say what we know' as well as 'know what was said' (because of biographical determinations) which is compounded by the problem of having knowledge emerge when needed and/or when not needed. If so little about knowledge is under the control of those who possess it, then the uttering of a message from a knowledge base can only ever be decoded by insufficient understanding of how the message was encoded. This ultimately renders the decoding of almost all information as sporadic and unpredictable.

In fact, it is possible one might not even know one had received information or where the information came from, and the whole process could be beyond the knowing mind right up until the point where knowledge unexpectedly *emerges* from a seemingly chaotic sea of information. Obviously, this poses a problem for the systematic study of knowledge yet if more was understood about how it is created perhaps more could be known about how to control it.

There are so many questions that need to be asked right now about the creation of knowledge which poses a further problem. What are the conceptual questions that need to be asked about the topic in order to understand it? A simple approach to comprehension is to make a detailed interrogation of the fundamental conceptual questions regarding knowledge. In search of the fundamental questions that can be asked, there exists an interesting phenomenon in the English language (and many others languages) that may offer a good indication of a range of questions that would cover a reasonable spectrum of fundamental concepts.

This observation of the English language is credited to Noam Chomsky, an Institute Professor and professor emeritus of linguistics at the Massachusetts Institute of Technology. According to the Arts and Humanities Citation Index in 1992, Chomsky was cited as a source more often

than any other living scholar during the 1980–1992 time period, and is the eighth-most cited scholar in any time period.[12]

Chomsky noted that "*wh-movement* (or wh-fronting or wh-extraction) is a *syntactic*[13] phenomenon found in many languages around the world, in which interrogative words[14] (sometimes called *wh-words*) show a special word order. Unlike ordinary phrases, such wh-words appear at the beginning of an *interrogative clause*[15]. The term wh-movement is due to the fact that most English interrogative words start with *wh-*, for example, *what*, *where*, *why*, etc. The term wh-movement tends to be applied universally, even when the interrogative words of a given language (such as French) do not start with *wh-*. In some Romance languages, the preferred term is "movement-q", since interrogative words of Latin origin often start with *qu-*"[16]

Most English interrogative words start with wh-, so if it were possible to make a conceptual interrogation of the topic of knowledge creation, perhaps that will serve as an acceptable systemic logic to reveal as much information on the spectrum of knowledge creation in the shortest space possible. It seems logically convenient that most interrogative words start with 'wh' so what remains to be known is an exhaustive list of all the possible 'wh-words'.

"In linguistics[17], an *interrogative word* is a function word[18] used for the item interrupted in an information statement. *Interrogative words* are sometimes also called *wh-words* because most of English interrogative words start with *wh-*…

List of interrogative words in English:

interrogative determiner

which, *what*

whose (interrogative possessive determiner)

interrogative pro-form

---

[12] "Chomsky is Citation Champ", MIT News Office, April 1992.

[13] http://en.wikipedia.org/wiki/Syntax

[14] http://en.wikipedia.org/wiki/Interrogative_word

[15] http://en.wikipedia.org/wiki/Question

[16] http://en.wikipedia.org/wiki/Wh-movement (source: Chomsky N. 1977. On Wh-Movement. *Formal Syntax*. New York; Lai-Sheng C. *Wh-Movement: Moving On*. The MIT Press, 2007)

[17] http://en.wikipedia.org/wiki/Linguistics

[18] http://en.wikipedia.org/wiki/Function_word

interrogative pronoun

who, *whom* (human)

what, *which* (nonhuman)

interrogative pro-adverb

where (location)

whence (source)

whither (goal)

when (time)

how (manner)

why, *wherefore* (reason)

whether (choice between alternatives)[19]

By asking all the the interrogative questions, something of the truth must be revealed. So, what needs to be constructed from this evidence is one simple[20] interrogative clause per wh-word. Before that can be done though it seems necessary to first understand the exact definition of each wh-word in order to answer the question as accurately as possible.

[19] http://en.wikipedia.org/wiki/Interrogative_word

[20] Using an (a) *interrogative word* once and (b) the 3rd person singular present of *be* ie 'is' and (c) the subject/object in question eg "What is Knowledge creation?"

Whose – a grammatical word used to talk or ask about the person or thing something belongs to[21]

Who – used to introduce a question asking about the name or identity of a person or people[22]

Which - used to ask for something to be identified from a known larger group or range of possibilities[23]

What – a grammatical word used in direct and indirect questions to request information, e.g. about the identity or nature of somebody, or about the purpose of something[24]

Where – an adverb used to ask a question about the place that somebody or something is in, at, coming from, or going to[25]

Whence – as result: from which cause or origin[26]

Whither – to what state, condition, outcome, or degree[27]

When – an adverb used to ask at what time or at what point something happens[28]

How – used to ask or report questions or to introduce statements about the manner in which something happens or is done[29]

Why – an adverb used to ask or talk about the reason, purpose, or cause of something[30]

Whether – used to indicate alternatives in an indirect question or a clause following a verb that expresses or implies doubt or the possibility of choice[31]

Utilising these definitions questions can be defined to interrogate knowledge creation from an objective point of view in a procedural manner. The only subjective element that remains is in

---

[21] http://encarta.msn.com/dictionary_/whose.html

[22] http://encarta.msn.com/dictionary_1861713004/who.html

[23] http://encarta.msn.com/dictionary_/Which.html

[24] http://encarta.msn.com/dictionary_/What%2520.html

[25] http://encarta.msn.com/dictionary_/Where.html

[26] http://encarta.msn.com/dictionary_/Whence.html

[27] http://encarta.msn.com/dictionary_/Whither.html

[28] http://encarta.msn.com/dictionary_/When.html

[29] http://encarta.msn.com/dictionary_/how.html

[30] http://encarta.msn.com/dictionary_/why.html

[31] http://encarta.msn.com/dictionary_/Whether%2520.html

what order the questions are answered. This will always remain within the authors discretion and so is only to be trusted if the logic is found to be sound.

Chapter 2

The Cognitive History of Knowledge Creation

1 Whence is Knowledge Created?

When considering the process of knowledge creation, it appeared that the question of whence knowledge is created seemed of initial significance. So the question is:

Whence is knowledge created?

Whence – what is the *origin* of knowledge creation?

In other words, if it were possible to find the origin of the first *recorded* period in human history to utilise the knowledge creation process, what would that reveal?

To answer that question it is necessary to find a significant point in the development of the species and examine where the most remarkable change took place in our cognitive ability to create. This point of origin is not hard to find in the discipline of Archaeology. It is a commonly accepted point in human development widely known as the 'Transition', the 'Revolution' or 'Big Bang' in human development.

"Most archaeologists agree that something drastic must have happened to earlier forms of the human mind to account for the west European evidence of the Transition ... How else, they ask, can one explain the comparatively sudden appearance of an abundance of body decoration, burials and art?"[32]

The transition is seen to have occurred approximately "fifty thousand years ago... [people] suddenly developed a remarkable range of new talents. These people - whose primitive stone culture had previously been very different from that of their ancestors- began painting. They invented music and the instruments to play it. They fashioned jewellery and clothing, created fishing poles and tackle as well as bows and arrows, constructed the oldest substantial houses, and buried their dead with ritual and ceremony. This creative explosion, occurring over such a

[32] Lewis Williams D.L. 2004. *The Mind in the Cave: Consciousness and the Origins of Art* Thames&Hudson

remarkably short period, has been called the "big bang" of human culture. It was the fourth in a series of punctuated events that have marked the history of human evolution. The first occurred between 5 and 7 million years ago…when a group of African apes… began to walk upright. The next occurred about two and a half million years ago when… the first stone-tool makers emerged. The third occurred about 1.8 million years ago when humans developed modern body proportions."[33]

This extract is taken from Richard G. Klein's book 'The Dawn of Human Culture'. Klein is currently "Professor of Anthropological Sciences at Stanford University. He is the Anne T. and Robert M. Bass Professor in the School of Humanities and Sciences. He earned his Ph.D. at the University of Chicago in 1966, and was elected to the National Academy of Sciences in April of 2003. His research interests include paleoanthropology, Africa, and Europe. His primary thesis is that modern humans evolved in East Africa some 100,000 years ago and, starting 50,000 years ago, began spreading throughout the non-African world"[34]

It would be insufficient though to take just one point of view on the significance of this particular period and it would only be proper to confirm this period with several sources.

"Anatomically modern humans first emerged around 100,000 years ago. However, thereafter there seems to have followed a period of around 60,000 years when the lifestyle of the modern humans changed little from that of their predecessors. It was not till around 40,000 years ago that the archaeological record reveals the emergence of technical and social advances, which a modern human can understand as fundamentally like our own. This dramatic change is known as the Upper Palaeolithic Revolution. The revolution comprised new technologies, hunting techniques, human burials and an artistic tradition of astonishing competency."[35]

Finding text to reference the notion that "…modern human behaviour originated … more than 40,000 years ago"[36] is not very difficult. A brief search on the net revealed an article saying "as long as 160,000 years ago, people who looked like modern humans roamed Africa. For more than 100,000 years, these populations remained small in number and were confined largely to Africa. Approximately 50,000 years ago, despite no apparent physical change, a subset of these people dramatically altered their behaviour, producing the first artefacts unequivocally deemed

---

[33] Klein RG, Edgar B. 2002. *The Dawn of Human Culture* Wiley, New York

[34] http://en.wikipedia.org/wiki/Richard_G._Klein

[35] http://www.newarchaeology.com/articles/uprevolution.php

[36] http://www.sciencedaily.com/releases/1998/07/980707073901.htm

to be jewellery and inventing new technologies, such as projectile weapons, that allowed them to fish and to hunt dangerous prey"[37]

As a matter of causality, it is important to confirm that this event in human history is not due to any anatomical change in the human biology. It is clearly stated by Steven Mithen - current professor of Archaeology at the University of Reading – in his book 'The Prehistory of the Mind: Cognitive origins of Art, Religion and Science'.

"We can see that there were two major spurts in brain enlargement, one between 2.0 and 1.5 million years ago, which seems to related to the appearance of Homo habilis, and a less pronounced one between 500,000 and 200,000 years ago. Archaeologists tentatively link the first spurt to the development of toolmaking, but can find no major change in the nature of the archaeological record correlating with the second period of rapid brain expansion"[38]

In summary, it can be seen that approximately 40 000 years ago there was a significant change in the course of human history. There was a creative explosion in a relatively short period because where, as Klein says, they began to *paint*. It is fairly safe to state then from the evidence so far, that the most successful advancement in humankind's cognitive ability to create was during this period and it is not attributed to any anatomical change of some kind. This is not to say that humans had not been creating artefacts prior to this point - on the contrary, toolmaking, harnessing fire and bead making were activities in practice for thousands of years already. What is significant about this period is the increase in creative output during and subsequent to it.

It seems what needs to be looked at in more detail now is the precise nature of *how* these ancient humans went about depicting their art on rock and *how* this could affect the human ability to create knowledge to the extent that has been recorded.

2 How and When is Knowledge Created?

Further investigation into the archaeology of knowledge creation takes us down a branch of archaeology termed 'Cognitive Archaeology'. It will eventually reveal very plausible answers to the questions of *how* and *when* knowledge is created. Surprisingly, the answer remains the same for both questions. The questions are:

When is knowledge created?

---

[37]Klarreich E. April 2004. Biography of Richard G. Klein *PNAS*. Vol 101 no 16, 5705–5707 (source: http://www.pnas.org/cgi/content/full/101/16/5705)

[38] Mithen SJ. 1996. *The prehistory of the mind : a search for the origins of art, religion, and science.* London, Thames and Hudson

At what point knowledge creation happens

How is knowledge created?

The manner in which knowledge creation happens

What is significant about cognitive archaeology is that "cognition is [understood as] the act or faculty of knowing; the word refers to the ways in which people conceive of the world and humankind's place in it. Cognitive archaeology thus deals with ancient beliefs, symbols, rituals and religions."[39]

Now within the field of cognitive archaeology there is not just one answer to why the people of the Upper Palaeolithic began creating art on rock. The theoretical and interpretive approaches that have been are numerous, "art for art's sake, totemism, hunting magic, and the binary oppositions of Levi-Straussian structuralism are all considered. Then … the view that presently provokes debate - shamanism."[40]

It is this particular view that was first proposed by South African Professor David Lewis-Williams. He "is well-known in rock-art circles as the author of a series of articles drawing on ethnographic material and shamanism (notably connected with the San rock art of southern Africa) to gain new insights into the Palaeolithic cave art of Western Europe. Some 15 years ago, with Thomas Dowson, he proposed that Palaeolithic art owed its inspiration at least in part to trance experiences (altered states of consciousness) associated with shamanistic practices. Since that article appeared, the shamanistic hypothesis has both been widely adopted and developed in the study of different rock-art traditions, and has become the subject of lively and sometimes heated controversy"[41]

What is important here is the art that was being produced by these ancient humans was inspired by the ritualistic practice of inducing altered states of consciousness and then using those experiences as the inspiration for their creations.

What's more, Lewis-Williams takes his argument even further "and combines the shamanistic hypothesis with an interpretation of the development of human consciousness.

---

[39] Lewis-Williams DL. 1989. Southern Africa's place in the archaeology of human understanding. *Suid-Afrikaanse Tydskrif vir Wetenskap*. Vol 85, 47-52

[40] Lewis-Williams DL. 2003. (Review Feature: Pearson JL. 2002. *Shamanism and the Ancient Mind: A Cognitive Approach to Archaeology.* Walnut Creek, Altamira Press). *Journal of Anthropological Research.* vol 59, 94)

[41] Lewis-Williams DL. 2003. (Review Feature: Lewis-Williams DL. 2002. *The Mind in the Cave: Consciousness and the Origins of Art.* London, Thames & Hudson). *Cambridge Archaeological Journal.* vol 13, 263-279

He thus enters another contentious area of archaeological debate, seeking to understand west European cave art in the context of (and as a marker of) the new intellectual capacities of anatomically modern humans. Radiocarbon dates for the earliest west European cave art now place it contemporary with the demise of the Neanderthals around 30,000 years ago, and cave art, along with carved or decorated portable items, appears to announce the arrival and denote the success of modern humans in this region. Lewis-Williams argues that such cave art would have been beyond the capabilities of Neanderthals, and that this kind of artistic ability is unique to anatomically modern humans. Furthermore, he concludes that the development of the new ability cannot have been the product of hundreds of thousands of years of gradual hominid evolution, but must have arisen much more abruptly, within the novel neurological structure of anatomically modern humans."[42]

It sounds farfetched that the rational knowledge used throughout the logical world today is derived from an ancient people who sought to ritualistically alter their consciousness. And then to go on further and say that these rituals were within the context of newly developed intellectual capacities[43,44,45]. It would seem a very unlikely case that all that can be appreciated through a conscious mind is rooted in an altered state of consciousness. What if these ancient people were just making art for the fun of it?

This artistic ability is very clearly stated not to be the result of some sort of "aesthetic drive" [46] innate to human beings and therefore the reason for the creation of this art. The aesthetic motive for artistic creation "developed in various historically-contingent ways *after* people started making images".[47]

Lewis Williams presents a very thorough argument carefully outlining the fact that in confronting "the explosion of cave art that took place 30 to 35 thousand years ago we are

---

[42] Lewis-Williams DL. 2003. (Review Feature: Lewis-Williams DL. 2002. *The Mind in the Cave: Consciousness and the Origins of Art.* London, Thames & Hudson) *Cambridge Archaeological Journal.* vol 13, 263-279

[43] Mithen SJ. 1996. *The prehistory of the mind : a search for the origins of art, religion, and science.* London, Thames and Hudson

[44] Stephen Mithen in his book proposed "The Cathedral Metaphor" which provides a modular breakdown of the different types of intelligence. He goes on to show how the change in human cognition during the Transition were brought about by the capacity for humans to effectively integrate the varying modules through abstraction (hence creating the capacity to understand and apply metaphor between the different modules of intelligence eg the hunt for food could now be understood as analogous to the pursuit of a suitable mate.) Please see this link for a diagram on this.

[45] Mithen SJ. 1996. *Explaining the human mind. British Archaeology.* vol 15, June

[46] Lewis-Williams DL. 2003. (Review Feature: Lewis-Williams DL. 2002. *The Mind in the Cave: Consciousness and the Origins of Art.* London, Thames & Hudson) *Cambridge Archaeological Journal.* vol 13, 263-279

[47] Lewis-Williams DL. 2003. (Review Feature: Lewis-Williams DL. 2002. *The Mind in the Cave: Consciousness and the Origins of Art.* London, Thames & Hudson). *Cambridge Archaeological Journal.* vol 13, 263-279

confronting the very origins of human understanding as we know it."[48] Humans had somehow managed to develop an incredible new ability attributed to nothing other than ritualised *shamanistic practices*. It's surprising then that one of the best available answer ("most widely adopted") to the question of *how* knowledge is created and *when* knowledge is created, the answer to both being through and when in altered states of consciousness.

What would be necessary to comprehend this answer further is an examination of exactly what an altered state of consciousness is? What were these people seeing? And how is this relevant to modern day man? The answers to these questions will continue to refine the 'how' of knowledge creation.

3 How is Knowledge Created?

'Shamanism' sounds an odd word to use in scientific terms. Lewis Williams is particular to note that the term "shaman" is used "rather than the more usual "medicine man," but we do not thereby imply anything about the social position of the person, his or her mental health, or, indeed, many of the other characteristics often associated with the very heterogeneous phenomenon called shamanism. Instead we emphasise what we believe to be the most important and overriding feature of shamanism and the one with which this paper is principally concerned-altered states of *consciousne*ss."[49]

It's important to understand the author's intent over the meaning of Shamanism. It seems that his intent is to simplify the classification of the concept (with enough diversity) to account for the different ways of altering consciousness. This is the only scientific significance that needs to be derived from the use of the term.

With the same rigour, the author continues to also define the spectrum of consciousness which "is divided up by each society or subculture in its own way. What passes for madness in one community may be esteemed as divine revelation in another. What is a vision to some people is, to others, hallucination. The definitions of variously distinguished altered states are therefore socially situated"[50]

It is worth branching beyond archaeology into the sociological domain and find the well known French philosopher and sociologist Michel Foucault, who also notes the socially

---

[48] Lewis-Williams DL. 1989. Southern Africa's place in the archaeology of human understanding. *Suid-Afrikaanse Tydskrif vir Wetenskap*. Vol 85, 47-52

[49] Lewis- Williams JD. 1981. *Believing and Seeing: Symbolic Meanings in Southern San Rock Paintings*. London: Academic Press (pg204)

[50] Lewis-Williams DL, Clottes J. 1998. Altered Consciousness in the Upper Paleolithic. *Anthropology of Consciousness*. Vol 9, 15

situated definitions of consciousness. [51] "He argues that "the 'normal' self, the 'normal' consciousness, is constituted by the various ways in which communities define and treat altered consciousness and madness. If there is at least one assumption about the Upper Palaeolithic that can be made with confidence, it is that 'altered' consciousness and 'madness' were defined and accommodated differently from the ways in which they are defined and accommodated in late 20th-century Western society."[52]

So when looking at the spectrum of consciousness and an urge is felt to classify a particular state based on the name given to it, it is worth keeping in mind that the constituents of normality and madness are the product of each individual socialisation, especially when looking at the deeply altered and fully hallucinatory states of consciousness because they are only "part of a continuum, or spectrum, of mental conditions. *Everyone* has experienced profound, enveloping reveries, hypnagogic hallucinations, and dreams"[53] which also are a part of the spectrum.

The fact that it can be said with absolute surety that *everyone* has experienced a 'dream' is self evident. It can then be said that everyone has experienced an altered state of consciousness. In fact, through dreams alone, if an average day includes 8 hours of sleep a day then it could be said that a third of a lifetime is spent in an altered state of consciousness.

Consider the "present-day Western emphasis on acute, alert intelligence, we (rightly) dismiss any suggestion that dreams are the voices of gods or spirits urging us to adopt certain courses of action."[54]

Lewis-Williams considers the state of consciousness we enter while asleep to be rather insignificant by saying we "rightly" dismiss the content of such a state and yet he still considers the entering of altered states as the origins of human understanding. Perhaps he views the "cognitive science of religion to examine the possibility that such ideas [shamanism] and the artefacts and practices they inform are the consequence of our very

---

[51] Foucault M. 1965. *Madness and civilization*. New York, Random House.

[52] Lewis-Williams DL. 1997. Agency, art and altered consciousness: a motif in French (Quercy) Upper Palaeolithic parietal art. *Antiquity*: Vol 7, 274

[53] Lewis-Williams DL. 2003. (Review Feature: Lewis-Williams DL. 2002. *The Mind in the Cave: Consciousness and the Origins of Art*. London, Thames & Hudson). *Cambridge Archaeological Journal*. vol 13, 263-279

[54] Lewis-Williams DL. 2003. (Review Feature: Lewis-Williams DL. 2002. *The Mind in the Cave: Consciousness and the Origins of Art*. London, Thames & Hudson). *Cambridge Archaeological Journal*. vol 13, 263-279

ordinary, garden variety cognitive processes."[55] This would negate the necessity to enter an altered state of consciousness in order to effectively initiate the knowledge creating process.

While it remains a possibility that what was achieved by those ancients humans was sufficient to initiate the knowledge creating process (and subsequently make it unnecessary to enter an altered state of consciousness for knowledge creation purposes), it would seem like quite a waste to account for a third of a lifetime as insignificant. Nonetheless, delving into this now will start to answer 'why' altered states of consciousness are accessed and that would be more logically appropriate after a comprehensive assessment of how consciousness is altered.

According to Lewis-Williams, the "ways in which the brain is neurologically structured and the ways in which it functions electro-chemically suggest that we should think of consciousness as a comprehensive spectrum with 'alert' and 'autistic' ends."[56] The alert end obviously being what is experienced as awake and the autistic end is the fully hallucinatory state.

The induction of an altered state could be through a "a wide range of factors that include the ingestion of psychotropic drugs, audio-driving[57], hyper ventilation, sensory and social deprivation, pain, intense concentration and certain pathological conditions[58]."[59] This provides an extensive list of the various means of inducing an altered state.

To define the different states that can be achieved along a trajectory, Lewis-Williams' provides a schematic representation as a linear progression.

---

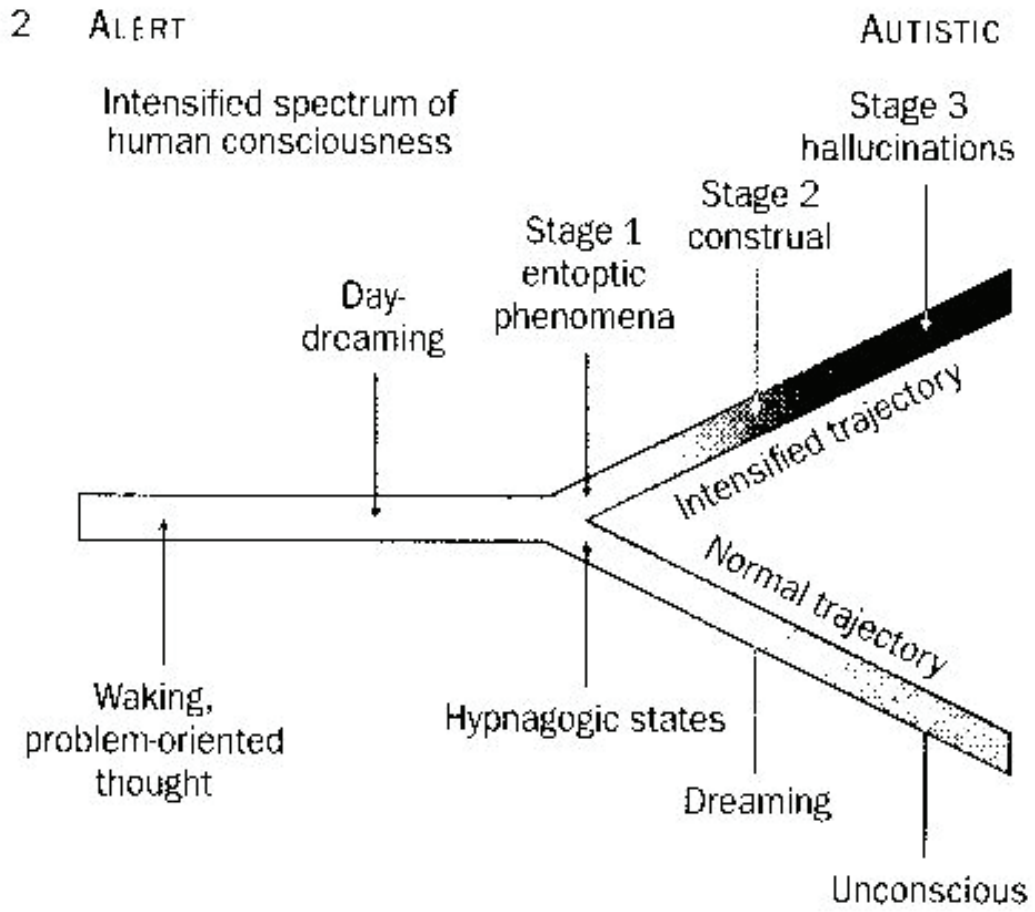
[55] Thomas Lawson E. 2003. (Review Feature: Lewis-Williams DL. 2002. *The Mind in the Cave: Consciousness and the Origins of Art.* London, Thames & Hudson). *Cambridge Archaeological Journal.* vol 13, 263-279

[56] Lewis-Williams DL. 2003. (Review Feature: Lewis-Williams DL. 2002. *The Mind in the Cave: Consciousness and the Origins of Art.* London, Thames & Hudson). *Cambridge Archaeological Journal.* vol 13, 263-279

[57] An induction technique that was commonly used by the San bushman and it involved the use of percussion instruments, usually a drum and once a session had achieved sufficient force to affect the physiology of those taking part, an altered state of consciousness could be experienced.

[58] Such as schizophrenia or temporal lobe epilepsy

[59] Lewis-Williams DL, Clottes J. 1998. Altered Consciousness in the Upper Paleolithic. *Anthropology of Consciousness.* Vol 9, 15



60

Lewis-Williams divided the normal trajectory with an intensified trajectory. The reason being to accommodate for the type of altered state that is induced through the use of external stimulus (sensory deprivation, fasting, drugs, frenzied dancing, or other vigorous bodily movements.[61])

Moreover, he introduces this trajectory as a three staged phenomenon. Stage 1 is defined by entoptic phenomenon. Entoptic meaning the subject would experience "geometric visual percepts that include dots, grids, zigzags, nested catenary curves, and meandering lines."[62] These visual percepts are described as visual overlays and not completely replacing normal visual input, very similar to rubbing you eyes and seeing a phosphene[63] pattern emerge. Stage 2

---

[60] Lewis-Williams DL. 2002. *The Mind in the Cave: Consciousness and the Origins of Art.* London, Thames & Hudson

[61] Thomas Lawson E. 2003. (Review Feature: Lewis-Williams DL. 2002. *The Mind in the Cave: Consciousness and the Origins of Art.* London, Thames & Hudson). *Cambridge Archaeological Journal.* vol 13, 263-279

[62] Lewis-Williams DL. 2002. *The Mind in the Cave: Consciousness and the Origins of Art.* London, Thames & Hudson

[63] a sensation of seeing light caused by pressure or electrical stimulation of the eye (source: http://encarta.msn.com/dictionary_1861725692/phosphene.html)

the subject will try to "make sense of entoptic phenomena by elaborating them into iconic forms, that is, into objects that are familiar to them from their daily life."[64]

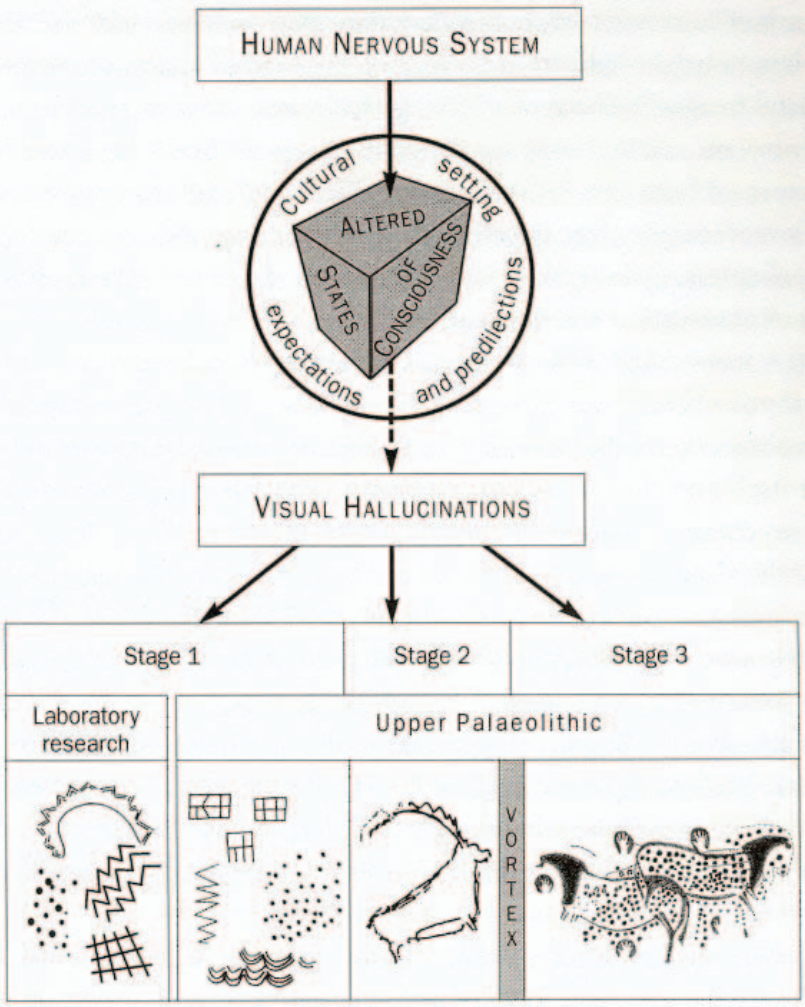
By stage 3 the subject will "experience a swirling vortex or rotating tunnel that seems to surround them and to draw them into its depths. There is a progressive exclusion of information from the outside: the subject is becoming more and more autistic. The sides of the vortex are marked by a lattice of squares like television screens. The images on these 'screens' are the first spontaneously produced iconic hallucinations; they eventually overlie the vortex as entoptic phenomena give way to iconic hallucinations."[65] This particular progression has been well documented within different cultures throughout the world as they describe through the images they associate with most easily. From tunnels to funnels, pits, corridors, holes etc it remains common to all because "these percepts are 'wired' into the human nervous system, all people, no matter what their cultural background, have the potential to experience them"[66]

Lewis Williams has a schematic to represent his three stage model–

[64] Lewis-Williams DL. 2002. *The Mind in the Cave: Consciousness and the Origins of Art*. London, Thames & Hudson

[65] Lewis-Williams DL. 2002. *The Mind in the Cave: Consciousness and the Origins of Art*. London, Thames & Hudson

[66] Lewis-Williams DL. 2002. *The Mind in the Cave: Consciousness and the Origins of Art*. London, Thames & Hudson



26 The neuropsychological model. How the functioning of the human nervous system is shaped by the cultural circumstances of people experiencing altered states of consciousness.

[67]

What is also included here is evidence collected from laboratory research where subjects were administered certain psychotropic substances and asked to interpret their experience visually. The result show remarkable similarity to what was documented by the ancient humans of the Upper Palaeolithic.

This evidence reinforces the notion that if "Upper Palaeolithic people entered an altered state of consciousness, their nervous systems would have responded in the same way as the... nervous systems of modern Western subjects who participate in laboratory experiments on altered states of consciousness."[68]

---

[67] Lewis-Williams DL. 2002. *The Mind in the Cave: Consciousness and the Origins of Art.* London, Thames & Hudson

[68] Lewis-Williams DL. 1989. Southern Africa's place in the archaeology of human understanding. *Suid-Afrikaanse Tydskrif vir Wetenskap.* Vol 85, 47-52

This is what Lewis Williams agues is an undisputable "link with the Upper Palaeolithic, not the only link but at least a starting point: there is a neurological bridge between us and that remote period."[69] By confirming a neurological link with the consciousness and altered states of consciousness with the people of the Upper Palaeolithic, it could be assumed that what was relevant to them in terms of the creation of knowledge could also be relevant to us modern day humans.

There is a sociological aspect of this assumption which is particularly significant. Consider that many "people have found bliss in the mental introversion of meditation and prayer. It is these conditions that provide 'ordinary' people with glimpses of 'other realms' and mental states that predispose them to accept what the seers tell them, often in charged emotional circumstances." [70]

This interprets that the access to altered states was limited to those known as 'seers' and within the right environment, these seers could use the predisposition of their followers (limited by glimpses and not 'true sight') to believe in what was seen by only a selected few. "In doing so, they entrenched a form of cross-cutting *social discrimination* that was independent of age, sex and physical strength. Complex society as we know it was thus being born."[71]

Unfortunately when Sigmund Freud said, "The first human who hurled an *insult* instead of a stone was the founder of civilisation"[72] he was not far from the truth.

The historical reality of how a consciousness is altered has been the topic of discussion so far in order to understand *whence* knowledge is created. A spectrum of consciousness has been considered with alert and autistic ends with recognisable states along a trajectory. An account has also been made of the external stimulus required to initiate an altered state and the typical imagery that can be seen in an altered state according to the three stage model. Stephen Mithen has been footnoted as the most likely change in the cognitive ability to create, that of integration of different modules of intelligence (via abstraction). His metaphor is elegant but difficult to substantiate empirically. What has also been argued extensively is the

---

[69] Lewis-Williams DL, Clottes J. 1998. Altered Consciousness in the Upper Paleolithic. *Anthropology of Consciousness.* Vol 9, 15

[70] Lewis-Williams DL. 2003. (Review Feature: Lewis-Williams DL. 2002. *The Mind in the Cave: Consciousness and the Origins of Art.* London, Thames & Hudson). *Cambridge Archaeological Journal.* vol 13, 263-279

[71] Lewis-Williams DL. 2003. (Review Feature: Lewis-Williams DL. 2002. *The Mind in the Cave: Consciousness and the Origins of Art.* London, Thames & Hudson). *Cambridge Archaeological Journal.* vol 13, 263-279

[72] Sigmund Freud (Austrian neurologist and Founder of psychoanalysis 1856-1939)

neurological (and less extensively the sociological) link all of these considerations have with present day humans. It therefore does not remain merely as an aspect of the ancient past but a current phenomenon which continues to this day.

However, to talk about altering consciousness from an archaeological perspective is useful up to a historical point, but to talk about it in terms that make it approachable scientifically in this day and age requires a very different perspective. The question of how consciousness is altered can be very well explained from a neurological perspective as well. It would be a start to think that when entering an altered state of consciousness "the nervous system itself becomes a 'sixth sense' that produces a variety of images including entoptic phenomena. The brain attempts to decode these forms as it does impressions supplied by the nervous system in an alert, outwardly directed state."[73]

It seems that the nervous system is emulating a sense because it is producing a range of images to be decoded by the brain. However, that would make this 'sixth' sense the only sense that is the source of the very information that it is to decode. All the other senses receive information from a multitude of sources outside of its physical location on the body.

To clarify the matter, it now becomes imperative to investigate the nature of these phenomena within the field of neurology to substantiate the extent of the 'neurological link' argued by Lewis Williams. This new field of enquiry will continue to expand on how knowledge is created in significantly more neurological detail.

[73] Lewis-Williams DL. 2002. *The Mind in the Cave: Consciousness and the Origins of Art.* London, Thames & Hudson

Chapter 3

The Behavioural Neuroscience of Knowledge Creation

1 How is Knowledge Created? A Modern Perspective

The discussion of how consciousness is altered will now continue from a neurological perspective. This will serve to refashion the view of altering consciousness from the realms of shamanism to the realms of biological fact. The major difference being that the process of altering consciousness is more a neurological phenomenon rather than a process exclusive for shamanistic purposes. Lewis Williams suggests that "the literature reports research showing that the full range of hallucinations, as encompassed by the three-stage model, can all be experienced in circumstances that do not include drug ingestion, and, moreover, that the experiences derive from the structure of the human cortex."[74]

So this means that it may not be necessary to ingest chemicals to alter consciousness and what is suggested is that by manipulating the structure of the human cortex, the result would be the same if drugs were ingested.

This train of thought is very closely mirrored by the research of a Dr Michael Persinger of the Laurentian University based in Sudbury, Ontario.

The biological foundation cortical phenomenon is neurologically evident when considering that the "cells of all living systems are immersed within the earth's magnetic field. Life is likely to have evolved within and have been guided by the intrinsic temporal variations within the geomagnetic field. Most of their peak-to-peak intensities range between 1 picoTesla (one-trillionth of a Tesla) to over 1000 nT (1 millionth of a Tesla) within frequencies between 0.001 Hz (1 mHz) and 100 Hz. The larger intensities, between 50 nT and 1000 nT, involve slower variations. A component of this band is well within the major spectrum of electroencephalographic (EEG) activity of the human brain and looks very

[74] Lewis-Williams DL. 2004. Neuropsychology and Upper Palaeolithic Art: Observations on the Progress of Altered States of Consciousness *Cambridge Archaeological Journal.* 14(1), 107-11

similar to the classic shapes of "*brain waves*". The complexities of these variations have not been measured because of their immensity. However they have the potential to simulate every known electromagnetic pattern that mediates the effects of the brain's own neurotransmitters upon cell receptors and to imitate all of the consequences of pharmacological agents (drugs).”[75]

The significant comment from this extract is that Persinger believes that electromagnetic patterns can imitate the effects of *all and any* drug. One just has to think of all the different effects one can experience from all the pharmacological agents known to man to realise the impact electromagnetic field patterns can have on the brain.

Persinger also gives some technical attention to the complexities in the variation of the electromagnetic fields that are present all around us, those predominantly being the *geomagnetic* frequencies generated by the earth. The whole range of frequencies that are generated by the earth and the entire range of intensities they can be produced at makes the whole spectrum of geomagnetic waves *immense*.

There is much that is not known about all the different geomagnetic field variations yet it is Dr Persinger’s firm belief that all electromagnetic activity that is produced by the *brain* is within the band of *geomagnetic* frequencies produced by the earth. It is interesting to note that he also believes that life is likely to have been guided by the ‘temporal variations within the geomagnetic field’. If that were true beyond all doubt, it could be surmised that the events that occurred 40 000 years ago, as discussed in chapter 1, could have been guided by a variations in the geomagnetic field.

To consider the writings of Dr Persinger with confidence, it should be noted that he initiated the Behavioural Neuroscience program at Laurentian University in 1984, which became one of the first programs ever to integrate chemistry, biology and psychology. It was Persinger’s aspiration within the sciences to find the common ground between the differing disciplines and integrate them on a fundamental level thereby unifying our understanding of the physical and non physical universe. During his time at Laurentian he has published more than 200 articles in refereed journals and written six books.

Regardless of whether we believe Dr Persinger’s conviction that electromagnetic patterns can mimic the affect of any drug, what is of more interest is the research he has been replicating in his labs for nearly 30 years. The procedure begins with a volunteer sitting in a dark room, a

[75] http://oldwebsite.laurentian.ca/neurosci/_research/geomagnetic.htm

specially adapted helmet with numerous electromagnetic coils is fitted to the head and then by "applying specific patterns of weak magnetic fields that imitate the brains own activities, about 80% of the normal population report the experience of "another"."[76]

What is of archaeological interest here is the "source of discovery: the neurocognitive processes of *creativity*. We had been impressed by the many historical and cross-cultural examples of ordinary people who accessed sophisticated knowledge well beyond their level of education or intellect when the right hemisphere was likely to have been stimulated. To test this association we experimentally simulated the condition. We applied specific complex magnetic fields of less than 1 microTesla over the right hemisphere. The most frequent result was the experience of the sense of a presence or of another Sentient Being."[77,78,79]

The mention of this "sophisticated knowledge" has direct reference to the events as described in Chapter 1. People of our ancient past, 40 000 years ago, began creating knowledge beyond recorded comparison to the previous six millennia of our species. The question of why they started doing this is because they started to alter their consciousness through the stimulation of the right hemisphere. And what's more, Persinger has hinted that this might even have been initiated by variations in geomagnetic field. Bizarre as that may be, it is definitely not a foreign thought to believe that the development (and downfall) of the human race is guided by nothing other than the earth itself.

Of more importance though, it is Persinger who links the "source of discovery" to the stimulation of the right hemisphere and the consequent experience of a "Sentient Being". As Lewis Williams three stage model would indicate, experience of a sentient being would be classed within the third stage of the model and is the furthermost point along the intensified trajectory of altered consciousness. In addition, in accordance with Lewis Williams' first stage in his model, phosphene phenomena have also been recorded in laboratory manipulation of the brain with magnetic fields.[80]

---

[76] http://oldwebsite.laurentian.ca/neurosci/_research/mystical.htm
[77] http://oldwebsite.laurentian.ca/neurosci/_research/mystical.htm

[78] Persinger MA. 1987. *Neuropsychological bases for god beliefs*. NY, Praeger.

[79] Persinger MA, Healy F. 2002. Experimental Facilitation of the Sensed Presence: Possible Intercalation between the Hemispheres Induced by Complex Magnetic Fields *Journal of Nervous and Mental Diseases*. Vol 190, No 8, 533-41

[80] Hallet M.. 2000. Trancranial Magnetic Stimulation and the Human Brain. *Nature*. Vol 406, 147-150

The fact that the “neurological process of creativity” is linked with the experience of a sentient being is rather perplexing. It might help at this stage to examine exactly how Dr Persinger achieved his results and how those results coincide with our very natural ability to create.

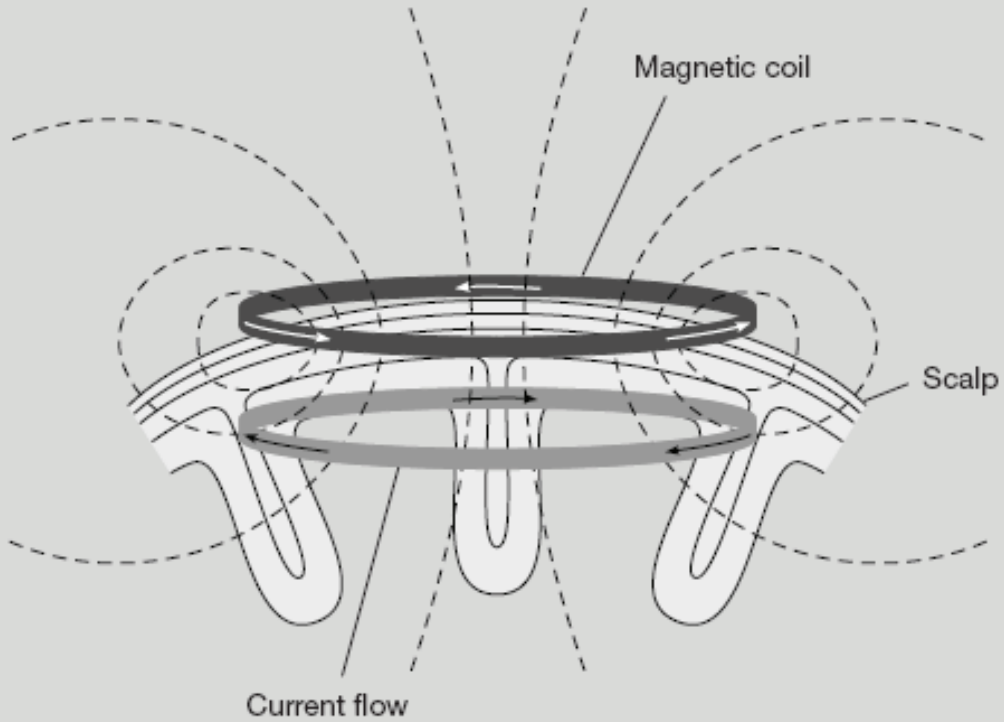
3.1 Transcranial Magnetic Stimulation

Dr Persinger utilises a process by the name of Transcranial Magnetic Stimulation (TMS) on his volunteers when inducing altered states. The following diagram succinctly defines the physics involved:

Physics and mechanism of action of TMS

For magnetic stimulation a brief, high-current pulse is produced in a coil of wire, called the magnetic coil, which is placed above the scalp. A magnetic field is produced with lines of flux passing perpendicularly to the plane of the coil (see Figure). An electric field is induced perpendicularly to the magnetic field. In a homogeneous medium, the electric field will cause current to flow in loops parallel to the plane of the coil. The loops with the strongest current will be near the circumference of the coil itself. The current loops become weak near the centre of the coil, and there is no current at the centre itself. Magnetic coils may have different shapes. Round coils are relatively powerful. Figure-eight-shaped coils are more focal, producing maximal current at the intersection of the two round components. The precise extent of neuronal activation is not known, but it clearly varies with the intensity of stimulation. TMS ordinarily does not activate corticospinal neurons directly; rather it activates them indirectly through synaptic inputs. This has been determined by the observation that TMS produces a corticospinal volley with indirect waves (I-waves) rather than with an early direct wave (D-wave)[39].

Single-pulse TMS, which is very safe, has been most commonly used. Devices are now available that can deliver high-frequency (1–30 Hz), repetitive TMS (rTMS). This has greater effects than single-pulse TMS, but also has the potential to cause seizures even in normal individuals. Safety guidelines have been published which should prevent problems[40].



[81]

[81] Hallet M.. 2000. Trancranial Magnetic Stimulation and the Human Brain. *Nature*. Vol 406, 147-150

TMS is clearly mostly unknown in terms of the full range of effects that it can produce, what is known is that different effects can be produced by modulating the intensity of the field, the frequency of the field and also whether its single pulse or repetitive. Discovering the modulation settings that create an effect is therefore quite challenging as changing one setting invariably changes the combined effect of all the other settings at the same time. Naturally, discovery of the effects of TMS is very much in the trial and error domain of experimental research.

In a recent experiment conducted by Dr Persinger in his lab, he took 48 participants between the ages of 18 to 25 and divided them into 4 groups. The first group would receive a sham treatment of TMS, the second would receive stimulation to the left hemisphere of the brain, the third group would receive right hemisphere stimulation and the fourth group bilateral stimulation. There were equal numbers of men to woman.

The procedure involved placing the participant in a darkened room and sitting them down in a comfortable armchair within a commercial acoustic chamber. Goggles were then placed over their eyes and a modified helmet was fitted. "On both sides of the helmet were four equidistant solenoids that were arranged in an elliptical pattern[82]. Each solenoid on one side of the helmet was connected to the homologous solenoid on the other side of the helmet."[83]

For 20 minutes each participant was exposed to a series of weak, complex magnetic fields (except for the sham participants) and then asked to complete an exit questionnaire once the session was over. Each question asked if a particular event had occurred during the session and the required answer was either 0 for never, 1 for once and 2 for more than once. Here are the results compiled using the statistical mean of all responses:

---

[82] Richards PM, Persinger MA, Koren SA. 1993. Modification of activation and evaluation properties of narratives by weak complex magnetic field patterns that simulate limbic burst firing. *Int J Neurosci* 71:71–85

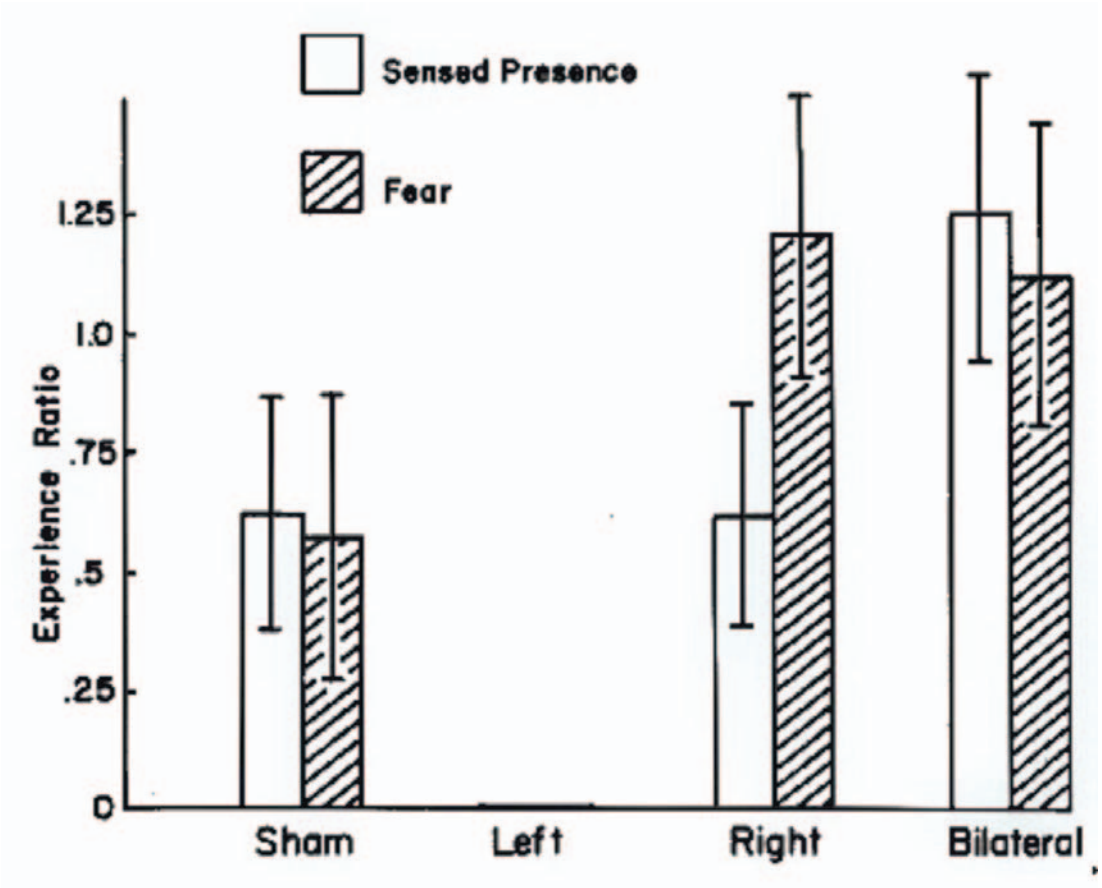
[83] Persinger MA, Healy F. 2002. Experimental Facilitation of the Sensed Presence: Possible Intercalation between the Hemispheres Induced by Complex Magnetic Fields *Journal of Nervous and Mental Diseases*. Vol 190, No 8, 533-41

Means and SD for Responses of Various Experiences		
Recalled after 20 Min of Treatment		
Primary Experience of Item	Mean	SD
1. Dizzy or odd	.9	.7
2. Sensed presence	.5	.6
3. Tingling sensations	1.0	.7
4. Visual images	1.0	.8
5. Vibrations through body	.7	.8
6. Detachment or out-of-body	.5	.7
7. Anger	.2	.4
9. Thoughts "not from own mind"	.3	.6
10. Ticking sounds	.4	.7
11. Odd smells	.2	.4
12. Fear or terror	.4	.6
13. Odd tastes	.1	.4
14. Felt as if somewhere else	.6	.8
15. Memories from childhood	.7	.6
16. Same thought kept repeating	.8	.8
17. Spinning or vortical experiences	.3	.5
18. Remembered a dream	.4	.6
****** 0 never,1 at least once, and 2 several times ******		

[84]

The SD notation stands for the standard deviation or standard error[85] from the mean values. This is probably better understood in the following graph.

[84] Persinger MA, Healy F. 2002. Experimental Facilitation of the Sensed Presence: Possible Intercalation between the Hemispheres Induced by Complex Magnetic Fields *Journal of Nervous and Mental Diseases*. Vol 190, No 8, 533-41



Means and standard errors of the mean for the ratio of the incidence of sensed presences and fears relative to the average of all experiences during the experimental session as a function of treatment. [86]

So here, the mean value of sensed presence and fear is represented by the respective bars and the standard error on that value is represented by the value marked beneath each bar and the value above each bar. The graph is more useful because it delineates the values according to the manner of stimulation.

The results could also be looked at in terms of the participants who either experienced a presence or did not experience a presence and say the "percentages of subjects (*N* _ 12/treatment) who reported a presence were as follows: sham, 33%; left hemisphere, 0%; right hemisphere, 42%; and both hemispheres, 66%."[87]

---

[85] in statistics, the standard deviation of the sample in a frequency distribution divided by the square root of the number of values in the sample. It is a measure of the variability that a constant would be expected to show during sampling.

[86] Persinger MA, Healy F. 2002. Experimental Facilitation of the Sensed Presence: Possible Intercalation between the Hemispheres Induced by Complex Magnetic Fields *Journal of Nervous and Mental Diseases*. Vol 190, No 8, 533-41

[87] Persinger MA, Healy F. 2002. Experimental Facilitation of the Sensed Presence: Possible Intercalation between the Hemispheres Induced by Complex Magnetic Fields *Journal of Nervous and Mental Diseases*. Vol 190, No 8, 533-41

So, from all the statistical results of the experiment, when considering the manner of stimulation and the resulting effects "the groups who had received the magnetic field stimulations predominantly over the right hemisphere or equally across both hemispheres reported more frequent presences and experiences of fear or terror relative to the group who had received the same stimulation over the left hemisphere."[88]

The results of this study and many other studies completed by Dr Persinger similar to this one "support the hypothesis that weak complex magnetic fields that were applied with a slightly higher intensity over the right hemisphere relative to the left or with equal intensity over both hemispheres can facilitate the experience of a sensed presence."[89]

It is also important to consider the results that came from the sham stimulation group. In all of Persinger's study's regarding the above hypothesis, the sham group has always exhibited a tendency to experience a sensed presence. In this particular study the sham group results showed a slight increase in the incidence of a sensed presence however it was still nowhere as strong as the results from the groups who had received the specific transcerebral magnetic fields. According to Persinger, "the measurement of this enhancement emphasizes the minimal energy requirements required to increase the probability of the sensed presence within relatively mundane settings."[90]

The mundane setting being within a chamber where all sensory inputs are depraved to some degree and the participant will experience a heightened level of suggestibility. Essentially, entering a suggestible state is comparable to altering consciousness as both entail the deprivation of sensory information which Lewis Williams' argued, is one of the ways to encourage the altering of consciousness.

So for a participant to sit in that chamber, their conscious state can change quite easily and increase the probability of experiencing a sensed presence. But it's not just the participants and the TMS device displaying magnetic properties, "all matter, including molecular aggregates, cellular organizations, and whole organisms, displays magnetic properties. The information, which controls the reactions of molecules, the actions of cells, and the behaviours of organisms, is determined by the spatial and temporal complexity of electromagnetic

---

[88] Persinger MA, Healy F. 2002. Experimental Facilitation of the Sensed Presence: Possible Intercalation between the Hemispheres Induced by Complex Magnetic Fields *Journal of Nervous and Mental Diseases*. Vol 190, No 8, 533-41

[89] Persinger MA, Healy F. 2002. Experimental Facilitation of the Sensed Presence: Possible Intercalation between the Hemispheres Induced by Complex Magnetic Fields *Journal of Nervous and Mental Diseases*. Vol 190, No 8, 533-41

[90] Persinger MA, Healy F. 2002. Experimental Facilitation of the Sensed Presence: Possible Intercalation between the Hemispheres Induced by Complex Magnetic Fields *Journal of Nervous and Mental Diseases*. Vol 190, No 8, 533-41

fields."[91] Electromagnetic fields that are all around us all the time, the one that is common to everyone being the geomagnetic field that envelops the earth which embody the field that envelops each and every human being. All of which contain information that a participant can affect and also be affected by without the need for artificial encouragement like Transcranial Electromagnetic Stimulation.

That is a plausible explanation for the for the sham group results but what also needs to be understood in more depth is the result from the group who had left hemisphere stimulation. Persinger says that "both experimental and clinical evidence that left hemispheric stimulation might decrease the occurrence of phenomena that require involvement of the right hemisphere." Tiller and Persinger (1994) found that exposure to right hemispheric stimulation and then left hemispheric stimulation by these weak, complex magnetic fields promoted suggestibility. However, the reversed order of presentation, left hemispheric stimulation followed by right hemispheric stimulation, was not effective."[92]

This is interesting because the implication is that it is mainly the right hemisphere which is responsible for the experience of a sensed presence. Moreover, there is something significant about the order of interaction, initiated by the right hemisphere with the left hemisphere, which promotes these experiences.

It is this order of stimulation (specifically the function the right hemisphere serves in this order) that can explain the results of simply stimulating the left hemisphere of the brain. Stimulation of the left hemisphere seems to undermine the process toward sensed presence and therefore produce results even lower than that of the sham group.

Understanding the results of the study through the manner of stimulation reveals somewhat more detail about how consciousness is altered in order to experience a sensed presence. Briefly, in terms of sensing a presence, the right hemisphere stimulation was nearly as successful as no stimulation at all. Left hemisphere stimulation seems to completely negate experiencing a sensed presence and bilateral stimulation is by far (about double) the most successful way to promote the experience of "another". It is these experiences that Persinger believes is the "source of discovery" and "the neurocognitive processes of creativity" as depicted from the experiences of our ancestors of the ancient past in exactly the same way it is experienced today.

---

[91] http://oldwebsite.laurentian.ca/neurosci/_research/bioelectromagnetic.htm

[92] Persinger MA, Healy F. 2002. Experimental Facilitation of the Sensed Presence: Possible Intercalation between the Hemispheres Induced by Complex Magnetic Fields *Journal of Nervous and Mental Diseases*. Vol 190, No 8, 533-41

However, there is still more evidence that can be presented to delineate exactly what part of the brain is causing this ephemeral phenomenon and a hypothetical approach presented by Dr Persinger on the process that creates these occurrences.

Persinger makes it clear that "bilateral stimulation affected processes within the brain with which the experiences of the sensed presence, fear, odd smells, and anger"[93] are associated more than likely originated in the amygdaloid-hippocampal. This formation "would be a primary candidate for the neural substrate for this cluster of experiences, of which have been evoked by direct surgical stimulation within epileptic patients[94]."[95]

Now, if "the pathways within the normal brain are similar to those revealed in limbic epileptics (Gloor et al., 1993), then stimulation of the right hippocampal formation and amygdale may evoke neuronal patterns that could enter the entorhinal cortices (parahippocampal gyrus) of the left hemisphere (and awareness) without first involvement of the right temporal lobe and corpus callosum. Hence, the sudden awareness of this "information" might be experienced as "not from the self" or "ego-alien"."[96]

The reference to the particular areas of the brain is quite technical but to put it simply, electromagnetic "information" is entering the left hemisphere that has not undergone processing by the right hemisphere (as is the usual procedure) and the sudden "awareness" of this information is incorporated by the brain into the presence of another being.

So, to build from Persinger's hypothetical process, it would seem the "source of discovery" being the "neurocognitive processes of creativity" is the brain's way of accounting for information that has bypassed the normal path of informational input. In this case, creativity would be defined as the *ability to incorporate unknown information into a comprehendible format*, a format that typically seems to take the shape of a being that embodies what is mostly unknown to us, and consequently something that is generally feared as well.

It seems to be a logical step for the brain to incorporate unknown information sources in this way. The brain applies a vast knowledge framework when incorporating information from

---

[93] Persinger MA, Healy F. 2002. Experimental Facilitation of the Sensed Presence: Possible Intercalation between the Hemispheres Induced by Complex Magnetic Fields *Journal of Nervous and Mental Diseases*. Vol 190, No 8, 533-41

[94] Halgren E, Walter RD, Cherlow DG, Crandall PH. 1978. Mental phenomena evoked by electrical stimulation of the human hippocampal formation and amygdala. *Brain* 101:83–117

[95] Persinger MA, Healy F. 2002. Experimental Facilitation of the Sensed Presence: Possible Intercalation between the Hemispheres Induced by Complex Magnetic Fields *Journal of Nervous and Mental Diseases*. Vol 190, No 8, 533-41

[96] Persinger MA, Healy F. 2002. Experimental Facilitation of the Sensed Presence: Possible Intercalation between the Hemispheres Induced by Complex Magnetic Fields *Journal of Nervous and Mental Diseases*. Vol 190, No 8, 533-41

normal sensory input yet when confronted with an unknown information source, it cannot ignore the information so it creates a familiar format to embody the phenomenon. However, by doing that, it leaves us wondering where the physical representation of this information is located. This remains speculative thought based upon a hypothetical process that has been supported but as yet unproven yet it remains a very engaging notion.

To give a clearer idea of exactly how the participants felt about experiencing the presence, Persinger has noted that "about half of these subjects stated they (although blindfolded) felt "someone else" in the chamber and wondered how someone entered (because the double doors of the chamber had been closed before the experiment). Another approximately half of the subjects refer to a sentient being who moved when the subject tried to "focus attention" upon the presence. Of those subjects, about one third attributed the presence to a deceased member of the family or to some cultural equivalent of a "spirit guide"."[97]

For those who believe the presence is real, they have a problem confronting the logical problem of how this person entered the room if the doors had been closed, those who tried to apply more attention to the precise location of the being, found the problem of pinning it down to one location. It is also interesting to note that some of the participants likened the presence to a deceased family member or "spirit guide" of some kind. This shows that the type of embodiment the information acquires varies depending on the closest approximation, from person to person, of how to *embody the unknown*.

Dr Persinger has throughout his numerous studies documented many different interpretations of this presence and it is interesting to note that from a sociological point of view, Lewis – Williams and Persinger share the same conclusions about those who attribute the sensed presence to God, Allah and any other variant of any other belief a person may choose to comprehend the experience.

They invariably utilize the experience as "cosmic consent for the validity of personal and institutional beliefs as well as the execution of correlative behaviors."[98] Religious beliefs "in large part reinforced by personal experiences of sensed presences, are a persistent and powerful variable in large-scale killings of groups who endorse the belief in one kind of god by other groups who define themselves by a belief in a different god."[99] Understanding of the

---

[97] Persinger MA, Healy F. 2002. Experimental Facilitation of the Sensed Presence: Possible Intercalation between the Hemispheres Induced by Complex Magnetic Fields *Journal of Nervous and Mental Diseases*. Vol 190, No 8, 533-41

[98] Slaver JL, Rabin J. 1997.The neural substrates of religious experience. *J Neuropsychiatry Clin Neurosci.* 9:498–510

[99] Persinger MA. 1987. *Neuropsychological bases for god beliefs*. NY, Praeger.

neuroelectrical patterns that "generate the sensed presence and the isolation of the multiple stimuli that provoke this experience may have survival value for our species."[100]

Just as Lewis Williams saw the birth of social discrimination through the attribution of special powers to those who could "see" the Sentient Being, so too does Persinger realize the "historical fact that most wars and group degradations are coupled implicitly to god beliefs and to the presumption that those who do not believe the same as the experient are somehow less human and hence expendable"[101]

What can be said so far for sure, from Dr Persinger's research, is that the brain is very responsive to electromagnetic stimulation and the type of responses that Dr Persinger has elicited is rather intriguing as well. Electromagnetic waves are converted by the brain into the presence of another being that has no physical location. This conversion process is seen by Persinger as the source of discovery and consists of the neurological processes of creativity.

These electromagnetic fields are all around us all the time and clearly they must be affecting us in ways we are mostly unaware of. In terms of consciousness, what is known is that the "electromagnetic basis of consciousness appears to involve cohesive waves of electromagnetic fields, generated from the cortical manifold, that are recreated ("refreshed") within the 40 Hz range. These quanta of consciousness occur too quickly to be discerned within the range of what we experience as "now" which is the ability to discriminate between sequences separated by more than about 40 msec to 50 msec. There may be different types or states of consciousness, such as dreaming, each of which have different characteristics and properties." [102] This is the natural dynamic of the brain which means that it is cyclic. Consciousness is the result of a cyclical electromagnetic pulse that occurs too rapidly for anyone to discern one pulse from the next.

"If consciousness is "recreated" every 20 to 25 msec ("40 Hz") rather than maintained as a continuous stream, then what happens between the end of one increment and the beginning of the next? This question generates several interesting questions. Could information from outside of the brain be acquired during this "infinite infinitesimal" interval? Could this information then be incorporated into the stream of experience generated by the normal

---

[100] Persinger MA, Healy F. 2002. Experimental Facilitation of the Sensed Presence: Possible Intercalation between the Hemispheres Induced by Complex Magnetic Fields *Journal of Nervous and Mental Diseases*. Vol 190, No 8, 533-41

[101] http://oldwebsite.laurentian.ca/neurosci/_people/Persinger.htm

[102] http://oldwebsite.laurentian.ca/neurosci/_research/conscious.htm

volleys of sensory neurons? Could normal consciousness be considered a type of "insulation" that prevents access from the myriad of stimuli that we typically do not detect?"[103]

These scintillating questions depend entirely on the content of the electromagnetic information that affects the brain and the information the brain is insulated from. To think that human beings could potentially use the brain as a sensory device to interpret the substance and source of any electromagnetic field within range is not a question to answer right now.

More would have to be known about how electromagnetic fields affect the brain and how the brain is transducing the fields into sensory information like it transduces the frequencies of light into visual imagery.

The only way to understand this electromagnetic information is by its effects. The effect on the brain and the body will help us understand just how important it is to distinguish how this information changes people.

So, the argument so far shows that the most important shift in cognitive ability to create knowledge can be traced back to a creative moment in time about 40 000 years ago. A moment in time that subsequently allowed civilisation to flourish because they began accessing altered states of consciousness. These altered states of consciousness are directly *comparable* to what can be experienced by participants in laboratory experiments today by stimulating the brain with electromagnetic fields. These fields can therefore be seen as the necessary "information" to create knowledge.

The ability to create then may be seen not so much as an emerging enigma of consciousness but rather the ability to biologically transduce (decode and transmit) electromagnetic patterns within the brain.

This process of transduction can be seen as the biological mechanism through which electromagnetic information is processed by the brain. Persinger had theorised as to how this information can alter the brain's normal information flows and create a sensed presence but there is no scientific consensus to date that can positively verify exactly how this biological mechanism works. This would take the investigation of how knowledge is created onto a biological level offering insights into the molecular and cellular physiology of electromagnetic transduction.

---

[103] http://oldwebsite.laurentian.ca/neurosci/_research/conscious.htm

Right now focus must shift to knowing the true value of this electromagnetic information. Considering the ancient foundations of civilisation and the experience of a sensed presence is not sufficient evidence to prove the value of electromagnetic information. It does however enlighten us on the methods employed to attain the information, so what remains to be seen now is how comprehensively this information affects human beings from present day research.

Thus the argument must shift from the investigation of how knowledge is created toward the question of whither is knowledge created.

Chapter 4

Neurological Evidence from the Medical Sciences

1 Whither is Knowledge Created?

To what state, condition, outcome, or degree is knowledge created?

The answer to this question lies in examining the effect electromagnetic information has on the body. It is clear from the work of Lewis Williams and Dr Persinger that electromagnetic information has the potential to augment sensory perception which Lewis William showed with his three stage model and Persinger with his experiment yet the effects of electromagnetic information is enormously more inclusive on biological processes.

So, keeping in mind that knowledge creation is part of a process of transducing electromagnetic fields, it becomes evident that a study must be made on the *comprehensive and all inclusive* effects of electromagnetic fields within variable ranges relative to measurable human neural responses. However, that task is endless due to the immense spectrum of electromagnetic fields.

The scientific method of investigation in the medical sciences has revealed the most information on the bioelectromagetic phenomena within the human brain. "While several treatments based on the use of magnetic fields have been reported in peer-reviewed journals, the only ones that have been approved by the FDA are the use of pulsed magnetic fields to aid non-union bone fractures. Transcranial magnetic stimulation is currently under active study in multiple research centres, and will likely become an approved therapy in the future."[104]

So currently, TMS is one of the significant techniques in the experimental investigation into electromagnetic fields. TMS is widely considered a powerful, non-invasive method to treat diseased and disordered nervous systems by altering neural firing rates (thresholds) through electromagnetic current induction.

---

[104] http://en.wikipedia.org/wiki/Bioelectromagnetics

It may be confusing to consider the process of knowledge creation as a treatment modality so to clarify this the main argument must be kept in mind, that being the perception of knowledge creation as a sensory ability, which means to some degree a reflex reaction to information from the environment.

With this in mind, it is exciting to consider that humans might possess a sensory ability that is *also* a treatment modality when exposed to certain electromagnetic information. Let's take a closer look at the current research.

2 Transcranial Magnetic Stimulation

Within the fields of medicine and neuroscience there is frequent enquiry about Transcranial Magnetic Stimulation (and other types of electromagnetic stimulation) not only because of its effectiveness as a treatment modality but also because of its use as an investigative tool into the functioning of the brain.

Anatomically, the function of a magnetic field is to penetrate the "skull and brain meninges, subsequently inducing electric current in the brain tissues that produces neuronal depolarization[105] and generation of action potentials[106]."[107] So magnetic fields have the ability to stimulate an electric current in the brain. The subsequent depolarisation and firing of the neuron also implies it has an effect on the neurochemical and synaptic processes in neurons.

A basic understanding of this biological process gives transcranial electromagnetic stimulation applications "in

1. the investigation of cortical and spinal excitability,
2. the investigation of neuronal plasticity,
3. the investigation of neuronal connectivity,
4. functional mapping, and
5. the treatment of some neurological and psychiatric disorders.

Transcranial magnetic stimulation alone or in combination with other noninvasive neuroimaging (PET--positron emission topography, MRI--magnetic resonance imaging) and

---

[105] is a decrease in the absolute value of a cell's membrane potential. Thus, changes in membrane voltage in which the membrane potential becomes less positive or less negative are both depolarizations. In neurons and some other cells, a depolarization large enough may result in an action potential. (source: http://en.wikipedia.org/wiki/Depolarisation)

[106] pulse-like wave of voltage that travels along several types of cell membranes (source: http://en.wikipedia.org/wiki/Action_potential)

[107] Griskova I, Höppner J, Ruksenas O, Dapsys K. 2006. Transcranial magnetic stimulation: the method and application. *Medicina (Kaunas)*. 42(10):798-804

neurofunctional (EEG--electroencephalography, ERP--event-related potentials, fMRI--functional magnetic resonance imaging) methods allows conducting research on almost all brain functions."[108]

In fact, "transcranial magnetic stimulation (TMS) appears to be 'coming of age' in cognitive neuroscience and promises to reshape the way we investigate brain-behaviour relations. Among the many methods now available for imaging the activity of the human brain, magnetic stimulation is the only technique that allows us to interfere actively with brain function."[109] Active interference is defined as measuring the effect of the electromagnetic stimulation on the brain immediately, in 'real time' thereby giving conclusive evidence for causal relationships in the brain.

"As illustrated by several experiments over the past couple of years, this property of TMS allows us to investigate the relationship between focal cortical activity and behaviour, to trace the timing at which activity in a particular cortical region contributes to a given task, and to map the functional connectivity between brain regions."[110] Essentially that means:

1. record brain activity and the associated cognitive/behavioural event
2. trace the timing of the event in the brain from initiation to completion
3. repeated event timing studies will eventually coordinate a map of brain connectivity according to the concept of neural plasticity

Previously, the only way to examine the brain was with patients who had suffered irreversible brain lesions. The cognitive and behavioural impairments associated with the particular area of the lesion would give researchers information on the function of that particular area of the brain. With TMS, it is possible to create what is known as a "virtual transient lesions in healthy people or modulate the brain activity, increasing or decreasing the activity of the stimulated areas." [111]

What has been revealed in studies with healthy patients is that "single TMS over motor cortex can produce simple movements [behaviour]. Several groups have applied TMS to the study of

---

[108] Griskova I, Höppner J, Ruksenas O, Dapsys K. 2006. Transcranial magnetic stimulation: the method and application. *Medicina (Kaunas).* 42(10):798-804

[109] Pascual-Leone A, Walsh V, Rothwell J. 2000. Transcranial magnetic stimulation in cognitive neuroscience--virtual lesion, chronometry, and functional connectivity. *Curr Opin Neurobiol.* 10(2):232-7

[110] Pascual-Leone A, Walsh V, Rothwell J. 2000. Transcranial magnetic stimulation in cognitive neuroscience--virtual lesion, chronometry, and functional connectivity. *Curr Opin Neurobiol.* 10(2):232-7

[111] Boggio PS, Fregni F, Rigonatti SP, Marcolin MA, Silva MT. 2006. [Transcranial magnetic stimulation in neuropsychology: new horizons for brain research]. *Rev Bras Psiquiatr.* 28(1):44-9.

visual processing and found an impaired detection of visual stimuli [sensory perception]. In the same way, TMS can disrupt speech when it is delivered in the language dominant hemisphere. Studies on the memory effects [as well as] diminution in reaction time during an analogic reasoning task [have led to cognitive enquiries]."[112] This gives electromagnetic stimuli effect in sensory, behavioural and cognitive performance.

Of course, TMS has also shown its effectiveness as a therapeutic modality too. Many of the studies conducted so far "have supported a significant effect of TMS, but in some studies the effect is small and short lived. Several groups have reported on the use of repetitive transcranial electromagnetic stimulation (rTMS) as a treatment in resistant major depression and the impact on cognition functioning. Most of results tend to find no adverse cognitive effects after several weeks of daily rTMS in depressed patients, compared to Electroconvulsivo-therapy (ECT)."[113]

Through the study of TMS as a technique for inducing neurological phenomenon, it will be possible to generate a comprehensive set of effects of electromagnetic stimulation on the brain.

Effect such as the:

- *Therapeutic Effect*
- *Behaviour Modification*
- *Suppression or Facilitation of Cognition*
- *Modulation of Sensory Perception*

Only by knowing all the effects may insight be gained into the diversity of information present in electromagnetic fields. By understanding the diversity of the information, its value from the transduction of electromagnetic stimuli (most perceptible through altered states of consciousness) may become apparent.

---

[112] Verdon CM, Saba G, Januel D. 2004. [Transcranial magnetic stimulation in cognition and neuropsychology] *Encephale.* 30(4):363-8

[113] Verdon CM, Saba G, Januel D. 2004. [Transcranial magnetic stimulation in cognition and neuropsychology] *Encephale.* 30(4):363-8

4.1 Therapeutic Effect

The following section will build a comprehensive understanding of the physical effects of electromagnetic fields on the body through the brain with reference to TMS. It is said to have potential therapeutic applications in "cognitive neuroscience, neurophysiology, psychiatry, and neurology"[114] which clearly gives rise to a diverse application base in the neurosciences.

From publications in reputable medical journals, it will be shown to be useful in the treatment of:

- Depression
- Chronic pain syndrome
- Migraine
- Multiple sclerosis
- Diabetes
- Parkinson's Disease,
- Stroke
- Tinnitus
- Fibromyalgia
- Insomnia

The list goes on as researchers also continue to find potential for electromagnetic field treatment in schizophrenia[115], obsessive-compulsive disorder[116], attention deficit hyperactivity disorder[117], epilepsy[118] and other psychiatric disorders[119].

4.1.1 Depression

The first disorder of consideration is clinical depression. It "afflicts more than 18 million Americans, many of whom don't respond to conventional antidepressants like Prozac and Zoloft. But a promising new type of therapy is gaining wider use. The technique, called

---

[114] Wagner T, Valero-Cabre A, Pascual-Leone A. 2007. Noninvasive human brain stimulation. *Annu Rev Biomed Eng.* 9:527-65

[115] Levit-Binnun N, Handzy NZ, Moses E, Modai I, Peled A. 2007. Transcranial Magnetic Stimulation at M1 disrupts cognitive networks in schizophrenia. *Schizophr Res.* 93(1-3):334-44

[116] Berney A, Vingerhoets F. 2005. [Novel brain stimulation techniques: therapeutic perspectives in psychiatry]. *Rev Med Suisse.* 1(33):2162-4, 2166

[117] Schneider M, Retz W, Freitag C, Irsch J, Graf P, Retz-Junginger P, Rösler M. 2007. Impaired cortical inhibition in adult ADHD patients: a study with transcranial magnetic stimulation. *J Neural Transm Suppl.* (72):303-9

[118] Theodore WH, Fisher R. 2007. Brain stimulation for epilepsy. *Acta Neurochir Suppl.* 97(Pt 2):261-72

[119] Kluger BM, Triggs WJ. 2007. Use of transcranial magnetic stimulation to influence behavior. *Curr Neurol Neurosci Rep.* 7(6):491-7

transcranial magnetic stimulation, uses pulse s of magnetic energy to induce electric currents in specific brain regions. While no one knows exactly why it works, researchers say the treatment can alleviate depression."[120]

It interesting that it's not known exactly why TMS works; this is probably because the exact biological mechanism reacting to the electromagnetic fields is inconclusive nonetheless it has begun to prove itself therapeutically.[121]

In one study researchers observed that "changes from the relevant phase baseline in scores on the 21-item Hamilton depression scale showed that repetitive transcranial magnetic stimulation significantly improved mood over sham treatment. During the active-treatment phase, Hamilton depression scale scores decreased 5 points, while during sham treatment the scores increased or worsened by 3 points. No adverse effects were noted. Conclusions: these placebo-controlled results suggest that daily left prefrontal repetitive transcranial magnetic stimulation has antidepressant activity"[122] The Hamilton depression scale is a 21 item questionnaire originally published by Max Hamilton in 1960. It is one of the most commonly used scale rating in medical research related to depression.

In a further study the researchers chose to isolate a part of the brain previous studies have suggested being involved in major depression. The suggested region is known as the left dorsolateral prefrontal cortex (DLPFC) and again they used a type of TMS called repetitive Transcranial stimulation (rTMS). This type of stimulation has shown to exhibit longer lasting effects for patients.

The objective of the study was to "examine in vivo neurochemical alterations... in 17 patients with unipolar major depression before and after 10 days of high-frequency (20Hz) rTMS of the left DLPFC using 3-tesla proton magnetic resonance spectroscopy. [The]... results indicate that

---

[120] Huang *GT*. 2004. Zapping the Blues. *Technology Review, Cambridge*. Vol 107, Iss 2, pg 26

[121] As we know, TMS is a pulsed magnetic field that "creates current flow in the brain and can temporarily excite or inhibit specific areas." Now it also interesting to note from TMS that this excitation or inhibitory effect on the brain can create different effect altogether, "TMS of motor cortex can produce a muscle twitch or block movement; TMS of occipital cortex can produce visual phosphenes or scotomas. TMS can also alter the functioning of the brain beyond the time of stimulation, offering potential for therapy." (source: http://www.nature.com/nature/journal/v406/n6792/full/406147a0.html)

[122] George MS, Wassermann EM, Kimbrell TA, Little JT. 1997. Mood improvement following daily left prefrontal repetitive transcranial magnetic stimulation in patients with depression: A placebo-controlled crossover trial. *The American Journal of Psychiatry*. Vol. 154, Iss 12, pg 1752

metabolic, state-dependent changes within the left DLPFC in major depressive disorder involve the glutamate system and can be reversed in a dose-dependent manner by rTMS."[123]

In a similar study researchers "investigated the longitudinal, long-term antidepressant efficacy of daily left prefrontal cortex (PFC) rTMS for a 1-week period... The Beck Depression Inventory[124] and the Hamilton Depression Rating Scale were used to assess severity of depression at 1, 4 and 12 weeks post-therapy. A significant reduction of baseline depression scores was observed after 1 week of active treatment that lasted for 1 month, indicating improvement of depressive symptoms. No significant effects were observed in patients receiving sham treatment. The results of this controlled study are in agreement with the findings of previous studies suggesting that daily left PFC rTMS has an antidepressant effect."[125]

It is clear from the evidence that TMS is a very promising alternative to pharmacological equivalents such as Prozac. A medical drug that has gained wide acceptance as the best treatment available for depression regardless of the numerous side effects[126] reported in clinical trials. It was noted in the first study that TMS exhibited no adverse side effects which makes it even more viable as a treatment modality.

The fact that electromagnetic information can be used to alleviate depression is interesting. The fact that there is currently no understanding of how it works makes it even more curious.

4.1.2 Pain

A further effect of rTMS is its ability to relieve pain. The type of pain it can resolve is of the kind normally treated with painkillers or analgesics (such as paracetamol). In one study, the objective was to "assess, using a double-blind procedure, the pain-relieving effects of rTMS against placebo, and their predictive value regarding the efficacy of implanted motor cortex

---

[123] Luborzewski A, Schubert F, Seifert F, Danker-Hopfe H, Brakemeier EL, Schlattmann P, Anghelescu I, Colla M, Bajbouj M. 2007. Metabolic alterations in the dorsolateral prefrontal cortex after treatment with high-frequency repetitive transcranial magnetic stimulation in patients with unipolar major depression. *J Psychiatr Res.* 41(7):606-15

[124] is a 21-question multiple-choice self-report inventory that is one of the most widely used instruments for measuring the severity of depression. The most current version of the questionnaire is designed for individuals aged 13 and over and is composed of items relating to depression symptoms such as hopelessness and irritability, cognitions such as guilt or feelings of being punished, as well as physical symptoms such as fatigue, weight loss, and lack of interest in sex (source: http://en.wikipedia.org/wiki/Beck_Depression_Inventory)

[125] Bortolomasi M, Minelli A, Fuggetta G, Perini M, Comencini S, Fiaschi A, Manganotti P. 2007. Long-lasting effects of high frequency repetitive transcranial magnetic stimulation in major depressed patients *Psychiatry Res.* 30;150(2):181-6

[126] The side effects include nausea, insomnia somnolence anorexia anxiety nervousness asthenia and tremor. Rash or urticaria, sometimes serious, has also been observed as well as akathisia, which is an inner tension, restlessness, and the inability to stay still. Patients reported akathisia to make them feel suicidal and said this had led to previous suicide attempts (source: http://en.wikipedia.org/wiki/Prozac)

stimulation (MCS). Methods: Three randomised, double-blinded, 25 min sessions of focal rTMS (1 Hz, 20 Hz and sham) were performed in 12 patients, at 2 weeks intervals. Effects on pain were estimated from daily scores across 5 days before, and 6 days after each session. Analgesic effects were correlated with those of subsequent implanted motor cortex stimulation (MCS). Results: Immediately after the stimulating session, pain scores were similarly decreased by all rTMS modalities. Conversely, during the following week, 1 Hz stimulation provided significantly less analgesia than 20 Hz and placebo, and was pro-algesic in some patients. Placebo and 20 Hz rTMS were effective on different patients, and only 20 Hz rTMS predicted the efficacy of subsequent MCS, with no false positives. Conclusions: while 1Hz rTMS should not be used with analgesic purposes, high-frequency rTMS may become useful to select candidates for MCS"[127]

The facts of this study seem quite convincing. It's also useful to point out the biggest problem associated with treatment by TMS which is finding the most effective *frequency ranges* to test within. The 1Mhz rTMS was actually pro-algesic meaning it caused further pain in some patients.

Another problem pointed out in the following study is exactly what area of the brain to target when applying the rTMS. "The precentral gyrus (M1) is a representative target for electrical stimulation therapy of pain. To date, few researchers have investigated whether pain relief is possible by stimulation of cortical areas other than M1... With this in mind, we therefore examined several cortical areas as stimulation targets using a navigation-guided rTMS and compared the effects of the different targets on pain"[128] The researchers decided to look at the postcentral gyrus, premotor area and the supplementary motor areas of the brain.

Evaluating pain by the McGill Pain questionnaire, they found "ten of the 20 patients (50%) indicated that stimulation of M1, but not other areas, provided significant and beneficial pain relief ($p<0.01$). Results indicated a statistically significant effect lasting for 3 hours after the stimulation of M1 ($p<0.05$). Stimulation of other targets was not effective"[129]

---

[127] André-Obadia N, Peyron R, Mertens P, Mauguière F, Laurent B, Garcia-Larrea L. 2006. Transcranial magnetic stimulation for pain control. Double-blind study of different frequencies against placebo, and correlation with motor cortex stimulation efficacy. *Clin Neurophysiol.* 117(7):1536-44

[128] Hirayama A, Saitoh Y, Kishima H, Shimokawa T, Oshino S, Hirata M, Kato A, Yoshimine T. 2006. Reduction of intractable deafferentation pain by navigation-guided repetitive transcranial magnetic stimulation of the primary motor cortex. *Pain.* 122(1-2):22-7

[129] Hirayama A, Saitoh Y, Kishima H, Shimokawa T, Oshino S, Hirata M, Kato A, Yoshimine T. 2006. Reduction of intractable deafferentation pain by navigation-guided repetitive transcranial magnetic stimulation of the primary motor cortex. *Pain.* 122(1-2):22-7

These two studies point out the enormity of the task at hand for researchers in this area of TMS. The range of potential frequencies and the potential areas of the brain to be stimulated will hamper progress. However, the initial research is promising and it seems only a matter of time before rTMS can be regarded as a comprehensive therapy for the relief of pain.

4.1.3 Migraines

Another effect closely related to general pain is migraines and so far the research has been very promising. In the following study the objective "was to assess the impact of transcranial magnetic stimulation (TMS) on pain and the autonomic nervous system (ANS) in migraine. Forty two people [mean age 41.43+/-11.69 (SD) years, 36 females] were randomised into high vs. low TMS stimulation groups and received 2 brief pulses of TMS. Thirty-three (33/42) individuals had heart-rate variability assessed, before and after stimulation. No group effects were found. Pain decreased by 75%; 32% of people after 1 treatment reported no headache after 24hrs... TMS produces immediate, sustained reductions in pain and modification of the ANS"[130] The effectiveness of TMS in this study is unmistakable; it has immediate and sustained effects after a brief exposure to TMS yet there is no account for a placebo effect in this experiment.

In the following study a double blind, placebo controlled study was initiated to assess the "efficacy of 4 weeks of impulse magnetic-field therapy (16 Hz, 5 microTs)... for different types of headache and migraine. Eighty-two patients were randomly assigned to receive either active treatment or placebo (n = 41 each) and were characterized according to one of seven diagnoses (migraine, migraine combined with tension, tension, cluster, weather-related, posttraumatic, or other). Efficacy was assessed in terms of duration, severity, and frequency of migraine and headache attacks, as well as ability to concentrate. Data for 77 patients were analyzed. In the active-treatment group, all assessed criteria were significantly improved at the end of the study ($P < .0001$ vs baseline and placebo). Seventy-six percent of active-treatment patients experienced clear or very clear relief of their complaints."[131]

These are extremely encouraging results for further developments of TMS in the field of migraine treatment. Both studies display results above 75% in the reduction of pain which is an extremely large measure of statistical significance.

---

[130] Clarke BM, Upton AR, Kamath MV, Al-Harbi T, Castellanos CM. 2006. Transcranial magnetic stimulation for migraine: clinical effects. *J Headache Pain*. 7(5):341-6

[131] Pelka RB, Jaenicke C, Gruenwald J. 2001. Impulse magnetic-field therapy for migraine and other headaches: a double-blind, placebo-controlled study. *Adv Ther*. 18(3):101-9

4.1.4 Multiple Sclerosis

MS, as it is known, is a physiologically and cognitively debilitating disease. It is an auto immune condition that attacks the central nervous system and leads to demyelination.[132] There is no known cure and symptomatic treatment is the only relief for sufferers.

Magnetic stimulation has displayed good therapeutic potential for MS as one placebo controlled study showed, patients with MS who were exposed to "weak, extremely low frequency pulsed electromagnetic fields showed significant improvements on a composite symptom measure... Evidence from this randomized, double-bind, placebo controlled trial is consistent with results from smaller studies suggesting that exposure to pulsing, weak electromagnetic fields can alleviate symptoms of MS."[133]

Since the symptoms of MS vary in accordance with the respective nerve fibres (sensations, movement, and cognitive ability) it would help to know exactly what symptoms are alleviated in order to understand more about how electromagnetic energy is affecting patients with MS.

Fatigue is one of the most common symptoms associated with MS. "75%-90% of patients with multiple sclerosis report having fatigue, and 50%-60% describe it as the worst symptom of their disease. Fatigue is significantly associated with reduced quality of life and is also a major reason for unemployment, especially for patients with otherwise minor disability. The mechanisms underlying abnormal levels of fatigue in multiple sclerosis are poorly understood. Non-pharmacological management of fatigue in multiple sclerosis includes inpatient rehabilitation and endurance training. There is also evidence, that pulsing electromagnetic fields may improve fatigue associated with multiple sclerosis."[134]

Its sounds promising yet inconclusive, however, compared to current treatments it would seem any alternative would be worth investigating. Immunotherapy is currently the best method available in managing MS which takes into consideration the current stage of the disease, symptomatic treatment and modification of the course of the disease. Even though it has a relatively small success rate (as it is effective only in patients with a low degree of disability) it is still regarded as the best solution available.

---

[132] impairs the conduction of signals in the affected nerves, causing impairment in sensation, movement, cognition, or other functions depending on which nerves are involved. (source: http://en.wikipedia.org/wiki/Demyelinating_disease)

[133] Lappin MS, Lawrie FW, Richards TL, Kramer ED. 2003. Effects of a pulsed electromagnetic therapy on multiple sclerosis fatigue and quality of life: a double-blind, placebo controlled trial. *Altern Ther Health Med.* 9(4):38-48

[134] Zifko UA. 2003. Therapy of day time fatigue in patients with multiple sclerosis. *Wien Med Wochenschr.* 153(3-4):65-72

Alternatively, "in view of some recent reports concerning the possibility of utilisation of variable magnetic fields in the treatment of MS... [a] study was undertaken to evaluate the effectiveness of impulses generated by magnetic field obtained by means of VIOFOR JPS stimulator." [135] This system of stimulation is different to TMS in that is exposes the whole body to the electromagnetic field and not just the cranium. In this way the treatment aims at targeting the entire nervous system which naturally is all composed entirely of neurons.

So, the VIOFOR JPS stimulation was carried out on "76 subjects with long-term history of clinically confirmed MS. The mean duration of the disease was 8.5 years, and the mean age of the patients 37.8 years. The patients were divided into two groups: the study group and the controls. In the study group the patients were exposed to magnetic fields generated by VIOFOR JPS. Magnetic stimulation was not applied in the control group. The progress of the disease according to EDDS and the quality of life according to Testa and Simonson Questionnaire were assessed on admission and after 21 days of stimulation. No significant differences between the groups were found with respect to motor impairment evaluated using the EDDS score ... The quality of life was found to be significantly better in the group exposed to magnetic field stimulation than in the controls ($p < 0.01$). Particular variables contributing to the physical, psychological and social component of quality of life were analysed in detail. The most significant difference was observed with respect to the improvement of mental condition of the patients (alleviation of depression, elimination of anxiety, better emotional control), as well as to the decrease of muscle tone, dysaesthesia and painful sensations. No side effects were observed in any of the cases. The obtained effects encourage us to recommend magnetic stimulation as a method supplementing symptomatic treatment of patients with multiple sclerosis." [136]

This provides for conclusive evidence that electromagnetic information has the potential to significantly reduce the symptoms suffered by MS patients. However, it seems the application of almost any treatment will always serve as only partly effective simply because the "cause of the disease and its pathogenesis remain unknown. The last 20 years have seen only meagre advances in the development of effective treatments for the disease. No specific treatment modality can cure the disease or alter its long-term course and eventual outcome. Moreover, there are no agents or treatments that will restore premorbid neuronal function. A host of

---

[135] Brola W, Wegrzyn W, Czernicki J. 2002. Effect of variable magnetic field on motor impairment and quality of life in patients with multiple sclerosis *Wiad Lek*. 55(3-4):136-43

[136] Brola W, Wegrzyn W, Czernicki J. 2002. Effect of variable magnetic field on motor impairment and quality of life in patients with multiple sclerosis *Wiad Lek*. 55(3-4):136-43

biological phenomena associated with the disease involving interactions among genetic, environmental, immunologic, and hormonal factors, cannot be explained on the basis of demyelination alone and therefore require refocusing attention on alternative explanations" [137] The knowledge of the cause of MS is therefore still in the research stages which makes treating the disease rather complex. The search for an alternative explanation to understand the disease will hopefully clarify the means to discover an effective treatment.

One of the forefront researchers on the disease at the moment, Dr Reuven Sandyk, has implicated the "the pineal gland as pivotal. The pineal gland functions as a magnetoreceptor organ. This biological property of the gland provided the impetus for the development of a novel and highly effective therapeutic modality, which involves transcranial applications of alternating current (AC) pulsed electromagnetic fields in the picotesla flux density."[138]

To isolate one tiny gland in the brain as the pivotal advocate of the disease would be a major breakthrough is realising the best possible treatment. It would suppose that the degradation of the rest of the central nervous system is directed by the pineal, which functions as a magnetoreceptor. It also functions very differently to the rest of the brain because it produces melatonin, a hormone said to regulate our sleeping and waking patterns ie circadian rhythms.

This is a point of interest when we consider the significance of shifting down the trajectory of normal consciousness into the hypnogogic and dream states. For both Lewis Williams and Persinger, accessing these states is a means to access information beyond normal consciousness. Information shown to be transduced from the electromagnetic information that surrounds everyone, that consequently can potentially help in the symptomatic (and perhaps curative) treatment of diseases and disorders. So perhaps to stimulate the pineal area of the brain with TMS will serve as an important step in the effective treatment of MS while also offering experimental insight into how the pineal acts as a gateway to altered states of consciousness.

4.1.5 Diabetes

Interestingly, pulsed electromagnetic fields have also been found to have positive effect on Diabetic sufferers. "Clinical and electroneuromyographic studies were performed in 121 patients with diabetic polyneuropathy (DPN) before and after courses of treatment with pulsed

---

[137]Sandyk R. 1997. Therapeutic effects of alternating current pulsed electromagnetic fields in multiple sclerosis. *J Altern Complement Med.* 3(4):365-86

[138]Sandyk R. 1997. Therapeutic effects of alternating current pulsed electromagnetic fields in multiple sclerosis. *J Altern Complement Med.* 3(4):365-86

electromagnetic fields with complex modulation (PEMF-CM) at different frequencies (100 and 10 Hz)... Application of PEMF-CM facilitated regression of the main clinical symptoms of DPN, improved the conductive function of peripheral nerves, improved the state of la afferents[139], and improved the reflex excitability of functionally diverse motoneurons in the spinal cord. PEMF-CM at 10 Hz was found to have therapeutic efficacy, especially in the initial stages of DPN and in patients with diabetes mellitus for up to 10 years."[140] Naturally, the positive effects recorded here are all directly linked to the central nervous system, the conductive functions of the peripheral nerves and the state of afferent neurons and functionality of motoneurons in the spinal cord. This is because diabetes polyneuropathy is of a group of neuropathic disorders (associated with Diabetes Mellitus) that does specific damage to nerve tissue through lack of blood supply (microvascular injury). It seems that even if the nerve tissue has been afflicted by diabetes for up to 10 years, electromagnetic stimulation is still able offer effective treatment.

In a similar experiment the "the clinical-electroneuromyography investigations were performed for objective evaluation of low-power electromagnetic therapy effectiveness in 12 patients with diabetic polyneuropathies. It is established that combination of low-power electromagnetic therapy using "ANET-UHF", "ANET-SHF" apparatus and low-power variable magnetic field using AMT apparatus give the stable positive effects. The positive changes were confirmed by following: the decrease of neurological deficit and required insulin daily dose, nerve conduction velocity increase, increase of the muscle compound action potentials (muscle power) and peripheral outflow in some patients."[141] What these results are hinting at inconclusively is that the application of electromagnetic stimulation to the peripheral and central nervous system has a *regenerative* effect.

In fact, the results from both the Multiple Sclerosis studies as well as the Diabetes Polyneuropothy studies have indicated that even after years of neurons being subjected to each disease, relatively short periods of exposure to certain electromagnetic frequencies have restored some functionality to neural activity. The nervous tissue that surrounds the body after years of attack from these diseases can still respond immediately to electromagnetic

---

[139] afferent neurons--otherwise known as sensory or receptor neurons--carry nerve impulses from receptors or sense organs *toward* the central nervous system (source: http://en.wikipedia.org/wiki/Afferent_nerve)

[140] Musaev AV, Guseinova SG, Imamverdieva SS. 2003. The use of pulsed electromagnetic fields with complex modulation in the treatment of patients with diabetic polyneuropathy. *Neurosci Behav Physiol.* 33(8):745-52

[141] Chebotar'ova LL, Chebotar'ov HIe. 2003. [Use of low-power electromagnetic therapy in diabetic polyneuropathy]. *Fiziol Zh.* 49(2):85-90

information to restore movement, sensory capability and cognitive functions. It almost seems like the body is primed to transduce electromagnetic frequencies.

In two recent studies[142,143] done on rats, the objective was "to determine if exposure to PMF influences regeneration, we used electrophysiological recordings and ultrastructural examinations. After the measurements of conduction velocity, the sucrose-gap method was used to record compound action potentials (CAPs) from sciatic nerves. PMF treatment during the 38 days following the crush injury enhanced the regeneration." [144] Interesting results that have little applications for humans at the moment yet the potential is very encouraging.

4.1.6 Parkinson's Disease

Parkinson's disease (PD) is a degenerative disorder of the central nervous system and well known for the motor impairment it can cause however since it can affect the whole nervous system it also causes dysfunction related to sensation and cognition.

It has been shown in previous studies "patients with Parkinson's disease have reported that a single session of repetitive transcranial magnetic stimulation (rTMS) can improve some or all of the motor symptoms for 30 to 60 minutes. A recent study suggested that repeated sessions of rTMS lead to effects that can last for at least 1 month... Interestingly, the effect was restored and maintained for the next month by the booster sessions. [In this study the researchers]... conclude that 25 Hz rTMS can lead to cumulative and long-lasting effects on motor performance."[145] That type of treatment could almost fit the definition of a miracle, to have one brief treatment relieve some or all motor symptoms associated with PD is remarkable.

Obviously the effects due eventually fade thereby necessitating regular treatment, so in order to optimise the treatment, it is of technical significance to understand the nature of the neurochemical changes rTMS induces.

This is difficult to analyse in humans without cutting open the brain post rTMS application and actually measuring chemical responses. So, in a recent study done on rats the researchers used invasive methods to monitor "the effects of acute rTMS (20 Hz) on the intrahippocampal,

---

[142] Mert T, Gunay I, Gocmen C, Kaya M, Polat S. 2006. Regenerative effects of pulsed magnetic field on injured peripheral nerves. *Altern Ther Health Med.* 12(5):42-9

[143] De Pedro JA, Pérez-Caballer AJ, Dominguez J, Collía F, Blanco J, Salvado M. 2005. Pulsed electromagnetic fields induce peripheral nerve regeneration and endplate enzymatic changes. *Bioelectromagnetics.* 26(1):20-7

[144] Mert T, Gunay I, Gocmen C, Kaya M, Polat S. 2006. Regenerative effects of pulsed magnetic field on injured peripheral nerves. *Altern Ther Health Med.* 12(5):42-9

[145] Khedr EM, Rothwell JC, Shawky OA, Ahmed MA, Hamdy A. 2006. Effect of daily repetitive transcranial magnetic stimulation on motor performance in Parkinson's disease. *Mov Disord.* 21(12):2201-5

intraaccumbal and intrastriatal release patterns of dopamine and its metabolites (homovanillic acid, 3,4-dihydroxyphenylacetic acid).”[146] Now dopamine is one of the neurotransmitters[147] in the brain whose effect is associated with a general sense of well being and in patients with PD, it is known to cause reduction in the secretion of dopamine.

“In the dorsal hippocampus, the shell of the nucleus accumbens and the dorsal striatum the extracellular concentration of dopamine was significantly elevated in response to rTMS. Taken together, these data provide the first in vivo evidence that acute rTMS of frontal brain regions has a modulatory effect on both the mesolimbic and the mesostriatal dopaminergic systems. This increase in dopaminergic neurotransmission may contribute to the beneficial effects of rTMS in the treatment of affective disorders and Parkinson’s disease.”[148] So this neurchemical effect can increase the secretion of dopamine and alleviate depression. Depression is one of the main symptoms of PD and now we can see how rTMS works on a chemical level to treat major depressive disorder as well as sufferers of PD.

In addition, the decrease in dopamine secretion for PD patients is also the cause of the motor and cognitive impairment. Evidence of the effect rTMS has on motor improvement has been noted so the cognitive effects remain to be seen.

They can be observed in a study made by Dr Reuven Sandyk on a “74 year old retired building inspector with a 15 year history of Parkinson's disease (PD) presented with severe resting tremor in the right hand, generalized bradykinesia[149], difficulties with the initiation of gait[150] with freezing, mental depression and generalized cognitive impairment despite being fully medicated.”[151] It seems unreasonable that even though this patient has been chemically medicated the severity of the condition persists while at the same time wide variety of side effects have to be endured.

Before the application of TMS, test were done on “constructional abilities employing various drawing tasks [and the results] demonstrated drawing impairment compatible with severe left

---

146 Keck ME, Welt T, Muller MB, Erhardt A, Ohl F, Toschi N, Holsboer F, Sillaber I. 2002. Repetitive transcranial magnetic stimulation increases the release of dopamine in the mesolimbic and mesostriatal system. *Neuropharmacology*. 43(1):101-9

147 Neurotransmitters are chemicals that are used to relay, amplify and modulate signals between a neuron and another cell (source: http://en.wikipedia.org/wiki/Neurotransmitters)

148 Keck ME, Welt T, Muller MB, Erhardt A, Ohl F, Toschi N, Holsboer F, Sillaber I. 2002. Repetitive transcranial magnetic stimulation increases the release of dopamine in the mesolimbic and mesostriatal system. *Neuropharmacology*. 43(1):101-9

149 Literally “slow movement”

150 Walk

151 Sandyk R. 1997. Reversal of cognitive impairment in an elderly parkinsonian patient by transcranial application of picotesla electromagnetic fields. *Int J Neurosci*. 91(1-2):57-68

hemispheric dysfunction. After receiving two successive transcranial applications, each of 20 minutes duration, with AC pulsed electromagnetic fields (EMFs) of 7.5 picotesla flux density and frequencies of 5Hz and 7Hz respectively, his tremor remitted and there was dramatic improvement in his drawing performance. Additional striking improvements in his drawing performance occurred over the following two days after he continued to receive daily treatments with EMFs. The patient's drawings were subjected to a Reliability Test in which 10 raters reported 100% correct assessment of pre-and post drawings with all possible comparisons ($X^2 = 5.0$; $p < .05$). This case demonstrates in PD rapid reversal of drawing impairment related to left hemispheric dysfunction by brief transcranial applications of AC pulsed picotesla flux density EMFs and suggests that cognitive deficits associated with Parkinsonism, which usually are progressive and unaffected by dopamine replacement therapy, may be partly reversed by administration of these EMFs. Treatment with picotesla EMFs reflects a cutting edge approach to the management of cognitive impairment in Parkinsonism."[152]

It seems cutting edge not only because of the dramatic improvements experienced by this patient but also because of the miniscule amount of energy that is required. To put it in perspective, from bigger to smaller energy emissions:

- loudspeakers are around 1.5 *telsa*
- a refrigerator magnet is about 5 *millitelsas*
- the earth magnetic field is at 31 *microtelsas*
- then there's still *nanotelsas*
- and then there are *picotelsas*.

The brain emits it own electromagentic field at between 0.1 to 1 picotelsa which relates quite plainly to Dr Persinger's belief that the "more we simulate natural electromagnetic patterns displayed by living systems the less the amount of energy is required to affect the organism"[153]

In yet another study, Dr Reuven Sandyk was interested in examining the cognitive symptom of dementia in PD patients. From his research he has estimated that 30% of cognitive impairment

[152] Sandyk R. 1997. Reversal of cognitive impairment in an elderly parkinsonian patient by transcranial application of picotesla electromagnetic fields. *Int J Neurosci.* 91(1-2):57-68

[153] http://oldwebsite.laurentian.ca/neurosci/_research/bioelectromagnetic.htm

for PD eventually results in dementia and in addition, 90% of patients eventually suffer from visuospatial problems due to degradation of the right hemispheric functions.

The "Rey-Osterrieth Complex Figure[154] (ROCF) Test has been employed in the assessment of right hemispheric functions and particularly for the evaluation of visuoconstructive abilities and short-term visual memory." As he has shown from the previous study the "external application of electromagnetic fields (EMFs) in the picotesla (pT) range intensity is an effective nonpharmacological modality in the management of the motor and cognitive deficits of Parkinsonism."[155] It is already becoming apparent from this research how electromagnetic fields affect behaviour and cognition, of course, this is still only derived from sufferers of PD yet the results are promising.

In the following study, Dr Sandyk has chosen 3 patients fully medicated and nondemented with a mean age of 68, a mean duration of illness of 9 years and a mean disability rating according to the Hoehn and Yahr[156] scale of stage three[157]. "They were tested on the ROCF Test before and after a series of treatments with EMFs. In response to the administration of EMFs the group demonstrated a mean of 23.1 +/- 13.6% improved performance on copy of the ROCF and a 39.3 +/- 13.4% improvement of short-term recall of the ROCF. These findings demonstrate that treatment with pT EMFs improves deficits in visuospatial functions and visual memory in Parkinsonism which usually remain unaffected during standard treatment with dopaminergic pharmacotherapy."[158] It is interesting to note that even when dopamine is administered through pharmacotherapy it seems to have very little effect on the cognitive deficit experienced by PD patients yet when miniscule amounts of electromagnetic energy are processed by the brain, cognitive deficits are somewhat alleviated. The ability of electromagnetic energy to stimulate dopamine secretion is the brain is a tantalising question to be asked of the neurochemists.

---

[154] Neuropsychological method of assessment in which many different abilities are needed for a correct performance. It permits the evaluation of different functions such as visuospatial abilities, memory or attention, planning and working memory (source: http://en.wikipedia.org/wiki/Rey-Osterrieth_Complex_Figure)

[155] Sandyk R. 1995. Improvement in short-term visual memory by weak electromagnetic fields in Parkinson's disease. *Int J Neurosci.* 81(1-2):67-82

[156] Commonly used system for describing how the symptoms of Parkinson's disease progress. The scale allocates stages from 0 to 5 to indicate the relative level of disability. (source: http://en.wikipedia.org/wiki/Hoehn_and_Yahr_scale)

[157] Stage 3: Balance Impairment Mild to moderate disease. Physically independent (source:http://en.wikipedia.org/wiki/Hoehn_and_Yahr_scale)

[158] Sandyk R. 1995. Improvement in short-term visual memory by weak electromagnetic fields in Parkinson's disease. *Int J Neurosci.* 81(1-2):67-82

4.1.7 Stroke

It's a very well known disease because of its notoriety as the second most common cause of death in the world and perhaps soon to become the leading cause of death known to man.[159] It leads to rapid loss in brain function due to the lack of supply of blood to the brain. The brain tissue needs a regular supply of blood before it suffers tissue death and irreversible brain damage for the sufferer.

Consequently stroke "produces a major burden to society, largely through long-lasting motor disability in survivors. Recent studies have broadened our understanding of the processes underlying recovery of motor function after stroke." If it were possible for motor function to be restored a degree of normal functioning could be returned.

Researchers say they now have a better insight into the bilateral motor regions of the brain that undergo "substantial reorganization after stroke, including changes in the strength of interhemispheric inhibitory interactions. Our understanding of the extent to which different forms of reorganization contribute to behavioural gains in the rehabilitative process, although still limited, has led to the formulation of novel interventional strategies to regain motor function. Transcranial magnetic stimulation... [offers] noninvasive brain stimulation techniques that modulate cortical excitability in both healthy individuals and stroke patients. These techniques can enhance the effect of training on performance of various motor tasks, including those that mimic activities of daily living." [160] The neurological result of applying TMS shows that either it can "enhance or suppress cortical excitability, and may move to the clinical arena as strategies to enhance the beneficial effects of customarily used neurorehabilitative treatments after stroke."[161]

The facilitation or suppression of cortical excitability can be seen as the binary functions of TMS (like in an electronic circuit, it is either off or on). The technical variation in all neural circuits between these two binary parameters can determine whether cortical excitability facilitates or suppresses *conscious abilities* such as sense, cognition, behaviour and neurological health. Measuring the alterations of these functions in a normal state of consciousness is a question of experimentation with TMS on ever more smaller locations in and

---

[159] Feigin VL. 2005. Stroke epidemiology in the developing world. *Lancet.* 365 (9478): 2160–1

[160] Lefaucheur JP, Drouot X, Nguyen JP. 2001. Interventional neurophysiology for pain control: duration of pain relief following repetitive transcranial magnetic stimulation of the motor cortex. *Neurophysiol Clin.* 31(4):247-52

[161] Lefaucheur JP, Drouot X, Nguyen JP. 2001. Interventional neurophysiology for pain control: duration of pain relief following repetitive transcranial magnetic stimulation of the motor cortex. *Neurophysiol Clin.* 31(4):247-52

around the brain. If it is possible to measure and affect the pathway of a single neuron and if the result of the *affected*[162] effect is measurable, it will eventually render a complete map of conscious functions relating 'areas of cortical excitability' with 'ability in neurological function in a normal state of consciousnesses'. The same variable of cortical excitability can be placed against 'ability in neurological functions in *altered states* of consciousness' which would render another map of conscious functions.

The difference between the two maps is what Lewis Williams might call the Big Bang in human civilisation or to Persinger the creative source of human discovery. More importantly, what the maps would reveal is the pinpoint accuracy on how to modulate the brain with TMS in order to affect the desired alteration in neurological function.[163]

Now, in relation to one specific symptom of stroke i.e. neurogenic[164] pain, other techniques that have been considered as treatment is the "chronic electrical stimulation of a motor cortical area corresponding to a painful region of the body."[165] The implication for a patient is to have surgically-implanted epidural electrodes located around the cranium. This is a validated method of treatment for stroke patients suffering from neurogenic pain that is resistant to medication.

On the other hand there is "repetitive transcranial magnetic stimulation [which] permits to stimulate non-invasively and precisely [within] the motor cortex."[166] A study was performed in which a "20-min session of rTMS of the motor cortex at 10 Hz using a 'real' or a 'sham' coil in a series of 14 patients with intractable pain due to thalamic stroke or trigeminal neuropathy. [The researchers] studied the effects of rTMS on pain levels assessed on a 0–10 visual analogue scale from day 1 to day 12 following the rTMS session. A significant pain decrease was observed up to 8 days after the 'real' rTMS session. This study shows that a transient pain relief can be induced in patients suffering from chronic neurogenic pain during the week that follows a 20-min session of 10Hz-rTMS applied over the motor cortex."[167] It seems the sensible choice

---

[162] artificial

[163] If this were to be possible either through a mechanical device or purely through normal cognitive intervention, the control it could offer a human of neurological functions, the functions that control most physical and non-physical occurrences, would be much greater. That power can lead to either dire or desirable ends, depending on the competence of the operator.

[164] Related to the nervous system

[165] Lefaucheur JP, Drouot X, Nguyen JP. 2001. Interventional neurophysiology for pain control: duration of pain relief following repetitive transcranial magnetic stimulation of the motor cortex. *Neurophysiol Clin.* 31(4):247-52

[166] Lefaucheur JP, Drouot X, Nguyen JP. 2001. Interventional neurophysiology for pain control: duration of pain relief following repetitive transcranial magnetic stimulation of the motor cortex. *Neurophysiol Clin.* 31(4):247-52

[167] Lefaucheur JP, Drouot X, Nguyen JP. 2001. Interventional neurophysiology for pain control: duration of pain relief following repetitive transcranial magnetic stimulation of the motor cortex. *Neurophysiol Clin.* 31(4):247-52

by default should be to seek validation of non-invasive treatment modalities long before attempting to surgically implant electrodes into the cranium.

When looking at rTMS as treatment for stroke victims, it has shown the potential to restore motor functionality in patients. The manner of stimulation is normally on the unaffected side of the patient and the effect is known to be short lasting.

To investigate this one researcher conducted a "a randomized, sham-controlled, phase II trial to evaluate whether five sessions of low-frequency rTMS can increase the magnitude and duration of these effects and whether this approach is safe...Conclusions: These results support and extend the findings of previous studies on rTMS in stroke patients because five consecutive sessions of rTMS increased the magnitude and duration of the motor effects. Furthermore, this increased dose of rTMS is not associated with cognitive adverse effects and/or epileptogenic activity."[168] So not only is the treatment effective towards long term increment in motor functionality, it is also free of any adverse side effects.

Another symptom of stroke is aphasia. This is where patients lose the ability to either produce or comprehend language to some degree because of damage to the areas of the brain that control these functions. rTMS has shown particular potential in patients who suffer from aphasia, specifically nonfluent aphasia (loss of ability to articulate but normal comprehension abilities).

Through the use of functional brain imaging researchers have noted that patients suffering from nonfluent aphasia have shown increase cortical activation in the right hemisphere language homologues. These areas of "overactivation may represent a maladaptive strategy that interferes with, rather than promotes, aphasia recovery. Repetitive transcranial magnetic stimulation (rTMS) is a painless, noninvasive procedure that utilizes magnetic fields to create electric currents in discrete brain areas affecting about a 1-cm square area of cortex. Slow frequency, 1 Hz rTMS reduces cortical excitability. When rTMS is applied to an appropriate cortical region, it may suppress the possible overactivation and thus modulate a distributed neural network for language."[169]

---

[168] Fregni F, Boggio PS, Valle AC, Rocha RR, Duarte J, Ferreira MJ, Wagner T, Fecteau S, Rigonatti SP, Riberto M, Freedman SD, Pascual-Leone A. 2006. A Sham-Controlled Trial of a 5-Day Course of Repetitive Transcranial Magnetic Stimulation of the Unaffected Hemisphere in Stroke Patients. *Stroke.* 37:2115

[169] Martin PI, Naeser MA, Theoret H, Tormos JM, Nicholas M, Kurland J, Fregni F, Seekins H, Doron K, Pascual-Leone A. 2004. Transcranial magnetic stimulation as a complementary treatment for aphasia. *Speech Lang.* (2):181-91

In one study researchers report on "preliminary results following rTMS application to R Broca's area (posterior, R pars triangularis) in four stroke patients with nonfluent aphasia (5-11 years after left hemisphere stroke). Following 10 rTMS treatments, significant improvement in naming pictures was observed. This form of rTMS may provide a novel, complementary treatment for aphasia."[170] This evidence clearly illustrates how the binary parameter of cortical excitability through location specific treatment is able to improve the neurological condition of non-fluent aphasia. If this type of measured response is made of all conscious functions in healthy patients, the respective model of neurological function would be very intriguing.

4.1.8 Tinnitus

Tinnitus is known as a symptom of underlying causes rather than a disease and is mostly a subjective phenomenon. The description of the symptom is the perception of sound that cannot be correlated to any external stimulus. The perception of this sound is persistent which can be severely disabling, especially when there is no satisfactory treatment available.

However, TMS offers a "new, non-invasive method of modifying the excitability of the cerebral cortex, which has proven effective in auditory hallucinations and other disorders. Some early studies have been published in which TMS has been used in the treatment of tinnitus."[171]

Tinnitus is more common than previously thought as some literature reports the prevalence of the disorder affects "8.2% in subjects aged 50 years and over, and may be associated with great distress"[172] because tinnitus sufferers are unable to avoid the persistent perception.

"Tinnitus is frequently associated with deafness, and may be the result of a pathological plasticity[173] process. Neuroimaging studies demonstrate increased activity within the central auditory system. TMS is a non-invasive method of modulating excitability in cerebral cortex. It uses electromagnetic principles and has been successfully employed in the treatment of other conditions associated with increased activity of the cerebral cortex... Conclusion: There is a good theoretical basis and early research evidence suggesting that transcranial magnetic

---

[170] Martin PI, Naeser MA, Theoret H, Tormos JM, Nicholas M, Kurland J, Fregni F, Seekins H, Doron K, Pascual-Leone A. 2004. Transcranial magnetic stimulation as a complementary treatment for aphasia. *Speech Lang.* (2):181-91

[171] Langguth B, Hajak G, Kleinjung T, Pridmore S, Sand P, Eichhammer P. 2006. Repetitive transcranial magnetic stimulation and chronic tinnitus. *Acta Otolaryngol Suppl.* (556):102-5

[172] Langguth B, Hajak G, Kleinjung T, Pridmore S, Sand P, Eichhammer P. 2006. Repetitive transcranial magnetic stimulation and chronic tinnitus. *Acta Otolaryngol Suppl.* (556):102-5

[173] refers to the changes that occur in the organization of the brain as a result of experience. A surprising consequence of neuroplasticity is that the brain activity associated with a given function can move to a different location as a consequence of normal experience or brain damage/recovery. (source: http://en.wikipedia.org/wiki/Neuroplasticity)

stimulation (TMS) may have treatment potential in tinnitus. Further studies with larger sample sizes and additional assessment of neurobiological effects are necessary."[174]

Looking at the most recent research, an important consideration is the cause of the disorder. It commonly occurs when the auditory mechanisms of the ear sustain injury and the phantom auditory perception is said to arise from "maladaptive neuroplasticity and subsequent hyperactivity in an extended neuronal network including the primary auditory cortex, higher-order association areas, and parts of the limbic[175] system" [176]

With this understanding of the of the overly excited cortical areas associated with tinnitus, a study was completed where "TMS was performed at 1 Hz and 120% of the motor threshold for 5, 15, and 30 min, navigated to the individual maximum of tinnitus-related cortical hyperactivity. A noncortical stimulation site with the same distance to the ear served as sham control. Tinnitus loudness was reduced after temporoparietal, PET-guided low-frequency rTMS. This reduction, lasting up to 30 min, was dependent on the number of stimuli applied, differed from sham stimulation, and was negatively correlated with the length of the medical history of tinnitus in our patients. These data show the feasibility and effectiveness of rTMS guided by individual functional imaging to induce a lasting, dose-dependent attenuation of tinnitus. Of note, these effects were related to stimulation of cortical association areas, not primary auditory cortex, emphasizing the crucial role of higher-order sensory processing in the pathophysiology of chronic tinnitus."[177]

The useful outcome of this study was to isolate the role of the higher-order sensory processing areas associated with tinnitus to design more effective treatment. This would definitely be helpful in designing treatments that could reduce the tinnitus for longer than 30 minutes.

Toward this objective, a further study was initiated where the researchers used a technique called neuronavigation. The technique consisted of scanning the primary auditory cortex displaying the greatest amount of activity (since it has been observed that tinnitus may be

---

[174] Langguth B, Hajak G, Kleinjung T, Pridmore S, Sand P, Eichhammer P. 2006. Repetitive transcranial magnetic stimulation and chronic tinnitus. *Acta Otolaryngol Suppl.* (556):102-5

[175] is a term for a set of brain structures including the hippocampus and amygdala and anterior thalamic nuclei and a limbic cortex that support a variety of functions including emotion, behavior and long term memory (source: http://en.wikipedia.org/wiki/Limbic)

[176] Plewnia C, Reimold M, Najib A, Brehm B, Reischl G, Plontke SK, Gerloff C. 2007. Dose-dependent attenuation of auditory phantom perception (tinnitus) by PET-guided repetitive transcranial magnetic stimulation. *Hum Brain Mapp.* 28(3):238-46

[177] Plewnia C, Reimold M, Najib A, Brehm B, Reischl G, Plontke SK, Gerloff C. 2007. Dose-dependent attenuation of auditory phantom perception (tinnitus) by PET-guided repetitive transcranial magnetic stimulation. *Hum Brain Mapp.* 28(3):238-46

related to hyperactivity) with Positron Emission Tomography (PET)[178]. The hyperactive areas are then marked on a Computer Tomography (CT)[179] and correlated to the PET image. A composition system is then used to "calibrate the three-dimensional CT image with anatomic landmarks on the subject's head (e.g., the incisure, nasal tip, and nasofrontal angle). The TMS coil could then be navigated over a region of interest in the subject's brain corresponding precisely with the area marked on the CT scan."[180]

This is the type of theory combined with technique that can greatly enhance the effectiveness of TMS. As mentioned earlier, the mapping of the brain, or more importantly mapping the electromagnetic activity in the brain, it becomes possible to correlate the conscious functional effects with the cortical locations and pathways in an excitatory or inhibitory state in order to effectively treat those regions with the correct stimulation.

The technology currently available to do this is the size of a room, operable only by experienced scientists and not in real time, however it is worthwhile considering that the first computers where just as big and cumbersome when the technology was initially introduced. Useful to only a few at first until the necessary breakthroughs in technology were made (ie transistor and user friendly operating systems) and then it became a device everyone could use. The possibility of this happening to the technology required for brain mapping and stimulation in real time may potentially follow a similar progression.

An example of the artificial technique was used by the researchers in a "randomized, placebo-controlled (sham stimulation) crossover study. Methods: Patients received 5 consecutive days of active, low-frequency rTMS or sham treatment (using a 45-degree coil-tilt method) before crossing over. Subjective tinnitus was assessed at baseline, after each treatment, and 4 weeks later. Positron emission tomography/computed tomography (PET/CT) scans were obtained at baseline and immediately after active treatment to examine change in cortical asymmetry. Attentional vigilance was assessed at baseline and after each treatment using a simple reaction time test. Results: All patients had a response to active (but not sham) rTMS, as indicated by their best tinnitus ratings; however, tinnitus returned in all patients by 4 weeks after active

---

[178] a nuclear medicine imaging technique which produces a three-dimensional image or map of functional processes in the body (source: http://en.wikipedia.org/wiki/Positron_Emission_Tomography)

[179] Digital geometry processing is used to generate a three-dimensional image of the inside of an object (source: http://en.wikipedia.org/wiki/Computer_tomography)

[180] Smith JA, Mennemeier M, Bartel T, Chelette KC, Kimbrell T, Triggs W, Dornhoffer JL. 2007. Repetitive transcranial magnetic stimulation for tinnitus: a pilot study. *Laryngoscope*. 117(3):529-34

treatment." Compared to the previous study, 4 weeks is a significant improvement on the duration tinnitus reduction compared to 30 minutes.

Active rTMS treatment was made after the 4 week period to which all patients had reduced cortical activity as shown by the PET scans. "Conclusions: rTMS is a promising treatment modality that can transiently diminish tinnitus in some individuals, but further trials are needed to determine the optimal techniques required to achieve a lasting response... PET/CT scans immediately after treatment suggest that improvement may be related to reduction of cortical asymmetry associated with tinnitus."[181]

4.1.9 Fibromyalgia

Fibromyalgia is characterised by the onset of diffuse or specific muscle, joint, or bone pain, fatigue, and a wide range of other symptoms. Pain is often associated with painful reactions to non-painful stimulus (ie. tactile Allodynia) as well. The pain is not directly life threatening but the disability associated with it reduces quality of life; it also does not cause inflammation of the affected tissues, and does not lead to joint damage or deformity.

These set of recognisable symptoms are what classify Fibromyalgia as a syndrome as the underlying cause is largely unknown. Fibromyalgia apparently affects more men than women by a ration of 9:1 according to the American College of Rheumatology and it affects a significant amount of the general population by as much as 6%, most commonly between the ages of 20 to 50 years old.

The symptoms of Fibromyalgia are closely associated with those symptoms associated with sufferers of chronic pain syndrome, as mentioned earlier. The success of those treatments with rTMS has led researchers to target similar areas of the brain, such as the motor cortex, to try and modify the central pain modulatory systems and reduce pain. "Neuroimaging studies have shown bilateral activation of a large number of structures, including some of those involved in pain processing, suggesting that such stimulation may induce generalized analgesic effects." [182] So if there was a way to control the cortical activity in the motor cortex it means that every person who has ever needed the use of painkillers (generalised analgesic) can now exercise a technique, either through a device or by self modulation that will control their sensation to pain.

---

[181] Smith JA, Mennemeier M, Bartel T, Chelette KC, Kimbrell T, Triggs W, Dornhoffer JL. 2007. Repetitive transcranial magnetic stimulation for tinnitus: a pilot study. *Laryngoscope*. 117(3):529-34

[182] Passard A, Attal N, Benadhira R, Brasseur L, Saba G, Sichere P, Perrot S, Januel D, Bouhassira D. 2007. Effects of unilateral repetitive transcranial magnetic stimulation of the motor cortex on chronic widespread pain in fibromyalgia. *Brain*. 130(Pt 10):2661-70

I would assume that method of treatment to be of much more benefit to the end user than the current method.

In order to test the validity of electromagnetic induction on cortical activity to control pain, a study was performed where rTMS was applied to one side of the motor cortex for "chronic widespread pain in patients with fibromyalgia. Thirty patients with fibromyalgia syndrome (age: 52.6 +/- 7.9) were randomly assigned, in a double-blind fashion, to two groups, one receiving active rTMS (n = 15) and the other sham stimulation (n = 15), applied to the left primary motor cortex in 10 daily sessions. The primary outcome measure was self-reported average pain intensity over the last 24 h, measured at baseline, daily during the stimulation period and then 15, 30 and 60 days after the first stimulation." [183]

In order to measure the outcomes batteries of tests were used, they included:

- Sensory and affective pain[184] - McGill pain Questionnaire
- Quality of life - Brief Pain Inventory[185] and the Fibromyalgia Impact Questionnaire
- Mood and anxiety - Hamilton Depression Rating Scale, Beck Depression Inventory, Hospital Anxiety and Depression Scale[186]

As the results showed, application of rTMS "significantly reduced pain and improved several aspects of quality of life (including fatigue, morning tiredness, general activity, walking and sleep) for up to 2 weeks after treatment had ended.

The analgesic effects were observed from the fifth stimulation onwards and were not related to changes in mood or anxiety. The effects of rTMS were more long-lasting for affective than for sensory pain, suggesting differential effects on brain structures involved in pain perception. Only few minor and transient side effects were reported during the stimulation period. Our data indicate that unilateral rTMS of the motor cortex induces a long-lasting decrease in chronic

---

[183] Passard A, Attal N, Benadhira R, Brasseur L, Saba G, Sichere P, Perrot S, Januel D, Bouhassira D. 2007. Effects of unilateral repetitive transcranial magnetic stimulation of the motor cortex on chronic widespread pain in fibromyalgia. *Brain.* 130(Pt 10):2661-70

[184] The affective dimension of pain is made up of feelings of unpleasantness and emotions associated with future implications, termed secondary affect (source: http://www.sciencemag.org/cgi/content/abstract/288/5472/1769)

[185] Provides information on the intensity of pain (the sensory dimension) as well as the degree to which pain interferes with function (the reactive dimension). The BPI also asks questions about pain relief, pain quality, and the patient's perception of the cause of pain. (source: http://www.lsdregistry.net/fabryregistry/hcp/partic/assess/freg_hc_p_BPI.asp)

[186] Instrument for detecting states of depression and anxiety in the setting of an hospital medical outpatient clinic. The anxiety and depressive subscales are also valid measures of severity of the emotional disorder. (source: http://www.ncbi.nlm.nih.gov/pubmed/6880820)

widespread pain and may therefore constitute an effective alternative analgesic treatment for fibromyalgia."[187]

It seems the technical variation in the technique used to stimulate the brain was between affecting the sensation of *sensory pain* verse *affective pain*. Sensory pain seems to be of a higher order of pain since it is more resistant to treatment than affective pain (affective pain representing the psychiatric realm of disorders which make up a spectrum of common ailments in society)[188].

If the origin of the disorders were electromagnetic in nature as well, the ability not to sense electromagnetic changes in the environment and affect necessary corrective treatment may eventually be of dire consequence. One such environmental change purely magnetic in nature would be the reversal of the magnetic poles of the earth, even slight changes in the orientation of the earth could potentially have subversive effects since, as it has been shown, the more closely environmental patterns match natural brain patterns, the easier it is to affect it. Environmental patterns at the moment, natural and manmade, cover the brain's natural patterns as well as unnatural ones, the effects of which remain disputed.

4.1.10 Insomnia

There have been some remarkable results in the treatment of insomnia with electromagnetic fields. As discussed earlier, melatonin secreted by the pineal gland regulates sleeping and waking states constituting the circadian rhythm that works roughly on a 24 hour cycle. It would seem a logical step to see what effect electromagnetic stimulation might have on insomniacs.

In one study, 101 patients participated in a double blind, placebo-controlled trial where 50 received magnetic stimulation and 51 a placebo. "Seventy percent (n = 34) of the patients given active treatment experienced substantial or even complete relief of their complaints; 24% (n = 12) reported clear improvement; 6% (n = 3) noted a slight improvement. Only one placebo patient (2%) had very clear relief; 49% (n = 23) reported slight or clear improvement; and 49%

---

[187] Passard A, Attal N, Benadhira R, Brasseur L, Saba G, Sichere P, Perrot S, Januel D, Bouhassira D. 2007. Effects of unilateral repetitive transcranial magnetic stimulation of the motor cortex on chronic widespread pain in fibromyalgia. *Brain.* 130(Pt 10):2661-70

[188] "The **affective spectrum** is a grouping of related psychiatric and medical disorders which may accompany bipolar, unipolar, and schizoaffective disorders at statistically higher rates than would normally be expected. These disorders are identified by a common positive response to the same types of pharmacologic treatments. They also aggregate strongly in families and may therefore share common heritable underlying physiologic anomalies". (Investigate the link to see just how many disorders, http://en.wikipedia.org/wiki/Affective_spectrum)

(n = 23) saw no change in their symptoms. No adverse effects of treatment were reported."[189] If the cortical area of the pineal can be naturally or artificially modulated by electromagnetic current induction, it would open up the potential to control human biological cycles related to circadian rhythms, antioxidant activity, immune system functioning and even dreaming. Melatonin supplement users frequently report higher intensity and frequency of vivid dreaming as well as experiencing dramatically increased REM times.

[189] Pelka RB, Jaenicke C, Gruenwald J. 2001. Impulse magnetic-field therapy for insomnia: a double-blind, placebo-controlled study. *Adv Ther*. 18(4):174-80

4.2 Behaviour Modification

The means to affect behaviour can be done both directly and indirectly. The indirect method is mostly attributed to the modulation of sensory and cognitive ability or change in neurological condition which can eventually create a resulting behaviour, be it habitual or random. While this is the natural way to do it, the artificial way is much more direct.

This would entail applying TMS to specific regions in the brain and evoke a muscular movement elsewhere in the body. This is by no means an exact science yet, but the studies so far have shown some intriguing results.

Within the motor cortex of the brain the representation of all the different body parts or muscles overlap extensively. Likewise, within the body all the different muscle groups overlap and intertwine extensively as well. "This hampers the assessment of excitability in individual muscles with transcranial magnetic stimulation (TMS), even if so-called "focal" stimulating coils are used."[190]

It then becomes necessary to devise novel means to advance the science as shown in one study where researchers devise a unique "mapping paradigm based on high-density surface electromyography (HD-sEMG) to investigate the spatial selectivity of TMS in the forearm musculature." [191]

By mapping the brain's activity while the muscle is at rest and while it contracts, they are able to compare the 'motor evoked potential' (MEP) by the difference between the two maps. This is trickier than it sounds because the recording has to be made in the background against a foreground of biological signals and ambient noise. The researchers knew this so they also set out to test the hypothesis that "selective stimulation can be improved by a voluntary background contraction of the target muscle." [192]

From their study they found that "when standard EMG montages are used, the recorded MEPs are not necessarily evoked in the target muscle alone. Stimulation during a voluntary background contraction of the target muscle may enhance the selectivity of TMS. It however remains essential to use stimulus intensities as low as possible, to minimize the contribution of

---

[190] van Elswijk G, Kleine BU, Overeem S, Eshuis B, Hekkert KD, Stegeman DF. 2008. Muscle imaging: mapping responses to transcranial magnetic stimulation with high-density surface electromyography. *Cortex*. 44(5):609-16

[191] van Elswijk G, Kleine BU, Overeem S, Eshuis B, Hekkert KD, Stegeman DF. 2008. Muscle imaging: mapping responses to transcranial magnetic stimulation with high-density surface electromyography. *Cortex*. 44(5):609-16

[192] van Elswijk G, Kleine BU, Overeem S, Eshuis B, Hekkert KD, Stegeman DF. 2008. Muscle imaging: mapping responses to transcranial magnetic stimulation with high-density surface electromyography. *Cortex*. 44(5):609-16

surrounding non-target muscles to the MEP."[193] The results of the study give depth to the problem facing researchers in finding the best possible means to not only map the brain but to stimulate it as well. Unfortunately, the level of accuracy required for their intentions is beyond the reach of technology for the time being.

It seems the approach researchers are taking to studying the brain are just as novel as the results they are getting. Perhaps while the technology still has to refine itself the researchers are afforded the opportunity to creatively refine methods of investigation.

The following study is another novel attempt at diversifying the known means of TMS application. Researchers wanted to investigate the possibility of stimulating "both motor cortices during transcranial magnetic stimulation (TMS) to evoke abdominal muscle responses."[194] This is another binary variable of cortical activity initiated by TMS over the motor cortex. Cortical activity in that area seems to build up until a very specific point where the neural impulses cause a behavioural (physical) event. The amount of artificial stimulation required is measurable through TMS and known as the *motor threshold* of any particular muscle movement (measured as motor evoked potential on the muscle), such as abdominal flexes.

"Electromyographic activity (EMG) of transversus abdominis (TrA) was recorded bilaterally in eleven healthy volunteers using fine-wire electrodes. TMS at 120% motor threshold (MT) was delivered at rest and during 10% activation at 1cm intervals from the midline to 5 cm lateral, along a line 2 cm anterior to the vertex." [195]

Through the investigation it was found the optimal site to evoke responses in the specific abdominal muscle was 2cm lateral to the vertex[196]. "The findings suggest that stimulation of both motor cortices is possible when TMS is delivered less than 2 cm from midline. Concurrent stimulation of both motor cortices can be minimised if TMS is delivered at least 2 cm lateral to midline."[197]

---

[193] van Elswijk G, Kleine BU, Overeem S, Eshuis B, Hekkert KD, Stegeman DF. 2008. Muscle imaging: mapping responses to transcranial magnetic stimulation with high-density surface electromyography. *Cortex*. 44(5):609-16

[194] Tsao H, Galea MP, Hodges PW. 2008. Concurrent excitation of the opposite motor cortex during transcranial magnetic stimulation to activate the abdominal muscles. *J Neurosci Methods*. 171(1):132-9

[195] Tsao H, Galea MP, Hodges PW. 2008. Concurrent excitation of the opposite motor cortex during transcranial magnetic stimulation to activate the abdominal muscles. *J Neurosci Methods*. 171(1):132-9

[196] Crown of the head

[197] Tsao H, Galea MP, Hodges PW. 2008. Concurrent excitation of the opposite motor cortex during transcranial magnetic stimulation to activate the abdominal muscles. *J Neurosci Methods*. 171(1):132-9

Methods of investigation can become quite unconventional. In this study, the researchers decided to apply "structural equation modeling (SEM)... to positron emission tomographic (PET) images acquired during transcranial magnetic stimulation (TMS) of the primary motor cortex (M1(hand))."[198] What they hoped to avoid, using their SEM process, was the assumption of "connections in the form of an a priori model (confirmatory approach)"[199] It seems they were seeking to develop an approach that avoided the trial and error approach to investigation by devising a model-generating strategy to understanding the thresholds of the motor cortex.

TMS was applied across a range of intensities whereby "regions of interest (ROIs) were identified through an activation likelihood estimation (ALE) meta-analysis of TMS studies. That these ROIs represented the network engaged by motor planning and execution was confirmed by an ALE meta-analysis of finger movement studies."

The findings of the "regions and connections... were in good agreement with the known anatomy of the human and primate motor system. The model-generating SEM strategy thus proved highly effective and successfully identified a complex set of causal relationships of motor connectivity."[200] Definitely an 'outside in' versus an 'inside out' approach to the understanding of the brain which makes observations 'regional' and a 'likely estimate' however the creative direction of the approach is a necessity in this field of research right now.

So to is it necessary in the study of the functionality of the corticospinal[201] pathway. Naturally, TMS is the tool of choice and in this study a sinlge-pulsed TMS was used "at different intensities and during different levels of grasping force, to stimulate the hand area of the left primary motor cortex (M1)."[202]

The researchers then aimed to derive the TMS evoked forces or motor evoked forces (MEF) from a three fingered grasp, in conjunction with the conventional motor evoked potentials (MEP) from the forearm and hand muscles. By analysing the timing, amplitude and direction of

---

[198] Laird AR, Robbins JM, Li K, Price LR, Cykowski MD, Narayana S, Laird RW, Franklin C, Fox PT. 2008. Modeling motor connectivity using TMS/PET and structural equation modeling. *Neuroimage*. 41(2):424-36

[199] Laird AR, Robbins JM, Li K, Price LR, Cykowski MD, Narayana S, Laird RW, Franklin C, Fox PT. 2008. Modeling motor connectivity using TMS/PET and structural equation modeling. *Neuroimage*. 41(2):424-36

[200] Laird AR, Robbins JM, Li K, Price LR, Cykowski MD, Narayana S, Laird RW, Franklin C, Fox PT. 2008. Modeling motor connectivity using TMS/PET and structural equation modeling. *Neuroimage*. 41(2):424-36

[201] massive collection of axons that travel between the cerebral cortex of the brain and the spinal cord. (source: http://en.wikipedia.org/wiki/Corticospinal)

[202] Baud-Bovy G, Prattichizzo D, Rossi S. 2008. Contact forces evoked by transcranial magnetic stimulation of the motor cortex in a multi-finger grasp. *Brain Res Bull*. 75(6):723-36

the MEF's and MEP's they "found that the TMS evoked synergistic increases of the force magnitudes, akin to those observed when participants voluntarily increased the grip force. The MEF sizes and MEP amplitudes increased with TMS intensity in most cases. The grip force (which measures the overall force involved in the grasp) and the net force (which measures the net effect of all contact forces exerted on the object) seem to be differently affected by single TMS pulses of the motor cortex.[203]

The introduction of the MEF can therefore not be seen as an effective measurement in the understanding of the corticospinal functionality yet further results will ultimately prove the viability of this inventive approach.

In all studies related to the application of TMS in modulating human behaviour as a means to understand the brain, pioneering thought needs to be directed toward all aspects of research. This is especially necessary because of the lack of refinement in current technology to operate at the level required. More importantly though, if a comprehensive understanding of the brain is ever to be achieved within the foreseeable future, researchers need to be able to conjoin the traditions of conventional research with the innovative methods of contemporary science.

[203] Baud-Bovy G, Prattichizzo D, Rossi S. 2008. Contact forces evoked by transcranial magnetic stimulation of the motor cortex in a multi-finger grasp. *Brain Res Bull.* 75(6):723-36

4.3 Suppression or Facilitation of Cognition

So the question continues "Whither is knowledge created?"

So far, we are able to see the beginnings of an enquiry into the brains ability to transduce electromagnetic information with some extremely beneficial results. It seems our sense of this unconventional information reveals some rather unconventional effects. In this next section, we will be able to see just how the cognition can be affected by electromagnetic information in terms of:

- Memory and the different types:
    - Procedural, Working, Learning (declarative & non-declarative)
- Language
- Emotion

These are by no means an exhaustive list that makes up the "process of knowing"[204,205] but it will provide a good platform for insight. It might be argued that the sensory effect should be joined under cognition which is an agreeable point however, the proximity of sensory modulation to the central hypothesis allows it separate attention.

4.3.1 Memory

The mapping of cognition through the effects of TMS is not as straight forward as in the behavioural and therapeutic studies. Measurement is sometimes more quantitative and results more subjective than the conventional hard sciences. However, the potential for discovery is just as radical.

An interesting study into the facilitation of memory was completed while the patient was still asleep. It is noted that "during much of sleep, cortical neurons undergo near-synchronous slow oscillation cycles in membrane potential, which give rise to the largest spontaneous waves observed in the normal electroencephalogram (EEG). Slow oscillations underlie characteristic features of the sleep EEG, such as slow waves[206] and spindles[207]."[208]

---

[204] http://dictionary.reference.com/browse/cognition

[205] http://en.wiktionary.org/wiki/cognition

[206] made up of the two deepest stages of non-rapid eye movement sleep, and these two stages are often referred to as deep sleep (source: http://en.wikipedia.org/wiki/Slow-wave_sleep)

[207] a burst of brain activity visible on an EEG that occurs during stage 2 sleep. It consists of 12-16 Hz waves that occur for 0.5 to 1.5 seconds (source: http://en.wikipedia.org/wiki/Sleep_spindle)

[208] Massimini M, Ferrarelli F, Esser SK, Riedner BA, Huber R, Murphy M, Peterson MJ, Tononi G. 2007. Triggering sleep slow waves by transcranial magnetic stimulation. *Proc Natl Acad Sci U S A.* 104(20):8496-501

Slow waves and spindles are very unique features of the sleeping process both occurring in the different stages (there are 4 stages) of sleep but denominated by slow oscillation cycles. The researchers then decided to stimulate their sleeping patients with a TMS pulse and found that "slow waves and spindles can be triggered noninvasively and reliably... with appropriate stimulation parameters, each TMS pulse at <1 Hz evokes an individual, high-amplitude slow wave that originates under the coil and spreads over the cortex." [209]

The value of creating an individual, high amplitude slow wave is that it will lead to a "deepening of sleep and to an increase in EEG slow-wave activity (0.5-4.5 Hz), which is thought to play a role in brain restoration and memory consolidation."[210]

This provides conclusive evidence that brain activity can be modified during sleep but does little to convince us that it can facilitate cognition in a significant way. Two interesting implication are mentioned about,

- brain restoration and
- memory consolidation[211]

which are thought to occur during slow wave activity. Those are fairly big claims so let's first consider the evidence in terms of memory consolidation.

The problem with slow oscillation cycles (also known as brain potentials), which primarily arise from the prefrontal neocortex, is that they are commonly considered "to be mere epiphenomena that reflect synchronized activity arising from neuronal networks, which links the membrane and synaptic processes of these neurons in time. Whether brain potentials and their extracellular equivalent have any *physiological meaning* per se is unclear, but can easily be investigated by inducing the extracellular oscillating potential fields of interest." [212] The shortcoming of this study was its inability to conclusively argue the physiological meaning of inducing brain potentials.

In this study though, through the application of TMS, the researchers showed that the induction of slow oscillation potential fields during "early nocturnal non-rapid-eye-movement sleep, that

---

[209] Massimini M, Ferrarelli F, Esser SK, Riedner BA, Huber R, Murphy M, Peterson MJ, Tononi G. 2007. Triggering sleep slow waves by transcranial magnetic stimulation. *Proc Natl Acad Sci U S A.* 104(20):8496-501

[210] Massimini M, Ferrarelli F, Esser SK, Riedner BA, Huber R, Murphy M, Peterson MJ, Tononi G. 2007. Triggering sleep slow waves by transcranial magnetic stimulation. *Proc Natl Acad Sci U S A.* 104(20):8496-501

[211] broadly defined, is the process by which recent memories (short-term memories) are crystallised into long-term memory (source: http://en.wikipedia.org/wiki/Memory_consolidation)

[212] Marshall L, Helgadóttir H, Mölle M, Born J. 2006. Boosting slow oscillations during sleep potentiates memory. *Nature.* 444(7119):610-3

is, a period of emerging slow wave sleep, enhances the retention of hippocampus-dependent declarative memories in healthy humans."[213]

To reinforce their finding the researchers also used a different frequency of TMS associated with rapid eye movement sleep and found it to decrease slow oscillations and leave declarative memory unchanged. The evidence is clear that "endogenous slow potential oscillations have a causal role in the sleep-associated consolidation of memory, and that this role is enhanced by field effects in cortical extracellular[214] space."[215]

In a further study, these results were confirmed and in both studies they used a similar means to test declarative memory. Both studies used word pairs to test declarative memory and also used mirror tracing skills to test non-declarative memory, each of which was learned prior to a period of electromagnetic stimulation. Each task was "tested after this period and compared with retention performance after placebo stimulation as well as after retention intervals of wakefulness. Compared with placebo stimulation, anodal tDCS[216] during SWS-rich sleep distinctly increased the retention of word pairs ($p < 0.005$). When applied during the wake retention interval, tDCS did not affect declarative memory. Procedural memory was also not affected by tDCS. Mood was improved both after tDCS during sleep and during wake intervals." [217] Interesting that mood would be affected but it perhaps was not a completely objective measurement since the goal of the study was to test memory.

A comprehensive result nonetheless, giving good evidence that electromagnetic stimulation enhances the "generation of slow oscillatory EEG activity considered to facilitate the processes of neuronal plasticity."[218] In this case, neuronal plasticity refers to the process whereby "shifts

---

[213] Marshall L, Helgadóttir H, Mölle M, Born J. 2006. Boosting slow oscillations during sleep potentiates memory. *Nature*. 444(7119):610-3

[214] "In cell biology, molecular biology and related fields, the word **extracellular** (or sometimes **extracellular space**) means "outside the cell". This space is usually taken to be outside the plasma membranes, and occupied by fluid. The term is used in contrast to intracellular (inside the cell). The composition of the extracellular space includes metabolites, ions, proteins, and many other substances that might affect cellular function. For example, neurotransmitters "jump" from cell to cell to facilitate the transmission of an electric current in the nervous system." (source: http://en.wikipedia.org/wiki/Extracellular)

[215] Marshall L, Helgadóttir H, Mölle M, Born J. 2006. Boosting slow oscillations during sleep potentiates memory. *Nature*. 444(7119):610-3

[216] TMS allows neurostimulation and neuromodulation, while tDCS is a purely neuromodulatory application. (source: Marshall L, Helgadóttir H, Mölle M, Born J. 2006. Boosting slow oscillations during sleep potentiates memory. *Nature*. 444(7119):610-3)

[217] Marshall L, Helgadóttir H, Mölle M, Born J. 2006. Boosting slow oscillations during sleep potentiates memory. *Nature*. 444(7119):610-3

[218] Marshall L, Helgadóttir H, Mölle M, Born J. 2006. Boosting slow oscillations during sleep potentiates memory. *Nature*. 444(7119):610-3

in extracellular ionic concentration in frontocortical tissue... facilitate sleep-dependent consolidation of declarative memories."[219]

Referring back to the claim made about TMS's ability to cause brain restoration, Dr. Agatino Battaglia has confirmed in his research that "TMS enhanced LTP [long term potentiation[220]] in all areas of the brain tested, by modifying key glutamate receptors so that they stayed active for longer. The team also saw large increases in the proliferation of stem cells in the dentate gyrus hippocampus. These cells divide throughout life and are now believed to play a crucial role in memory and mood regulation." [221]

Battaglia noted that the "effect on the stem cells is the most exciting finding," and he has already presented his result at the American Academy of Neurology in Boston to highlight his recent discovery. It symbolises a remarkable period in neurology because of the difficulty in accurately stimulating stem cell growth. It is known that physical activity and a few antidepressants can achieve neuron growth but nothing as precise as what can be achieved with TMS.

The stimulation of the brain during sleep to facilitate declarative and non declarative memory is quite different compared to memory modulation in conscious patients. The manner of stimulation used on sleeping patients was a global single pulse that affected the entire brain as opposed to a focal point of interest.

What is necessary then to affect the conscious facilitation of memory is the induction of reversible TMS induced lesions that will "allow for the precise temporal and spatial dissection of the brain processes underlying learning and remembering" [222] which will provide for the basic functional maps of cognition. Consequently, once the maps are detailed, "repetitive TMS (rTMS) appears necessary to affect most cognitive processes in measurable ways" [223] as opposed to single pulse TMS.

---

[219] Marshall L, Helgadóttir H, Mölle M, Born J. 2006. Boosting slow oscillations during sleep potentiates memory. *Nature*. 444(7119):610-3

[220] In neuroscience, **long-term potentiation** (**LTP**) is the long-lasting improvement in communication between two neurons that results from stimulating them simultaneously.[1] Since neurons communicate via chemical synapses, and because memories are believed to be stored within these synapses,[2] LTP and its opposing process, long-term depression, are widely considered the major cellular mechanisms that underlie learning and memory (source: http://en.wikipedia.org/wiki/Long_term_potentiation)

[221] Linda G. 2007. Magnets bolster neural connections. *New Scientist*. 194(2605):14-5

[222] Grafman J, Wassermann E. 1999. Transcranial magnetic stimulation can measure and modulate learning and memory. Neuropsychologia. 37(2):159-67

[223] Grafman J, Wassermann E. 1999. Transcranial magnetic stimulation can measure and modulate learning and memory. Neuropsychologia. 37(2):159-67

The evidence so far indicates that rTMS may "have the capability of facilitating various aspects of memory performance. From a research perspective rTMS has demonstrated site- and time-specific effects primarily in interfering with explicit retrieval of episodic information from long-term memory. rTMS may also be able to modulate retrieval from semantic memory as evidenced by response-time and accuracy changes after rTMS." [224]

The evidence in terms of the effect of TMS on declarative and non-declarative memory is frequently the result of application on verbal and non-verbal memory encoding, naturally verbal being equivalent to declarative memory and non-verbal to non-declarative memory. Previous studies indicated a "differential contribution of prefrontal cortex (PFC) to successful encoding depending on the stimulus material."[225]

In the following study, researchers used an "experimental design that evaluated encoding of both words and abstract shapes in the same healthy volunteers. A transient virtual lesion of the left or the right PFC was elicited with transcranial magnetic stimulation (TMS) while subjects memorized verbal and nonverbal items. We found that encoding of verbal material was disrupted by left PFC stimulation, whereas encoding of nonverbal material was disrupted by right PFC stimulation. These results demonstrate a functionally relevant lateralization of prefrontal contribution for verbal and nonverbal memory encoding."[226]

So, from these results it is clear that there are suppressive effects of TMS on declarative/non-declarative memory. When it comes to the facilitation of memory, there are studies that report a fairly unique declarative memory benefit through the use of TMS. In particular, the researchers were looking at phonologically similar word groups (eg mell, gell, rell) as more difficult to remember, likely because they create a mutual interference coming from the same phonetical word store in memory.

"Low-frequency transcranial magnetic stimulation (TMS), guided by functional magnetic resonance imaging (fMRI) was used to disrupt this phonological confusion by stimulation of the left inferior parietal (LIP) lobule. Subjects received TMS or placebo stimulation while remembering sets of phonologically similar or dissimilar pseudo-words. Consistent with behavioural performance of patients with neurological damage, memory for phonologically

---

[224] Grafman J, Wassermann E. 1999. Transcranial magnetic stimulation can measure and modulate learning and memory. Neuropsychologia. 37(2):159-67

[225] Floel A, Poeppel D, Buffalo EA, Braun A, Wu CW, Seo HJ, Stefan K, Knecht S, Cohen LG. 2004. Prefrontal cortex asymmetry for memory encoding of words and abstract shapes. *Cereb Cortex*. 14(4):404-9

[226] Floel A, Poeppel D, Buffalo EA, Braun A, Wu CW, Seo HJ, Stefan K, Knecht S, Cohen LG. 2004. Prefrontal cortex asymmetry for memory encoding of words and abstract shapes. *Cereb Cortex*. 14(4):404-9

similar, but not dissimilar, items was enhanced following TMS relative to placebo stimulation."[227]

Somehow, TMS influences a cognitive mechanism enabling us to remember words with similar phonetics. The mechanism thereby reduces "phonological confusion and leads to facilitation of phonological memory"[228] thereby enhancing declarative memory.

If we now turn our attention to the facilitation of working memory[229] through TMS, the research is very encouraging so far. Researchers utilised a "delayed match-to-sample task[230]... in which repetitive TMS (rTMS) at 1, 5, or 20 Hz was applied to either left dorsolateral prefrontal or midline parietal cortex during the retention (delay) phase of the task."[231]

The results showed that stimulation to the parietal area during retention phase actually managed to significantly increase response speed without a corresponding decrease in accuracy. Stimulation of the dorsolateral prefrontal had no effect. The results were replicated even when stimulation was administered during different phases of the task but the most significant effect was achieved during the retention phase. The evidence suggests that "TMS may improve working memory performance, in a manner that is specific to the timing of stimulation relative to performance of the task, and to stimulation frequency."[232] Understanding the correct phase to apply stimulation as well as the most beneficial frequency to facilitate performance is therefore the key to unlocking not only the door to memory facilitation/suppression, but total cognitive performance.

The disruption of working memory is also very possible with TMS. The following study targets the prefrontal cortex and posterior regions of association cortex (e.g. the inferior temporal lobes) in order to "investigate the potential role of primary somatosensory cortex (SI) in a working memory task with tactile stimuli. Subjects were required to compare the frequencies of

---

[227] Kirschen MP, Davis-Ratner MS, Jerde TE, Schraedley-Desmond P, Desmond JE. 2006. Enhancement of phonological memory following transcranial magnetic stimulation (TMS). *Behav Neurol.* 17(3-4):187-94

[228] Kirschen MP, Davis-Ratner MS, Jerde TE, Schraedley-Desmond P, Desmond JE. 2006. Enhancement of phonological memory following transcranial magnetic stimulation (TMS). *Behav Neurol.* 17(3-4):187-94

[229] A theoretical construct within cognitive psychology that refers to the structures and processes used for temporarily storing and manipulating information (source: http://en.wikipedia.org/wiki/Working_memory)

[230] An example of a task: "a monkey might be presented with a field of four dots, and is required to keep that in memory after the display is taken away. Then, after a delay period of several seconds, a second display is presented. If the number on the second display match that from the first, the monkey has to release a lever." (source: http://en.wikipedia.org/wiki/Numerical_cognition)

[231] Luber B, Kinnunen LH, Rakitin BC, Ellsasser R, Stern Y, Lisanby SH. 2007. Facilitation of performance in a working memory task with rTMS stimulation of the precuneus: frequency- and time-dependent effects. *Brain Res.* 1128(1):120-9

[232] Luber B, Kinnunen LH, Rakitin BC, Ellsasser R, Stern Y, Lisanby SH. 2007. Facilitation of performance in a working memory task with rTMS stimulation of the precuneus: frequency- and time-dependent effects. *Brain Res.* 1128(1):120-9

two vibrations separated by a retention interval of 1500 msec. Their performance was significantly disrupted when we delivered a pulse of transcranial magnetic stimulation (TMS) to the contralateral SI early (300 or 600 msec) in the retention interval." [233]

So it appears that the primary somatosensory cortex has a role to play "not only as a center for on-line sensory processing but also as a transient storage site for information that contributes to working memory."[234]

In a similar study the researchers decided to target a nearby region of the brain on one side i.e. the left dorsolateral prefrontal cortex (LDLPFC) using TMS. They applied "double-pulse TMS having a 100-ms inter-pulse interval to LDLPFC immediately after the subjects finished reading the sentences of the reading span test (RST) task, an efficient measure of verbal working memory, in which dual tasks that include both sentence comprehension and word maintenance are required. Using eight normal participants... [the researchers] found a significant deterioration of performance, i.e., decreased number of correctly reported words, in RST due to TMS stimulation of LDLPFC. Evidence suggests that transient functional disruption of the LDLPFC impairs performance in the maintenance processing of the RST task." [235]

So by targeting a slightly different brain region using a double pulse versus single pulse TMS achieved a similar effect on working memory. In addition, there seem to be numerous tasks involving the use of working memory to test subjects with which makes TMS's effect on working memory an expansive area of research.

4.3.2 Language

The understanding of language has been well assisted by the introduction of TMS technology. From the identification of the language areas in the brain to the expression of language as a function of the brain, TMS can result in either "inhibition or facilitation of language processes

---

[233] Harris JA, Miniussi C, Harris IM, Diamond ME. 2002. Transient storage of a tactile memory trace in primary somatosensory cortex. *J Neurosci.* 22(19):8720-5

[234] Harris JA, Miniussi C, Harris IM, Diamond ME. 2002. Transient storage of a tactile memory trace in primary somatosensory cortex. *J Neurosci.* 22(19):8720-5

[235] Osaka N, Otsuka Y, Hirose N, Ikeda T, Mima T, Fukuyama H, Osaka M. 2007. Transcranial magnetic stimulation (TMS) applied to left dorsolateral prefrontal cortex disrupts verbal working memory performance in humans. *Neurosci Lett.* 18;418(3):232-5

and may operate directly at a presumptive site of language cortex or indirectly through intracortical networks."[236]

Studies on participants have shown that "rapid-rate TMS over the left inferior frontal region blocks speech output in most subjects. However, the results are not those predicted from classic models of language organization. Speech arrest is obtained most easily over facial motor cortex, and true aphasia[237] is rare, whereas right hemisphere or bilateral lateralization is unexpectedly prominent."[238]

It's interesting that TMS can offer insight into the functioning of the brain that differs from the predictions of the classic models of language organisation. It may be seen as metaphorical to the development in understanding of human anatomy. Hippocrates is the forefather of modern medicine and yet in his time it was forbidden to dissect a human body, even when dead. The functioning of the body was based on theory and models, most of which disproven through development in technologies allowing detailed observation of the anatomy. Perhaps TMS will do for our understanding of the brain as the simple act of dissection did for the understanding of the human body.

The effect of TMS to suppress the ability of speech can be seen as the induction of non-fluent (expressive) aphasia , the same type of disorder suffered by stroke patients after specific regions die due to lack of blood supply. Clearly, the regions inducing speech arrest are the same regions that deteriorate in stroke patients.

What should also be considered when blocking the capacity to speak overtly (speech arrest, SA) is if it also affects the cognitive ability to speak covertly (internal speech). The following study was conducted to investigate the issue through two experiments using rTMS. In the first experiment, the researchers "stimulated two left frontal lobe sites. The first was a motor site (left posterior site) and the second was a nonmotor site located in correspondence to the posterior part of the inferior frontal gyrus (IFG) (left anterior site). The corresponding right hemisphere nonmotor SA site was stimulated as a control.

In the second experiment, [the reseraxchers] focused on the right hemisphere and stimulated a right hemisphere motor site (right posterior site), and, as control sites, a right hemisphere

---

[236] Epstein CM. 1998. Transcranial magnetic stimulation: language function. *J Clin Neurophysiol.* 15(4):325-32

[237] Selective impairments in reading, writing, or the recognition of words. These disorders may be quite selective. For example, a person is able to read but not write, or is able to write but not read (source: http://en.wikipedia.org/wiki/Aphasia#Fluent.2C_non-fluent_and_.22pure.22_aphasias)

[238] Epstein CM. 1998. Transcranial magnetic stimulation: language function. *J Clin Neurophysiol.* 15(4):325-32

nonmotor site corresponding to the IFG (right anterior site) and a left hemisphere anteromedial site (left control)."[239] So, the purpose of the two experiments was to compare the effect by location of the stimulus either over the right hemisphere or the left hemisphere.

In order to measure the effect on participants the researchers asked them to perform a syllable counting task. "Longer latencies in this task imply the occurrence of an overt and/or covert SA. All participants showed significantly longer latencies when stimulation was either over the left posterior or the left anterior site, as compared with the right hemisphere site (Experiment 1). This result was observed for the overt and covert speech task alike. During stimulation of the posterior right hemisphere site, a dissociation for overt and covert speech was observed. An overt SA was observed but there was no evidence for a covert SA (Experiment 2). Taken together, the results show that rTMS can induce a covert SA when applied to areas over the brain that are pertinent to language. Furthermore, both the left posterior/motor site and the left anterior/IFG site appear to be essential to language elaboration even when motor output is not required."[240]

This shows for an interesting example on disagreement with the classic theoretical functioning of the brain. Why would the so called 'motor' regions of the brain influence the purely mental task of covert speech? The definition of the brain by absolute functions such as 'motor' may soon be a notion of the past. Concepts such as brain plasticity will be useful in navigating this new understanding of the brain.

The therapeutic significance of inducing speech arrest remains unknown yet its value purely as an effect on consciousness is intriguing. What has been shown to be significant is the use of TMS on stroke victims to alleviate non-fluent aphasia (ability to produce speech).

As we know verbal memory and non-verbal memory are directly disrupted by stimulation of the left and right prefrontal cortex respectively. In addition, "numerous TMS studies have demonstrated facilitation of language-related tasks, including oral word association, story recall, digit span, and picture naming. Conversely, speech output also facilitates motor responses to TMS in the dominant hemisphere. Such new and often-unexpected findings may provide important insights into the organization of language."[241] TMS has already refuted the

---

[239] Aziz-Zadeh L, Cattaneo L, Rochat M, Rizzolatti G. 2005. Covert speech arrest induced by rTMS over both motor and nonmotor left hemisphere frontal sites. *J Cogn Neurosci.* 17(6):928-38

[240] Aziz-Zadeh L, Cattaneo L, Rochat M, Rizzolatti G. 2005. Covert speech arrest induced by rTMS over both motor and nonmotor left hemisphere frontal sites. *J Cogn Neurosci.* 17(6):928-38

[241] Epstein CM. 1998. Transcranial magnetic stimulation: language function. *J Clin Neurophysiol.* 15(4):325-32

classical modes of language organisation by offering practical information on the function of speech arrest; it can be assumed that the majority of the new discoveries surrounding electromagnetic stimulation will attest traditional ideas on much of commonly accepted neurological theory.

In the following study of the language related task, researchers wished to examine the effect of rTMS on the naming of pictures with healthy patients. In fifteen right handed male individuals "rTMS trains of 20 Hz with a duration of 2 seconds and an intensity of 55% of maximum stimulator output were delivered either to Wernicke's area, to the right-hemisphere homologue of Wernicke's area, to Broca's area, or to the primary visual cortex. Twenty black-and-white line drawings, which the individuals had to name as quickly as possible, were shown immediately after the completion of rTMS and again 2 minutes later."[242]

The results showed that directly after the application of the rTMS to the Wernicke's area patients showed a significant increase in response speed to the naming of the pictures as compared to those who received no rTMS. "No significant effects on picture naming were observed 2 minutes later or at any time after stimulation of the right-hemisphere homologues of Wernicke's area, Broca's area, or the visual cortex. Conclusion: Repetitive transcranial magnetic stimulation over Wernicke's area leads to a brief facilitation of picture naming by shortening linguistic processing time."[243] It's curious that the facilitation would be so brief when the nature of rTMS is to induce long lasting effects after the application. In the study done on the stroke patients, the effects lasted much longer thereby making it an effective therapy which makes for a peculiar difference in results.

4.3.3 Emotion

Not much is known in terms of specific brain regions responsible for emotional responses to TMS, what has been demonstrated so far in electrical stimulation in animals is "cerebellar[244] connectivity to brain structures involved in cognitive and emotive functions. Human

---

[242] Mottaghy FM, Hungs M, Brügmann M, Sparing R, Boroojerdi B, Foltys H, Huber W, Töpper R. 1999. Facilitation of picture naming after repetitive transcranial magnetic stimulation. *Neurology*. 10;53(8):1806-12

[243] Mottaghy FM, Hungs M, Brügmann M, Sparing R, Boroojerdi B, Foltys H, Huber W, Töpper R. 1999. Facilitation of picture naming after repetitive transcranial magnetic stimulation. *Neurology*. 10;53(8):1806-12

[244] is a region of the brain that plays an important role in the integration of sensory perception and motor control. (source: http://en.wikipedia.org/wiki/Cerebellar)

electrophysiological data to support cerebellum involvement in the latter functions are however lacking." [245]

To investigate the matter a study was conducted where responses "were recorded to single-pulse transcranial magnetic stimulation (TMS) over the vermis[246] in healthy human volunteers. Increased theta activity was observed after single-pulse vermis TMS as compared to sham and occipital TMS." [247]

The relevance of "theta oscillations are with respect to emotion (Snider and Maiti, 1976; Heath et al., 1978; Inanaga, 1998;Schmahmann, 2000; Aftanas and Golocheikine, 2001; Hyman et al.,2005) and memory (Vertes et al., 2001; Başar, 2005; Onton et al.,2005; Pape et al., 2005) associated with the septo–hippocampal complex. There is an extensive line of animal research by McNaughton and Gray that has established the link between the septo–hippocampal complex and theta activity in relation to anxiety and behavioral inhibition (for a review, see McNaughton and Gray,2000). Human research has shown that changes in theta activity are linked to emotional information processes"[248]

It difficult to determine if the evidence is conclusive but as a matter of interest, the exact functioning of human emotion is not fully understood in neurological terms, it would therefore be difficult to measure scientifically. To know that it is affected by electromagnetic stimulation is even more difficult.

However, from the research so far, what can be said with fair confidence is that electromagnetic stimulation demonstrates the "cerebellar involvement in the modulation of the core frequencies related to cognitive and emotive aspects of human behavior."[249]

Alternatively, a study was performed to test for the induction of side specific mood changes with rTMS targeting the bilateral prefrontal cortex. The finding showed "significant improvements with TMS for performance in the digit symbol substitution and verbal fluency tests, but no change of mood on a number of measures. There was also a reduction of pulse rate

---

[245] Schutter DJ, van Honk J. 2006. An electrophysiological link between the cerebellum, cognition and emotion: frontal theta EEG activity to single-pulse cerebellar TMS. *Neuroimage*. 33(4):1227-31

[246] a narrow, wormlike structure between the hemispheres of the cerebellum... It is the site of termination of the spinocerebellar pathways that carry subconscious proprioception (source: http://en.wikipedia.org/wiki/Vermis)

[247] Schutter DJ, van Honk J. 2006. An electrophysiological link between the cerebellum, cognition and emotion: frontal theta EEG activity to single-pulse cerebellar TMS. *Neuroimage*. 33(4):1227-31

[248] Schutter DJ, van Honk J. 2006. An electrophysiological link between the cerebellum, cognition and emotion: frontal theta EEG activity to single-pulse cerebellar TMS. *Neuroimage*. 33(4):1227-31

[249] Schutter DJ, van Honk J. 2006. An electrophysiological link between the cerebellum, cognition and emotion: frontal theta EEG activity to single-pulse cerebellar TMS. *Neuroimage*. 33(4):1227-31

after TMS. The only side-specific TMS-effect was on mean arterial pressure, which decreased pressure after left, but not after right prefrontal TMS." [250] That's actually positive results in terms of the safety factor in using TMS (side effects minimal), it also significant in the cognitive facilitation of language related task such as digit symbol substitution and verbal fluency but unfortunately no confirmation on emotion modulation.

To test the effect of TMS on mood improvement, a study was conducted within a "double-blind and placebo-controlled setting on 18 healthy subjects. At the same time an established learned helplessness paradigm was applied to induce dysphoria[251], which consisted of unsolvable anagrams... stimuli were applied to the right or to the left frontal cortex, or on the occipital cortex as a placebo condition... TMS on either of the two frontal locations did not influence mood."[252] Once again the stimulation over the frontal cortex yielded no effect on mood.

Even though mood may be considered an emotional state[253], it seems emotions are more specific, more intense and more likely to be triggered by specific events and it seems in this case, more than likely triggered by a different area of the brain to moods. Nonetheless this area of research is lacking in conclusive evidence to support the notion that TMS affects emotions yet it seems this might be in the difficulty in finding effective measurement tools when trying to objectively define emotional responses. Progress in that area of scientific investigation might reveal more substantial evidence.

---

[250] Jenkins J, Shajahan PM, Lappin JM, Ebmeier KP. 2002. Right and left prefrontal transcranial magnetic stimulation at 1 Hz does not affect mood in healthy volunteers. *BMC Psychiatry*. 2:1

[251] generally characterized as an unpleasant or uncomfortable mood, such as sadness (depressed mood), anxiety, irritability, or restlessness (source: http://en.wikipedia.org/wiki/Dysphoria)

[252] Habel U, Wild B, Topka H, Kircher T, Salloum JB, Schneider F. 2001. Transcranial magnetic stimulation: no effect on mood with single pulse during learned helplessness. *Prog Neuropsychopharmacol Biol Psychiatry*. 25(3):497-506

[253] http://en.wikipedia.org/wiki/Mood_%28psychology%29

4.4 Modulation of Sensory Perception

To examine the modulation of sensation possible by electromagnetic stimulation, it is necessary to consider *all* the senses. One commonly recognised classification system that includes all the human senses is:

- Chemoreception – taste, smell
  - the physiological response of an organism or sense organ to a chemical stimulus[254]
- Photoreception - sight
  - the perception, absorption, and use of light, e.g. for vision in animals or photosynthesis in plants[255]
- Mechanoreception – hearing, touch
  - a sensory receptor of a nerve that responds to pressure, vibration, or another mechanical stimulus[256]
- Thermoception – temperature
  - the sense by which an organism perceives temperature[257]
- Proprioception – movement
  - a sensory nerve ending in muscles, tendons, and joints that provides a sense of the body's position by responding to stimuli from within the body[258]
- Nociception – pain
  - the perception of physical pain[259]
- Equilibrioception – balance (direction, speed, acceleration)
  - sense of balance is one of the physiological senses. It helps prevent humans and animals from falling over when walking or standing still.[260]

---

[254] http://encarta.msn.com/dictionary_/chemoreception.html

[255] http://encarta.msn.com/dictionary_/Photoreception.html

[256] http://encarta.msn.com/dictionary_/mechanoreception%2520.html

[257] http://en.wikipedia.org/wiki/Thermoception

[258] http://encarta.msn.com/dictionary_1861736463/proprioceptor.html

[259] http://encarta.msn.com/dictionary_/Nociception%2520.html

[260] http://en.wikipedia.org/wiki/Equilibrioception

4.4.1 Smell/Taste

What is relevant to the modulation of this sense is within the results of a study conducted by Dr Persinger shown on page 39, here Dr Persinger lists one of the potential experiences of receiving TMS to be either an "odd smell" or an "odd taste".

The results show that a small percentage of the volunteers actually experienced an odd smell or odd taste which leads to the possibility that TMS may have the potential to affect these sensory systems. Further research is needed to bring about conclusive evidence in this regard.

4.4.2 Sight

Sight is probably one of the most commonly used senses on a daily basis which makes the available research on it quite abundant. Some of the "earliest applications of TMS have been directed toward the investigation of human visual perception. For example, a strong TMS pulse delivered to the occipital cortex in a sighted or even blind individual can evoke the sensation of perceiving light (visual phosphenes).

TMS can also be used to suppress visual perception and investigate the timing of visual information processing. Furthermore, the functional connectivity between different brain areas can be mapped using TMS, thus establishing a causal link between visual cortical function and visual perception."[261] So the investigation into the mechanics of visual perception has been greatly assisted with the introduction of TMS technology.

The measurable effects of electromagnetic stimulation on the visual cortex are quite diverse. This diversity is best understood with the neural mechanics of the effect firmly in mind. The information processing ability of the cerebral cortex can be seen as a measurement of the membrane potential[262] of all the neurons and spike sequences in the emission of brain waves.

Both of these measurements can be directly influenced through external modulation by either TMS or TDS (Transcranial Direct Current). "These methods induce reversible circumscribed cortical excitability changes, either excitatory or inhibitory, outlasting stimulation in time...

---

[261] Merabet LB, Theoret H, Pascual-Leone A. 2003. Transcranial magnetic stimulation as an investigative tool in the study of visual function. *Optom Vis Sci.* 80(5):356-68

[262] "is the electrical potential difference (voltage) across a cell's plasma membrane. The plasma membrane surrounds the cell to provide a stable environment for biological processes. Membrane potential arises from the action of ion transporters embedded in the membrane which maintain viable ion concentrations inside the cell. The term "membrane potential" is sometimes used interchangeably with cell potential but is applicable to any lipid bilayer or membrane. The membrane potential of most cells is kept relatively stable. Unlike most cells, neurons are specialized to use changes in membrane potential for fast communication, primarily with other neurons. When a neuron fires, the action potential travels down the axon to the synapses: the magnitude of the axonal membrane potential varies dynamically along its length. On reaching a (chemical) synapse, a neurotransmitter is released causing a localized change in potential in the membrane of the target neuron by opening ion channels in its membrane" (source: http://en.wikipedia.org/wiki/Membrane_potential)

Whereas rTMS induces externally triggered changes in the neuronal spiking pattern and interrupts or excites neuronal firing in a spatially and temporally restricted fashion, tDCS modulates the spontaneous firing rates of neurons by changing resting-membrane potential." [263] So the fundamental change caused by both techniques is the rate of neuron firing, that being the quintessential dynamic allowing for all measurable effects.

Determining the thresholds of neuron firing is key to understanding the measurable effects. As it has been shown the "easiest and most common way of evaluating the cortical excitability changes is by applying TMS to the motor cortex, since it allows reproducible quantification through the motor-evoked potential. Threshold determinations at the visual cortex or psychophysical methods usually require repeated and longer measurements and thus more time for each data set."[264]

So, what has been derived from the measurements so far on the changes to visual perception include "contrast as well as motion detection and visuo-motor coordination" [265] all of which are researched and interpreted within the field of visual psyhophysics.

These functions of perception can either be facilitated or suppressed by external modulation depending on the threshold levels of activity in the specific region of interest. When TMS as targeted "over the motion selective region V5/MT[266] during a simple motion-detection task, subjects' motion-detection ability was impaired. Similarly, suppression of V5/MT activity using off-line 1 Hz repetitive TMS (rTMS) disrupted performance in a subsequent motion-detection task. However, paradoxically, on-line V5/MT TMS had a facilitatory effect on motion detection if V5/MT had been suppressed by off-line 1-Hz rTMS prior to the motion-detection task."[267]

The results of this study indicate the importance of neuron firing thresholds. It seems that the suppression of neural firing using offline[268] rTMS on the V5/MT will disrupt motion detection

---

[263] Antal A, Paulus W. 2008.Transcranial direct current stimulation and visual perception. *Perception*. 37(3):367-74

[264] Antal A, Paulus W. 2008.Transcranial direct current stimulation and visual perception. *Perception*. 37(3):367-74

[265] Antal A, Paulus W. 2008.Transcranial direct current stimulation and visual perception. *Perception*. 37(3):367-74

[266] **Visual area V5**, also known as **visual area MT** (middle temporal), is a region of extrastriate visual cortex that is thought to play a major role in the perception of motion, the integration of local motion signals into global percepts and the guidance of some eye movements. (source: http://en.wikipedia.org/wiki/Visual_cortex)

[267] Silvanto J, Cattaneo Z, Battelli L, Pascual-Leone A. 2008. Baseline cortical excitability determines whether TMS disrupts or facilitates behavior. *J Neurophysiol*. 99(5):2725-30

[268] where performance at a task is measured initially and then repetitive TMS is given over a few minutes, and the performance is measured again. (source: http://en.wikipedia.org/wiki/Transcranial_magnetic_stimulation)

and yet if the suppression of that same area is followed by online[269] TMS it serves to facilitate motion detection. The change in suppressed state after the first stimulation, with the subsequent stimulation, created the facilitation effect thereby highlighting the importance of the "initial activation state of the targeted neural population."[270] In other words, however active the neuron was before it is stimulated will determine the effect of the stimulation, in this case suppressive stimulation decreased the activity level of the target neural population and then subsequent online stimulation led to a facilitative effect.

The following study examined the perceptual functions of "object identification and the ability to interpret object orientation, using transcranial magnetic stimulation (TMS) to momentarily interfere with ongoing cortical activity. Short trains of TMS pulses (12 Hz) were applied to a site overlying the right intraparietal sulcus/inferior parietal lobe while subjects performed either object identification tasks (i.e., picture-word verification and categorizing objects as natural or manufactured) or object orientation judgment tasks (i.e., picture-arrow verification and deciding whether an object was rotated clockwise or counterclockwise)." [271]

The results showed that that TMS to the right parietal suppressed judgments in orientation, but facilitated the identification of objects (compared to a control group were TMS was applied to the brain vertex). "These complementary findings demonstrate that the right parietal lobe--a region belonging to the dorsal visual stream[272]--is critical for processing the spatial attributes of objects, but not their identity. The observed improvement in object recognition, however, suggests an indirect role for the right parietal lobe in object recognition."[273]

The direct role of the parietal lobe in object attributes and indirect role in object identification is a poorly understood neural mechanism that requires more research yet the results TMS effect on sight speak for themselves. From the suppression of sight the creation of light (phosphenes, even in blind patients) and then to the modulation of normal perception in various ways, the

---

[269] where subjects perform the task and at a specific timepoint (usually in the order of 1-200ms) of the task, a TMS pulse is given to a particular part of the brain. This should affect the performance of the task specifically, and thus demonstrate that this task involves this part of the brain at this particular time point. (source: http://en.wikipedia.org/wiki/Transcranial_magnetic_stimulation)

[270] Silvanto J, Cattaneo Z, Battelli L, Pascual-Leone A. 2008. Baseline cortical excitability determines whether TMS disrupts or facilitates behavior. *J Neurophysiol.* 99(5):2725-30

[271] Harris IM, Benito CT, Ruzzoli M, Miniussi C. 2008. Effects of right parietal transcranial magnetic stimulation on object identification and orientation judgments. J Cogn Neurosci. 20(5):916-26

[272] is a pathway for visual information which flows through the visual cortex, the part of the brain which provides visual processing. It is involved in spatial awareness: recognizing where objects are in space. The dorsal stream is one of two main pathways of the visual cortex, the other being the ventral stream (source: http://en.wikipedia.org/wiki/Dorsal_stream)

[273] Harris IM, Benito CT, Ruzzoli M, Miniussi C. 2008. Effects of right parietal transcranial magnetic stimulation on object identification and orientation judgments. J Cogn Neurosci. 20(5):916-26

effect are comprehensive. It seems to have more to do with the 'initial activation state' of groups of neurons rather than the intensity of the stimulation yet knowing which parts of the brain to target to what visual psyhophysical end remains to be seen.

4.4.3 Hearing

It has already been shown how TMS can be useful in the treatment of tinnitus as a means to suppress the severity of internal auditory 'noise'. The research showing how TMS can facilitate the perception of sound for humans is unfortunately unattainable at this point but there is research explaining out how hearing can be modulated.

In the following study researchers used suggestions from previous research to target the posterior parietal cortex (PPC) to study auditory space perception. They wished to test the hypothesis that by "combining repetitive focal transcranial magnetic stimulation (rTMS) of the right PPC with a task of pointing to free-field-sound stimuli. After a period of 15 min rTMS at 1Hz, subjects exhibited an overall signed error in pointing by 2.5 degrees, directed to the left and downward, with reference to a baseline condition with "sham rTMS". No effects of rTMS on the general precision of sound localization (unsigned errors) were found."

It seems that rTMS affected the elevation and bearing of the source of sound by a small degree. This type of modulation of the auditory spatial coordinates clearly must have altered normal neural firing patterns. It supports the view that "the PPC may represent a neural substrate of the perceptual stability in spatial hearing."[274] So it seems the parietal lobe plays quite an important role in not only hearing but sight as well.

In fact, in terms of audio and visual perception of humans, it seems they are very closely intertwined. It is often noted how one sense will compensate for another when it is impaired in some way; this model of sensory adaptation is of particular interest in the relationship between the audio and visual functions in humans.

In this study, the researchers wanted to test this relationship using TMS as a sensory inhibitor while measuring the response of the other sense. "Single-pulse TMS was applied over the occipital pole at short delays (30-150 ms) after external stimulus onset. Relative to TMS over a control site, reactions times (RTs) to unisensory visual stimuli were prolonged by TMS at 60-75 ms poststimulus onset (visual suppression effect), confirming stimulation of functional visual cortex. Conversely, RTs to unisensory auditory stimuli were significantly shortened

[274] Lewald J, Wienemann M, Boroojerdi B. 2004. Shift in sound localization induced by rTMS of the posterior parietal lobe. *Neuropsychologia*. 42(12):1598-607

when visual cortex was stimulated by TMS at the same delays (beneficial interaction effect of auditory stimulation and occipital TMS)."[275]

This clearly points out that through suppressive stimulation on the occipital pole, visual perception was significantly impaired and yet at the same time, while reaction speed for visual stimuli decreased, the reaction time for auditory stimuli increased. This accounts for an indirect method to facilitate auditory perception using TMS.

4.4.4 Touch

Further evidence of this cross-modal interaction within sensory perception can be seen in the tactile perception of certain object properties which are affected by visual stimulus. To analyse the relationship between vision and touch in normal healthy humans, researchers used Positron Emission Tomography to "demonstrate activation of a region of [the] extrastriate visual cortex[276], near the parieto-occipital fissure, during tactile discrimination of grating orientation. Transcranial magnetic stimulation (TMS) over this region interfered with performance of this tactile task."[277]

So interference in the extrastriate visual cortex led to interference in tactile discrimination which means that this cortical region is not only required for visual perception but also implicated in optimal tactile perception of orientation. An interesting implication of this finding is that the "visual cortex in Braille-reading in the blind should be evaluated from this perspective."[278]

In that regard, researchers have further investigated the cross-modal responses of the visual cortex with a range of non-visual inputs in early blind subjects. They "systematically stimulated the entire occipital cortex using single pulse transcranial magnetic stimulation (TMS) in early blind subjects and in blindfolded seeing controls. Whereas blindfolded seeing controls reported only phosphenes following occipital cortex stimulation, some of the blind subjects reported

---

[275] Romei V, Murray MM, Merabet LB, Thut G. 2008. Occipital transcranial magnetic stimulation has opposing effects on visual and auditory stimulus detection: implications for multisensory interactions. *J Neurosci.* 28(1):1-2.

[276] is the region of the occipital cortex of the mammalian brain located next to the striate cortex (which is also known as the primary visual cortex). (source: http://en.wikipedia.org/wiki/Extrastriate)

[277] Sathian K, Zangaladze A. 2002. Feeling with the mind's eye: contribution of visual cortex to tactile perception. *Behav Brain Res.* 135(1-2):127-32

[278] Sathian K, Zangaladze A. 2002. Feeling with the mind's eye: contribution of visual cortex to tactile perception. *Behav Brain Res.* 135(1-2):127-32

tactile sensations in the fingers that were somatotopically organized onto the visual cortex."[279] This study is a good example of how the brain defers function in the case of sensory perception and provides good support for the neural plasticity hypothesis.

When it comes to the tactile sensation of vibration it is thought that the somatosensory cortices are responsible for this tactile discrimination. More specifically, the primary somatosensoty cortex (SI) and the secondary somotssensory cortex (SII) are responsible for lower and higher frequencies of vibration respectively. In one study, researchers "employed transcranial magnetic stimulation (TMS) over SI in human subjects to investigate the extent to which the inactivation of SI disrupted the discrimination of vibrotactile stimulation at frequencies that give rise to the tactile sensations of flutter (30 Hz) and vibration (200 Hz). Frequency discrimination around the 30-Hz standard following application of TMS to SI was reduced in seven of the eight subjects, and around the 200-Hz standard was reduced in all eight subjects. The average change in discrimination following TMS was about 20% for both low and high frequencies of vibrotactile stimulation."[280]

These results suggest that it is possible to directly disrupt the tactile perception of low frequency vibration through TMS of the SI and also indirectly disrupt tactile perception of high frequency vibration through inter cortical connection between the two brain regions.

So far we have looked at modulations of tactile perceptions that have either directly impaired perception or indirectly improved it. It remains to be seen if TMS can directly enhance tactile perception and so, in the following study, researchers show with human subjects that "through a combination of psychophysical assessment of two-point discrimination thresholds and functional magnetic resonance imaging (fMRI), that brief periods of 5 Hz rTMS evoke lasting perceptual and cortical changes. rTMS was applied over the cortical representation of the right index finger of primary somatosensory cortex" [281]

What is of interest from these results is that from an fMRI done of the somatosensory cortex after stimulation, it was revealed that the representation of the right index finger had been enlarged which was correlated with an rTMS induced perceptual improvement in the same

---

[279] Ptito M, Fumal A, de Noordhout AM, Schoenen J, Gjedde A, Kupers R. 2008. TMS of the occipital cortex induces tactile sensations in the fingers of blind Braille readers. *Exp Brain Res.* 184(2):193-200

[280] Morley JW, Vickery RM, Stuart M, Turman AB. 2007. Suppression of vibrotactile discrimination by transcranial magnetic stimulation of primary somatosensory cortex. *Eur J Neurosci.* 26(4):1007-10.

[281] Tegenthoff M, Ragert P, Pleger B, Schwenkreis P, Förster AF, Nicolas V, Dinse HR. 2005. Improvement of tactile discrimination performance and enlargement of cortical somatosensory maps after 5 Hz rTMS. *PLoS Biol.* (11):e362

finger. It provides a good indication of a close link between cortical area representation and perception variations.

From this it can be said that "repetitive, unattended stimulation from outside the brain... are effective in driving persistent improvement of the perception of touch. The underlying properties and processes that allow cortical networks, after being modified through TMS pulses, to reach new organized stable states that mediate better performance remain to be clarified."[282]

4.4.5 Temperature

Thermal sensations are thought to be perceived in the region of the human thalamic somatic sensory nucleus, more specifically the area within that region known as the ventral caudal (Vc). In one study, researchers used a type of stimulation called microstimulation which translates as the application of very small electrical stimulation. It does not resemble TMS directly yet it closely resembles TDS in that direct current is applied and the similarities in TMS and TDS have been noted.

So, in this study the researchers applied microstimulation to the Vc and found that "warm sensations were evoked more frequently in the posterior region than in the core. [The] proportion of sites where microstimulation evoked cool and pain sensations was not different between the core and the posterior region." [283] The posterior part of the ventral medial nucleus also seemed to evoke cool, warm and pain sensations.

It seems they were able to modulate thermal sensations towards warm, cool and along with that painful responses were also recorded. From the results it is clear that "thermal and pain sensations are processed in the region of Vc ... Thermal and pain sensations seem to be mediated by neural elements in a region likely including the core of Vc, VMpo, and other nuclei posterior and inferior to Vc."[284]

To some degree, the thresholds of thermal perception are sensed in conjunction within the normal volleys of pain perception. Microstimulation is not the only technique available to modulate this cross-modal sensation as "TMS of the motor cortex appears to alter pain

---

[282] Tegenthoff M, Ragert P, Pleger B, Schwenkreis P, Förster AF, Nicolas V, Dinse HR. 2005. Improvement of tactile discrimination performance and enlargement of cortical somatosensory maps after 5 Hz rTMS. *PLoS Biol.* (11):e362

[283] Ohara S, Lenz FA. 2003. Medial lateral extent of thermal and pain sensations evoked by microstimulation in somatic sensory nuclei of human thalamus. *J Neurophysiol.* 90(4):2367-77

[284] Ohara S, Lenz FA. 2003. Medial lateral extent of thermal and pain sensations evoked by microstimulation in somatic sensory nuclei of human thalamus. *J Neurophysiol.* 90(4):2367-77

perception in healthy adults and in patients with chronic neuropathic pain."[285] Of course, it has been mentioned already that TMS can be a treatment for pain sufferers (TMS as a treatment modality) and what is known now is that it can alter the perception of pain too (which we will look at in a little more detail in the next section).

From TMS studies so far the evidence points to the prefrontal cortex as the primary brain region responsible for the perception of pain and therefore the calculated target to test inhibition to thermal pain in humans. The following study looked specifically at the left prefrontal cortex and using TMS the researchers measured pain perception in healthy adults. "Twenty healthy adults with no history of depression or chronic pain conditions volunteered to participate in a pilot laboratory study in which thermal pain thresholds were assessed before and after 15 min of repetitive TMS (rTMS) over the left prefrontal cortex (10 Hz, 100% resting motor threshold, 2 s on, 60 s off, 300 pulses total). Subjects were randomly assigned to receive either real or sham rTMS and were blind to condition."[286]

The results showed a statistically significant increase in thermal pain thresholds which means that the patients were able to withstand exposure to high temperature stimulus without sensing pain. A clear example of how thermal perception can be suppressed through electromagnetic stimulation.

4.4.6 Movement

The perception of movement or proprioception is the sensation of one of the body parts moving and once in motion it provides dynamic feedback of the relative position of that body part in relation to the rest of the body. It has been claimed that TMS "of the human motor cortex can produce a sense of movement of the contralateral hand, even when the hand is paralysed."[287]

It is has been shown that an amputee patient can experienced a conscious sense of movement (SoM) in a phantom hand "without significant activity in remaining muscles, when transcranial

---

[285] Borckardt JJ, Smith AR, Reeves ST, Weinstein M, Kozel FA, Nahas Z, Shelley N, Branham RK, Thomas KJ, George MS. 2007. Fifteen minutes of left prefrontal repetitive transcranial magnetic stimulation acutely increases thermal pain thresholds in healthy adults. *Pain Res Manag.* 12(4):287-90

[286] Borckardt JJ, Smith AR, Reeves ST, Weinstein M, Kozel FA, Nahas Z, Shelley N, Branham RK, Thomas KJ, George MS. 2007. Fifteen minutes of left prefrontal repetitive transcranial magnetic stimulation acutely increases thermal pain thresholds in healthy adults. *Pain Res Manag.* 12(4):287-90

[287] Ellaway PH, Prochazka A, Chan M, Gauthier MJ. 2004. The sense of movement elicited by transcranial magnetic stimulation in humans is due to sensory feedback. *J Physiol.* 556(Pt 2):651-60

magnetic stimulation (TMS) is applied at appropriate intensity over the corresponding sector of contralateral motor cortex."[288]

First, the neural correlates of the sense of movement had to be mapped from the brain using fMRI and then the intensity of TMS had to measured in such as way that it was "low enough not to produce overt activity in remaining muscles; but high enough to produce a phantom SoM".[289]

In a further study, TMS was used over optimal scalp locations with ideal current direction which were determined by "induction of MEPs in abductor pollicis brevis (APB), first dorsal interosseous (FDI), and adductor digiti minimi (ADM)" Results showed a sense of movement was stimulated "in digits 2 and 5 in an ischemically paralyzed hand"[290] These experiments provide good evidence of how electromagnetic frequencies can facilitate the perception of movement and thereby modulate proprioception in humans.

4.4.7 Pain

The suppression of pain has been successfully shown with TMS in patients suffering from chronic pain syndrome, it has also been shown how the thermal thresholds of pain can be manipulated through TMS. However, the precise location of pain perception remains divided over numerous areas of the brain.

Painful stimuli were mapped using neuroimaging techniques to show activity in multiple cortical areas which raises the question as to which areas of the brain are responsible for the particular aspects of pain perception. To address this problem, TMS was used "as an 'interference approach' tool to test the consequence on pain perception of disrupting activity in several areas of cortex known to be activated by painful input."[291]

To stimulate pain, a weal laser was used on the dorsum of the left hand around threshold levels and subsequent to that pairs of TMS pulses were applied over either the "right sensorimotor cortex (SMI), midline occipital cortex (OCC), second somatosensory cortex (SII), or medial

---

[288] Bestmann S, Oliviero A, Voss M, Dechent P, Lopez-Dolado E, Driver J, Baudewig J. 2006. Cortical correlates of TMS-induced phantom hand movements revealed with concurrent TMS-fMRI. *Neuropsychologia*. 44(14):2959-71

[289] Bestmann S, Oliviero A, Voss M, Dechent P, Lopez-Dolado E, Driver J, Baudewig J. 2006. Cortical correlates of TMS-induced phantom hand movements revealed with concurrent TMS-fMRI. *Neuropsychologia*. 44(14):2959-71

[290] Pascual-Leone A, Cohen LG, Brasil-Neto JP, Valls-Solé J, Hallett M. 1994. Differentiation of sensorimotor neuronal structures responsible for induction of motor evoked potentials, attenuation in detection of somatosensory stimuli, and induction of sensation of movement by mapping of optimal current directions. *Electroencephalogr Clin Neurophysiol*. 93(3):230-6

[291] Kanda M, Mima T, Oga T, Matsuhashi M, Toma K, Hara H, Satow T, Nagamine T, Rothwell JC, Shibasaki H. 2003. Transcranial magnetic stimulation (TMS) of the sensorimotor cortex and medial frontal cortex modifies human pain perception. *Clin Neurophysiol*. 114(5):860-6

frontal cortex (MFC). Subjects were instructed to judge whether or not the stimulus was painful and to point to the stimulated spot on a drawing of subject's hand."[292]

The results of the experiment showed that TMS to the sensorimoto cortex actually managed to facilitate the perception of pain by lowering the pain threshold whereas the stimulation of the medial frontal cortex resulted in the suppression of pain perception by 'interfering' with the normal pain threshold. This provides good support for the potential for electromagnetic fields to interfere with and eventually modulate pain perception.

4.4.8 Equilibrioception

Unfortunately, there do not seem to be any studies directly examining the effect of TMS on the perception of balance or body direction, speed and acceleration. However, what is plainly apparent from almost all studies done using TMS is the likelihood that it can induce "headaches or dizziness"[293] as one of the mild side effects.

Dizziness is directly related to the sense of balance and it seems this is possible to disrupt in some patients. Dr Persinger also uses dizziness as one of the potential experiences of participants in his study and its occurrence almost achieves as much statistical significance as the sensed presence.

So since it is apparent that the application of TMS can cause "dizziness afterward"[294] it does not provide conclusive evidence on the potential for electromagnetic fields to modulate balance, it does definitely open the door for further investigation.

3 Summary

And so, after a lengthy look the range of effects of electromagnetic fields on the human brain it should become apparent how fundamental the medium really is. It has the ability to modulate sensory perception, cognition, behaviour and neurological health which together, one could argue, represent all of the functional capacities humans require to create and comprehend what is called knowledge.

The exact definition of knowledge remains ambiguous for every definition has merit according to the context from whence it came, however, what is of concern are the biological faculties

---

[292] Kanda M, Mima T, Oga T, Matsuhashi M, Toma K, Hara H, Satow T, Nagamine T, Rothwell JC, Shibasaki H. 2003. Transcranial magnetic stimulation (TMS) of the sensorimotor cortex and medial frontal cortex modifies human pain perception. *Clin Neurophysiol.* 114(5):860-6

[293] http://www.webmd.com/depression/experimental-treatments-depression

[294] http://www.wired.com/science/discoveries/news/2006/02/70085

that allow knowledge to be created; the prerequisites of knowledge. The above mentioned are those faculties and it just so happens they are modulated by electromagnetic fields thereby implying that knowledge creation is modulated by electromagnetic fields.

To create knowledge a human being requires the ability to sense itself and the environment to form a sensory perception, it requires the ability to incorporate the sensory information into cognitive functions. It also requires the ability to execute appropriate behaviour based on the most accurate information available and finally all of those abilities require the human being to be in a neurologically healthy condition because physical damage to neural circuits can interfere with the capacity to create knowledge. These clearly can be seen as the required faculties to produce knowledge and as it has been shown, they are all affected by electromagnetic fields.

If this is the case, the value of electromagnetic fields has been shown by revealing an answer to the question of 'whither is knowledge created?' which means the value of this informational medium can now be understood through its effects.

With that clarified, it is possible to go back to the question of exactly 'how knowledge is created'. Remember that question was paused while the value of the effects of electromagnetic field was confirmed. Persinger had revealed his theory on how interference in the normal flow of information led to the brain trying to adapt to the 'surprising' appearance of information.

Persinger asked if normal consciousness a type of insulation against the myriad of potential stimuli available and then again how exactly are electromagnetic fields transduced?

One thing is for certain, if the creation of knowledge can clearly be seen as a process of transducing electromagnetic fields then not only is it a sense, it is *the* one sense that can modulate all other senses as well as cognition, behaviour and neurological health and therefore not only change the very way in which knowledge is created but also the experience of life as a human being.

Chapter 5

Sensory Modulation

1 How is Knowledge Created?

Again this question is asked thereby continuing the investigation into the sensory mechanisms that initiate and modulate knowledge creation. It is important to remember that "not all information gathered by the senses is processed at the conscious level, and there is no physiological principle that would preclude the subliminal detection of EMFs by the nervous system. Indeed, considering both the rich frequency spectrum of naturally-present EMFs that has existed throughout the evolutionary period, and its known relationship to geological, atmospheric, and cosmological phenomena," [295] it would be quite surprising if the human body did not posses rather well developed biological mechanisms to transduce electromagnetic fields in some way.

The mechanics of normal sensory transduction would probably function fairly similarly to electromagnetic transduction. In order to understand this more, normal sensory transduction should be understood.

Sensory transduction occurs through a non-neuronal cell where the initial "receipt of a stimulus is via a specialized cellular "organ" called a sensory receptor that is located at the end of the nerve fiber, or fibers, connecting it to the central nervous system. In some instances these are highly specialized, large anatomical structures such as the eyes, which are sensitive to that portion of the electromagnetic spectrum which we call light. Others are microscopic and specialized to receive mechanical stimuli, such as the pressure-sensitive Pacinian corpuscles and the stretch-sensitive muscle spindles. In the latter instance the receptor itself is clearly a modified muscle fiber that has a particularly intimate connection to its nerve. These mechanical receptors produce an electrically measurable response when stimulated by pressure or stretch." [296] This electrical measure is not to be confused with action potential (neural cell circuitry) and so it is called a 'generator potential'.

---

[295] Becker RO, Marino AA. 1982. *Electromagnetism and Life.* New York State University, New York Press. ISBN 0-87395-560-9. pg90

[296] Becker RO, Marino AA. 1982. *Electromagnetism and Life.* New York State University, New York Press. ISBN 0-87395-560-9. pg26

Generator potential is different to action potential because its measure is "graded (i.e., varying in magnitude in direct relationship to the magnitude of the mechanical stimulus) and regardless of its magnitude, nonpropagating (i.e., decreasing rapidly over microscopic distances). Apparently, the action of the generator potential is to produce sufficient depolarization of the associated nerve fiber membrane to start a propagated action potential which then proceeds centrally along the associated nerve fiber carrying the sensory message. The mechanism of the sensory receptor itself seems to be an excellent example of an analog transducer, with the generator potential being the DC output signal."[297]

It would then seem that a similar transducer mechanism needs to be shown representing the human responsiveness to electromagnetic fields. If human responsiveness to electromagnetic fields were a "form of sensory transduction, one would expect that fields could trigger evoked potentials, as do other sensory stimuli."[298]

This expectation was put to the test in a study were researchers examined "electroencephalograms from 17 subjects for the presence of evoked potentials caused by the onset and by the offset of 2 G, 60 Hz (a field strength comparable to that in the general environment). Both linear (time averaging) and nonlinear (recurrence analysis) methods of data analysis were employed to permit an assessment of the dynamical nature of the stimulus/response relationship. Using the method of recurrence analysis, magnetosensory evoked potentials (MEPs) in the signals from occipital derivations were found in 16 of the subjects ($P<0.05$ for each subject). The potentials occurred 109-454 ms after stimulus application, depending on the subject, and were triggered by onset of the field, offset of the field, or both. Using the method of time averaging, no MEPs were detected. MEPs in the signals from the central and parietal electrodes were found in most subjects using recurrence analysis, but no MEPs were detected using time averaging. The occurrence of MEPs in response to a weak magnetic field suggested the existence of a human magnetic sense."[299]

So what can be causing these magnetosensory evoked potentials? The obvious answer is to look for any molecular or cellular material in the brain that is magnetic, if there is magnetic material then clearly it would be responsive to electromagnetic fields and perhaps offer a

---

[297] Becker RO, Marino AA. 1982. *Electromagnetism and Life*. New York State University, New York Press. ISBN 0-87395-560-9. pg26

[298] Carrubba S, Frilot C 2nd, Chesson AL Jr, Marino AA. 2007. Evidence of a nonlinear human magnetic sense. *Neuroscience*. 5;144(1):356-67

[299] Carrubba S, Frilot C 2nd, Chesson AL Jr, Marino AA. 2007. Evidence of a nonlinear human magnetic sense. *Neuroscience*. 5;144(1):356-67

possible solution to the transduction mechanism essential to the question of how electromagnetic fields are processed.

In this regard, studies have been conducted to test for the "presence of magnetite[300] in human brain tissue and to determine whether magnetite is present in living brain tissue" [301]

In one study researcher "examined tissue samples resected from six patients during amygdalo-hippocampectomy operations. The tissue samples were sealed in sterilized vials in the operating theater and placed into liquid nitrogen directly after removal to prevent changes in tissue chemistry after the death of the brain cells. The low temperature magnetic properties of the tissue were measured in order to determine the presence of ferro- or ferrimagnetic material in the tissue. The results of these experiments indicate that magnetite is present in the tissue. In addition, results of experiments designed to control for airborne contamination and contamination during cauterization of vessels during surgery indicate that these are not significant sources of magnetite contamination in the tissue."[302]

Similar studies to these have been conducted and it has been found that "these magnetic particles in the human brain are diffusely and homogeneously distributed over all cerebral lobes, the cerebellum, basal ganglia, and midbrain"[303] which leaves no doubt as to the existence of a magnetic material in the human brain. Moreover, magnetite one of the *most* magnetic materials of all the naturally occurring minerals on earth and now it has been found to occur in humans as well.

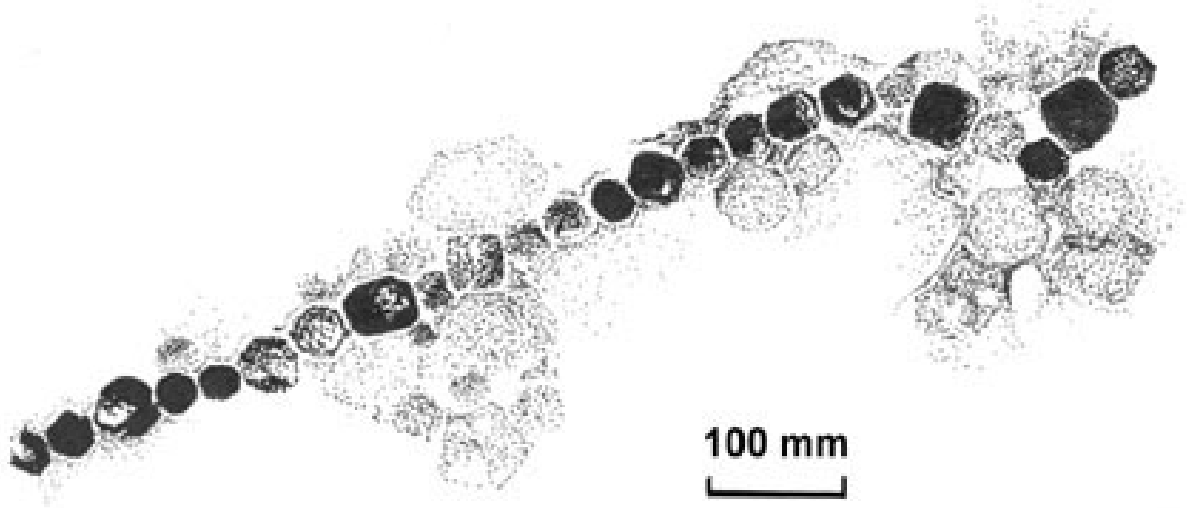
---

[300] is a ferrimagnetic mineral with chemical formula $\mathbf{Fe_3O_4}$... Magnetite is the most magnetic of all the naturally occurring minerals on Earth (source: http://en.wikipedia.org/wiki/Magnetite)

[301] Dobson J, Grassi P. 1996. Magnetic Properties of Human Hippocampal Tissue: Evaluation of Artefact and Contamination Sources. *Brain Res. Bull.* 39: 255-259

[302] Dobson J, Grassi P. 1996. Magnetic Properties of Human Hippocampal Tissue: Evaluation of Artefact and Contamination Sources. *Brain Res. Bull.* 39: 255-259

[303] Kirschvink JL, Kobayashi-Kirschvink A, Woodford BJ. 1992. Magnetite biomineralization in the human brain. *Proc. Natl. Acad. Sci.* 89: 7683-7687



[304]

"These magnetite crystals were found to be organized into linear, membrane-bound chains a few micrometers in length, with up to 80 crystals per chain."[305]

So now there is an interesting link between how humans respond to electromagnetic fields and a magnetically responsive mineral in human tissue. The link seems obvious but it would be sensible to first look at how magnetite is known to function in other animals and then investigate how it may function in humans.

In magnetite-containing bacteria "magnetite crystals turn the bacteria into swimming needles that orient with respect to the earth's magnetic fields. Magnetite has also been found in animals that navigate by compass direction, such as bees, birds, and fish."[306] It seems the predominant function is orientation in bacteria and navigation in insects and lower mammals yet its function in the higher mammals remains unclear.

What is of comparative interest for human magnetite is that "many of the crystal morphologies and structures strongly resemble those precipitated by magnetotactic bacteria and fish."[307] Since we know magnetite to exhibit a purposeful function in bacteria and fish, it would seem unlikely that a magnetite of similar crystal morphology would not serve a purposeful function in humans. So it can be said with good confidence that biogenic

---

[304] Coetzee H. 2003. Biomagnetism and Bio-Electromagnetism: The Foundation of Life. *Future History*. Vol 8

[305] Coetzee H. 2003. Biomagnetism and Bio-Electromagnetism: The Foundation of Life. *Future History*. Vol 8

[306] Coetzee H. 2003. Biomagnetism and Bio-Electromagnetism: The Foundation of Life. *Future History*. Vol 8

[307] Kirschvink JL, Kobayashi-Kirschvink A, Woodford BJ. 1992. Magnetite biomineralization in the human brain. *Proc. Natl. Acad. Sci.* 89: 7683-7687

magnetite in the human brain may account for the "variety of biological effects of low-frequency magnetic fields."[308]

A model for this mechanism of electromagnetic interaction has been proposed by Joseph Kirschvink as the "ferromagnetic transduction model"[309]. Kirschvink suggests that the "coupling of biogenic magnetite particles in the human brain to mechanosensitive membrane ion gates may provide a mechanism for interactions of environmental magnetic fields with humans." [310]

Beyond a mechanosensitive mechanism of transduction, Kirschvink has also suggested that transduction can occur through ferromagnetic resonance. "Energy absorbed by this process is first transduced into acoustic vibrations at the microwave carrier frequency within the crystal lattice via the magnetoacoustic effect then, the energy should be dissipated in cellular structures in close proximity to the magnetite crystals."[311]

The case for electromagnetic transduction is clear as "compelling evidence exists [for] the physical basis of this response is tiny crystals of single-domain magnetite (Fe3O4). It is ... [possible] that all magnetic field sensitivity in living organisms... is the result of a highly evolved, finely-tuned sensory system based on single-domain, ferromagnetic crystals."[312]

In terms of sensory perception, this finally identifies a mechanism by which the process of knowledge creation is initiated and modulated. So, to sum up the argument, what has been discussed is how ancient humans found the means to alter consciousness by altering the neural firing rates and successfully utilising the knowledge creation process. Persinger showed how this is achieved through electromagnetic fields applied external to the brain, the effects of which are evident on sensory perception, cognition, behavior and neurological condition. The most likely mechanism in the brain responsible for the effect is ferromagnetic transduction which would then define the knowledge creation process as a sensory ability, modulated by electromagnetic fields.

---

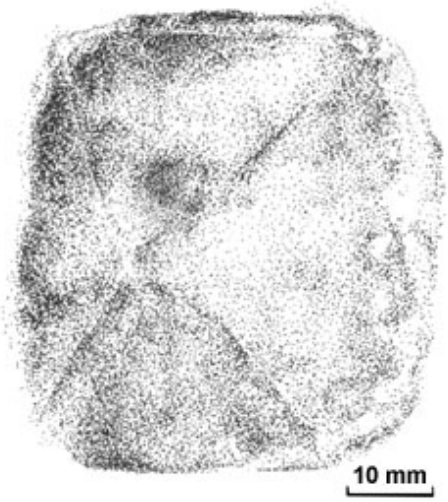
[308] Kirschvink JL, Kobayashi-Kirschvink A, Woodford BJ. 1992. Magnetite biomineralization in the human brain. *Proc. Natl. Acad. Sci.* 89: 7683-7687

[309] Dobson J, St. Pierre T. 1996. Application of the Ferromagnetic Transduction Model to D.C. and Pulsed Magnetic Fields: Effects on Epileptogenic Tissue & Implications for Cellular Phone Safety. *Biochem. Biophys. Res. Comm.* 227(3):718-723

[310] Dobson J, St. Pierre T. 1996. Application of the Ferromagnetic Transduction Model to D.C. and Pulsed Magnetic Fields: Effects on Epileptogenic Tissue & Implications for Cellular Phone Safety. *Biochem. Biophys. Res. Comm.* 227(3):718-723

[311] Kirschvink JL. 1996. Microwave absorption by magnetite: a possible mechanism for coupling nonthermal levels of radiation to biological systems. *Bioelectromagnetics.* 17(3):187-94

[312] Kirschvink JL, Walker MM, Diebel CE. 2001. Magnetite-based magnetoreception. *Curr Opin Neurobiol.* 11(4):462-7



[313]

"A single pyramid shaped Magnetite crystal in the human brain"[314]

To take the argument further would be to embellish in realms of scientific theory which remain to be proven unequivocally yet the elegance of one particular theory is worth mentioning. It comes from a South African by the name of Dr H. Coetzee and he has shown that the pyramid shaped cells of magnetite are "arranged in layers in the cortex of the two cerebra. The pyramidal cells act as electro-crystal cells immersed in extra-cellular tissue fluids, and seem to operate in the fashion of a liquid crystal oscillator in response to different light commands, or light pulses which, in turn, change the orientation of every molecule and atom within the body."[315] That would seem plausible since the function of magnetite in bacteria is to change it orientation to the direction of the field and as it is known, the crystal morphology of magnetite in bacteria is very similar to that of human magnetite.

"Biogravitational encoded switches present in the brain allow a type of liquid network to release ions that induce currents to the surrounding coiled dendrites. Electron impulses from a neuron, on reaching the dendrite coil of the abutted cell, generate a micro amperage magnetic field, causing the ultra thin crystal, or liquid crystal in the pyramidal cell to be activated --- in a very unusual way. On flexing, this ultra thin crystal becomes a piezoelectric oscillator, producing a circular polarized light pulse that travels throughout the body, or travels as a transverse photonic bundle of energy."[316] That would imply that the human brain is immersing the body in a *liquid light* influencing our senses, cognition, behavior and

---

[313] Coetzee H. 2003. Biomagnetism and Bio-Electromagnetism: The Foundation of Life. *Future History,* Volume 8

[314] Coetzee H. 2003. Biomagnetism and Bio-Electromagnetism: The Foundation of Life. *Future History,* Volume 8

[315] Coetzee H. 2003. Biomagnetism and Bio-Electromagnetism: The Foundation of Life. *Future History,* Volume 8

[316] Coetzee H. 2003. Biomagnetism and Bio-Electromagnetism: The Foundation of Life. *Future History,* Volume 8

neurological health, an unlikely notion that may one day reveal itself as valid concept in vitalistic medicine.

It can be argued that the investigation so far is a comprehensive analysis of how knowledge is created according to the original hypothesis stating knowledge creation as a sensory ability. The questions of ‘how’ and ‘whither’ have been the dominant questions simply because of the nature of the inquisition.

However, there will probably remain some elements of doubt to the veracity of the hypothesis and in the rational logic used to resolve the claim. It is to this effect that a further question can be asked:

Whether knowledge is created?

‘Whether’ being a question that implies doubt to a preceded answer so to ask this question might offer further evidence toward the legitimacy of the hypothesis.

Chapter 6

Neural Threshold Manipulation

1 Whether Knowledge is Created?

If the proposed process of knowledge creation is considered, the fundamental dynamic toward stimulating the process lay in the modulation of neural thresholds. The threshold levels represent the potential energy required to get a neuron to fire and whether the result of stimulus is facilitative or inhibitive, the ferromagnetic transduction process will either inhibit neural activity or facilitate it, the total effect allowing for new *overall patterns* of neural activity.

6.1 Cognitive Facilitation

From a cognitive perspective, one 'activity pattern' under investigation is related to the difficulty in accessing "lower level neural information. We are aware of object labels, not the attributes used by our brains to formulate the labels. Such attributes are normally suppressed from conscious awareness."[317] This suppression of information from cognitive awareness is a trait of the knowledge creating process, access to which would give us much greater detail of what becomes known after processing through sensory perception, cognition, behavior and neurological condition.

In terms of perception, a good example is "we are not consciously aware of the subtle shading across a spherical object which our brain uses to derive its shape and label it sphere; otherwise, we would be better at drawing natural scenes without training. But, a rare form of brain impairment enables savants to have access to such information. Our findings suggest that low frequency TMS mimics this brain impairment by shutting down part of the left frontal-temporal lobe. The possible (disinhibiting) neural mechanisms that underlie TMS induced access to information"[318] is a function of neural threshold modulation comparable to the savant-like skills seen to be made "accessible by altered states of perception[319]... Sacks

---

[317] Young RL, Ridding MC, Morrell TL. 2004. Switching skills on by turning off part of the brain. *Neurocase.* 10(3):215-22

[318] Young RL, Ridding MC, Morrell TL. 2004. Switching skills on by turning off part of the brain. *Neurocase.* 10(3):215-22

[319] This was shown to be evident in the conscious altering experiments described by Persinger through electromagnetic stimulation

provides support for the former view [when] he produced camera-like precise drawings only when under the influence of amphetamines. Early (savant-like) cave art has [also] been attributed to mescaline induced perceptual states."[320]

It's an interesting observation to make considering the initial topic of investigation in this thesis. Perhaps it can be seen that those ancient humans were not only inducing the imagery or visions to paint on their rock canvas but perhaps also the necessary skills to carry out the task.

Nonetheless, what this means is that the extraordinary cognitive skills "of savants, including mathematics and drawing, are within us all but cannot normally be accessed without some form of brain damage… [yet] such skills can be made accessible to normal people by switching off part of their brain artificially using magnetic pulses."[321]

In a further study, researchers used rTMS to alter neural activity and showed that "savant-type skills improved in 5 out of 17 participants during the period of stimulation. The enhanced skills included declarative memory, drawing, mathematics, and calendar calculating. In addition to overall improvement being observed, striking improvements in individual performance on various tasks were also seen."[322]

In another study it comes as no surprise that three of the four participants "experienced altered psychological states after stimulation" which subsequently made the participant feel as though they were "more alert and conscious of detail."[323] An interestingly anomaly from this study is that the participants did not return to the baseline convention 45 minutes after the stimulation which means that it might be "possible that the altered psychological states persisted beyond this time frame or that the newly acquired schema was preserved once learnt under magnetic stimulation"[324] Whichever one, that result would suggest TMS could be used as a therapy for cognitive enhancement.

The interpretation of these findings stems from the subconscious suppression of attributive information by the brain. What is clear is that savants lack the neural activity for this

---

[320] Young RL, Ridding MC, Morrell TL. 2004. Switching skills on by turning off part of the brain. *Neurocase.* 10(3):215-22

[321] Young RL, Ridding MC, Morrell TL. 2004. Switching skills on by turning off part of the brain. *Neurocase.* 10(3):215-22

[322] Young RL, Ridding MC, Morrell TL. 2004. Switching skills on by turning off part of the brain. *Neurocase.* 10(3):215-22

[323] Young RL, Ridding MC, Morrell TL. 2004. Switching skills on by turning off part of the brain. *Neurocase.* 10(3):215-22

[324] Young RL, Ridding MC, Morrell TL. 2004. Switching skills on by turning off part of the brain. *Neurocase.* 10(3):215-22

information suppression, enabling an overall pattern of neural activity cognitive benefits similar to those experienced by subjects who receive TMS to the frontal lobes.

These cognitive benefit are linked to the perceptual phenomenon of blindsight[325] which is the "remarkable ability to guess correctly about attributes of stimuli presented to the blind hemifield." Normally appearing in individuals with brain injury to visual cortex, this phenomenon can also be replicated using TMS to the occipital lobe. In a study concerning blindsight it was concluded that the "availability of conscious information suppresses access to unconscious information, supporting the idea of consciousness as a repressant of unconscious tendencies."[326]

Both blindsight and cognitive abilities induced by TMS represent a suppression of normal neural activity (consciousness) and allow for the detection of lower neural activity (unconscious tendency).

This is precisely what Persinger had theorised when he labeled normal consciousness as a "type of insulation that prevents access from the myriad of stimuli that we typically do not detect". That could accurately define the case for both the phenomena described above. It seems that normal consciousness could act like a buffer against this lower neural activity and effectively block access to some incredible cognitive abilities. The reasoning shown here may provide a suitable answer to this question raised earlier in the thesis (pg48).

To consider all the questions generated by Persinger "if consciousness is "recreated" every 20 to 25 msec ("40 Hz") rather than maintained as a continuous stream, then what happens between the end of one increment and the beginning of the next? Could information from outside of the brain be acquired during this "infinite infinitesimal" interval?" Yes, in the form of electromagnetic fields which influence neural firing patterns thereby altering the information content of the neurons.

"Could this information then be incorporated into the stream of experience generated by the normal volleys of sensory neurons?" Definitely, the transduction of electromagnetic fields

---

[325] "phenomenon in which people who are perceptually blind in a certain area of their visual field demonstrate some response to visual stimuli, without any qualitative experience ('qualia'). In Type 1 blindsight subjects have no awareness whatsoever of any stimuli, but yet are able to predict, at levels significantly above chance, aspects of a visual stimulus, such as location, or type of movement, often in a forced-response or guessing situation. Type 2 blindsight is when subjects have some awareness of, for example, movement within the blind area, but no visual percept, or quale". (source: http://en.wikipedia.org/wiki/Blindsight)

[326] Jacob J, Lamme VAF. 2005. Repression of unconscious information by conscious processing: Evidence from affective blindsight induced by transcranial magnetic stimulation *Proceedings of the National Academy of Sciences of the United States of America.* 102(30):10747

alters neural firing patterns modulating not only sensory perception but cognition, behavior and neurological conditions.

6.2 Behavioural Modification

So it seems the modulation of neural firing rates can lead to some interesting effects, however what has been looked is mainly an artificial method of neural threshold modulation i.e. TMS. What would seem appropriate is to mention some of the more natural ways to encourage the transduction of magnetic fields to alter brain activity. One of the most natural transitions in brain activity is sleep.

Recent discoveries about the nature of sleep have been made by neuroscientists Denis Pare and Rodolfo Llinas who have found that "the brain's simultaneous 40 Hz 'neural oscillations', which are associated with consciousness, also occur during REM sleep"[327] This is an astounding observation as it means that "Pare and Llinas were led to the conclusion that the only difference between our dreaming and waking states is that in waking states, the "closed system that generates oscillatory states [or sleep]" is modulated by incoming stimuli from the outside world. In other words, what we call "waking state" is really an REM dream state, with a sensory topping. Or, as Ouspensky put it, we shouldn't speak of being either asleep or awake, but of "sleep plus waking state."[328] The states of awake and asleep, normally seen as dichotomous occurrences, can now be seen as simultaneous occurrences in terms of brain activity.

What this means is that the knowledge creating process must also be active during REM sleep which would create a special relationship between knowledge creation and REM. It seems that "during REM, the summed activity of the brain's neurons is quite similar to that during waking hours; for this reason, the phenomenon is often called *paradoxical sleep*. This means that there are no dominating brain waves during REM sleep"[329]

This paradoxical relationship of REM and awake states is also researched in the "covert-rapid eye movement … sleep hypothesis of dreaming [which] suggests that elements of REM sleep emerge during sleep onset, leading to vivid hypnagogic imagery."[330] The researchers tested

---

[327] http://www.forteantimes.com/features/articles/227/hypnagogia.html

[328] http://www.forteantimes.com/features/articles/227/hypnagogia.html

[329] http://en.wikipedia.org/wiki/REM_sleep

[330] Bódizs R, Sverteczki M, Mészáros E. 2008. Wakefulness-sleep transition: emerging electroencephalographic similarities with the rapid eye movement phase. *Brain Res Bull.* 76(1-2):85-9

"the physiological part of this hypothesis by analysing scalp-recorded electroencephalograms of 15 human subjects during wake–sleep transition and subsequent night time sleep. Wake–sleep transition was categorised semi-automatically as alpha activity, alpha dropout and as early Stage 2 sleep. The slow oscillation, the slow and the fast subdivisions of the delta and the theta frequencies respectively, as well as alpha and sigma bands were analysed... A significant increase in composite similarity with the whole night REM sleep emerged in the period of alpha dropout and diminished in early Stage 2 sleep. The alpha dropout period was more similar to whole night REM sleep than to whole night Stage 2 sleep. These region-independent effects were mirrored in region-specific manner by frequency bands of the delta-slow theta range. Findings are in accordance with the covert REM sleep hypothesis."[331]

So waking consciousness and REM sleep share very similar traits and what seems to encompass the paradoxical experience of being between the two is the phenomenon of hypnagogia. "The term 'hypnagogic' was coined by the 19th-century French psychologist LF Alfred Maury, and is derived from two Greek words, Hypnos (sleep) and agogeus (guide, or leader).[332] An interesting choice of words to define the state since Lewis Williams and Persinger might agree on the use of the term 'guide' where the sentient beings referred to in their research would complement the definition of this unusual altered state of consciousness.

As far as the research goes on hypnagogia, the most authoritative work on the subject has been done by "the psychologist Andreas Mavromatis, who in 1987 published Hypnagogia, an exhaustively researched and deeply pondered exploration of all aspects of the experience. Mavromatis links hypnagogia to dreams, schizophrenia, creativity, meditation, mystical experience, and, most strikingly, paranormal experience."[333]

Those are a divergent set of claims yet the most interesting link is between hypnagogia and creativity. Mavromatis believed that conscious creative insights or "intuitional experiences are only distinguishable from hypnagogia "by the subject's set of beliefs and the setting in which the experiences take place." Many scientists might be surprised to learn how often the intuitional process contributes to scientific insights."[334]

---

[331] Bódizs R, Sverteczki M, Mészáros E. 2008. Wakefulness-sleep transition: emerging electroencephalographic similarities with the rapid eye movement phase. *Brain Res Bull.* 76(1-2):85-9

[332] http://www.forteantimes.com/features/articles/227/hypnagogia.html

[333] http://www.forteantimes.com/features/articles/227/hypnagogia.html

[334] http://www.innerworkingsresources.com/articles/mindwhispers.html

Thomas Edison, attributed with over 1000 U.S. patents, would spend many hours thinking over potential inventions. "Then when he would reach a sticking point he would take one of his famous 'cat naps'. He would doze off in his favourite chair, holding steel balls in the palms of his hands. As he would fall asleep - drifting into alpha - his arms would relax and lower, letting the balls fall into pans on the floor. The noise would wake Edison and very often he would awaken with an idea to continue with his project."[335]

Another "example of the intuitional scientific insight is Kekule von Stradonitz's discovery of the ring of the benzene molecule."[336] "He said that he had discovered the ring shape of the benzene molecule after having a reverie or day-dream of a snake seizing its own tail (this is a common symbol in many ancient cultures known as the Ouroboros). This vision, he said, came to him after years of studying the nature of carbon-carbon bonds."[337]

That was 19th century, the is also evidence from the 18th century "philosopher, scientist and visionary Emmanuel Swedenborg [who] developed a method of inducing and exploring hypnagogic states, during which he travelled to heaven, hell and other planets."[338] Toward the end of Swedenborg's life "small reading groups formed in England and Sweden to study the truth they saw in his teachings and several writers were influenced by him, including William Blake, August Strindberg, Ralph Waldo Emerson, Charles Baudelaire, Balzac, William Butler Yeats, Sheridan Le Fanu and Carl Jung. The theologian Henry James Sr. was also a follower of his teachings, as were Johnny Appleseed and Helen Keller."[339]

If we go even further back it has been noted that one of the first to comment on the phenomenon of hypnagogia was "Aristotle, who spoke of the "affections we experience when sinking into slumber," and "the images which present themselves to us in sleep." In the third century AD, Iamblichus, the Neo-Platonic philosopher, wrote of the "voices and bright and tranquil light that came to him in the condition between sleeping and waking and which he believed were a form of god-sent experience."[340]

Other who have been known explorers of the hypnagogic phenomenon include "William Blake, Samuel Taylor Coleridge, Thomas De Quincey, Edgar Allen Poe, Gerard de Nerval,

---

335 http://www.forteantimes.com/features/articles/227/hypnagogia.html

336 http://www.innerworkingsresources.com/articles/mindwhispers.html

337 http://en.wikipedia.org/wiki/Friedrich_August_Kekul%C3%A9_von_Stradonitz#Benzene

338 http://www.forteantimes.com/features/articles/227/hypnagogia.html

339 http://en.wikipedia.org/wiki/Emmanuel_Swedenborg

340 http://www.forteantimes.com/features/articles/227/hypnagogia.html

Havelock Ellis, CG Jung, Jean Paul Sartre, Ernst Jünger and the novelist Robert Irwin, to name just a few."[341]

And probably the greatest thinker of them all, "Albert Einstein... obtained some of the basic concepts of the relativity of mass, time and distance through hypnagogic methods"[342] When Einstein said that "imagination is more important than knowledge"[343] perhaps he was in part referring to the ability to utilise the intuitive experience of hypnagogia.

6.3 A Force of Nature

If the medium of the knowledge creation process is considered on an atomic level, electromagnetic fields are in fact a fundamental force of nature. It represents one of the four fundamental forces in physics which make up the mechanism through which particles interact with each other. The four forces are in order of highest to lowest in strength:

- Strong Nuclear (which hold atomic nuclei together)
- Electromagnetic
- Weak Nuclear (which cause certain forms of nuclear decay)
- Gravity

The electromagnetic force accounts for practically "all the phenomena encountered in daily life, with the exception of gravity. All the forces involved in interactions between atoms can be traced to the electromagnetic force acting on the electrically charged protons and electrons inside the atoms. This includes the forces we experience in "pushing" or "pulling" ordinary material objects, which come from the intermolecular forces between the individual molecules in our bodies and those in the objects. It also includes all forms of chemical phenomena, which arise from interactions between electron orbitals."[344]

This fundamental force of nature was probably best explored by Dr. Robert O. Becker who was nominated twice for the Nobel Prize for his research on the effects of electromagnetic fields on living systems. He found that the "migratory behaviour of the Atlantic eel [is affected] by the earth's electrostatic field, the navigational aid furnished homing pigeon [is affected] by the earth's magnetic field, the apparent cue for the timing of biological cycles [is affected] by the

---

341 http://www.forteantimes.com/features/articles/227/hypnagogia.html

342 Goldberg B. 2003. *Dream Your Problems Away: Heal Yourself While You Sleep*. The Career Press Inc

343 http://www.realityseeds.com/category/dreams

344 http://en.wikipedia.org/wiki/Electromagnetism

earth's magnetic field, and the direct relationship between reversals of the earth's magnetic field and the extinction of whole species in the geological past." [345] As a fundamental force, it's not unbelievable that it could have such a fundamental effect on all the inhabitants of this planet.

An immense variety of bioelectromagnetic phenomena shown to be affected by the earth's electromagnetic field was extensively analysed by Dr Becker and constitutes a valuable body of research into how it affects all living organisms.

Research of the earth's magnetic field is a phenomenon scientists have investigated for centuries and yet "only within the past few decades has its true complexity been revealed. Far from being static and unvarying, the magnetic field exhibits variations ranging from catastrophic polarity reversals, in which the north and south poles exchange position, to a small but definite, cyclic variation in its magnitude at a circadian (about a day) rate." [346] This fluctuation will continue to naturally affect biological systems in *unknown* quantities until more is known about the electromagnetic potential of all living organisms.

The complexity of the earth's field is developed further by the interaction of the earth's field, the sun and the galaxy which "impose other cycles with periods ranging from several weeks to centuries. Magnetohydrodynamic[347] factors, arising in part from the resonant cavity formed between the earth's surface and the ionosphere, produce "micropulsations" in the magnetic field at frequencies ranging from 0.01 to 20 hz.

Transients (magnetic storms) occur in the total [magnetic] field in response to major solar events such as flares, injecting large numbers of charged particles into the earth's field. Lightning discharges in the atmosphere produce radio-frequency energy in the kilocycle range which propagates along the lines of force of the magnetic field, literally "bouncing" back and forth between the northern and southern hemispheres many times before dying out.

A complex electrostatic field exists between the surface of the earth and the ionosphere within which atmospheric atoms are ionized. Large electrical currents flow within the earth itself (telluric currents[348]), as well as within the ionosphere. All of these factors are naturally present, and have been since the formation of the planet. The earth's electromagnetic environment is

---

[345] Becker RO, Marino AA. 1982. *Electromagnetism and Life*. New York State University, New York Press. ISBN 0-87395-560-9. pg3

[346] Becker RO, Marino AA. 1982. *Electromagnetism and Life*. New York State University, New York Press. ISBN 0-87395-560-9

[347] the dynamics of electrically conducting fluids. (source: http://en.wikipedia.org/wiki/Magnetohydrodynamic)

[348] an electric current which moves underground or through the sea. Telluric currents result from both natural causes and human activity, and the discrete currents interact in a complex pattern. The currents are extremely low frequency and travel over large areas at or near the surface of the Earth. (source: http://en.wikipedia.org/wiki/Telluric_current)

rich and complex, with its interrelated factors continually varying in a dynamic fashion."[349] The current understanding of the full extent of effects of all these complex electromagnetic fields on living organisms, especially humans, is far from complete.

If all life since its origination has been submersed in electromagnetic information and adapted to respond to its *cyclic variations,* then perhaps a comparative means of artificial or self-induced electromagnetic stimulation would be the most effective means to alter the electromagnetic potential of a living system. Understanding the natural cyclical variations in electromagnetic field activity may offer the most effective means to induce the transduction mechanism in living organisms, more particularly the threshold modulation of neural firing rates in humans.

Toward understanding the effect of the earth's natural magnetic flux on human cycles, Professor Rutger Wever has conducted research at the Max Planck Institute on the biological cycles of human beings by creating a unique environment in which to test the susceptibility of humans to electromagnetic fields.

The underground testing station consisted of one room completely free of external stimuli such as light, noise and temperature, the other room was identical except is also completely shielded out all DC and AC electromagnetic fields. Wever made extensive measurements of "body temperature, sleep-activity cycles, and urinary excretion of sodium, potassium and calcium. Human subjects placed in both rooms soon demonstrated a "free running" rhythm. Those in the room not shielded from the electromagnetic environment had an essentially normal circadian rate, while those in the shielded room demonstrated a significantly longer cycle time.

In the nonshielded room some subjects would, after the passage of 7 to 10 days, show an apparent desynchronization in some of the measured variables. In this situation one or more of the measured variables would maintain the normal circadian rate while others would show a gradual shift in cycle time away from this norm. However, these would eventually stabilize at some frequency which was directly related to the circadian rate (e.g. to two-to-one relationship).

Subjects in the totally shielded room on the other hand, would demonstrate real desynchronization with several variables shifting away from the primary rate (which was not a normal circadian cycle to begin with) and stabilizing finally at a rate that had no harmonic

---

[349] Becker RO, Marino AA. 1982. *Electromagnetism and Life.* New York State University, New York Press. ISBN 0-87395-560-9. pg60

relationship to the primary rate. All of these phenomena were statistically significant in a large series of subjects."[350]

If the earth's magnetic field allows humans to create harmony between its biological cycles it becomes clear that to maintain that harmony the "normal earth magnetic field is an important parameter of the environment for living things."[351]

In complimentary research Dr Becker has shown how changes in the normal field in the past have exerted evolutionary pressure on living systems and "possibly even to have been associated with biogenesis[352]." [353] Biogenesis being one of the most basic cycles of all living forms, that of procreation. If that is the case then the "question of the biological effects of abnormal electromagnetic parameters introduced into the environment by man's activities becomes of some importance."[354]

With all the tests performed with different variations of electromagnetic stimulation it has been shown that "pulsed fields, square waves and D.C. fields also could force open the membrane gates long enough to disrupt normal neurophysiological processes [which] may provide a plausible mechanism linking exposure to magnetic fields from discontinuous transmission cellular telephones and disruption of normal cellular processes in the human brain."[355] At the moment this is an extremely contentious issue in the scientific community, so attempting to resolve the issue here is not within the parameters of the hypothesis yet it should be noted that if the enormous utility of cellular communication is considered, it is to be expected there would be a vested interest in refuting these claims.

As a force of nature, electromagnetic energy is a binding factor for all living organism. Since it is a fundamental characteristic of the functioning of the planet it is therefore not a gap to far to cross in logical terms and yet, for all that is known, the full extent the effects on all living systems still remains a mystery, particular with humans.

So to return to the question at hand and ask 'whether knowledge is created' it would be very difficult to understand how it cannot be. Electromagnetic information clearly affects the human

---

[350] Becker RO, Marino AA. 1982. *Electromagnetism and Life*. New York State University, New York Press. ISBN 0-87395-560-9. pg66

[351] Becker RO, Marino AA. 1982. *Electromagnetism and Life*. New York State University, New York Press. ISBN 0-87395-560-9. pg74

[352] Biogenesis is the process of lifeforms producing other lifeforms (source: http://en.wikipedia.org/wiki/Biogenesis)

[353] Becker RO, Marino AA. 1982. *Electromagnetism and Life*. New York State University, New York Press. ISBN 0-87395-560-9. pg74

[354] Becker RO, Marino AA. 1982. *Electromagnetism and Life*. New York State University, New York Press. ISBN 0-87395-560-9. pg74

[355] Dobson J, St. Pierre T. 1996. Application of the Ferromagnetic Transduction Model to D.C. and Pulsed Magnetic Fields: Effects on Epileptogenic Tissue & Implications for Cellular Phone Safety. *Biochem. Biophys. Res. Comm.* 227(3):718-723

faculties necessary for knowledge creation and the results of those effects are demonstrated on cognition through artificial electromagnetic stimulation and through natural behavioural traits. The fact that humans are affected is of planetary significance since human beings have been immersed in the earth's sea of electromagnetic energy from the origination of the species and have adapted to the cyclical nature of this force.

Chapter 7

The Implications

1 Synopsis

It would now be of value to review the entire argument as it has been laid out so far and provide some clarity on certain issues. The argument began within the field of knowledge management whereby it is firstly described as a completely human phenomenon providing a frame of reference for the conceptual investigation to follow. The problem of defining knowledge is then also made clear which simultaneously gives rise to a conceptual methodology. The methodology is designed to assist in asking an exhaustive set of questions that may return the most direct means to understanding the conceptual nature of knowledge and knowledge creation.

What follows is a sequential attempt at answering all the necessary questions that would assist in understanding the hypothetical claim the thesis makes about knowledge creation. The first question of 'whence is knowledge created?' is answered by delving into the discipline of cognitive archaeology to discover the history of human cognition. Not only does this reveal the first period in recorded human history where there was a significant shift in the creative potential of human beings, it also reveals in detail how the humans of that era modulated their brains to achieve their creative insights.

This method of brain modulation is linked to the research of modern day behavioural neuroscience and shown to provide a neurological bridge from the humans of that era to the humans of this era. The research shows that the physics behind the neurological mechanics is a well studied medium of brain stimulation known as Transcranial Magnetic Stimulation. The technique can be used to modulate brain activity as well as provide for an interesting range of other effects on neurological condition, behaviour, cognition and sensory perception.

These list of effects are all directly involved in the knowledge creation process and therefore essential to the successful execution of the procedure i.e. sensory information is retrieved by the senses and then processed by cognitive procedures to extract any and all useful information about the environment. This is necessary to elicit an appropriate behaviour which will more than likely be based on total accumulated sensory information, all of which is not possible

unless the operator is within a healthy neurological condition as any disease or disorder of the central nervous system will prohibit the knowledge creating process.

So it becomes clear that the complete range of effects elicited by electromagnetic stimulation have a greater function on the brain than simply altering consciousness, it seems electromagnetic fields, as a medium of information, direct the fundamental faculties of knowledge creation i.e. sensory perception, cognition, behaviour and neurological condition. Without these faculties knowledge creation is not possible and at the same time, modulation of brain activity can affect either one of the faculties with varied results on the knowledge creating process.

The extent of the potential effects of electromagnetic stimulation remain largely unknown, from the TMS device to power lines, much remains to be uncovered regarding the electromagnetic nature of human beings. What is exciting from the research so far is the amazing utility it has in the treatment of diseases and disorders, this is by far the most vigorous area of exploration within electromagnetic field research.

What will certainly aid intelligible query into this new region of neurological research is a comprehensive understanding of the biological mechanisms that area activated by the presence of electromagnetic fields. The best interpretation to date of this mechanism is known as the ferromagnetic transduction model which stipulates that the existence of magnetite in the human brain as the necessary magneto-sensitive material to induce modulation of neural firing rates thereby adjusting the faculties of knowledge creation.

With this model in mind there is a line of logic showing how the act of creating knowledge initiates as a sensory ability linked to the transduction of certain environmental electromagnetic fields. The transduction process is perpetuated by the electromagnetic potential of brain activity that maintains and adapts miniscule electromagnetic fields to further modulate the knowledge creation process.

The final step in the argument considers the cognitive value current research has to offer by turning off areas of the brain to modulate total brain activity thereby allowing healthy human subjects some of the cognitive skills of savants. Similarly, the behavioural phenomenon of hypnagogia is examined as an altered state of consciousness and shown to exhibit enormous assistance to many of the great scientists, authors, poets, artists, visionaries etc of recorded history. This nearly brings the argument to a close except for one last item that by no means is the least to be discussed.

2 Why is Knowledge Created?

There is one more question to look at briefly and although it is has been left for last it could not be answered otherwise. The answer to 'why is knowledge created?' will help provide a reason or purpose for the creation of knowledge.

The significance of creating knowledge can be seen from the order in which the evidence has been presented. The work of Lewis Williams highlights the most important period in human history where the creation of complex society was made possible by the creation of all the rich symbolic systems that surround almost every human being in some form or another. It is these systems of science, art, and religion (to name a few) which have allowed the human race to achieve extraordinary feats of ingenuity by simply providing for the means for every person to create, share and understand abstract information.

This particular point in history is the most important one because it is the first recorded period in history describing a shift in consciousness that all people can associate with, even the distantly remote people living deep within the few remaining rain forests of the world who have developed complex systems of governance through customs, traditions and rituals which were born from a cognitive shift at some point long ago. All people can thereby appreciate the significance of a permanent shift in consciousness, initiated by individuals who have the ability to temporarily alter consciousness and gain access to information beyond 'normal' consciousness.

Dr Persinger shows that this ability is not locked away in the distant past but an accessible phenomenon to every person by simply modulating the neural thresholds giving rise to variations in brain activity. These variations can inevitably be seen as the source of every human's creative output, so if neural threshold modulation (and the effect on total brain activity) could be understood more comprehensively, it may allow for another tipping point in the development of humankind. It may be possible for humans to one day to look back into the past as we look back to the ancient humans of the Palaeolithic and realise just how far we have come.

And yet, as it seems apparent by now, this development is marred for the potential of every human to abuse creative ability and utilise it for selfish intent. Lewis William noted how the visionaries would use their ability to socially discriminate themselves from others as a means to gain power and thereby further their selfish desire for personal gain. The sociological consequences of that have been passed down along with the benefits that complex society

provides. An excellent example of this two sided coin is the monumental scientific insight into the splitting of the atom, on one side it brought enormous potential to mankind and yet on the other, it could also just as easily wipe the human race off the face of the earth.

Dr Persinger also noted how the experiences within altered states of consciousness can mislead the experient to create a false belief in a deity that depended on a particular person's cultural socialisation. This can eventually lead to a fanatical belief in the superiority of one belief over another, facilitating the destructive consequences that arise when those fanatics have access to the creative breakthroughs of science (i.e. splitting of the atom).

The sociological implications of an individual's choices within the knowledge creating process are clear to see and it remains the responsibility of those who seek to create knowledge to be well informed on the mistakes history has made evident.

And so for those who seek the keys to the creation of knowledge, according to this hypothesis, it seems that the potential means are divided amongst the artificial and natural methods. The artificial techniques (such as TMS) are administered through a device that should base its treatment frequencies on real time neuroimaging data supplied by an alternative device (hopefully technology will eventually allow for this to be contained within one device that any person could carry with them as easily as a cell phone). Through precise neuroimaging the stimulation supplied by the TMS device should exactly correspond to the particular individual's needs, of course these needs will have to be based on well calculated predictions that the device will need to adapt to in real time.

The results of stimulation will obviously always need to reflect the intent of the user because any deviation from the intent of the user will be labelled a form of mind control, especially so because electromagnetic stimulation can influence sensory perception, cognitive ability, behaviour and neurological condition. From altering consciousness (sensed presence) to improving cognition (savants), artificial stimulation is a moral ground difficult to pass without confronting the ethical question of what is controlling the actions of the user. For this concern it would seem the natural means of modulating neural thresholds to be the most appropriate means of initiating the knowledge creation process.

On the contrary, artificial intervention must surely be deemed a necessary modality when the user is suffering from a neurological condition. The evidence available in this regard is abundant and is reflected in the research because of the immense utility it may offer victims of neurological conditions that seem mostly untreatable through conventional pharmacological

means. Perhaps it would seem that this is the best way to commence a course of exposure to neurological modulation since the faculty of neurological health is probably the most basic faculty ensuring effective ferromagnetic transduction of electromagnetic energy.

However, for people of sound neurological condition, it is probably in their best interest to use their natural ability to encourage the creation of knowledge so that there can never be any confusion as to the original intent of the creation. Hypnagogia is a good example of a means to access an altered state of consciousness without the intervention of external technology and therefore be free of any ethical concerns.

However, even through the use of natural techniques to achieve the act of creation, a change in neural thresholds that may have effect on sensory perception, cognition, behaviour and neurological condition is a concern because the incorrect modulation of the operator may result in extremely undesirable effects. It can lead an individual to believe in a notion that may create suffering for them and those around them which would seem a consequence well worth avoiding considering the perils history has already made clear.

Whatever path an individual may follow when pursuing the creation of knowledge, it seems the most sensible route entails a prudent understanding of the responsibilities that follow the act of creation.

Bibliography

Wilson TD. October 2002. The nonsense of 'knowledge management'. Information Research. *Vol 8 No* 1.

Schutz A. 1967. *The phenomenology of the social world.* Evanston, IL, Northwestern University Press

http://www.sveiby.com/TheLibrary/FAQs/tabid/85/Default.aspx#Whatis

Wilson, TD. Review of: Choo, CW. 2007. *The knowing organization: how organizations use information to construct meaning, create knowledge, and make decisions.* 2nd. ed. New York, Oxford: Oxford University Press, 2006 *Information Research*, **12**(3), review no. R264

Palmer NA. 2001. Polanyi's Concept of Tacit Knowing. T-656 Inquiry: Tacit Knowledge and Intuition, Harvard Graduate School of Education (source: http://www.gse.harvard.edu/~t656_web/From_2000-2001_students/Polanyi_Nina.htm)

MIT. 1992. Chomsky is Citation Champ. *MIT News Office.* Vol 36, 27

http://en.wikipedia.org/wiki/Syntax

http://en.wikipedia.org/wiki/Interrogative_word

http://en.wikipedia.org/wiki/Question

http://en.wikipedia.org/wiki/Wh-movement (source: Chomsky N. 1977. On Wh-Movement. *Formal Syntax*. New York; Lai-Sheng C. *Wh-Movement: Moving On*. The MIT Press, 2007)

http://en.wikipedia.org/wiki/Linguistics

http://en.wikipedia.org/wiki/Function_word

http://en.wikipedia.org/wiki/Interrogative_word

http://encarta.msn.com/dictionary_/whose.html

http://encarta.msn.com/dictionary_1861713004/who.html

http://encarta.msn.com/dictionary_/Which.html

http://encarta.msn.com/dictionary_/Where.html

http://encarta.msn.com/dictionary_/Whither.html

http://encarta.msn.com/dictionary_/When.html

http://encarta.msn.com/dictionary_/how.html

http://encarta.msn.com/dictionary_/why.html

http://encarta.msn.com/dictionary_/Whether%2520.html

Lewis Williams D.L. 2004. *The Mind in the Cave: Consciousness and the Origins of Art* Thames&Hudson (pg104)

Klein RG, Edgar B. 2002. *The Dawn of Human Culture* Wiley, New York

http://en.wikipedia.org/wiki/Richard_G._Klein

http://www.newarchaeology.com/articles/uprevolution.php

http://www.sciencedaily.com/releases/1998/07/980707073901.htm

Klarreich E. April 2004. Biography of Richard G. Klein *PNAS*. Vol 101 no 16, 5705–5707 (source: http://www.pnas.org/cgi/content/full/101/16/5705)

Mithen SJ. 1996. *The prehistory of the mind : a search for the origins of art, religion, and science*. London, Thames and Hudson. ISBN: 0500050813

Lewis-Williams DL. 1989. Southern Africa's place in the archaeology of human understanding *Suid-Afrikaanse Tydskrif vir Wetenskap* Vol. 85, 47-52

Lewis-Williams DL. 2003. (Review Feature: Pearson JL. 2002. *Shamanism and the Ancient Mind: A Cognitive Approach to Archaeology*. Walnut Creek, Altamira Press) *Journal of Anthropological Research,* vol. 59, 94)

Lewis-Williams DL. 2003. (Review Feature: Lewis-Williams DL. 2002. *The Mind in the Cave: Consciousness and the Origins of Art*. London, Thames & Hudson) *Cambridge Archaeological Journal* vol 13, 263-279

Lewis- Williams JD. 1981. *Believing and Seeing: Symbolic Meanings in Southern San Rock Paintings*. London: Academic Press (pg204)

Lewis-Williams DL, Clottes J. 1998. Altered Consciousness in the Upper Paleolithic. *Anthropology of Consciousness*. Vol 9, 15

Foucault M. 1965. *Madness and civilization*. New York, Random House.

Lewis-Williams DL. 1997. Agency, art and altered consciousness: a motif in French (Quercy) Upper Palaeolithic parietal art. *Antiquity*: Vol 7, 274

Thomas Lawson E. 2003. (Review Feature: Lewis-Williams DL. 2002. *The Mind in the Cave: Consciousness and the Origins of Art*. London, Thames & Hudson). *Cambridge Archaeological Journal*. vol 13, 263-279

http://encarta.msn.com/dictionary_1861725692/phosphene.html

Lewis-Williams DL. 2004. Neuropsychology and Upper Palaeolithic Art: Observations on the Progress of Altered States of Consciousness *Cambridge Archaeological Journal*. 14(1), 107-11

http://oldwebsite.laurentian.ca/neurosci/_research/geomagnetic.htm

http://oldwebsite.laurentian.ca/neurosci/_research/mystical.htm

Persinger MA. 1987. *Neuropsychological bases for god beliefs*. NY, Praeger.

Persinger MA, Healy F. 2002. Experimental Facilitation of the Sensed Presence: Possible Intercalation between the Hemispheres Induced by Complex Magnetic Fields *Journal of Nervous and Mental Diseases*. Vol 190, No 8, 533-41

Hallet M. 2000. Trancranial Magnetic Stimulation and the Human Brain. *Nature*. Vol 406, 147-150

http://oldwebsite.laurentian.ca/neurosci/_research/bioelectromagnetic.htm

Halgren E, Walter RD, Cherlow DG, Crandall PH. 1978. Mental phenomena evoked by electrical stimulation of the human hippocampal formation and amygdala. *Brain* 101:83–117

Slaver JL, Rabin J. 1997.The neural substrates of religious experience. *J Neuropsychiatry Clin Neurosci*. 9:498–510

http://oldwebsite.laurentian.ca/neurosci/_people/Persinger.htm

http://oldwebsite.laurentian.ca/neurosci/_research/conscious.htm

http://en.wikipedia.org/wiki/Depolarisation

http://en.wikipedia.org/wiki/Action_potential

Griskova I, Höppner J, Ruksenas O, Dapsys K. 2006. Transcranial magnetic stimulation: the method and application. *Medicina (Kaunas)*. 42(10):798-804

Pascual-Leone A, Walsh V, Rothwell J. 2000. Transcranial magnetic stimulation in cognitive neuroscience--virtual lesion, chronometry, and functional connectivity. *Curr Opin Neurobiol*. 10(2):232-7

Boggio PS, Fregni F, Rigonatti SP, Marcolin MA, Silva MT. 2006. [Transcranial magnetic stimulation in neuropsychology: new horizons for brain research]. *Rev Bras Psiquiatr*. 28(1):44-9.

Verdon CM, Saba G, Januel D. 2004. [Transcranial magnetic stimulation in cognition and neuropsychology] *Encephale*. 30(4):363-8

Theodore WH, Fisher R. 2007. Brain stimulation for epilepsy. *Acta Neurochir Suppl*. 97(Pt 2):261-72

Schneider M, Retz W, Freitag C, Irsch J, Graf P, Retz-Junginger P, Rösler M. 2007. Impaired cortical inhibition in adult ADHD patients: a study with transcranial magnetic stimulation. *J Neural Transm Suppl*. (72):303-9

Berney A, Vingerhoets F. 2005. [Novel brain stimulation techniques: therapeutic perspectives in psychiatry]. *Rev Med Suisse*. 1(33):2162-4, 2166

Levit-Binnun N, Handzy NZ, Moses E, Modai I, Peled A. 2007. Transcranial Magnetic Stimulation at M1 disrupts cognitive networks in schizophrenia. *Schizophr Res*. 93(1-3):334-44

Wagner T, Valero-Cabre A, Pascual-Leone A. 2007. Noninvasive human brain stimulation. *Annu Rev Biomed Eng*. 9:527-65

Kluger BM, Triggs WJ. 2007. Use of transcranial magnetic stimulation to influence behavior. *Curr Neurol Neurosci Rep*. 7(6):491-7

George MS, Wassermann EM, Kimbrell TA, Little JT. 1997. Mood improvement following daily left prefrontal repetitive transcranial magnetic stimulation in patients with depression: A placebo-controlled crossover trial. *The American Journal of Psychiatry*. Vol. 154, Iss 12, pg 1752

Huang *GT*. 2004. Zapping the Blues. *Technology Review, Cambridge*. Vol 107, Iss 2, pg 26

http://en.wikipedia.org/wiki/Prozac

Bortolomasi M, Minelli A, Fuggetta G, Perini M, Comencini S, Fiaschi A, Manganotti P. 2007. Long-lasting effects of high frequency repetitive transcranial magnetic stimulation in major depressed patients *Psychiatry Res*. 30;150(2):181-6

http://en.wikipedia.org/wiki/Beck_Depression_Inventory

Luborzewski A, Schubert F, Seifert F, Danker-Hopfe H, Brakemeier EL, Schlattmann P, Anghelescu I, Colla M, Bajbouj M. 2007. Metabolic alterations in the dorsolateral prefrontal cortex after treatment with high-frequency repetitive

transcranial magnetic stimulation in patients with unipolar major depression. *J Psychiatr Res.* 41(7):606-15

André-Obadia N, Peyron R, Mertens P, Mauguière F, Laurent B, Garcia-Larrea L. 2006. Transcranial magnetic stimulation for pain control. Double-blind study of different frequencies against placebo, and correlation with motor cortex stimulation efficacy. *Clin Neurophysiol.* 117(7):1536-44

Pelka RB, Jaenicke C, Gruenwald J. 2001. Impulse magnetic-field therapy for migraine and other headaches: a double-blind, placebo-controlled study. *Adv Ther.* 18(3):101-9

Clarke BM, Upton AR, Kamath MV, Al-Harbi T, Castellanos CM.. 2006. Transcranial magnetic stimulation for migraine: clinical effects. *J Headache Pain.* 7(5):341-6

Hirayama A, Saitoh Y, Kishima H, Shimokawa T, Oshino S, Hirata M, Kato A, Yoshimine T. 2006. Reduction of intractable deafferentation pain by navigation-guided repetitive transcranial magnetic stimulation of the primary motor cortex. *Pain.* 122(1-2):22-7

Zifko UA. 2003. Therapy of day time fatigue in patients with multiple sclerosis. *Wien Med Wochenschr.* 153(3-4):65-72

Lappin MS, Lawrie FW, Richards TL, Kramer ED. 2003. Effects of a pulsed electromagnetic therapy on multiple sclerosis fatigue and quality of life: a double-blind, placebo controlled trial. *Altern Ther Health Med.* 9(4):38-48

http://en.wikipedia.org/wiki/Demyelinating_disease

Brola W, Wegrzyn W, Czernicki J. 2002. Effect of variable magnetic field on motor impairment and quality of life in patients with multiple sclerosis *Wiad Lek.* 55(3-4):136-43

Sandyk R. 1997. Therapeutic effects of alternating current pulsed electromagnetic fields in multiple sclerosis. *J Altern Complement Med.* 3(4):365-86

Chebotar'ova LL, Chebotar'ov HIe. 2003. [Use of low-power electromagnetic therapy in diabetic polyneuropathy]. *Fiziol Zh.* 49(2):85-90

Musaev AV, Guseinova SG, Imamverdieva SS. 2003. The use of pulsed electromagnetic fields with complex modulation in the treatment of patients with diabetic polyneuropathy. *Neurosci Behav Physiol.* 33(8):745-52

http://en.wikipedia.org/wiki/Afferent_nerve

Khedr EM, Rothwell JC, Shawky OA, Ahmed MA, Hamdy A. 2006. Effect of daily repetitive transcranial magnetic stimulation on motor performance in Parkinson's disease. *Mov Disord.* 21(12):2201-5

Mert T, Gunay I, Gocmen C, Kaya M, Polat S. 2006. Regenerative effects of pulsed magnetic field on injured peripheral nerves. *Altern Ther Health Med.* 12(5):42-9

De Pedro JA, Pérez-Caballer AJ, Dominguez J, Collía F, Blanco J, Salvado M. 2005. Pulsed electromagnetic fields induce peripheral nerve regeneration and endplate enzymatic changes. *Bioelectromagnetics.* 26(1):20-7

Keck ME, Welt T, Muller MB, Erhardt A, Ohl F, Toschi N, Holsboer F, Sillaber I. 2002. Repetitive transcranial magnetic stimulation increases the release of dopamine in the mesolimbic and mesostriatal system. *Neuropharmacology.* 43(1):101-9

http://en.wikipedia.org/wiki/Neurotransmitters

Sandyk R. 1997. Reversal of cognitive impairment in an elderly parkinsonian patient by transcranial application of picotesla electromagnetic fields. *Int J Neurosci.* 91(1-2):57-68

http://oldwebsite.laurentian.ca/neurosci/_research/bioelectromagnetic.htm

http://en.wikipedia.org/wiki/Rey-Osterrieth_Complex_Figure

Sandyk R. 1995. Improvement in short-term visual memory by weak electromagnetic fields in Parkinson's disease. *Int J Neurosci.* 81(1-2):67-82

http://en.wikipedia.org/wiki/Hoehn_and_Yahr_scale

http://en.wikipedia.org/wiki/Hoehn_and_Yahr_scale

Lefaucheur JP, Drouot X, Nguyen JP. 2001. Interventional neurophysiology for pain control: duration of pain relief following repetitive transcranial magnetic stimulation of the motor cortex. *Neurophysiol Clin.* 31(4):247-52

Feigin VL. 2005. Stroke epidemiology in the developing world. *Lancet.* 365 (9478): 2160–1

Martin PI, Naeser MA, Theoret H, Tormos JM, Nicholas M, Kurland J, Fregni F, Seekins H, Doron K, Pascual-Leone A. 2004. Transcranial magnetic stimulation as a complementary treatment for aphasia. *Speech Lang.* (2):181-91

Fregni F, Boggio PS, Valle AC, Rocha RR, Duarte J, Ferreira MJ, Wagner T, Fecteau S, Rigonatti SP, Riberto M, Freedman SD, Pascual-Leone A. 2006. A Sham-Controlled Trial of a 5-Day Course of

Repetitive Transcranial Magnetic Stimulation of the Unaffected Hemisphere in Stroke Patients. Stroke. *37:2115*

Plewnia C, Reimold M, Najib A, Brehm B, Reischl G, Plontke SK, Gerloff C. 2007. Dose-dependent attenuation of auditory phantom perception (tinnitus) by PET-guided repetitive transcranial magnetic stimulation. *Hum Brain Mapp.* 28(3):238-46

http://en.wikipedia.org/wiki/Limbic

http://en.wikipedia.org/wiki/Neuroplasticity

Langguth B, Hajak G, Kleinjung T, Pridmore S, Sand P, Eichhammer P. 2006. Repetitive transcranial magnetic stimulation and chronic tinnitus. *Acta Otolaryngol Suppl.* (556):102-5

Smith JA, Mennemeier M, Bartel T, Chelette KC, Kimbrell T, Triggs W, Dornhoffer JL. 2007. Repetitive transcranial magnetic stimulation for tinnitus: a pilot study. *Laryngoscope*. 117(3):529-34

http://en.wikipedia.org/wiki/Computer_tomography

http://en.wikipedia.org/wiki/Positron_Emission_Tomography

Plewnia C, Reimold M, Najib A, Brehm B, Reischl G, Plontke SK, Gerloff C. 2007. Dose-dependent attenuation of auditory phantom perception (tinnitus) by PET-guided repetitive transcranial magnetic stimulation. *Hum Brain Mapp.* 28(3):238-46

http://www.ncbi.nlm.nih.gov/pubmed/6880820

http://www.lsdregistry.net/fabryregistry/hcp/partic/assess/freg_hc_p_BPI.asp

http://www.sciencemag.org/cgi/content/abstract/288/5472/1769

Passard A, Attal N, Benadhira R, Brasseur L, Saba G, Sichere P, Perrot S, Januel D, Bouhassira D. 2007. Effects of unilateral repetitive transcranial magnetic stimulation of the motor cortex on chronic widespread pain in fibromyalgia. *Brain.* 130(Pt 10):2661-70

Rosenberg PB, Mehndiratta RB, Mehndiratta YP, Wamer A, Rosse RB, Balish M. 2002. Repetitive transcranial magnetic stimulation treatment of comorbid posttraumatic stress disorder and major depression. *J Neuropsychiatry Clin Neurosci.* 14(3):270-6

Pelka RB, Jaenicke C, Gruenwald J. 2001. Impulse magnetic-field therapy for insomnia: a double-blind, placebo-controlled study. *Adv Ther*. 18(4):174-80

van Elswijk G, Kleine BU, Overeem S, Eshuis B, Hekkert KD, Stegeman DF. 2008. Muscle imaging: mapping responses to transcranial magnetic stimulation with high-density surface electromyography. *Cortex*. 44(5):609-16

Laird AR, Robbins JM, Li K, Price LR, Cykowski MD, Narayana S, Laird RW, Franklin C, Fox PT. 2008. Modeling motor connectivity using TMS/PET and structural equation modeling. *Neuroimage*. 41(2):424-36

Tsao H, Galea MP, Hodges PW. 2008. Concurrent excitation of the opposite motor cortex during transcranial magnetic stimulation to activate the abdominal muscles. *J Neurosci Methods*. 171(1):132-9

Baud-Bovy G, Prattichizzo D, Rossi S. 2008. Contact forces evoked by transcranial magnetic stimulation of the motor cortex in a multi-finger grasp. *Brain Res Bull*. 75(6):723-36

http://en.wikipedia.org/wiki/Corticospinal

http://en.wikipedia.org/wiki/Sleep_spindle

http://en.wikipedia.org/wiki/Slow-wave_sleep

http://dictionary.reference.com/browse/cognition

http://en.wiktionary.org/wiki/cognition

Marshall L, Helgadóttir H, Mölle M, Born J. 2006. Boosting slow oscillations during sleep potentiates memory. *Nature*. 444(7119):610-3

http://en.wikipedia.org/wiki/Memory_consolidation

Massimini M, Ferrarelli F, Esser SK, Riedner BA, Huber R, Murphy M, Peterson MJ, Tononi G. 2007. Triggering sleep slow waves by transcranial magnetic stimulation. *Proc Natl Acad Sci U S A*. 104(20):8496-501

Grafman J, Wassermann E. 1999. Transcranial magnetic stimulation can measure and modulate learning and memory. Neuropsychologia. 37(2):159-67

Floel A, Poeppel D, Buffalo EA, Braun A, Wu CW, Seo HJ, Stefan K, Knecht S, Cohen LG. 2004. Prefrontal cortex asymmetry for memory encoding of words and abstract shapes. *Cereb Cortex*. 14(4):404-9

http://en.wikipedia.org/wiki/Working_memory

Kirschen MP, Davis-Ratner MS, Jerde TE, Schraedley-Desmond P, Desmond JE. 2006. Enhancement of phonological memory following transcranial magnetic stimulation (TMS). *Behav Neurol.* 17(3-4):187-94

Luber B, Kinnunen LH, Rakitin BC, Ellsasser R, Stern Y, Lisanby SH. 2007. Facilitation of performance in a working memory task with rTMS stimulation of the precuneus: frequency- and time-dependent effects. *Brain Res.* 1128(1):120-9

http://en.wikipedia.org/wiki/Numerical_cognition

Osaka N, Otsuka Y, Hirose N, Ikeda T, Mima T, Fukuyama H, Osaka M. 2007. Transcranial magnetic stimulation (TMS) applied to left dorsolateral prefrontal cortex disrupts verbal working memory performance in humans. *Neurosci Lett.* 18;418(3):232-5

Harris JA, Miniussi C, Harris IM, Diamond ME. 2002. Transient storage of a tactile memory trace in primary somatosensory cortex. *J Neurosci.* 22(19):8720-5

Epstein CM. 1998. Transcranial magnetic stimulation: language function. *J Clin Neurophysiol.* 15(4):325-32

http://en.wikipedia.org/wiki/Aphasia#Fluent.2C_non-fluent_and_.22pure.22_aphasias

Aziz-Zadeh L, Cattaneo L, Rochat M, Rizzolatti G. 2005. Covert speech arrest induced by rTMS over both motor and nonmotor left hemisphere frontal sites. *J Cogn Neurosci.* 17(6):928-38

Mottaghy FM, Hungs M, Brügmann M, Sparing R, Boroojerdi B, Foltys H, Huber W, Töpper R. 1999. Facilitation of picture naming after repetitive transcranial magnetic stimulation. *Neurology.* 10;53(8):1806-12

Schutter DJ, van Honk J. 2006. An electrophysiological link between the cerebellum, cognition and emotion: frontal theta EEG activity to single-pulse cerebellar TMS. *Neuroimage.* 33(4):1227-31

http://en.wikipedia.org/wiki/Vermis)

http://en.wikipedia.org/wiki/Cerebellar

http://en.wikipedia.org/wiki/Mood_%28psychology%29

Habel U, Wild B, Topka H, Kircher T, Salloum JB, Schneider F. 2001. Transcranial magnetic stimulation: no effect on mood with single pulse during learned helplessness. *Prog Neuropsychopharmacol Biol Psychiatry*. 25(3):497-506

http://en.wikipedia.org/wiki/Dysphoria

Jenkins J, Shajahan PM, Lappin JM, Ebmeier KP. 2002. Right and left prefrontal transcranial magnetic stimulation at 1 Hz does not affect mood in healthy volunteers. *BMC Psychiatry*. 2:1

http://en.wikipedia.org/wiki/Equilibrioception

http://encarta.msn.com/dictionary_/Nociception%2520.html

http://encarta.msn.com/dictionary_1861736463/proprioceptor.html

http://en.wikipedia.org/wiki/Thermoception

http://encarta.msn.com/dictionary_/chemoreception.html

http://encarta.msn.com/dictionary_/Photoreception.html

http://encarta.msn.com/dictionary_/mechanoreception%2520.html

http://en.wikipedia.org/wiki/Membrane_potential

Merabet LB, Theoret H, Pascual-Leone A. 2003. Transcranial magnetic stimulation as an investigative tool in the study of visual function. *Optom Vis Sci*. 80(5):356-68

http://en.wikipedia.org/wiki/Visual_cortex

Antal A, Paulus W. 2008.Transcranial direct current stimulation and visual perception. *Perception*. 37(3):367-74

Harris IM, Benito CT, Ruzzoli M, Miniussi C. 2008. Effects of right parietal transcranial magnetic stimulation on object identification and orientation judgments. J Cogn Neurosci. 20(5):916-26

http://en.wikipedia.org/wiki/Dorsal_stream

Silvanto J, Cattaneo Z, Battelli L, Pascual-Leone A. 2008. Baseline cortical excitability determines whether TMS disrupts or facilitates behavior. *J Neurophysiol*. 99(5):2725-30

http://en.wikipedia.org/wiki/Transcranial_magnetic_stimulation

Lewald J, Wienemann M, Boroojerdi B. 2004. Shift in sound localization induced by rTMS of the posterior parietal lobe. *Neuropsychologia*. 42(12):1598-607

Sathian K, Zangaladze A. 2002. Feeling with the mind's eye: contribution of visual cortex to tactile perception. *Behav Brain Res.* 135(1-2):127-32

http://en.wikipedia.org/wiki/Extrastriate

Romei V, Murray MM, Merabet LB, Thut G. 2008. Occipital transcranial magnetic stimulation has opposing effects on visual and auditory stimulus detection: implications for multisensory interactions. *J Neurosci.* 28(1):1-2.

Morley JW, Vickery RM, Stuart M, Turman AB. 2007. Suppression of vibrotactile discrimination by transcranial magnetic stimulation of primary somatosensory cortex. *Eur J Neurosci.* 26(4):1007-10.

Ptito M, Fumal A, de Noordhout AM, Schoenen J, Gjedde A, Kupers R. 2008. TMS of the occipital cortex induces tactile sensations in the fingers of blind Braille readers. *Exp Brain Res.* 184(2):193-200

Ohara S, Lenz FA. 2003. Medial lateral extent of thermal and pain sensations evoked by microstimulation in somatic sensory nuclei of human thalamus. *J Neurophysiol.* 90(4):2367-77

Tegenthoff M, Ragert P, Pleger B, Schwenkreis P, Förster AF, Nicolas V, Dinse HR. 2005. Improvement of tactile discrimination performance and enlargement of cortical somatosensory maps after 5 Hz rTMS. *PLoS Biol.* (11):e362

Borckardt JJ, Smith AR, Reeves ST, Weinstein M, Kozel FA, Nahas Z, Shelley N, Branham RK, Thomas KJ, George MS. 2007. Fifteen minutes of left prefrontal repetitive transcranial magnetic stimulation acutely increases thermal pain thresholds in healthy adults. *Pain Res Manag.* 12(4):287-90

Ohara S, Lenz FA. 2003. Medial lateral extent of thermal and pain sensations evoked by microstimulation in somatic sensory nuclei of human thalamus. *J Neurophysiol.* 90(4):2367-77

Pascual-Leone A, Cohen LG, Brasil-Neto JP, Valls-Solé J, Hallett M. 1994. Differentiation of sensorimotor neuronal structures responsible for induction of motor evoked potentials, attenuation in detection of somatosensory stimuli, and induction of sensation of movement by mapping of optimal current directions. *Electroencephalogr Clin Neurophysiol.* 93(3):230-6

Bestmann S, Oliviero A, Voss M, Dechent P, Lopez-Dolado E, Driver J, Baudewig J. 2006. Cortical correlates of TMS-induced phantom hand movements revealed with concurrent TMS-fMRI. *Neuropsychologia*. 44(14):2959-71

Ellaway PH, Prochazka A, Chan M, Gauthier MJ. 2004. The sense of movement elicited by transcranial magnetic stimulation in humans is due to sensory feedback. *J Physiol*. 556(Pt 2):651-60

http://www.webmd.com/depression/experimental-treatments-depression

Kanda M, Mima T, Oga T, Matsuhashi M, Toma K, Hara H, Satow T, Nagamine T, Rothwell JC, Shibasaki H. 2003. Transcranial magnetic stimulation (TMS) of the sensorimotor cortex and medial frontal cortex modifies human pain perception. *Clin Neurophysiol*. 114(5):860-6

http://www.wired.com/science/discoveries/news/2006/02/70085

Becker RO, Marino AA. 1982. *Electromagnetism and Life*. New York State University, New York Press. ISBN 0-87395-560-9

Dobson J, Grassi P. 1996. Magnetic Properties of Human Hippocampal Tissue: Evaluation of Artefact and Contamination Sources. *Brain Res. Bull*. 39: 255-259

Coetzee H. 2003. Biomagnetism and Bio-Electromagnetism: The Foundation of Life. *Future History*. Vol 8

Kirschvink JL, Kobayashi-Kirschvink A, Woodford BJ. 1992. Magnetite biomineralization in the human brain. *Proc. Natl. Acad. Sci*. 89: 7683-7687

Dobson J, Grassi P. 1996. Magnetic Properties of Human Hippocampal Tissue: Evaluation of Artefact and Contamination Sources. *Brain Res. Bull*. 39: 255-259

Kirschvink JL. 1996. Microwave absorption by magnetite: a possible mechanism for coupling nonthermal levels of radiation to biological systems. *Bioelectromagnetics*. 17(3):187-94

Dobson J, St. Pierre T. 1996. Application of the Ferromagnetic Transduction Model to D.C. and Pulsed Magnetic Fields: Effects on Epileptogenic Tissue & Implications for Cellular Phone Safety. *Biochem. Biophys. Res. Comm*. 227(3):718-723

Kirschvink JL, Kobayashi-Kirschvink A, Woodford BJ. 1992. Magnetite biomineralization in the human brain. *Proc. Natl. Acad. Sci*. 89: 7683-7687

Kirschvink JL, Walker MM, Diebel CE. 2001. Magnetite-based magnetoreception. *Curr Opin Neurobiol.* 11(4):462-7

Young RL, Ridding MC, Morrell TL. 2004. Switching skills on by turning off part of the brain. *Neurocase.* 10(3):215-22

Jacob J, Lamme VAF. 2005. Repression of unconscious information by conscious processing: Evidence from affective blindsight induced by transcranial magnetic stimulation *Proceedings of the National Academy of Sciences of the United States of America.* 102(30):10747

http://en.wikipedia.org/wiki/Blindsight

Bódizs R, Sverteczki M, Mészáros E. 2008. Wakefulness-sleep transition: emerging electroencephalographic similarities with the rapid eye movement phase. *Brain Res Bull.* 76(1-2):85-9

http://en.wikipedia.org/wiki/REM_sleep

http://www.forteantimes.com/features/articles/227/hypnagogia.html

Persinger MA, Healy F. 2002. Experimental Facilitation of the Sensed Presence: Possible Intercalation between the Hemispheres Induced by Complex Magnetic Fields. *Journal of Nervous and Mental Diseases.* 190(8):534

http://www.innerworkingsresources.com/articles/mindwhispers.html

http://en.wikipedia.org/wiki/Friedrich_August_Kekul%C3%A9_von_Stradonitz#Benzene

Goldberg B. 2003. *Dream Your Problems Away: Heal Yourself While You Sleep.* The Career Press Inc

http://www.realityseeds.com/category/dreams

http://en.wikipedia.org/wiki/Electromagnetism

http://en.wikipedia.org/wiki/Telluric_current

http://en.wikipedia.org/wiki/Magnetohydrodynamic

Dobson J, St. Pierre T. 1996. Application of the Ferromagnetic Transduction Model to D.C. and Pulsed Magnetic Fields: Effects on Epileptogenic Tissue & Implications for Cellular Phone Safety. *Biochem. Biophys. Res. Comm.* 227(3):718-723

http://en.wikipedia.org/wiki/Biogenesis

http://en.wikipedia.org/wiki/Morphology_%28biology%29

http://www.innerworkingsresources.com/articles/mindwhispers.html

William J. Beckwith. 1992. Alpha-Theta Brainwave Training and Beta-Endorphin Levels in Alcoholics. *Megabrain Report*. 1(3)

Blank M, Goodman R. 1998. Do electromagnetic fields interact directly with DNA? *Bioelectromagnetics*. 18(2):111 – 115

http://en.wikipedia.org/wiki/Adenosine_triphosphate

http://en.wikipedia.org/wiki/Extracellular

Coetzee H. 2003. Biomagnetism and Bio-Electromagnetism: The Foundation of Life. *Future History*, Volume 8

http://en.wikipedia.org/wiki/Emmanuel_Swedenborg