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"UNDERSTANDING THE ARCHITECTURE OF HUMAN THOUGHT"? QUESTIONING THE MATHEMATICAL CONCEPTION OF NATURE WITH HEIDEGGER

¿COMPRENSIÓN DE LA ARQUITECTURA DEL PENSAMIENTO HUMANO? CUESTIONANDO LA CONCEPCIÓN MATEMÁTIC A DE LA NATURALEZA CON HEIDEGGER

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Abstract: New technologies, such as functional magnetic resonance imaging (fMRI) and transcranial magnetic stimulation (TMS), are currently touted as, not only giving us a better picture of the structure of the brain, but also a better understanding of our thinking. As Alan Snyder demonstrates when he claims his aim is to understand the 'architecture of *thought*' by investigating the brain. Against this backdrop, I will argue that new technologies present a worrying extension of mathematical natural science into the domain of human affairs. Extrapolating upon Heidegger, I will put forward that neuroscientific experiments force thinking to conform to the mathematical conception of nature, rather than reveal something about the 'true' nature of our thinking. In a time when the expansion of mathematical natural science threatens to reduce every domain to that which is quantifiable, I will conclude by suggesting that the responsibility of the philosopher is to question the presuppositions of modern science and psychology.

Key Words: *Ta Mathemata*, Heidegger, Neuroscience, Transcranial Magnetic Stimulation.

Resumen: Nuevas tecnologías como la imagen de resonancia magnética funcional (fMRI) y la estimulación magnética transcranial se consideran presumiblemente capaces de darnos no solo una mejor imagen de nuestro cerebro, sino también una mejor comprensión de nuestro pensamiento, tal como demuestra Alan Snyder cuando afirma que su objetivo es entender la "arquitectura del pensamiento" mediante la investigación del cerebro. Contra este marco general, argumentaré que las nuevas tecnologías nos presentan una preocupante extensión de la ciencia natural matemática al dominio de los asuntos humanos. Extrapolando a partir de Heidegger, propondré que los experimentos neurocientíficos fuerzan al pensamiento a conformarse a la concepción matemática de la naturaleza en vez de revelar algo sobre la verdadera naturaleza de nuestro pensamiento. Nos encontramos en un momento en que o la expansión de la ciencia natural matemática amenaza con reducir todos los dominios a lo que es cuantificable. Concluiré sugiriendo que la responsabilidad del filósofo es cuestionar los presupuestos de la ciencia moderna y de la psicología.

Palabras clave: *Ta Mathemata*, Heidegger, neurociencia, estimulación magnética transcranial.

> As axiomatic, the mathematical project is the anticipation (Vorausgriff) of the essence of things, of bodies; thus the basic blueprint (Grundriss) of the structure of everything and its relation to every other thing is sketched out in advance[1].

New techniques for investigating the brain are touted to give us direct access to observe and change the brain. With the increasing availability of these new techniques, brain-based accounts of the human mind are gaining interest from both researchers and the public. In some quarters, these new techniques for investigating the brain are taken as providing definitive evidence that the mind *is* the brain. The conviction that the mind *is* the brain has led to understanding these technologies as, not only a useful tool, but the tool *par excellence* for unlocking the secrets of the human mind. As the preeminent neuroscientist Professor Allan Snyder states 'I'm passionate about understanding the architecture of thought [...] Why are we wired up the way we are? Not how we are wired up but what is the master plan, the architectural plan'[2].

In this paper, I will question the claim that we now have 'evidence' that the mind *is* the brain by discussing the mathematical nature of natural science. To do so, I will draw upon two works of Martin Heidegger: 'The Modern Mathematical Science of Nature and the Origin of a Critique of Pure Reason', from his book *What is a Thing*[3]*,* and 'The Age of the World View'[4]. In both these works, Heidegger discusses what the mathematical means for modern natural science. I will argue that, rather than revealing the 'architecture of human thought' – as Alan Snyder has put it –, the increasing acceptance that the brain *is* the mind reveals a decisive extension of the modern mathematical conception of nature into the human sphere. I will not focus on whether the claim that the brain *is* the mind solves the Cartesian dualism or the problems with reducing mind to a

[1] Der mathematische Entwurf ist als axiomatischer der Vorausgriff in das Wesen der Dinge, der Körper; damit wird im *Grundriss* vorgezeichnet, wie jedes Ding under jede Bezeihung jedes Dinges zu jedem Ding gebaut ist'. Heidegger, Martin. "Die neuzeitliche mathematishe Naturwissenschaft und die Entstehung einer Kritik der reinen Vernunft", in *Die Frage nach dem Ding: Zu Kants Lehre von den transzendentalen Grundsätzen*. Tübingen, Max Niemeyer, 1987, 71. English translation: "The Modern Mathematical Science of Nature and the Origin of a Critique of Pure Reason", in *What Is a Thing?* Chicago, Illinois, Henry Regnery Company, 1967, 92. Henceforth, English page numbers [Original page numbers].

[2] See quote in Mercer, Phil. "Australian Thinking Cap Could Unleash our Hidden Genius", *Voice of America*, 17 October (2008), http://www.centreforthemind.com/newsmedia/VOANews_171008.pdf.

[3] Heidegger, Martin. *Die Frage nach dem Ding. Op. Cit.* English translation: *What is a Thing?* Trans. W. B. Barton and Vera Deutsch. Boston, University Press of America, 1967.

[4] Heidegger, Martin. "Die Zeit des Weltbildes", in *Holzwege*. Frankfurt am Main, Vittorio Klostermann, 2003 [1938]. English translation: "The Age of the World View", *Boundary 2*, Winter 1976 [1938]. Henceforth, English page numbers [Original page numbers].

material substrate. Instead, I will argue that the assumption that the mind *is* the brain objectifies human thought as a spatio-temporal location within mathematical nature.

To illustrate my argument I will focus upon one type of method used to investigate and map the brain: transcranial magnetic stimulation (TMS). TMS is touted as a novel and exciting technique for investigating the brain because it allows researchers to cause a change in the brain and, hence, is presented as a tool for establishing cause and effect between the brain and behaviour[5]. The effects of TMS are measured in different ways depending upon what the researcher is aiming to change. TMS is used to study a diverse range of topics from motor skills, to depression, to prejudice[6]. I will look at how the effects of using TMS are measured in an experiment designed to investigate prejudice[7]. Through showing how the operations of TMS are understood and its effects measured, I will argue, in line with Heidegger, that the observations made in the experiment are already shaped by mathematical nature and only what conforms to this definition of nature is allowed to reveal itself as an object of observation[8].

I will conclude by suggesting that the responsibility of the philosopher, in part, involves having 'the courage to question as deeply as possible the truth of our own presuppositions'[9] because 'constant questioning appears as the only human way to preserve things in their inexhaustibility, i.e., without distortion'[10]. Leaving the assumption that human thought can be explained through the mechanical operation of neurons threatens not only the integrity of our knowledge, but also the integrity of our human life.

[5] For an explanation see: Pascual-Leone, Alvaro. Bartes-Faz, David. and Keenan, Julian P. "Transcranial Magnetic Stimulation: Studying the Brain-Behaviour Relationship by Induction of 'Virtual Lesions'", *Philosophical Transactions of The Royal Society B* 354 (1999).
[6] For a review of the uses of TMS see: Hallett, Mark. "Transcranial Magnetic Stimulation and the Human Brain". *Nature*, 406, no. July (2000).
[7] I will use the following study: Jason Gallate et al., "Noninvasive Brain Stimulation reduces Prejudice Scores on an Implicit Association Test", *Neuropsychology* 25, no. 2 (2011).
[8] ee: Heidegger, Martin. "The Modern Mathematical Science of Nature", in particular 88-95 [69-73], and "The Age of the Worldview", in particular 342-47 [76-84].
[9] 'Der Mut, die Wahrheit der eigenen Voraussetzungen [...] zum Fragwürdigsten zu machen'. Heidegger, Martin. "The Age of the World View", 341 [75].
[10] 'Der Fragwürdigkeit erscheint als der einzige menschliche Weg, um die Dinge in ihrer Unerschöpflichkeit, d. h. Unverfälschtheit zu bewahren.' Heidegger, Martin. "The Modern Mathematical Science of Nature", 65 [50].

ESTABLISHING CAUSE AND EFFECT BETWEEN THE BRAIN AND BEHAVIOUR WITH TRANSCRANIAL MAGNETIC STIMULATION (TMS)

The Cause

Neurocognitive researchers understand the relatively new technique of TMS as a tool for establishing causal relationships between the brain and behaviour. TMS is posited as a tool which can change specific sections of the brain through magnetic fields. As Alvaro Pascual-Leone, Vincent Walsh and John Rothwell explain 'magnetic field induces a current in the subject's brain, and this stimulates the neural tissue'[11]. TMS was first proposed by Anthony Barker, Reza Jalinous and Ian Freestone[12]. They proposed TMS as 'a novel method of directly stimulating the human motor cortex by a contactless and non-invasive technique using a pulsed magnetic field'[13]. In more concrete terms they describe the process of TMS as 'when the coil is placed on the scalp, over the appropriate region of the motor cortex, movements of the opposite hand or leg are easily obtained without causing distress or pain'[14]. The increasing excitement regarding TMS[15] lies in that fact that cognitive neuroscientists understand this technique as enabling them to directly cause a change in the operations of the brain and measure its effect.

As Pascual-Leone, David Bartes-Faz and Julian Keenan explain 'traditionally, "lesion studies" have represented the best way of establishing a causal link between brain function and behaviour'.[16] They go on to explain that there are several problems with 'lesion studies' that bring into question the evidence these studies provide for causal links between the brain and behaviour. 'Lesion studies' are studies of acquired brain injury and, hence, these studies are generally opportunistic case studies that are conducted upon people who have multiple injuries and, importantly for Pascual-Leone and others, multiple brain injuries. As a result, 'lesion studies' are not generally amenable to experimental

[11] Pascual-Leone, Alvaro. Walsh, Vincent. and Rothwell, John. "Transcranial Magnetic Stimulation in Cognitive Neuroscience: Virtual Lesion, Chronometry, and Functional Connectivity", *Current Opinion in Neurobiology* 10, no. 2 (2000), 232.
[12] Barker, Anthony. Jalinous, Reza. and Freestone, Ian. "Non-Invasive Magnetic Stimulation of Human Motor Cortex", *The Lancet*, May 11 (1985).
[13] Ibid., 1106.
[14] Ibid., 1107.
[15] Repetitive Transcranial Magnetic Simulation (rTMS) is also frequently used, but the difference lies in the way the magnetic pulse is applied.
[16] Pascual-Leone, Bartes-Faz, and Keenan, "Transcranial Magnetic Stimulation", 1229.

research. The authors outline that what traditional 'lesion studies' lack, investigations that utilise TMS have. They claim that TMS creates 'a temporary "virtual brain lesion" [...] in normal subjects'.[17] The benefit of TMS is that researchers can plan and control the induction of 'virtual lesions' in 'normal subjects'. Thereby, neuroscientists posit TMS as allowing them to combine, what they consider to be, the two best methods for establishing causal relationships between the brain and behaviour: 'lesion studies' and the experiment[18].

The 'temporary virtual lesion' is the predominant explanation of the mechanism by which TMS works.[19] However, as Carlo Miniussi, Manuela Ruzzoli and Walsh point out 'the virtual lesion term is just that, words, and it is not informative about the possible mechanism of action of TMS'[20]. Their conclusion is that 'despite the widespread usage of transcranial magnetic stimulation (TMS) in clinical and basic research, the exact mechanisms of action and interactions with ongoing neural activity remain unclear'[21]. However, they are not suggesting that TMS research should stop until the mechanism of TMS is understood; they simply suggest that knowing how TMS works would be helpful in interpreting the results that researchers have already found[22].

A clue as to why TMS continues to be used, despite researchers' lack of clarity about the exact mechanism of TMS, is given in Pascual-Leone, Walsh and Rothwell's description of TMS:

> The investigative tools used in science determine the kinds of empirical observations that can be made. Very often, the results produced by new tools in the neurosciences force us to re-evaluate models of brain-behaviour relationships and even affect the kinds of question that are asked.[23]

In other words, using this technology will demonstrate what the new technique can tell researchers about how the brain works and, presumably, through this illustrate how TMS works. Their description outlines that, for neuroscien-

[17] Ibid.
[18] For a full explanation see: Ibid.: 1229-38. Also see: Pascual-Leone, Walsh, and Rothwell, "TMS in Cognitive Neuroscience".
[19] Miniussi, Carlo. Ruzzoli, Manuela. and Walsh, Vincent. "The Mechanism of Transcranial Magnetic Stimulation in Cognition", *Cortex* 46 (2010), 128. For an explanation of the 'virtual lesion' framework see Pascual-Leone, Walsh, and Rothwell, "TMS in Cognitive Neuroscience".; Pascual-Leone, Bartes-Faz, and Keenan, "Transcranial Magnetic Stimulation".
[20] Miniussi, Ruzzoli, and Walsh, "The Mechanism of TMS", 128.
[21] Ibid.
[22] Ibid.: 129.
[23] Pascual-Leone, Walsh, and Rothwell, "TMS in Cognitive Neuroscience", 232.

tists, the techniques used for observation are more important than theory and questions: 'investigative tools' are given precedence in their investigations of 'brain-behaviour relationships'.

Modern science, including neuroscience, is characterised by its reliance upon observation over and above theoretical concerns. However what is to count as an observation in the context of modern science is, as Heidegger states, decided in advance[24]. Researchers may claim that they do not know the exact mechanism of TMS, but, by using TMS, researchers have already decided upon the direction in which they will find their answers about how the brain works. It has already been decided that the brain is an electromagnetic circuit that can be changed through the application of an external magnetic force (e.g. TMS)[25] . By using TMS, researchers will only make more exact their electromagnetic explanations of the brain[26]. As part of neuroscientific experiments, it is not only the model of the brain – through which the cause is defined –, but also the effect, i.e. the behaviour, that is decided in advance.

The Effect

The way in which the effect of TMS is measured depends upon how the experiment is designed, i.e. which hypothesis the researchers are seeking to confirm or disconfirm. Hence, to illustrate how the effects of TMS are decided upon in advance, I will focus upon one experiment by Gallate, Wong, Ellwood, Chi and Snyder. They adopt TMS[27] as a way of investigating 'the neural basis of prejudice formation, maintenance, and extinction'[28]. For them, prejudice is a measure of the effect of TMS.

Gallate and others use TMS to investigate the function of the anterior temporal lobes (ATLs). On the basis of previous research, they state that there is 'emerging evidence that the anterior temporal lobes (ATLs) may be an area

[24] Heidegger, "The Modern Mathematical Science of Nature", 102 [79].
[25] For example see: 'Transcranial magnetic stimulation (TMS) is based on Faraday's principles of electromagnetic induction [...] In TMS studies, the stimulation coil is held over a subject's head and as a brief pulse of current is passed through it, a magnetic field is generated that passes through the subject's scalp and skull with negligible attenuation (only the decaying by the square of the distance). This time-varying magnetic field induces a current in the subject's brain, and this simulates the neural tissue'. Pascual-Leone, Walsh, and Rothwell, "TMS in Cognitive Neuroscience", 232.
[26] For a similar argument see: Keiper, Adam. "The Age of Neuroelectronics", *The New Atlantis: A Journal of Technology and Society* 11, no. Winter 2006 (2006).
[27] To be precise, Gallate and others use rTMS. For an explanation of the difference between TMS and rTMS see note 16.
[28] Gallate et al., "Brain Stimulation reduces Prejudice", 185.

involved in prejudice via mediating conceptual processing'[29]. Accordingly, they name the function of the ATLs as 'semantic association'[30]. They suggest that the ATLs play a role in prejudice because prejudice is a type of semantic association. Gallate and others' definition of prejudice as a semantic association is in line with cognitive psychological definitions of an attitude and a prejudice. In cognitive psychology, attitudes are defined as '*an association* between an act or object and an evaluation'[31]. A prejudice is understood as a type of attitude that is directed towards a person or group of people[32]. The common measure of prejudice in cognitive psychology is the Implicit Association Test (IAT)[33]. Gallate and others use the IAT as a measure of the function of the ATLs.

To explain the IAT, I will use Gallate and others' version of the measure. The researchers choose 'the association of *Arab* and *terrorist*' as the particular prejudice they will use as a measure of prejudice and, more generally, semantic association[34]. They designate 'Arab versus non-Arab sounding names (e.g., "Habib" vs. "Benoit")' as the object to be evaluated and 'terrorist versus law abiding words (e.g. "sniper" vs. "citizen")' as the evaluation. The IAT is a com-

[29] Ibid.: 186.
[30] Ibid.
[31] Burton, Lorelle. Westen, Drew. and Kowalski, Robin. *Psychology*, 2nd ed. Milton, Queensland, John Wiley & Sons Australia, 2009, 681, my italics. Although it is not preferred to use a textbook as an academic reference, psychology textbooks are the one place you can find simple definitions of psychological concepts. In the peer reviewed literature, researchers are too wary to give simple definitions because, as Norbert Schwarz admits 'attitudes are hypothetical constructs that psychologists invented to explain phenomena of interest', yet 'the explanatory power of the attitude [is] less than impressive'. Schwarz, Norbert. "Attitude Construction: Evaluation in Context", *Social Cognition* 25, no. 5 (2007): 638. For a review of attitude research in psychology see: Ajzen, Icek. "Nature and Operation of Attitudes", *Annual Review of Psychology* 52 (2001): 28.
[32] Burton, Westen, and Kowalski, *Psychology*, 693. The above note applies here as well. Prejudice is considered the attitude and discrimination the behaviour. Within research on prejudice, like other areas of social psychology, one of the biggest problems is that attitudes are not very good at predicting behaviour. For a discussion which relates specifically to the relationship between prejudice and discrimination see: Schofield, Janet Ward. and Steers-Wentzell, Katrina L. "Prejudice and Discrimination: Exploring Their Origins and Understanding Their Nature", *Human Development* 46, no. 5 (2003).
[33] Nosek, Brian A. Greenwald, Anthony G. and Banaji, Mahzarin R. "The Implicit Association Test at Age 7: A Methodological and Conceptual Review", in *Automatic Processes in Social Thinking and Behavior*, ed. J. A. Bargh, New York, Psychology Press, 2007, 267. The IAT was first developed by Anthony Greenwald, Debbie McGhee and Jordan Schwartz in 1998. The IAT was developed as a way of measuring Greenwald and Mahzarin Banaji's concept of implicit attitudes. Greenwald, Anthony. McGhee, Debbie. and Schwartz, Jordan. "Measuring Individual Differences in Implicit Cognition: The Implicit Association Test", *Journal of Personality and Social Psychology* 74, no. 6 (1998), 1464. The basic idea of implicit attitudes is that they are attitudes that we do not know we hold, yet they continue to influence our behaviour. Greenwald, Anthony. and Banaji, Mahzarin. "Implicit Social Cognition: Attitudes, Self-Esteem, and Stereotypes", *Psychological Review* 102, no. 1 (1995), 5. Due to the fact that we do not know that we hold these attitudes, researchers cannot simply ask a research participant about their attitudes (e.g. through self-report measures). Ibid., 19. The IAT is proposed as an indirect measure of attitudes that bypasses the problems associated with self-report measures of attitudes. Greenwald, McGhee, and Schwartz, "The Implicit Association Test". For a discussion of the problems association with self-report measures see the famous discussion by Nisbett, Richard. and Wilson, Timothy. "Telling More Than We Can Know: Verbal Reports on Mental Processes", *Psychological Review* 84, no. 3 (1977).
[34] Gallate et al., "Brain Stimulation reduces Prejudice", 185.

puter program, where research participants are required to respond to a series of words and names by pressing one of two keys: one for the left-hand and one for the right-hand side of the computer screen. On each side of the computer screen a name is paired with an evaluative word. That is, either 'Arab sounding names' are paired with 'terrorist' – which is called the stereotypical condition – or 'Arab sounding names' are paired with 'law-abiding' – which is called the non-stereotypical condition. A name or word is shown to the participant in the middle of the screen and the participant is required to indicate whether it is either an 'Arab' or 'non-Arab sounding name' or a 'terrorist' or 'law-abiding' word using either the left or the right response key[35]. The IAT is designed to measure reaction time and accuracy. Reaction time is the number of milliseconds a participant takes to press a key after the word is flashed up on the screen. Accuracy is whether the participant correctly identifies an 'Arab sounding name' as an 'Arab sounding name', a 'terrorist' word as a 'terrorist word', etc. Reaction time and accuracy are used to measure prejudice. The research participant is deemed as prejudiced, if she is quicker and more accurate when indicating which names and words belong to which category in the stereotypical condition – when 'Arab sounding names' are paired with 'terrorist' –, than the non-stereotypical condition – when 'Arab sounding names' are paired with 'law-abiding'[36]. The larger the difference in reaction times and accuracy between stereotypical and non-stereotypical conditions is posited as indicating the stronger the association between, in this case, 'Arab sounding names' and 'terrorist'. Thereby, the IAT is considered to measure the amount of the prejudice a research participant possesses through calculating reaction time and accuracy.

While Gallate and others adopt a cognitive psychological definition and measure of prejudice, they go one step further: they locate this 'association' between name and word as a physical connection between two locations in the brain. As stated previously, Gallate and others use TMS and the IAT to establish the function of a part of the brain known as the ATLs. They posit the ATLs perform the function of associating semantic concepts. Under the 'virtual lesion'

[35] Whether a name is 'Arab' or 'non-Arab' sounding or a word is associated with 'terrorist' or 'non-terrorist' is decided by the researcher. For a description of how a researcher decides upon the names (or images) and words in the first place see: Greenwald, McGhee, and Schwartz, "The Implicit Association Test".
[36] Gallate et al., "Brain Stimulation reduces Prejudice", 187.

framework, TMS is understood as a inducing 'a current in the subject's brain'[37] and, hence, 'interrupting'[38], what is considered to be, the 'normal currents' occurring in the brain. On this model, the 'semantic association' must be understood by Gallate and others as a physical connection between two locations in the brain; a prejudice as a current running between, in this case, the location of the concept of 'Arab sounding names' and the location of the concept of 'terrorist'[39]. From this, the researchers hypothesise that applying TMS, an external current, to the ATLs will reduce prejudice, as measure by the IAT, by 'interrupting' the 'normal currents' that occur in this part of the brain. For Gallate and others, it is already decided that the brain is a conductor that works via the flow of currents moving between locations in the brain, where the association between 'semantic concepts' is considered as a physical connection between two locations. What is to count as prejudice, as well as what is to count as the brain, is decided prior to any investigation.

Gallate and others use an experimental design to test their hypothesis that interrupting the function of the ATLs with TMS will reduce prejudice[40]. They find what they expect: their experiment confirms the hypothesis that using TMS to 'interrupt' the 'normal currents' occurring in the ATLs reduces prejudice. That is, presumably, TMS weakens the current that connects 'semantic concepts' (in this case, the concepts of 'Arab sounding names' and 'terrorist')[41] . Gallate and others conclude by stating that their findings add evidence to the previous literature that has found the function of the ATLs to be associating 'semantic concepts'[42].

By defining the ATLs as associating semantic concepts and by defining prejudice as a semantic association, the only role of Gallate and colleagues ex-

[37] Pascual-Leone, Walsh, and Rothwell, "TMS in Cognitive Neuroscience", 232.
[38] This terms is taken from: Hallett, "Transcranial Magnetic Stimulation and the Human Brain".
[39] In cognitive psychology it is important to note that a category is considered a group of objects (outside of the mind) that share common properties and a concept is considered a mental representation of a category, where a concept is considered a word and/or an image. See: Burton, Westen, and Kowalski, *Psychology*, 290.
[40] The researchers randomly assign 40 'neurologically normal, right-handed undergraduate' psychology students to four groups to ensure that there are no systematic differences between the groups. In other words, the four groups of participants are considered homogenous. Two groups receive TMS to the ATLs, one group to the left ATL and one group the right ATL. One group receives TMS to the motor cortex and one group receives a 'sham', i.e. a pretend, session of TMS. Gallate et al., "Brain Stimulation reduces Prejudice", 187. As the groups are posited as homogenous at the start of the experiment, any difference between prejudice scores after the application of real or pretend TMS are interpreted as a result of the TMS.
[41] Ibid.; 189.
[42] Ibid.: 191.

periment is to confirm or deny the hypothesis they set out to test. As Heidegger explains, modern mathematical scientific:

> inquiry is [...] predetermined by the outline of the project; a line of questioning can be instituted in such a way that it poses conditions in advance to which nature must answer in one way or another.[43]

Gallate and colleagues posit, in advance, that the ATLs' function is to associate semantic concepts and this function can be measured by the IAT. The results could have been different, they could have disconfirmed the hypothesis, but this result would only provide a different answer, not a different way of understanding the brain or prejudice. Whether the hypothesis was confirmed or disconfirmed, the model of the brain as a conductor and the concept of prejudice as a physical connection between two locations in the brain would remain unquestioned.

HEIDEGGER'S EXPLICATION OF MODERN MATHEMATICAL SCIENCE

In the next section, I will outline Heidegger's understanding of the mathematical character of science. My contention is that brain studies suggest a definitive extension of modern mathematical science into the human sphere, rather than providing evidence for an 'architecture of human thought'.[44] The notion that thinking can be explained through the movement of electromagnetic currents through spatio-temporal locations in the brain rests upon the modern scientific conception of mathematical nature. Heidegger argues that modern science is mathematical, not because of its reliance upon numbers, but rather the mathematical character of science explains both scientists' reliance upon numbers and the experiment.[45]

In "The Modern Mathematical Science of Nature" and "The Age of the World View", Heidegger inquires into the meaning of the mathematical and, in particu-

[43] 'Die Erkundung durch den Grundriss des Entwurfs vorbestimmt ist, kann das Befragen so angeleft werden, dass es im voraus Bedingungen setzt, auf welche die Natur so oder so antworten muss'. Heidegger, M. "The Modern Mathematical Science of Nature", 93 [72].
[44] See: Mercer, "Australian Thinking Cap Could Unleash our Hidden Genius".
[45] See: Heidegger, M. "The Age of the World View", 343-46 [78-82]. See also: Heidegger, M. "The Modern Mathematical Science of Nature", 76 & 93 [58 & 72].

lar, the meaning of the mathematical character of modern science.[46] Heidegger explains the mathematical through the Greek concept of Τὰ μαθήματα (Ta mathemata). Heidegger writes 'Ta mathemata means for the Greeks that which man knows prior to his observation of the existent and his acquaintance with things: of bodies – the corporeal; of plants – the vegetative; of animals – the animate; of man [sic.] – the human'[47]. Τὰ μαθήματα is what we must already be familiar with in order to see something as something, to learn about something and to use something. For example, without being familiar with what a toaster is, we would be unable to see something as a toaster or learn to use the toaster. As Heidegger points out, we would only have a vague and general conception of what a toaster is, but without a basic familiarity with what a toaster is, we would not be able to see it as such.[48] Heidegger explicates Τὰ μαθήματα as what we are already familiar with about things.[49] Numbers are mathematical, but the mathematical is not defined by the number.

Heidegger argues that numbers are 'the best known class of mathematicals'[50] because 'numbers are the closest to that which we recognize in things without creating it from them'.[51] To use his example, 'three' is something we know prior to counting. We are familiar with what 'threeness' is before counting three plates on the table. 'Three' is not something that comes from the thing itself, for we could count three plates, three cups or a cup, a plate and a table as three things. For Heidegger, numbers do not define the mathematical; rather numbers are mathematical because they are something that we are already familiar with about a thing that is not created from the thing itself. According to Heidegger, the narrowing down of the concept of the mathematical to the numerical is a consequence of the mathematical project of modern science.

[46] Heidegger, M. "The Modern Mathematical Science of Nature"; Heidegger, M. "The Age of the World View".
[47] ‚Τὰ μαθήματα bedeutet für die Griechen dasjenige, was der Mensch im Betrachten des Seienden und im Umgang mit den Dingen im voraus kennt: von den Körpern das Körperhafte, von den Pflanzen das Planzliche, von den Tieren das Tiermäßige, vom Menschen das Menschenartige'. Heidegger, M. "The Age of the World View", 343 [78]. Also see: Heidegger, M. "The Modern Mathematical Science of Nature", 73 [56].
[48] Ibid.
[49] Ibid.; 72-73 [56].
[50] 'Das Bekannteste unter dem Mathematischen darstellen.' Heidegger, M. "The Age of the World View", 343 [78].
[51] ‚Zählen am nächsten liegt von dem, was wir an den Dingen zur Kenntnis nehmen, ohne es aus ihnen zu schöpfen, deshalb sind die Zahlen das bekannteste Mathematische' Heidegger, M. "The Modern Mathematical Science of Nature", 75 [58].

Heidegger outlines the modern scientific conception of nature. Heidegger discusses Newton's law of inertia and shows how a decisive change in our understanding of nature is contained within this law.[52] The principle of inertia is that '"Every body continues in its state of rest, or uniform motion in a straight line, unless it is compelled to change that state by a force impressed upon it"'.[53] Newton posits the law of inertia as a universal law of nature.[54] In contrast to Aristotle's understanding of nature, Newton makes no distinction between things: all things – earthly and heavenly bodies – are alike.[55] Consequently, Newton also understands all places as the same. As Heidegger describes

> Each body can fundamentally be in any place. The concept of place itself is changed: place is no longer where a body belongs according to its nature, but only a position in relation to other positions.[56]

On Newton's account, there is no essential relationship between thing, motion and place; any thing can be in any place, where motion is the movement between any two points. For Newton, motion is no longer related to the nature of the body, but 'in reverse, the essence of force is determined by the fundamental law of motion: Every body, left to itself, moves uniformly in a straight line'.[57] The uniform linear nature of movement and its new designation as a change of location makes movement amenable to measurement because it is understood as a 'distance between places'; i.e. an 'amount' of change of place.[58] Heidegger concludes that Newton's new understanding of bodies, place and motion results in a general change in the conception of nature. Nature becomes uniform linear motion of mass through points connected in space-time.[59]

Heidegger points out that, although modern science is said to be based upon experience, the law of inertia, and the body to which it refers, cannot be

[52] Ibid.; 88 [68].
[53] Isaac Newton as cited by the translators W. B. Barton and Vera Deutsch in Ibid.; 78.
[54] Ibid.; 78 [60].
[55] Ibid.; 86 [67].
[56] ‚Jeder Körper kann grundsätzlich an jedem Ort sein. Der Begriff des Ortes selbst wird ein anderer. Ort ist nicht mehr der Platz, an den der Körper seiner inneren Natur nach hingehört, sondern nut eine Lage, die sich jeweils «beziehungsweise», in Beziehung auf beliebige andere Lage, ergibt'. Ibid.; 86 [67].
[57] ‚Die Bewegungen selbst warden nicht bestimmt gemäß verschiedenen Naturen, Vermögen und Kräften, den Elementen des Körpers, sondern umgekehrt: Das Wesen der Kraft bestimmt sich aus dem Grundgesetz der Bewegung. Dieses sagt: Jeder sich selbst überlassene Körper bewegt sich geradlinig-gleichförmig'. Ibid.; 87 [68].
[58] Ibid.; 87-88 [68].
[59] Ibid.; 88 [68]. Also see: Heidegger, M. "The Age of the World View", 344 [78].

experienced or observed.[60] We cannot find a 'body which is left to itself'[61] nor can we see a perfectly uniform and linear movement of such a body. As Heidegger succinctly states the law of inertia 'speaks of a thing that does not exist. It demands a fundamental representation of things which contradict the ordinary'.[62] It is for this reason that Heidegger argues that the mathematical character of modern science means that the blueprint of nature is decided upon in advance and that objects only appear as objects in so far as they conform to the mathematical projection of nature.

For Heidegger, the mathematical character of modern science means that the objects of science are determined in advance by something that is 'not experientially created out of the thing'.[63] Modern science is based upon the conception of natural bodies as masses moving through points connected in space-time and, this assumption, provides the outline of 'what nature is to mean for the knowledge of nature that is sought'.[64] Heidegger extends this claim by stating that 'natural bodies are only what they *show* themselves as, within this projected realm'.[65] For modern science, nature *is* mathematical and this is decided upon prior to any investigation of nature. The modern scientific conception of nature as mathematical establishes the method of knowing nature.

Modern scientific research relies upon numerical measurement and the experiment. Heidegger writes:

> Because the [mathematical] project [of science] establishes a uniformity of all bodies according to relations of space, time, and motion, it also makes possible and requires a universal uniform measure as an essential determinant of things, i.e. numerical measurement.[66]

Numbers do not differentiate between things; numbers can be used to count tables, chairs, rockets, atoms, etc. In addition, numbers are universal –

[60] Heidegger, M. "The Modern Mathematical Science of Nature", 89 [68].
[61] Ibid.; 89 [68].
[62] ‚[Bewegungsgesetz] spricht von einem Ding, das es nicht gibt. Er verlangt eine Grundvorstellung von den Dingen, die der gewöhnlichen widerspricht'. Ibid.; 89 [69].
[63] ‚Die Ansetzung einer Bestimmung des Dinges, die nicht erfahrungsmäßig aus diesem selbst geschöpft ist' Ibid.
[64] ‚Dieses Ausmachen betrifft nichts Geringeres als den Entwurf dessen, was fúr das gesuchte Erkennen der Natur künftig Nature soll'. Heidegger, M. "The Age of the World View", 344 [78].
[65] ‚Die Naturkörper sind nur das, als was sie sich im Bereich des Entwurfs *zeigen*'. Heidegger, M. "The Modern Mathematical Science of Nature", 93 [72], italics in translation.
[66] ‚Weil der Entwurf seinem Sinne nach eine Gleichmäßigkeit aller Körper nach Raum und Zeit und Bewegungsbeziehungen ansetzt, ermöglicht und fordert er zugleich als wesenliche Bestimmungsart der Dinge das durchgängig gleiche Maß, d. h. die zahlenmäßige Messung'. Ibid.

they are understood in the same way by everybody who is familiar with the system of numbers. Hence, numerical measurement becomes the best method for determining things considered as uniform bodies. By counting, measuring and calculating modern scientists designate in advance what is to be recognised about things by everyone. Along similar lines, Heidegger notes that the decisive feature of the experiment is that it:

> begins when the law is taken as a point of departure. To set up an experiment means to assume a situation where it becomes possible to trace a definite nexus of motions in the necessity of its course, that is, to control its calculation in advance.[67]

The experiment establishes a controlled situation in advance such that what is to be seen is determined in advance. The role of the experiment is not to see how nature reveals herself, but rather to force nature to answer the modern scientists' questions[68]. What is definitive about modern science is not the emphasis on simply observing facts, but its mathematical character. The mathematical character of science means that the 'essence of things, of bodies' is anticipated in advance on the basis of the conception of nature as mass uniformly and linearly moving through points connected in space-time.

It is my contention that the model of the brain as a conductor – upon which many of the new techniques for investigating the brain, including TMS, are based – is no more than an extension of the mathematical conception of nature into the human sphere. On the model of a conductor, the brain is conceived as a series of nodes connected together via neurons that conduct electrical charges through the brain. In other words, the brain is conceived on the model of a linear and uniform force which moves through locations in the brain connected together in space-time. When thinking is reduced the brain, the extension of this claim is that thought is a uniform motion from location to location in space-time. On the basis of Heidegger's explication of the mathematical character of modern science, neuroscientists are not recording the facts as they are given. Rather, the neuroscientific experiments and measuring techniques are opening

[67] ‚Denn hierbei fehlt durchgängig das Entscheidende des Experiments. Dieses beginnt mit der Zugrundelegung eines Gesetzes. Ein Experiment ansetzen heißt: eine Bedingung vorstellen, dergemäß ein bestimmter Bewegungszusammenhang in der Notwendigkeit seines Ablaufs verfolgbar und d. h. für die Berechnung im voraus beherrschbar gemacht werden kann'. Heidegger, M. "The Age of the World View", 345 [81].
[68] Heidegger, M. "The Modern Mathematical Science of Nature", 93 [72].

up a new domain where the thinking can reveal itself because it conforms to the mathematical conception of nature. As such, neuroscientists are not providing evidence for how the brain works – which is too often taken as synonymous with how thinking works – instead they are extending the mathematical conception of nature to include human thought.

CONCLUSION

Heidegger offers a way of thinking through the problems of extending modern mathematical science into the human sciences. A central problem for the human sciences is the circularity inherent in attempting to explain our thinking through scientific endeavour, when our thinking defines and makes possible scientific endeavour. As such, when we attempt to reduce our thinking to the mathematical brain, we are in danger of forgetting that we conduct the experiments and construct the measurements used within them: we designate nature as mathematical. It is only by acknowledging that we have defined nature as mathematical that we can question the presuppositions of modern mathematical science so that we can 'preserve things in their inexhaustibility',[69] rather than forcing things to show themselves only as quantifiable entities within our mathematical conception of nature. Questioning the presuppositions of modern mathematical science is particularly pressing when neuroscientists are attempting to conceive our own thinking as a quantifiable thing. We cannot quantify our thinking because it is not a thing and it is the condition of possibility for quantifying anything in the first place. Hence, before we take for granted that we can calculate, predict and control human thought – on the model of modern mathematical science – it is our responsibility to question the presuppositions upon which this endeavour rests. For, if modern mathematical science is unthinkingly extended into the human sphere, we threaten much more than just our knowledge.

[69] Ibid.; 65 [50]. See note 11 for German text.