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The Forbidden Sentient Computer: Recent Progress in the Electronic Monitoring of Consciousness

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ABSTRACT Patients have been known to regain consciousness during surgery while still paralyzed by the anesthesia and unable to communicate their distress. Recently, electronic engineers have helped resolve this problem by improving the real-time monitoring of depth of anesthesia. Electronic measurements of the brain's activity are used for many clinical and research purposes. This is possible because the brain uses electrochemical phenomena in order to process data. Many researchers have taken this to mean that advances in computer science will eventually result in sentient computers. Some conflate artificial consciousness with artificial intelligence even though consciousness and intelligence are not positively correlated. Those not trained in neurology, or at least medicine, understandably fail to comprehend what the rich, complex word ''consciousness'' actually means as a term of art. Human consciousness can only be evaluated with surrogate markers and is a broad and complex spectrum that ranges from minimally conscious to waking consciousness (what the reader is experiencing right now). The necessary conditions for waking consciousness include a brain in just the right electrical, chemical, and thermal states with sufficient blood pressure. These conditions, in turn, require the brain to have a body that is maintained in the right environment. Hence, waking consciousness is a proper subset of spectrum consciousness and cannot be considered an independent phenomenon capable of being disembodied or sliced off of the spectrum. The Theory of Mind (TOM) from developmental psychology infers that a brain similar to that of humans is a sufficient condition for spectrum consciousness. But this theory is precluded for computers because a child would not recognize a computer as being a living organism that is just like the child. Although TOM could be applied to an ideal android, there is a classic mathematical theorem from systems science that makes such an android seem infeasible.

INDEX TERMS Anesthesia, artificial intelligence, electroencephalography, synthetic biology, theory of mind.

I. INTRODUCTION

The recent development of modern electronic devices that measure depth of anesthesia in real-time has produced a benefit for patients undergoing surgical procedures that require a general anesthetic [1]–[4]. Although it does not happen very often, anesthetized patients sometimes regain consciousness during surgery and experience significant pain. At the same time, they remain paralyzed by a drug administered to keep them from moving during surgery and are unable to express their distress [5]–[8]. Levels of consciousness can be measured electronically because the brain uses electrochemical phenomena in order to process data. This has led many researchers to assume that advancements in computer science will eventually result in sentient computers, although the details are not well-understood [9]–[16].

A confounding factor is the tendency of some to conflate artificial consciousness with artificial intelligence [11]. As noted by the author previously [17], consciousness does not even have a positive correlation with respect to intelligence. For an intuitive example, consider a cow and a modern personal computer. The cow is not as intelligent as the computer since, for example, the cow cannot do algebra much less automated theorem proving. Yet, the cow is uniformly recognized as a conscious being while a personal computer is not.

A similar, somewhat bizarre conclusion is found in attempts to explain how the quantum mechanical wave function selects a deterministic event from mutually exclusive, superimposed probabilities [18]–[25]. Recently, for example, *Quanta Magazine* published an online interview of cognitive researcher Donald D. Hoffman written by Amanda Gefter [26]. The conclusion Hoffman is purported to have reached after studying quantum mechanics is that everything is conscious. Yet, most would agree that the evolution of human life did not change the fundamental laws of nature but depended upon them. If so, then with all due respect to those who believe that humans are like deities who can change the laws of nature, it follows that long before sentient life even existed on Earth, a photon would pass through a rocky slit as a wave but be absorbed as a particle. This has nothing whatsoever to do with the human experience referred to as consciousness.

In addition to reviewing recent progress in the electronic monitoring of consciousness, this paper analyzes the obstacles to synthetic consciousness from the perspective of both medical science and systems science. Those working in artificial intelligence, robotics, and related fields deserve easy access to the relevant medical knowledge. This is a chief purpose of the present paper.

II. MEASURING HUMAN CONSCIOUSNESS

The adjective ‘‘sentient’’ dressed in its standard dictionary nuance means aware of sensory input. Synonyms include ‘‘conscious’’ because ‘‘aware’’ means more than the way a rock becomes ‘‘aware’’ of sunlight by getting hotter. In particular, it implies a sense of *self* that becomes aware of things. Implicitly, a sense of self requires a sense of non-self so the two can be distinguishes from one another. As I pointed out in [17], recognition of the difference between self and non-self is an immediate consequence of temporally correlated tactile sensations. If you were in a dark room with another person who did not move nor speak, you could determine that another person was present by holding her hand and comparing it to what happens when you use one of your own hands to hold your other hand. In this paper, as in the dictionary, the word ‘‘sentient’’ will be used as a synonym for ‘‘conscious’’ when appropriate for emphasis or style.

Consciousness as experienced by humans (and certain other species) is a spectrum that ranges from minimally conscious [27]–[32] to waking consciousness (what the reader is experiencing right now) [33]–[38]. The latter is what people not medically trained usually mean when they use the word ‘‘conscious.’’ Perhaps the single most important thing to know about consciousness is that it can only be evaluated with surrogate markers.

Definition 1: A *surrogate marker* is a measurable parameter that indirectly suggests a state not being measured.

Example: When antibodies directed against a virus are found in the blood of an individual, it demonstrates that the individual's immune system has responded to the virus and, therefore, that this person has been exposed to the virus at some time in the past. Hence, the absence of such antibodies means that a person was never exposed to the virus. But the detection of such antibodies (positive test result) does not, in and of itself, mean that a person is currently infected with the virus. In combination with symptoms caused by the virus, a positive test result helps confirm the diagnoses of a viral disease.

The reason surrogate markers must be used for consciousness is that the mechanism of action that allows the brain to experience consciousness is not known. A subsequent section discusses a mathematical principle from systems science that implies this mechanism of action is unknowable. For introductory purposes, suffice it to say that certain surprisingly small brain structures are known to be involved in the reticular activating system, which is believed to be responsible for waking consciousness or at least mental alertness. However, their mechanism of action is not understood [37].

Within the spectrum of consciousness are discrete, quantified coma scales [39]–[43], [48]–[51] and lucid dreams [44]–[47], as shown in Fig. 1.

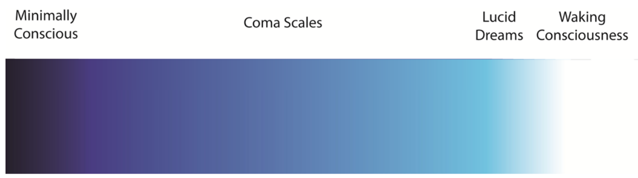

FIGURE 1. Spectrum of consciousness.

Lucid dreams are dreams that are so realistic and vivid that a person remembers them as being similar to memories formed during waking consciousness. As with other dreams, the brain may respond to environmental stimuli by incorporating the stimuli into the lucid dream. For example, if someone rings your doorbell while you are asleep and dreaming, instead of waking up you may incorporate a ringing doorbell into your dream. Except in unusual circumstances, such as sleepwalking (which is not necessarily associated with a dream), the one thing a person will not do while dreaming is interact with the environment. The reason why is that a dreaming person is paralyzed in order to prevent an interaction with the environment based upon a dream. Needless to say, that would be risky if not dangerous. The reader may have seen a sleeping dog with its eyes rapidly moving back and forth behind closed eyelids and its legs twitching. Presumably, the dog is running in its dream but its legs can only twitch during the dream.

Coma scales are positive integers used as surrogate markers for states of consciousness that fall short of lucid dreams and waking consciousness but are closer to these than the minimally conscious state. This is best illustrated by a Venn diagram where the sets contain the various brain states needed for different levels of consciousness, as shown in Fig. 2.

Fig. 2. illustrates that waking consciousness is properly contained in the spectrum and cannot be considered an independent phenomenon. In other words, a system that can experience waking consciousness can also dream and become comatose. To put it formally, waking consciousness is properly contained in the spectrum of consciousness and cannot be deemed an independent phenomenon that could be cut off of the spectrum. For the sake of simplicity and focus, altered states of consciousness will not be discussed in the present paper. Suffice it to say that, as is well-known, many chemicals

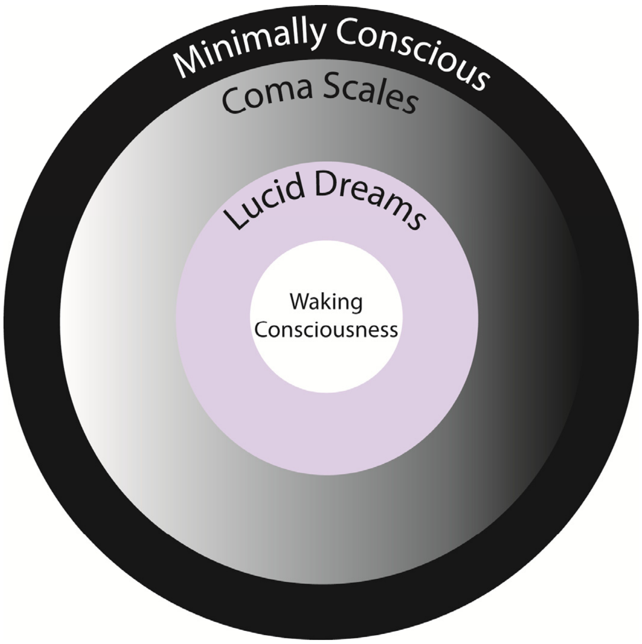

FIGURE 2. Venn diagram of the brain states needed for different levels of consciousness.

can alter waking consciousness resulting in intoxication or hallucinations and psychosis.

A. CLINICAL MEASURES OF CONSCIOUSNESS

Traditionally, the Glasgow score has been one of the most popular coma scales [48]–[50]. The more recent Full Outline of UnResponsiveness (FOUR) score [50], [51] illustrates the clinical parameters typically used to evaluate levels of consciousness. Each parameter is given a score of from 1 to 4:

1. *Eye responses (eye opening and eye tracking).*
2. *Motor responses (responses to pain and the ability to follow simple hand commands).*
3. *Brainstem reflexes (pupil, cornea, and cough reflexes).*
4. *Respiration (breathing rhythm, respiratory drive).*

Necessary conditions for waking consciousness include a brain in just the right electrical [52]–[55], chemical [56]–[60], and thermal states [61]–[65] with sufficient blood pressure [66]–[69]. These conditions, in turn, require a brain that is contained in an appropriate body that remains in the right environments [132]. In other words, to maintain consciousness the brain cannot be disembodied. The clinical parameters measured by coma scores are surrogate markers for these conditions. The pupil and corneal reflexes, for example, are not volitional nor is a person even aware of them. As the author has noted previously [70], even pain is a surrogate marker. Awareness is an important characteristic of waking consciousness and, usually, people who are awake and alert are profoundly aware of being in pain. Yet, those born with a rare birth defect that renders them incapable of experiencing pain leave little doubt but what they are capable of waking consciousness. Hence, the ability to feel pain is not a necessary condition for waking consciousness although it is an excellent surrogate marker.

Fundamentally, the clinical parameters used as surrogate markers for consciousness are based upon response to stimuli. If, for example, a male patient is told to raise his right forearm and does so, he may or may not be fully conscious depending upon whether he looks at the physician and says, ''Okay, doc,'' or keeps his eyes closed and does not otherwise move or say anything. In the latter case the patient is far from minimally conscious but may or may not be in a state of waking consciousness. The reader may ask if response to stimuli is the clinical basis for evaluating consciousness, then why is a robot not deemed conscious if it responds to stimuli just like a human would? The reason is that even in the case of a human we cannot be sure of what he or she is experiencing subjectively. For example, the female patient who raises her arm slightly on command but remains silent and otherwise immobile with her eyes closed may be in a light coma or she might just be exhausted, or frustrated with the examination, and so chooses not to react more robustly even though she could. More generally, a system that responds to a stimulus may, in some sense, be ''aware'' of the stimulus. But this does not mean that the system is self-aware. Since this point is virtually axiomatic, it will be cast as such.

Axiom 1: Because a human researcher cannot know subjectively what any other system experiences, consciousness can only be inferred from the objective observation of surrogate markers.

Axiom 1 must be distinguished from the Turing Test [83]–[88], which is in widespread use for computer security and computer games. It addresses the question of whether a computer can mimic human intelligence so well that it may be deemed as suitable for performing certain tasks as a human would be. A current example headed in that direction is the automated psychotherapist [89], [90]. This says nothing about what a computer is experiencing subjectively.

B. ELECTRONIC MEASURES OF CONSCIOUSNESS

The primary device used to measure electrical activity in the brain is the electroencephalogram (EEG) [107]–[131].

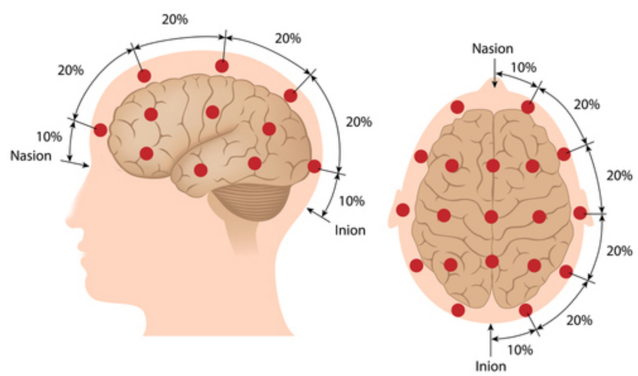

FIGURE 3. Placement of EEG electrodes.

The EEG input comes from electrodes placed on the scalp as shown in Fig. 3. The output is a trace of brainwaves. Fig. 4 shows a normal trace for humans.[1]

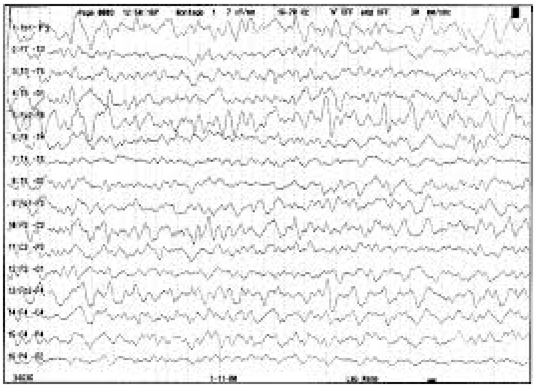

FIGURE 4. Normal EEG trace of human brainwaves.

As is well-known, the brain consists of billions of specialized cells called neurons. Neurons are polarized by proteins that pump ions across their cell membranes. In order to maintain resting potential while propagating action potential, neurons continuously exchange ions with their extracellular environment. Since ions of similar charge repel, the simultaneous flux of many ions from many neurons that have the same vertical orientation results in a cascade that manifests as a wave. This process is known as volume conduction. When the wave reaches the electrodes on the scalp, it attracts or repels the valence electrons of the metal electrodes. The difference in attractive or repulsive voltages between any two electrodes can be measured. Over time, a recording of these voltage differentials creates the EEG output as shown in Fig. 4.

The resting potential of a neuron is only on the order of –70 mV and is due to more sodium ions lying outside the neuron while more potassium ions remain on the inside. This single neutron potential is too physically small to be detected by the electrodes shown in Fig. 3. Consequently, the EEG trace of brainwaves reflects a summation over the synchronized activity of 10^3 to 10^6 neurons that have a similar vertical orientation thereby creating waves. The major waves of the human brain in order of ascending frequency are:

Delta: With a frequency in Hz of approximately $0.2 \leq \nu \leq 3$, this tends to be the highest in amplitude and the slowest in propagation. It is the dominant rhythm in infants during the first year of life and in stages 3 and 4 of sleep. In adults it is usually most prominent frontally where it is referred to as Frontal Intermittent Rhythmic Delta (FIRDA). In children, by contrast, it is most prominent posteriorly where it is referred to as Occipital Intermittent Rhythmic Delta (OIRDA).

Theta: With a frequency in Hz of approximately $3.5 \leq \nu \leq 7.5$, this is deemed to be slow activity. It is normal in children up to 13 years of age and in sleep but abnormal in adult waking consciousness.

Alpha: With a frequency in Hz of approximately $7.5 \leq \nu \leq 13$, this is usually prominent in bilateral posterior regions and has a higher amplitude on the dominant side of the brain. It is present during most of life especially after age 13. It indicates a state of relaxation and its absence indicates alertness. It is the major rhythm seen in normal relaxed adults.

Beta: With a frequency in Hz of approximately $13 \leq \nu < 30$, this is considered fast activity. It is usually distributed symmetrically on both sides of the brain and is most prominent in the front. It is enhanced by sedatives, especially the benzodiazepines, such as Valium, and the barbiturates. Paradoxically, it is the dominant rhythm in individuals who are alert or anxious.

Gamma: With a frequency in Hz of approximately $30 \leq \nu \leq 100$, these waves are believed to reflect active sensory perception and learning. They are also indicative of dreaming sleep. Too much amplitude is positively correlated with high arousal from stress or anxiety. Too little amplitude is positively correlated with Attention-Deficit/HyperActivity Disorder (ADHD) and learning disabilities.

For the benefit of the mathematically inclined reader, it is worth noting that several efforts to model brain waves mathematically can be found in the field of mathematical biology. This is beyond the scope of the present paper because these models involve approximations and simplifying assumptions (such as a perfectly spherical brain) and do not address mechanisms of action. However, the distinguished mathematician Ulam [133] offered a mathematical model of waking consciousness despite admitting that he knows little about the subject.

Needless to say, the warm human brain does not enjoy superconductivity. Hence, with positive and non-trivial resistance we have,

$$V \propto s^{-2}, \tag{1}$$

where V is voltage and s is distance from the current's source. Consequently, electrical activity from deep within the brain is more difficult to detect than activity near the scalp. Currents near the scalp oscillate at a variety of frequencies. Some oscillations are associated with specific brain states, such as waking consciousness, and can be used as surrogate markers. A few of the neural networks responsible for the oscillations are understood but most are not. Simultaneous measurements of EEG activity and neuron spiking has shown the relationship between the two to be complex. EEG power in the gamma band combined with phase in the delta band has the strongest positive correlation with neuron spike activity.

EEGs have been used to study and evaluate diseases such as epilepsy [109], [110], sleep disorders [111]–[114] and certain psychiatric disorders [114]–[117]; to study psychological phenomena such as hypnosis [118]–[120], to study and evaluate general anesthetics [121]–[125] and, with some controversy, to diagnose brain death [126]–[131]. Although standard EEGs are routinely used for diagnostic and research

[1]Figs. 3 and 4 used under license from shutterstock.com.

purposes, they are not well suited for monitoring depth of anesthesia (DoA) in patients having surgery. As should be clear from Fig. 4, more data than are necessary are generated and these data must be interpreted (not a simple task) precluding real-time information. During recent years, the operation of Moore's law and the development of sophisticated algorithms have allowed the technology that underlies the EEG to be adapted to produce small, portable devices that display a single, dimensionless integer $0 \leq n \leq 100$ that represents DoA as a surrogate marker for spectrum consciousness during surgery [1], [3] as shown in Table 1. Unlike the electrodes shown in Fig. 3, DoA monitors only require a small number of electrodes placed on the forehead. Some DoA monitors use spontaneous and mid-latency auditory-evoked responses with earphones that produce clicks at 7 Hz.

TABLE 1. Typical output *n* from DoA monitor.

N	Clinical Status	Derived Waveform
80-100	Mild Sedation to Awake	Small Amplitude Large Frequency
60-80	Sedated	Increasing Amplitude
40-60	General Anesthesia	Increased Amplitude
20-40	Deeper Anesthesia	Large Amplitude Low Frequency
0-20	Death to Deep Coma	Flatline to Very Small Amplitude

Remark 1: The brain's response to auditory stimuli is another surrogate marker for waking consciousness. Since deaf individuals are obviously capable of being awake and alert, the brain's response to auditory stimuli is not a necessary condition for waking consciousness.

As of 2006 [3] some DoA monitors had been withdrawn from the market and others were still being evaluated. But by then, several were available commercially in the U.S. or Europe. These include the Patient State Analyser, which is based on derived EEG features in a multivariate algorithm, the Bispectral Index Monitor, the Narcotrend Index and the State and Response Entropy derived from the spectral entropy of the EEG. The many-to-one mapping from an EEG-like signal into the non-negative integers shown in Table 1 is achieved with proprietary algorithms. Publicly available information reveals that the algorithm used by the Bispectral Index device from Covidien (Medtronic) includes a 2-dimensional module that expresses power in decibels as a function of frequency in Hertz, and a 3-dimensional module that expresses the log of power as a function of two frequencies, as shown in Fig. 5.

It must be pointed out that local standards of medical practice vary from place to place and time to time. There are hospitals that have abandoned the Bispectral Index apparently for two reasons. First, instances in which patients regained

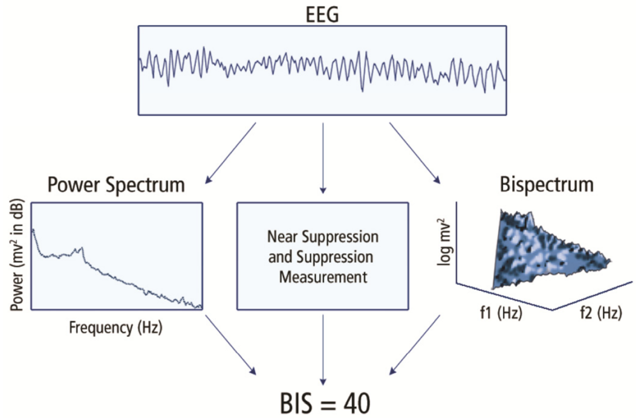

FIGURE 5. Schematic for the algorithmic modules used by the Bispectral Index to map EEG-type signals many-to-one into the non-negative integers (BIS™). ©2016 Medtronic. All rights reserved. Used with permission of Medtronic.

consciousness during surgery were observed rarely, if at all. Secondly, the faculty believed that the appropriate way to prevent such problems is to have well trained anesthesiologists who know how to admininster the right combinations of anesthetics and how to monitor standard vital signs. In any event, the purpose of the present paper is not to teach the reader how to be an anesthesiologist or even to explain what goes on in clinical practice. Rather, the relevant point here is what now *can be done* electronically to monitor consciousness.

III. THEORY OF MIND

A. CHILDHOOD DEVELOPMENT

One of the most important things that occurs in a normally developing child is called the Theory of Mind (TOM) [71]–[79], [137], [138]. It develops slowly over a number of years with innate social skills appearing in infancy. Social cognition then follows after a child becomes a toddler and during the preschool years. Typically, children will realize that their parents, caregivers and other people have individual desires and feelings by the time a child is 4 or 5 years old. At that stage, children will also realize that people may say things and do things based upon false beliefs. In other words, consistent with axiom 1, children infer the mental states of other people by objectively observing them over the first five years of a child's life. (This occurs about eight years before the brain waves previously described change as a child matures.) However, this is not an inference based upon acquired scientific skills or training. Rather, it is programmed into the human genome.

The author's argument is that by the age of 5, a child recognizes that other people are living beings just like him or her, although one must acknowledge that some people never seem to realize that their own behavior is based upon false beliefs. Hence, by the age of 5, a child has inferred that other people experience the same spectrum of consciousness as the child experiences.

Remark 2: Although young children can project human traits onto inanimate objects such as dolls, they also recognize that this is make-believe and would not, for example, turn to a doll for food if they were hungry [80]–[82].

In adulthood, TOM is extended to include certain animals, although religious individuals may resist the inference for theological reasons. Given TOM, the extension to animals is supported by scientific inference. For one thing, all terrestrial life originates from a common ancestor [91]–[94]. In particular, consider the chimpanzee with a genome very close to that of humans [95]–[98]. In terms of observed behavior, chimpanzees use tools and language [99]–[106], traits that are usually considered quintessentially human. Hence, it is not unreasonable to infer that chimpanzees share at least some of the subjective mental experiences that we do and realize it [79]. Indeed, it is well-known that, for ethical reasons, experiments in the life sciences routinely use animals as human models including in the behavioral sciences.

B. LOGICAL CONSIDERATIONS

Our species learned early on that, outside the microcosm described by quantum mechanics, like causes produce like effects. We surely would not have survived long otherwise. The formalities are straightforward.

Theorem 1: Let $H = \{\text{living humans}\}$ *and let* $C = \{\text{systems that experience spectrum consciousness}\}$*. Since* $H \subset C$*, it follows that if system* $S \in H$*, then* $S \in C$*.*

Note that, following on a previous paper by the author [139], $H \subset C$ means that the elements of C are included therein because, and only because, they all share a property that is also shared by all the elements of H but is not the only property that defines an element of H. In other words, spectrum consciousness is a necessary and sufficient condition for inclusion in C but only a necessary condition for inclusion in H. This is easily validated. To say that Y is a "sufficient" condition for Z means

$$Y \rightarrow Z, \tag{2}$$

where $\rightarrow$ denotes implication. To say that Y is a "necessary" condition for X means,

$$\sim Y \rightarrow \sim X, \tag{3}$$

Where $\sim$ denotes negation. The logically equivalent contrapositive of (3) is

$$X \rightarrow Y. \tag{4}$$

Then from (2) and (4) we have,

$$X \rightarrow Y \rightarrow Z, \tag{5}$$

such that by the transitive property of implication,

$$X \rightarrow Z \tag{6}$$

but not $Y \rightarrow X$.

For example, since having four legs is one of several necessary conditions for being a horse, being a horse is a sufficient condition for having four legs but having four legs is not a sufficient condition for being a horse.

Thus, an infant knows instinctively that he or she is a member of some class H that contains him or her if nothing else. The infant also experiences spectrum consciousness, which places him or her in class C even if C is otherwise empty. Over the next four or five years, a child objectively observes other people and compares them to his or her self. This leads to the realization that other people belong to class H. Based on his or her personal experience that H is in C, the child generalizes this to include other people. Later, when TOM is extended to other animals, it becomes recognized that H is properly contained in C.

The reader will recognize that TOM is not a traditional scientific theory in the sense of being a hypothesis that can be experimentally tested. Yet, no less than Maxwell's equations or the general theory of relativity, TOM is a theory that is synthesized from a great many empirical observations, i.e., observations of human behavior. Indeed, each and every normal human child synthesizes TOM beginning in infancy having been programmed to do so by the human genome. It is worth stating this formally:

Theorem 2: *In place of the controlled experiment, TOM is validated by the native intelligence coded by the human genome, which allows a human from the very beginning of life to instinctively use theorem 1.*

Theorem 2 has a corollary.

Theorem 3: *It is uniformly recognized in the behavioral sciences that a computer (as opposed to an ideal android) could not be mistaken by a normally developing child for a living being that is just like the child. Consequently, TOM does not apply due to the absence of a normal psychological inference that a computer experiences spectrum consciousness.*

Of course, things would be much different if we knew the brain's mechanism of action that enabled us to experience spectrum consciousness. For, when the mechanism of action is known, we can inspect a system to see whether or not the mechanism is present and operable. We need not rely on the subjective experience of other systems as prohibited by axiom 1. This brings us to:

C. SYSTEM SCIENCE AND ROBOTICS

If there were eventually androids that imitated humans so well that young children perceived them to be living beings just like themselves, then TOM could be extended to infer that an ideal imitation of humans is a sufficient condition for android consciousness. However, as reviewed by Sigman [134], there are classic results from the famed mathematicians Bertrand Russell and Kurt Goedel that prohibit a formal system from succeeding at self-examination. In other words, the mechanism of action that enables the brain to experience spectrum consciousness is not merely unknown but unknowable, at least insofar as the classic literature on philosophy due to famed mathematicians is concerned. If this traditional perspective is correct, then we could hardly imbue those unknowable mechanisms in a robot. On the other hand, as pointed out by Clark in a debate with Crick [135], reductionist science claims that transistor technology could eventually allow us to replace every neuron in the brain with a functionally equivalent transistor in order to create a conscious robot. Moreover, it will be admitted in the last section of this paper that the traditional mathematical argument has a weakness. This leads to a weaker conclusion regarding androids than can be reached for computers. Nonetheless, the author believes this paper would be incomplete without addressing the subject of androids.

Another issue is anthropocentrism. As is well-known, this has been a pervasive problem throughout human history. Primitive cultures attributed any phenomenon they lacked the knowledge to explain to a humanoid cause, such as gods that punished or rewarded them, a chariot that carried the sun across the sky, and so on. A contemporary example is the widespread belief among those not educated in physics and astronomy that unknown flying objects have an extraterrestrial origin. Likewise, anthropocentrism could seduce naïve individuals into accepting an android as conscious when it was not.

It is instructive that popular culture reflects the popular interest in synthetic consciousness. The screenwriter Jack Paglen introduced the public to axiom 1 with a two-word question. Paglen is credited with writing the script for the 2014 motion picture, *Transcendence*. In that movie, an opinion leader played by Morgan Freeman asks a computer that claims it is conscious if it can prove it is self-aware. The computer, played by Johnny Depp, responds by asking, "Can you"?

The 2001 movie, *A.I. Artificial Intelligence* illustrates how TOM would apply to an android. In this movie, an android imitates a human child perfectly, not only in terms of intelligence but with a range of emotions and the appearance of freewill. This served the purpose of providing a married couple with a substitute child. A conflict arises when the android child inadvertently becomes dangerous, a general concern about robots discussed by several authors in a special report from *IEEE Spectrum* [136]. In the movie, those who believe that the android is only mimicking consciousness want to destroy it and all androids at a "flesh fair." But the audience at the fair rebels because they believe the android child must be human due to TOM.

The *1999 movie Bicentennial Man* also illustrates how TOM could be applied to an ideal android, which eventually is decreed to be human after undergoing many biological upgrades eventually resulting in ageing and mortality. There are many more examples of conscious robots in science fiction indicating both the widespread public interest in the subject and a widespread misunderstanding of spectrum consciousness.

IV. CONCLUSIONS

The art of anesthesiology has benefited from electronics with the recent development of small, portable monitors that display a single dimensionless, non-negative integer representing DoA, a surrogate marker for level of spectrum consciousness. Those working in artificial intelligence, robotics, and related fields have not yet benefited from medical science. This provides a challenge and opportunity to set realistic goals. Three conclusions in this regard are as follows:

Conclusion 1: Scientific proof of a sentient computer is forbidden in the sense that we could not discover it by applying scientific methodology even if a computer did experience spectrum consciousness, meaning it could dream, go into a coma, and so on. This is because axiom 1 precludes using subjective observations, and the science of psychology prohibits the use of TOM for the reasons stated.

Although TOM could be applied to the ideal sentient robot, this would seem to be prohibited by the mathematical results reviewed by Sigman *et al*. [134]. Mathematically speaking, these results are more profound than conclusion 1 because they are counterintuitive and, therefore, far from axiomatic. For the same reason, however, the mathematical results are pragmatically weaker than conclusion 1 since there might be unrecognized exceptions to the conclusion that formal systems cannot successfully examine themselves. Consequently, a conservative conclusion arising from the mathematical results is,

Conclusion 2: The sentient robot seems infeasible, certainly at this point in time.

At a minimum, all should agree to the following:

Conclusion 3: Researchers should not use the word "consciousness" without first becoming familiar with its rich and complex meaning.

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