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Influencing Behavior in Mid-21st Century Asymmetric and Irregular Warfare

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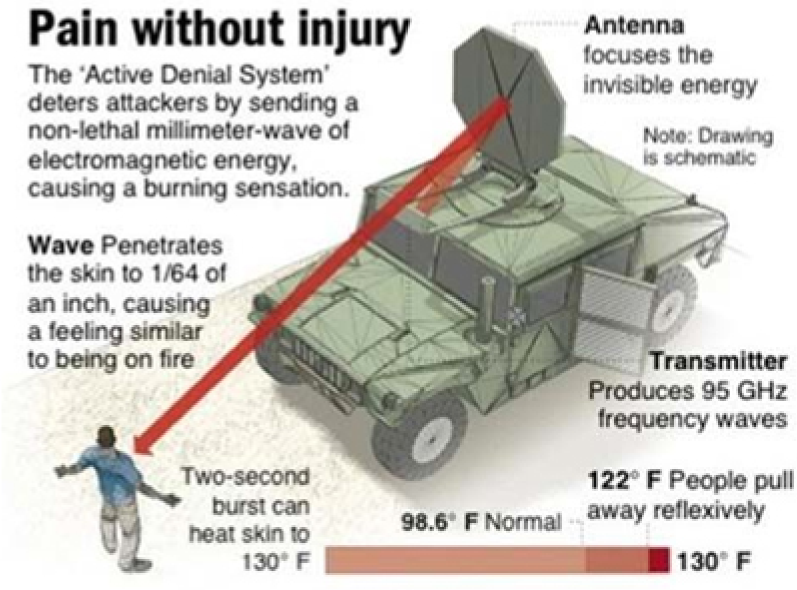
Problem and Desired Outcome

Less than Lethal or Non-Lethal measures such as The Active Denial System (ADS) have been considered over the years as alternatives to conventional fighting methods. Some, such as the Taser, require close proximity to the target; others such as the variety of weapons firing “beanbags” or rounds carrying CS gas payloads will work for civilian crowd dispersal purposes but are not suited to combat situations. There are also instances where the supposed “nonlethal” weapon has directly produced death.

We seek a weapon that could be used in combat situations, but its nonlethal aspects would also enable it to be used for civilian situations such as riot control. It should not produce excessive pain, one of the criticisms against the Active Denial System, and it should not have the possible neurological and cardiac effects of a Taser.

What is required is a weapon that will change the behavior, particularly the aggressive behavior, of a targeted individual or group but be completely nonlethal. Behavior is usually a cognitive factor so we believe that this weapon must directly affect the cognitive capabilities. It must be quick and if possible small and have the capability to be concealed from or not recognizable by the aggressor. This was another reason that the Active Denial System had limitations. Being Humvee mounted it could hardly be considered concealable.



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Since 1985 Transcranial Magnetic Stimulation has been well researched and some of the effects meet the desired requirements.

The Technology

Transcranial Magnetic Stimulation (TMS) is a technique for temporarily disrupting the function of specific cortical regions or possibly enhancing various regions. For example using transcranial magnetic stimulation focusing on the tempero-parietal junction has shown to help people reach logical conclusions based on reason and understanding.[ii] This works by boosting the region of the brain associated with critical thinking. Imagine this being used to help people overcome irrational political ideology or destructive religious beliefs.

The technique is non-invasive and has no reported long-term side effects;[iii] however it is noted that in the short-term, headaches, painful scalp sensations, and facial twitching has been reported by John Hopkins University when TMS is used in a medical capacity. Also, TMS machines tend to be loud and patients are given earplugs as patients were complaining of hearing related problems. This effect is not unusual with this type of equipment and the component of the research addressing the electro-mechanical components will address this noise problem. Depending upon the application this is not critical.

TMS disrupts the electrical side of neuronal function by inducing a fluctuating magnetic field that generates an electrical current. When the field pulses the electrical activity of the cortical region underneath the magnet is disrupted.

Specifically, TMS can produce changes in neuronal activity in regions of the brain implicated in mood regulation, such as the prefrontal cortex. Mood driven by emotion is at the core of what motivates people to take action. A weaponized version of TMS could effectively alter the negative emotions driving the problems behavior(s).

The effects are temporary lasting minutes although longer-term effect offering therapeutic benefits are being investigated. Certain effects are well known, these include speech arrest and the stopping various motor capabilities, hand or finger movement for example. One application is brain mapping prior to other treatment to identify the areas of the brain which control various actions. Cognitive skills, counting for example, can also be impacted.

Research has indicated no long-term negative effects. TMS is based on Faraday's principle of mutual induction, which states that electrical energy can be converted into magnetic energy, and vice versa. During TMS, a bank of capacitors repeatedly and rapidly discharges into an electric coil and produces a time-varying magnetic pulse. If the coil is placed near the head of a human or animal, the magnetic field penetrates unimpeded into the brain and induces an electric field in the underlying region of the cerebral cortex. This electric field in turn produces a charge across the excitable neuronal membranes and, if it is of sufficient intensity, induces neuronal depolarization and an action potential. The propagation of this action potential along nerve structures and neuronal networks constitutes the neuronal basis for TMS actions. TMS has both local effects, by stimulation of interneurons, and distant effects through stimulation of axonal connections. The magnetic field induced during TMS declines logarithmically with distance from the coil. In humans, this limits the effects of TMS to cortical depolarization (about, 2 cm below the skull). It is possible that improvements in the manufacturing of coils will allow the delivery of magnetic pulses to deeper brain areas. **[iv]** The equipment used is relatively small (size of a hand) and inexpensive. This equipment must be placed against the skull and is manipulated with regard to placement.

Hypothesis

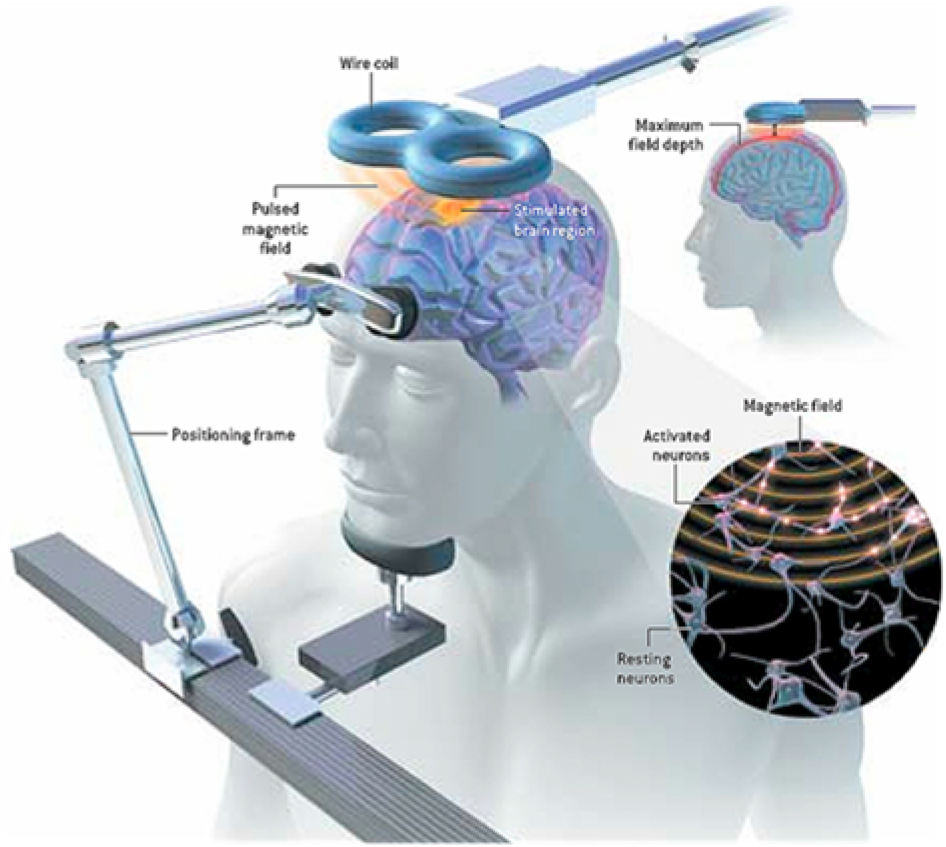
Based on existing studies we believe that TMS could be used to temporarily interrupt aggressive actions or even detonating an explosive device. Further study to demonstrate this would be relatively straight forward and involve little or no risk. Existing studies indicate this to be so. In order to achieve these ends we would test several of the apparent capabilities of TMS. An obvious one would be to turn on and turn then off the capability to perform physical actions. Some of the press reports have indicated a subject is incapable of coordinating finger and hand movements. They certainly would not be able to shoot a weapon, or press a detonator switch. In other cases some higher cognitive functions are disrupted, such as the ability to manipulate numbers. The suggested experimentation would extend to whether or not this could be also used to disrupt thought processes and render an aggressive person passive.

Methods Used and Progress to Date

For electrical stimulation between two electrodes placed on the scalp current flows from anode to cathode. Near the scalp the predominant direction of current flow is radial, but there are return loops that are tangential to the scalp. For magnetic stimulation, a brief, high-current pulse is produced in a coil of wire, called the magnetic coil. A magnetic field is produced with lines of flux passing perpendicularly to the plane of the coil, which ordinarily is placed tangential to the scalp. The magnetic field can reach up to about 2 Tesla and typically lasts for about 100 ?s. An electric field is induced perpendicularly to the magnetic field. The voltage of the field itself may excite neurons, but likely more important are the induced currents. In a homogeneous medium, spatial change of the electric field will cause current to flow in loops parallel to the plane of the coil, which will be predominantly tangential in the brain. The loops with the strongest current will be near the circumference of the coil itself. The current loops become weak near the center of the coil, and there is no current at the center itself. Neuronal elements are activated by the induced electric field by two mechanisms. If the field is parallel to the neuronal element, then the field will be most effective where the intensity changes as a function of distance. If the field is not completely parallel, activation will occur at bends in the neural element. **[v]**

The issue is standoff distance and focus from a distance. Positioning appears to be so important that one company has developed a robot to apply the coils. By automating the positioning of the TMS coil under the supervision of a neuronavigation system, Axilum Robotics TMS-Robot improves accuracy and repeatability of TMS protocols while keeping a high level of safety for the patients. Focus appears to be important for accurate focus enables stimulation of the exact portion of the cortex controlling the actions the operator needs to inhibit.

The amount of electrical energy needed for TMS to induce motor movement (called the motor threshold [MT]), varies widely across individuals. The intensity of TMS is dosed relative to the MT. Kozel et al observed in a depressed cohort that MT increases as a function of distance from coil to cortex. [vi] Other papers have expressed the same issues. For medical purposes distance is not particularly critical for it is more a convenience rather than an operational necessity. As TMS gains popularity in experimental and clinical domains, techniques for controlling the extent of brain stimulation are becoming increasingly important.



[vii]

At present, TMS intensity is typically calibrated to the excitability of the human motor cortex, a measure referred to as motor threshold (MT). Although TMS is commonly applied to nonmotor regions, most applications do not consider the effect of changes in distance between the stimulating device and underlying neural tissue. Here we show that for every millimeter from the stimulating coil, an additional 3% of TMS output is required to induce an equivalent level of brain stimulation at the motor cortex. [viii] The results imply that distinct patterns of cortical network activation may exist related to the distance-induced alterations when the coil is moved away from the skull. Further studies are required to elucidate the precise nature of the distance-related interactions of the magnetic field with the cortex. As stated previously existing studies are in terms of centimeters, not meters.

Data analysis and/or future research areas and ongoing related research plans (as applicable) (internal or external to submitting organization). There is inference in a BBC report about 10 years ago there may have been military interest in this technology. We have not been able to find further references in the open literature.

The Issues Requiring Further Research are as Follows

- Distance/power: as a practical matter how much can power be increased to offset distance while maintaining efficacy?
- What are the offsets of distance with regard to focus?
- Is it possible to obtain the same specific results – for example the loss of the ability or desire to pull a trigger – without undesirable collateral effects?
- If power and distance are increased and focus is not adjusted could the same detailed effects be obtained

Clearly as his power is increased so is the size of the equipment. We believe that with new technology the developers could avoid producing another piece of equipment requiring a Humvee to move it from place to place.

When the distance/focus/power/effects interrelationship has been resolved the next phase of the delivery concept will be resolved, U.S. military primacy, or Europe as a peaceful interstate community.

- Can the equipment be man portable and at what range?
- Is line of sight critical
- Does the form factor and weight allow the equipment to be mounted on an unmanned vehicle?

Given the ever increasing capability of drones, both with regard to size, maneuverability, and types of payload, we would suggest that the 2050 application would be looking at a possible swarm of small drones carrying packages capable of producing the same effects as the current TMS equipment developed for treatment.

The opinions expressed here are the sole ownership of the authors, and do not reflect those of the U.S. Army Special Operations Command, the U.S. Army, the Department of Defense, or the U.S. Government.

End Notes

[i] http://breakingdefense.com/tag/active-denial-system/

[ii] Young, Liane, Joan Albert Camprodon, Marc Hauser, Alvaro Pascual-Leone, and Rebecca Saxe. 2010. “Disruption of the Right Temporoparietal Junction with Transcranial Magnetic Stimulation Reduces the Role of Beliefs in Moral Judgments.” Proceedings of the National Academy of Sciences 107 (15): 6753–58. doi:10.1073/pnas.0914826107.

[iii] A clinical guide to transcranial magnetic stimulation, edited by Paul E. Holtzheimer, Geisel School of Medicine at Dartmouth, Lebanon, NH, William M. McDonald, MD, Emory University School of Medicine, Atlanta, GA.

[iv] NIH **http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3181669/**

[v] Transcranial Magnetic Stimulation: A Primer. Mark Hallett.

[vi] The transcranial magnetic stimulation motor threshold depends on the distance from coil to underlying cortex: a replication in healthy adults comparing two methods of assessing the distance to cortex. McConnell KA1, Nahas Z, Shastri A, Lorberbaum JP, Kozel FA, Bohning DE, George MS.

[vii] http://bipolarnews.org/?p=3382

[viii] Simple Metric For Scaling Motor Threshold Based on Scalp-Cortex Distance: Application to Studies Using Transcranial Magnetic Stimulation. Mark G. Stokes, Christopher D. Chambers, Ian C. Gould, Tracy R. Henderson, Natasha E. Janko, Nicholas B. Allen, Jason B. Mattingley. Journal of Neurophysiology Published 1 December 2005 Vol. 94 no. 6, 4520-4527 DOI: 10.1152/jn.00067.2005

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