Missouri S&T's Peer to Peer

Volume 1 | Issue 2 Article 11

May 2017

Entire Issue

Missouri S&T's Peer to Peer

An Undergraduate Student Research Journal
Spring 2017

Published by Scholars' Mine, 2017

Matthew Clarkson
Psychology at Missouri University of Science and Technology

CLINICAL USES FOR PSYCHEDELIC DRUGS

Abstract

Throughout the last forty years, psychedelic drugs have been illegal in the United States. Stigmatized due to the potential for abuse, the use of these drugs has been relegated to simple criminal activity and research stagnated for those 40 years. Slowly, research has begun to pick up as the restrictions begin to lift incrementally. However, the current restrictions are intense, further limiting the amount of research conducted that can reveal the medical benefits of these drugs. Through multiple studies, both open-label and double-blinded to show both feasibility and efficacy, as well as the biological impact of the drugs, significant anxiolytic, antidepressant, and anti-addictive effects of hallucinogens have been demonstrated. The medical use of these drugs could have a lasting effect regarding substance abuse addictions, severe cases of anxiety, and treatment resistant depression providing alternatives to current methods of treatment.

Clinical Uses for Psychedelic Drugs

Since the late 1960s, psychedelic drugs have been outlawed in the United States. Prior to their ban, psychedelic drugs were thought to have significant medical uses, showing promise in treating a broad array of psychological disorders. Because of their proposed medical uses, psychedelic drugs were often studied prior to the ban. However, in the late 1960s, a large part of the population began to abuse psychedelic drugs and because of this, scientific research regarding psychedelics had been slowed. Although some of the barriers to the research and medical use of psychedelic drugs have been lifted, they remain heavily stigmatized and restricted, limiting the amount and the extensiveness of the research that can be conducted. As the restrictions slowly start to lift, research on psychedelics has started to proceed. This research has been conducted on lysergic acid diethylamide (LSD), psilocybin, and ayahuasca, a hallucinogen originating from the Amazon region of South America. Throughout this paper, hallucinogenic and psychedelic drugs will be used interchangeably to refer to drugs that have the potential to induce hallucinations or an altered sense of reality. Typically, the hallucinations or altered sense of reality are the goals of abuse of these drugs and cause the stigmatization of these drugs. However, despite the ban on hallucinogens, the abuse of these drugs has not significantly diminished and only serves to majorly limit the research allowed for these drugs. Current research indicates that hallucinogens have medical benefits as shown through studies and biological processes. The purported uses of psychedelics are as antidepressants, anxiolytics, meaning antianxiety, and as anti-addictive drugs.

Biology

Outside of clinical trials, hallucinogens demonstrate potential efficacy in the treatment of mood disorders. Using functional magnetic resonance imaging (fMRI) to scan the brain, psychedelic

drugs exhibited effects correlated to a decrease in mood disorders. Hyperactivity in the medial prefrontal cortex of the brain is associated with depression. With administration of psilocybin as well as non-hallucinogenic-based treatments for depression, the medial prefrontal cortex displays lessened activity and eventually leading to normalization. fMRIs also revealed that amygdala activation resulting from threat related stimuli decreased with the use of psilocybin. The amygdala plays a significant role in the creation of emotions and the hyperactivity of this section of the brain due to negative stimuli has regularly been associated with negative mood states in depressed patients. (Mahaptra, 2017, p. 55) The use of the fMRI to link the activity of hallucinogenic drugs with a decrease in brain activity related to depression shows a biological basis for clinical use of these drugs. Additionally, since both psychedelic drugs and traditional methods of depression treatment created similar responses in the brain, the medical use of these drugs is further supported.

In addition to the changes in brain activity, other biological factors also contribute to the use of hallucinogens as medication. Mahapatra (2017) writes, "Downregulation of 5-HT_{2A} receptors is purported to mediate antidepressant and antianxiety effects of antidepressants and atypical antipsychotics…Because of the high binding affinity of psilocybin to the 5-HT_{2A} receptor, its effects are thought to be mediated." (p. 54) These receptors are responsible for regulation of serotonin, a neurotransmitter. A deficit of this neurotransmitter can often lead to depression. Furthermore, the 5-HT_{2A} receptors correspond to additional factors related to depression. Idell (2017) explains that expression of 5-HT_{2A} receptors link to neuroinflammation. (pg. 50) Heightened levels of neuroinflammation can lead to depression as well and is widely regarded as a risk factor for depression. Psilocybin has the potential to regulate the expression of 5-HT_{2A} receptors and decrease inflammation in the brain. (Idell, 2017, p. 50) The potential for

hallucinogens to reduce depression in patients further supports the proposal for the clinical uses of these drugs.

Antidepressant/Anxiolytic

The proposed clinical use of psychedelic drugs revolves primarily around their use as antidepressants. In a study consisting of 22 patients with depression were treated with LSD weekly for 5-6 weeks, eighty percent of patients exhibited improvements in signs of depression within 6-18 months. (Rucker et al, 2016) The improvement of eighty percent sits well above the threshold for clinical significance and demonstrates the efficacy of the drug. Alternatively, Ayahuasca has also been studied as a treatment option for depression. Dos Santos et al. (2016) writes "Ayahuasca administration produced statistically significant reductions of up to 82% in depressive scores between baseline and 1, 7 and 21 days after drug intake, according to the Hamilton Rating Scale for Depression (HAMD), the Montgomery–Åsberg Depression Rating Scale (MADRS), and the Anxious–Depression subscale of the Brief Psychiatric Rating Scale (BPRS)" (p. 201). In this study, statistically significant numbers relating to decline in depressive scores are reached in a short time period after administration of the drug. These numbers also appear across a wide range of depression scales. The short term and long term improvement of depression with two different psychedelic drugs shows promising signs in the treatment of depression. However, these two studies were open-label, meaning these studies show potential or feasibility rather than efficacy.

Other studies have been conducted in order to test the efficacy of hallucinogens. Ross et al. (2016) conducted a study on the efficacy of psilocybin and its role as an antidepressant and anxiolytic. This study treated patients with life-threatening cancer who also underwent serious anxiety and depression. Unlike the studies mentioned above, this study was double-blinded and

tested against Niacin, a placebo. The study concluded that "Psilocybin produced immediate and enduring anxiolytic and anti-depressant response rates, as well as significant anti-depressant remission rates (measured by the HADS D and BDI)." Using the HAD A and BDI as the scale, 83% of patients administered psilocybin exhibited an antidepressant response while only 14% of those given Niacin exhibited antidepressant responses. Anxiolytic responses occurred in 58% of those given psilocybin and only in 14% of those given Niacin (pg. 1175). The chasm between antidepressant and anxiolytic effects due to psilocybin and the placebo shows that psilocybin has clinical uses. Double-blinded placebo-controlled trials have mostly been done with psilocybin although other hallucinogens are used in other studies. Another study conducted in Switzerland in 2014 treated patients with anxiety resulting from life-threatening illness with LSD. This study observed similar effects to the double-blinded placebo-controlled psilocybin study. (Cameron, 2016) The success of LSD in the treatment of these patients shows that the anxiolytic and antidepressant effects are present in hallucinogens other than psilocybin. As both of these trials were conducted against the placebo in a randomized manner and displayed large increases in efficacy of their respective hallucinogens against the placebo, these trials provide ample evidence showing that hallucinogens can significantly improve depression and anxiety.

Anti-addictive

The most prominent concerns with these drugs are safety and dependence. The use of psychedelic drugs causes great concern regarding potential for dependence. However , Psychedelics "do not induce dependence." (Rucker et al, 2016, p. 1221) In addition to being non-addictive, psychedelics are also anti-addictive, meaning they combat dependence on other substances. The two substances studied in regards to the anti-addictive effects of psychedelics are tobacco and alcohol.

Tobacco Dependence

Hallucinogens have shown potential to combat addictions to tobacco through an open-label study. In this study, the average participant smoked 19 cigarettes per day and had smoked for approximately three decades. The study measured cigarettes per day prior to and after the administration of psilocybin. 6 months after the administration of psilocybin, 80% of the participants had not smoked. Additionally, the participants reported less desire to smoke throughout the entire duration of the study as well as higher confidence in their ability to withstand the temptation to smoke. (Dos Santos, 2016, p. 199-200) Because these smokers had smoked for a great length of time, their dependence on nicotine was rather strong. Although the study was open-label and undoubtedly affected by the placebo effect, the abstinence of 80% of the sample demonstrates massive potential in aiding those who have struggled with nicotine addiction.

Alcohol Dependence

Equally as tobacco dependence, psychedelic drugs lesson one's dependence upon alcohol. An open-label trial conducted in regards to alcohol dependence administered psilocybin to the patients. These patients had been considered alcohol dependent for an average of 15.1 years with 80% of the sample experiencing withdrawal symptoms prior to the start of the trial. In addition to the psilocybin, this trial also included seven sessions of motivational enhancement therapy. Throughout the course of the trial, the days in which alcohol was consumed as well as the days the patient drank heavily, consuming 4 or more drinks consisting of more than 14 g of alcohol, substantially decreased. Throughout the 36 weeks of the trial, the decrease in alcohol dependence remained consistent. (Dos Santos, 2016, p. 200) Compared to the length of time the patients depended on alcohol before the study, their decrease in dependence marks a huge improvement.

Like the Tobacco trial, the alcohol trial was also prone to the placebo effect as it was open-label. However, this trial still shows potential relating to the anti-addictive effects of hallucinogens.

Safety

The biggest issue concerning the use of hallucinogens to treat mood disorders stems from potential adverse effects relating to both physical health and mental health. In clinical trials conducted over the safety risks of hallucinogens, most or all patients report no serious adverse effects with exceptions regarding ayahuasca and vomiting in 50% of the sample. The patients involved in the ayahuasca trial did not regard the vomiting as "causing severe discomfort" (Dos Santos et al., 2016; Ross et al, 2016). At first glance the vomiting seems rather serious especially considering its appearance in half of the sample. However, out of the three hallucinogens commonly discussed in the treatment of mood disorders, only ayahuasca caused the patients to vomit. The lack of severe adverse effects by all of the hallucinogens reported means that the use of psychedelic drugs in a controlled setting has no known major health consequences. In addition to the aforementioned vomiting, other effects have been noted as well. The effects noticed were "non-clinically significant elevations in BP [blood pressure] and HR [heart rate] (76%), headaches/migraines (28%), and nausea (14%)... transient anxiety (17%) and transient psychotic-like symptoms (7%: one case of transient paranoid ideation and one case of transient thought disorder)" (Ross et al, 2016, p. 1173). Due to the short duration of most of these effects combined with a relatively low appearance in the sample, these effects are not significant or serious. The one effect that does appear in a large majority of the sample, a rise in blood pressure and heart rate, is classified as non-clinically significant. The low incidence in serious and clinically significant symptoms in addition to the the short duration of most symptoms demonstrates the relative safety of psychedelic drugs.

Additionally, appropriate dosing and drug quality plays a role in the safety of hallucinogenic drugs. One study on hallucinogenic drugs conducted by Baumeister et al. (2014) stated that adverse effects occurred in a minority of participants, they could all be calmed down without medication, and these effects only occurred in patients who had received high doses (p. 163). The presence of adverse effects in patient who had received high doses indicates a correlation between dosage and adverse effects indicating that if lower doses were administered, the presence of adverse effects would likely drop. Drug quality is another factor connected to severe symptoms. Rucker et al. (2016) writes "The majority of studies of adverse reactions, retrospective in nature, have described a constellation of premorbid characteristics in individuals seeking treatment for these reactions where drugs of unknown purity were taken in unsupervised settings." (p. 1227) The adverse reactions reported were noticeably low with proper dosages and pharmaceutical quality drugs. Additionally, since serious conditions were only noted in those who had received high doses and drugs of questionable quality, the use of hallucinogenic drugs have limited and non-life threatening side effects when used responsibly.

Discussion

Currently, psychedelic drugs are labeled as schedule 1 drugs, meaning these drugs have no medical purposes and high potential for abuse. However, as psychedelic drugs have shown to exhibit certain clinical uses, such as antidepressant and anxiolytic effects, and have shown promise curbing dependence on other substances, to claim these drugs have no medical use would be absurd. Additionally, although these drugs could be abused, they are non-addictive. Therefore, these drugs have no potential for dependence. Lower classifications do exist for drugs that meet the criteria of non-addictive, potential for abuse, and medical purposes. Changing the classifications on these drugs would result in lessened restrictions on research of these drugs and

their uses and possibly open the door for them to be used to treat mood disorders. Furthermore, opiates are currently used in medicine. Opiates have high addiction potential and incur more danger and yet morphine is still widely used to anesthetize patients. If drugs that incur considerably more danger and have higher addiction potential are commonly used in medicine, the use of psychedelic drugs should not be so stigmatized. Since only smaller scale studies have been conducted to measure the effects of hallucinogens, more research should be conducted before they enter into mainstream clinical use. Lastly, it is important to note that these drugs will not be a magical cure for depression. Depression results from both biological and behavioral interaction. Without the proper behavioral changes, these drugs will be ineffective. Accordingly, due to the multifaceted cause of depression, multiple treatments should be used. Hollister (1969) writes “The old adage that the lack of a single effective treatment encourages multiple treatments is nowhere more evident.” (p. 171) Since, depression has multiple interrelated causes, multiple treatments to combat the different interactions of its root causes becomes all the more necessary. Hallucinogenic drugs, if more research is conducted, may help curb the steadily increasing rates of depression.

References

Baumeister, D., & Barnes, G., & Giaroli, G., & Tracy, D. (2014) Classical hallucinogens as antidepressants? A review of pharmacodynamics and putative clinical roles. *Therapeutic Advances in Psychopharmacology*, Vol. 4(4) Retrieved from https://www.nlm.nih.gov/bsd/pmresources.html

Cameron, R. (2016) Look again at psychedelic drugs. *Nursingstandard.com* Vol. 30. Retrieved from https://www.nlm.nih.gov/bsd/pmresources.html

Dos Santos, R. G., & Osorio, F. L. & Crippa, J. A., & Riba, J., & Zuardi, A. W., & Hallak, J. E (2016) Antidepressive, anxiolytic, and anti-addictive effects of ayahuasca, psilocybin and lysergic acid diethylamide (LSD): a systematic review of clinical trials published in the last 25 years. *Therapeutic Advances in Psychopharmacology*, Vol. 6(3). Retrieved from https://www.nlm.nih.gov/bsd/pmresources.html

Hollister, L. E. (1969) Clinical use of psychotherapeutic drugs: Current Status. *Clinical pharmacology and therapeutics*, Vol. 10 Retrieved from https://www.nlm.nih.gov/bsd/pmresources.html

Idell, R.D., & Florova, G., & Komissarov, A. A., & Shetty, S., & Girard, R. B. S., & Idell, S. (2017) The fibrinolytic system: A new target for treatment of depression with psychedelics. *Elsevier*. Retrieved from https://www.nlm.nih.gov/bsd/pmresources.html

Mahapatra, A. & Gupta, R. (2017) Role of psilocybin in the treatment of depression. *Therapeutic Advances in Psychopharmacology*, Vol 7(1) Retrieved from https://www.nlm.nih.gov/bsd/pmresources.html

Ross, S., & Bossis, A. & Guss, J. & Gabrielle A. L., & Malone, T., & Cohen, B.,…& Corby, P., & Schmidt, B. L. (2016) Rapid and sustained symptom reduction following psilocybin

treatment for anxiety and depression in patients with life-threatening cancer: a randomized controlled trial. *Journal of Psychopharmacology*, Vol. 30. Retrieved from https://www.nlm.nih.gov/bsd/pmresources.html

Rucker, J. JH., & Jelen, L. A., & Flynn, S., & Frowde, K. D., & Young, A. H. (2016) Psychedelics in the treatment of unipolar mood disorders: a systematic review. *Journal of Pyschopharmacology*, Vol. 30. Retrieved from https://www.nlm.nih.gov/bsd/pmresources.html

Ashley Schmid
Mechanical Engineering at Missouri University of Science and Technology

AN ANALYSIS OF THE ENVIRONMENTAL IMPACT OF ELECTRIC VEHICLES

Abstract

Electric cars have the reputation as a possible solution to many modern environmental and economic issues. Electric motors have been an interest of many inventors since the 1830s, but fully electric vehicles were not prevalent until 2008 when Tesla Motors released the Roadster. The looming energy crisis is one of the main motivations for the advancement in renewable and alternative fuel technologies, but since the early 60s, it has been the environmental lobby that has been pushing for this change. The environment suffers from industrialized nations as the amount of greenhouse gas emissions reach new heights every year. Filtration systems and other air detoxifying routes are being explored, but a major reduction in greenhouse gas production will make the most significant climate difference. Fully electric vehicles claim to have zero tailpipe emissions, but that doesn't account for the emissions produced from the energy production used to charge those vehicles. This study evaluates the environmental impact of electric vehicles and the economic policy that is encouraging greater use of this technology.

An Analysis of the Environmental Impact of Fully Electric Vehicles

The electric vehicle market has been rapidly expanding since 2008. This market expansion is partially due to the technology becoming more widely used by car manufactures as well as a significant price decrease. Electric vehicles have also grown in popularity because of the increasing concern for the environmental impact that greenhouse gas emissions cause ("Car Emissions and Global Warming"). Global warming is still questioned, but more people around the world are slowly seeing it as a real concern. Some have suggested that the forests and oceans are soaking up the toxic emissions as fast as they are being produced. However, the United States Environmental Protection Agency released a report in January 2017 proving this argument false. \Others claim that global warming is a natural planetary process, and the EPA (2017) agrees that global warming is the process that keeps Earth at a livable temperature. However, the surplus of emissions that has caused the 1.5° fahrenheit increase in temperature over the last century. This is a great concern considering the ice age was only 5-9 degrees cooler than today's climate. This change in temperature due to greenhouse gasses has the potential to

This increase in emissions is due to the rising population and increased production and consumption of energy and transportation. From the year 1990 to 2012, only 22 years, the amount of greenhouse gas emissions increased by 41% internationally (Samimi & Zarinabadi, 2012). If the rise of emissions continues at this exponential rate, the coming centuries will have to deal with even higher temperature increases and more intense effects of global climate change. The United States makes up 4.5% of the world's population, but uses 19.2% of all the world's energy; it is the second largest energy consumer in the world, just behind China (Aslani & Wong, 2013). Many smaller countries have made efforts to decrease their emissions and to produce energy through renewable technologies, but even if 100% of the energy produced was green, their impact would be much smaller than if the big energy consumers reduced a large

portion of their emissions (Wilson, 2013). The transportation sector of the US accounts for 28% of the nation's greenhouse gas emissions, which means there is a big opportunity for a reduction in tailpipe emissions with greater use of electric vehicles (Jenn, Azevedo, & Michalek, 2016). This technology is reaching higher demands than ever before, which will increase their total impact; by 2020, the number of electric cars on the road is estimated to increase from the 740,000 in 2015, to several million (Patel, 2015). The emissions of fully electric vehicles (FEVs), when taking the energy production emissions into account, will be analyzed to prove that FEVs will make a significant reduction in greenhouse gas emissions.

Methodology

The most relevant scholarly articles from the time period of 2013 to the present were used to analyze the environmental impact of fully electric cars. Interest in the electric car industry spiked after Tesla's Roadster debuted; therefore, relevant articles were not produced until a few years after. Many of the articles used were highly referenced in the field and discussion of electric cars. The main databases used to search for articles were ScienceDirect, Environmental Science and Technology, American Chemical Society Publications, and the United States Department of Energy. I searched using phrases such as "environmental impact of fully electric cars", "power sources in the United States", and "lithium ion batteries in electric cars." As a mechanical engineer, my interest stems from new automotive technology; there were no preconceived notions on this topic and no encouragement from outside sources to produce a bias article.

Power Source

The most important part, and conveniently the most forgotten part, of the electric vehicle discussion is where the energy is coming from to charge these vehicles and the emissions associated with the production of that energy. The United States Department of Energy reported

in 2016 that natural gas and coal make up 64% of America's produced energy. Natural gas produces roughly half of the amount of emissions that coal does, but if two thirds of the country's energy is coming from these non-renewable sources, the amount of emissions is still high. The growth in the renewable energy field is extremely hopeful considering the amount of energy produced in 2012 was only 13.2% (Aslani & Wong, 2013). That increased to 34% in 2016 with the use of nuclear, hydro, wind, biomass, and solar energy (US Department of Energy, "Emissions", 2016). The country has a large potential for even more growth because of the wide open spaces in the west for solar panels and wind turbine farms .

Even with the energy coming from this two thirds non-renewable energy grid, fully electric cars still produced less than half the emissions of gasoline powered cars. Fully electric cars annually produce 4,587 pounds of CO2 while gasoline, hybrid, and plug-in hybrids produce 23,885 pounds of CO2 (US Department of Energy, "Emissions", 2016). This statistic only covers the emissions produced to charge the vehicles; it does not cover the emissions from vehicle manufacturing, power stations, combustion, upstream fuel production, and grid loses. With all those pieces taken into account, the estimated United States average emissions is 202g CO2e/km and the estimate for a gasoline vehicle is about 300g CO2e/km (Wilson, 2013). The more energy that is produced through renewable resources, the greener fully electric cars become and their claim of "zero emissions" becomes closer to the truth.

Batteries

The lithium-ion batteries store the energy for fully electric vehicles. Lithium-ion batteries also allow the vehicle to travel up to 335 miles on one charge; the actual travel mileage depends on the vehicle model(Lambert, 2017). Lithium-ion batteries have come a long way since 1992 when the were first sold to consumers. They now hold double the energy by weight and only cost

300 dollars per kilowatt-hour (Patel, 2015). When Tesla released the Roadster in 2008, the cost of a lithium-ion battery was upwards of 900 dollars. Although still expensive, this decrease has helped drive down the cost of fully electric vehicles. The reason these are the prefered batteries of choice is their “high power-to-weight ratio, high energy efficiency, good high-temperature performance, and low self-discharge” (US Department of Energy, “Batteries”, 2016). These factors make lithium-ion batteries the most promising form of on-board energy storage and management devices for fully electric vehicles.

A variety of chemical designs for the lithium-ion battery are currently being tested and produced. The Nissan Leaf and BMW i3 use a lithium nickel manganese cobalt battery which has an energy density of 140-180 Wh/kg (Patel, 2015). The issue is finding a chemical make-up that allows for an increase in energy capacity while still being stable at high-temperatures and repeated charging cycles. The new Tesla Model S uses a lithium nickel cobalt aluminum oxide battery which “boosts the energy density greater than 240 Wh/kg” (Patel, 2015). Researchers are continuing to test new materials for lithium-ion batteries in order to increase their energy density for electric car use; vehicles will be able to go further on a single charge which will make them more practical for car owners who drive 20-50 miles to work every day.

The applications for lithium-ion batteries extend far beyond electric cars. This market grew 73% between 2010 and 2014 (Narins, 2017). This could limit the growth of the electric car industry because of the relatively low supply of high quality lithium for these batteries. In December of 2015, the price of 99% lithium imported into China doubled to 13,000 dollars per ton; with almost half of an electric vehicle's production costs being made up by the cost of their batteries;, this poses a huge threat (Narins, 2017). The price is estimated to fall over time, which could cause another spike in electric vehicle production like what was seen in 2008. The greater

number of electric vehicles on the road, the greater the impact they will make on emissions production.

Economic Policy

The United States realizes that they are the world's second biggest energy consumer and has made efforts in the form of legal policy to reduce the country's emissions. In 1975 the US passed the Corporate Average Fuel Economy policy which enacted greenhouse gas emission standards on the transportation industry (Jenn, Azevedo, & Michalek, 2016). This bill has been revised and added to throughout the years and the EPA estimates that by 2050 it "will lead to reductions of 500 million metric tons of CO2 annually" (Jenn, Azevedo, & Michalek, 2016). This will help the environment eventually, but because of the rapid increase in emissions an immediate solution was necessary. The Energy Policy Act of 2005 offered immediate tax incentives and loan guarantees to companies that researched and produced renewable energy sources such as solar and wind (Aslani & Wong, 2013). These policies also started a pattern among the individual states to implement their own policies regarding emission standards and funding for renewable energy each year.

The economic crash of 2008 made renewable energy a low priority because the unemployment rate and economy state dominated the media. As the economy has recovered, more Americans have fought to see more environmental policy changes.The 2009 Omnibus Public Lands Management Act and the American Reinvestment and Recovery Act which gave 90 billion dollars for green projects (Sheppard, 2014). This push will further renewable energy research therefore making the grid and use of electric vehicles have an even greater impact in the reduction of greenhouse gasses.

Discussion

The use of fully electric vehicles does make a significant impact in reducing greenhouse gas emissions. Even with the energy production in the United States being two thirds non-renewable energy, electric vehicles still produce less than half the amount of CO2 as conventional gasoline cars do annually. The purpose of the study was to bring all the pieces of information together that create a full picture of the potential significance of this technology . While electric vehicles may be making a difference now, their impact could be increased if a substantial effort is made by the government and lobbying parties to encourage more policy change, research, and production of more electric vehicles. One of the limits of this study was the limited research done on cradle-to-grave emissions of the production of lithium-ion batteries. Since this is relatively new field and each battery has its own chemical background, emissions of production were not found. This is an important component of the electric vehicle discussion because the production of these batteries is not only the most expensive part of the car, it may alsobe the most energy consuming part of production. More research needs to be conducted on electric vehicles, renewable energy, and lithium-ion batteries, especially the various chemical make-ups of the batteries on the market . The country is on the right track to start making a significant reduction in greenhouse gasses, and with these reductions the planet should remain livable for centuries to come.

References

Aslani, A., & Wong, K. V. (2013, September 28). Analysis of renewable energy development to power generation in the United States. Retrieved March 13, 2017, from http://www.sciencedirect.com/science/article/pii/S0960148113004631

Car Emissions and Global Warming. (n.d.). Retrieved April 18, 2017, from http://www.ucsusa.org/clean-vehicles/car-emissions-and-global-warming#.WPbPS4jytPY

Emissions from Hybrid and Plug-In Electric Vehicles. (n.d.). Retrieved February 10, 2017, from http://www.afdc.energy.gov/vehicles/electric_emissions.php

Frequently Asked Questions About Climate Change. (2017, January 19). Retrieved March 25, 2017, from https://www.epa.gov/climatechange/frequently-asked-questions-about-climate-change

Jenn, A., Azevedo, I. M., & Michalek, J. J. (2016). Alternative Fuel Vehicle Adoption Increases Fleet Gasoline Consumption and Greenhouse Gas Emissions under United States Corporate Average Fuel Economy Policy and Greenhouse Gas Emissions Standards. Environmental Science & Technology, 50(5), 2165-2174. doi:10.1021/acs.est.5b02842

Lambert, F. (2017, April 13). Tesla Model S 100D officially takes top spot for longest range EV with EPA 335-mile rating. Retrieved April 14, 2017, from https://electrek.co/2017/04/13/tesla-model-s-100d-longest-range-ev-epa/

Narins, T. P. (2017). The battery business: Lithium availability and the growth of the global electric car industry. The Extractive Industries and Society. doi:10.1016/j.exis.2017.01.013

Patel, P. (2015, July 13). Improving the Lithium-Ion Battery. Retrieved March 25, 2017, from http://pubs.acs.org/doi/full/10.1021/acscentsci.5b00223

Samimi, A., & Zarinabadi, S. (2012). Reduction of Greenhouse gases emission and effect on the environment. Journal of American Science, 1011-1015. Retrieved February 04, 2017.

Sheppard, K. (2014, April 22). Congress Hasn't Passed A Major Environmental Law In 1,894 Days. Retrieved April 18, 2017, from http://www.huffingtonpost.com/2014/04/22/congress-environmental-laws_n_5193815.html

Wilson, L. (2013). The 'electric cars aren't green' myth debunked. Retrieved February 10, 2017, from http://shrinkthatfootprint.com/electric-cars-green

Hannah Reinbolt
Computer Science at Missouri University of Science and Technology

NETWORK SECURITY:
INTERNET PROTOCOL VERSION SIX SECURITY

Abstract

It is no secret that the pool of public internet addresses available with Internet Protocol version Four (IPv4) is gone. (Morphy, 2011) Thus the migration to the more roomy Internet Protocol version Six (IPv6) has begun. This migration is a complex process including different security procedures and updates that require time and knowledge. This paper will dive into scientific writings, with databases like Scopus and IEEE, about various security risks in the IPv6 protocol such as tunneling practices, router issues and issues with Internet Protocol Security (IPsec). This paper will overview security practices to better clarify common vulnerabilities in IPv6. While some configurations cause issues with host safety, it is commonly noted that due to user error most of the attacks escalate more than they should. Network professionals should be informed about IPv6 security issues in order to best protect a system. Information on IPv6 security risks is crucial to protecting against an attack before it happens and minimizing damage when real time attacks take place.

Network Security:

Internet Protocol Version Six Security

The transfer of information online allows many of systems of today to operate and Internet Protocol version Four (IPv4) does a great job working like a post office to organize digital traffic. IPv4 provides public internet addresses to communicate with networks but after its release in the 1970s and the rapid growth of the internet, the current demand for public internet addresses has reached its physical limit. By 1998 the Engineering Task Force deemed the new Internet Protocol version Six (IPv6) to be the successor to IPv4 and solve the address problem. The transfer to IPv6 allows a lot more flexibility, address space and security due to better architecture and physical space but unfortunately these two protocols were not meant to be interoperable. This makes the transfer complex and some vulnerabilities from IPv4 are implemented into IPv6.

Unfortunately many entities have not switched to IPv6 because of price and compatibility. Even with this barrier, Carlos Caicedo, James Joshi, and Summit Tuladhar explain in their journal titled 'IPv6 Security Challenges' that many Asian countries such as China, Korea and Japan have made the upgrade a priority by limiting IPv4 address space (2009). Nevertheless, due to physical address limits, the switch will have to be made in the coming years because IPv6 is the only infrastructure that can support the internet (Amutha, Albert Rabara, Meenakshi Sundaram, 2016.). Caicedo, Joshi and Tuladhar go on to explain one of the main security challenges being a lack of understanding IPv6 security infrastructures (2009). Since the internet is beginning to merge into IPv6, the hacker community has begun to exploit weaknesses. (Hauser, 2017) As more of the internet converts we will have greater knowledge and experience dealing with newly formed attacks. Network professionals need to be informed of as many security risks as possible to help protect this new IPv6 system and prevent common user error.

As the number of attacks continue to grow and IPv6 becomes more ingrained with the majority of Internet users, understanding how IPv6 infrastructure and security issues work become crucial. This paper takes scholarly writings from Google, Scopus and IEEE databases, then reviews them for information regarding IPv6 security practices and issues. Priority is focused on common security risks many users face. Results include findings on tunneling, packet issues IPsec vulnerabilities, and information of potential risks.

Internet Protocol Security Issues

Old features of IPv4 now being used as add ons for IPv6 may give rise to previous security issues. Amutha, Albert, and, Meenakshi remark in their paper about IPv4 and IPv6 transitions, "IPv6 is enmeshed with various issues: its global interoperability is limited due to the weakness of the encryption algorithm; IPSec [Internet Protocol Security] has not yet been fully standardized; there is no protection against Denial of Service/Flooding attacks." (2016). This paper explained that certain old vulnerabilities with IPv4 could be brought over with IPv6, such as Denial of Service or Flooding attacks. IPsec works like a lock on a package about to be mailed. It encrypts the data making it more secure for travel and protects the data until delivery. Features like IPsec are now being implemented as a requirement which is something to consider when planning to make the switch to IPv6. Denial of Service or Flooding attacks happen when the bandwidth of multiple servers are flooded with information in such a way that it disrupts the services the host provides. This can momentarily or permanently take that host down depending on the nature and intensity of the attack (McDowell, 2009).

There is also concern as to how IPsec can be secure in encryption. Zamani and Zubair state that strength of the encryption algorithms to ensure global interoperability is limited (2014). The complexity of the IPsec security algorithms is simplified due to export laws that regulate

who has access to US developments. While these laws help global workability they also make boundaries easier to break compared to more complicated algorithms.

The usage of a stronger encryption is looked down upon because the National Security Agency (NSA) fears it will make the intelligence gathering more difficult and possibly threaten national security (Tidball, Best, 1998). It is tricky to propose a stronger algorithm but still on the mind of experts when it comes to IPsec management. While Denial of Service attacks are more common than deficiency in algorithm strength, both papers bring up some concerning vulnerabilities in IPsec encryption. These papers suggest that a factor in helping increase security would be for "Security practitioners"(Amutha, Albert, Meenakshi, 2016) to educate themselves on IPv6 technology and workings in order to understand how to keep networks secure and decrease the chance of simple human errors letting the attacks escalate.

Tunneling Challenges

In the older protocol, IPv4, rogue traffic slipping by via tunneling is a challenge but with IPv6 having sixteen different tunnel and transition methods, it makes filtering more difficult. Going back on our post office examples, tunneling is like the route from the post office to a house. The post office truck carries all the packages safely to a house but has several paths to take in order to get there. Tunneling is like the path to the package destination with IPv6 having many more paths. Sharma notes in a study on IPv4 and IPv6 best security practices that, "As noted in many of the transition studies done, automatic tunneling mechanisms are susceptible to packet forgery and DOS (denial of service) attacks (2010). These risks are the same as in IPv4, but increase the number of paths of exploitation for adversaries." Information is being streamed through these IPv4 and IPv6 tunnels but these tunnels are set to filter out bad information and packets. In IPv4 it is possible to overflow the tunnels with information in Denial of Service attacks in hopes of

shutting down the host but is manageable by setting up the tunnels to be filtered. In IPv6 it would be harder to filter out the bad packets due to there being larger amounts of tunnels and transition methods. The damage that can be done by having a mass of unfiltered traffic flow through the IPv6 protocol could lead to damage to your host, exposure to bugs and other risks. Sharma goes on to say that if the network structure is dual stacked that it would need to heavily rely on these filtering methods. Static tunneling proves to be a lot more stable because it can secure a trust relationship between both ends of the tunnel. Proper tunneling management is important in protecting against mass attacks like Denial of Service or other bad packets in order to save time and information. While tunneling mechanisms should be a concern to all administrators it is not always considered since most traffic is blocked by default.

Tunneling methods should be reviewed in order to have optimal security. Gont & Liu (2014) seem to stress that, "Tunneling mechanisms should be a concern not only to network administrators that have consciously deployed them, but also to those who have not deployed them, as these mechanisms might be leveraged to bypass their security policies." It is discussed that tunneling mechanisms have been standardized and called 'automatic tunneling' mechanisms which might be put in place without the user or network administrators consent. Checking the setup to make sure there are no loopholes packets can slip through is a good way to prevent attacks from common user error. In most cases IPv6 will have traffic blocked but as Gont & Liu remark, it is important to check and make sure what is configured. If not managed properly these implications could lead to host exposure, evasion of security protocols, protocol-based vulnerabilities and others. In the case of what Sharma, and Gont & Liu said, one of the main concerns is making sure the current IPv6 configuration is known for each setup. In perspective,

attacks like Denial of Service are less likely to happen if careful consideration is taken to set up any tunnels and to be aware of current tunneling mechanics.

Routing and Packet Vulnerabilities

In addition to tunneling, routing headers being hijacked is a concern. Chasser (2010) warns about routing headers being manipulated to carry a blocked packet to a host processing header. A header is like a destination address on a package as it is on the way to be mailed while a packet is like a package to be mailed, carrying digital information. The destination of the packet would be manipulated and once it is headed towards the destination, the host must accept this address with a packet. Because the packet is linked to a good address, it is not properly dropped like it would have been before. This would be a way to sneak dangerous packets into your host through the levels of security already implanted. Chasser suggests verifying the waypoint of the router addresses so they appear only once for a destination. This is only a countermeasure to prevent suspicious activities but not guaranteed. However, this is not the only threat meant to derail the router process.

Supriyanto, Hasbullah, Murugesan, and Ramadass (2013) argue that a ‘hop’(bridge or gateway) router pretends to be a default router and then an attacker can send packets wherever desired, with the option of disturbing packet transmission. In detail this hop router will send a false transmission to the inform the host of the best way to send the packet. The host will think it is the default router and send the packet. Unfortunately rogue transmissions like this can cause false parameters and the packet to not arrive at its destination. Between Chasser, Supriyanto, Hasbullah, Murugesan, and Ramadass, they all bring to mind the importance of security and how it can affect IPv6. From big features like IPsec to small packets of corrupted information, all of these can cause major issues with the functionality of the host.

Discussion

IPv6 security is a complicated issue and many authors have a different approach on the subject. Here it was discussed that many different issues can lead to Denial of Service attacks, such as some current problems with the IPsec feature and proper tunneling techniques proving to be difficult. Here is is discussed that tunnel filtering is more challenging to accomplish with IPv6 due to more tunnels and more physical space. Algorithm strength was discussed, topics such as limits to the complexity and how those limits are fixed based on the national concerns of NSA. One of the main issues suggested by many of the articles reviewed was the notion of IPv6 administrators not being knowledgeable on IPv6 security and risks. Much of the IP usage is done with the old IPv4 protocol while IPv6 is still very new in the network society. It is encouraged for information about IPv6 security to be reviewed since it is slowly taking over IPv4. Many of these security flaws can be stopped and prevented if the correct procedures are taken in a timely manner.

Internet routing issues were also discussed, including spoofing and address header manipulation. Header manipulation can be prevented in most cases if the host checks makes sure the destination address did not change. Many of these issues are not fully developed and tested due to IPv6 only being used to a fraction of its full potential. As time goes on more threats will be unveiled, and the need for new preventive practices will emerge. More research is needed to properly investigate these security holes as this document only covers a small quantity of issues with IPv6 security. Many attacks and fixes are still theoretical at this stage since IPv6 is still small but because of the imminent switch from IPv4, these threats will only be put into play and even more research will be required.

References

Amutha J., Albert Rabara S., Meenakshi Sundaram R. (2016) *An Integrated Secure Architecture for IPv4/IPv6 Address Translation Between IPv4 and IPv6 Networks*. In: Satapathy S., Raju K., Mandal J., Bhateja V. (eds) Proceedings of the Second International Conference on Computer and Communication Technologies. Advances in Intelligent Systems and Computing, vol 380. Springer, New Delhi

Caicedo, C., Joshi, J., Tuladhar, S. (2009). *IPv6 Security Challenges*. IEEE. Vol. 42. No. 2. (p. 36-42). Retrieved on March 12 2017 from http://ieeexplore.ieee.org.libproxy.mst.edu/document/4781968/.

Chasser, J. M. (2010). Security Concerns in IPv6 and Transition Networks. *Information Security Journal: A Global Perspective*, *19*(5), 282-293. doi:10.1080/19393555.2010.514653

Gont, F., Liu, W. (2014). Security Implications of IPv6 on IPv4 Networks. Internet Engineering Task Force. Retrieved on April 14, 2017 from https://www.ietf.org/rfc/rfc7123.txt.

Hauser, Van. (2017). THC-IPV6. The Hacker's Choice. Retrieved on April 14, 2017 from https://www.thc.org/thc-ipv6/.

McDowell, M. (2009). *Understanding Denial-Of-Service Attacks*. Retrieved on April 14, 2017 from https://www.us-cert.gov/ncas/tips/ST04-015.

Morphy, E. (2011). *No Room At The Internet: IPv4 Addresses All Gone*. Tech News World. Retrieved on April 14, 2017 from http://www.technewsworld.com/story/71793.html

Sharma, V. (2010). *IPv6 and IPv4 Security Challenge Analysis and Best-Practice Scenario.* Int.J. of Advanced of Networking and Applications. Vol. 1. No. 4. (p. 258-269). Retrieved on February 2, 2017 from http://www.ijana.in/papers/4.9.pdf.

Supriyanto, Hasbullah, I., Murugesan, R., & Ramadass, S. (2013). Survey of internet protocol version 6 link local communication security vulnerability and mitigation methods. *IETE Technical Review, 30*(1), 64-71. doi:http://dx.doi.org.libproxy.mst.edu/10.4103/0256-4602.107341

Tinbal, K., Best, R. (1998). *The Encryption Debate: Intelligence Aspects*. The Library of Congress. Retreived on April 14, 2017 from http://www.sci-links.com/files/CRS-_Encryption_Intelligence-_11-98.pdf.

Zamani, A., Zubair, S. (2014). Deploying IPv6: Security and Future. International Journal of Advanced Studies in Computer Science and Engineering. Vol. 3. No. 4. (p. 1-9). Retrieved on April 14, 2017 from http://www.ijascse.org/volume-3-issue-4/Deploying_Ipv6_Security.pdf.

David Nicholas Skoff
Computer Science at Missouri University of Science and Technology

EXPLORING POTENTIAL FLAWS AND DANGERS INVOLVING MACHINE LEARNING TECHNOLOGY

Abstract

This paper seeks to explore the ways in which machine learning and AI may influence the world in the future and the potential for the technology to be misused or exploited. In 1959 Arthur Samuel defined machine learning as "the field of study that gives computers the ability to learn without being explicitly programmed" (Munoz). This paper will also seek to find out if there is merit to the current worry that robots will take over some jobs based in cognitive abilities. In the past, a human was required to perform these jobs, but with the rise of more complex automation a person may not be necessary. Many of the sources cited throughout this paper focus on the innovation of machine learning and AI and how dangerous the over automation of the world could be. Machine learning and the resulting AI's have their place in the world and more than likely they will do nothing but push the world towards a more fruitful future. Looking at potential risks of letting lines of code make important decisions is crucial given the consequences that negligence can have. There is a need to explore these topics because losing the human element in decision making can have some big implications if the AI is not programmed correctly. Machine learning has one of the greatest opportunities to impact the world. The need for caution however cannot be understated because of the potential dangers it may pose to jobs, security, and the overall stability of an ever changing world.

Exploring Potential Flaws and Dangers Involving Machine Learning Technology

Humans are always looking to evolve and automate tasks. Programming has come a long way since the early programming languages of FORTRAN and the like. Programming is now a complex task which creates complex solutions to problems plaguing all aspects of humanity. One of the complex solutions is artificial intelligence or AI. Machine learning and AI have created the potential for complete automation at home and in the workplace. There are of course problems with removing a human element from complex tasks. The potential effect on the workplace cannot be understated. Complete automation may even lead to more pressing issues. While the possibility of rogue AI seems straight from a science fiction film, the dangers of full automation are extensive. This danger could come from someone intentionally creating malicious AI or from a simple and innocent error in algorithm construction. In the future, there may need to be certain restrictions and sanctions targeting algorithms that could be used to create powerful AI's that could impact more than just the workplace. As the world nears complete automation in some sectors, security becomes paramount in ensuring safe execution of tasks. Machine learning can be a great tool for shaping the future, but its potential perils cannot be understated.

Workplace Impact

AI taking over the workplace removes the human element from decision making and introduces the potential for malicious attacks upon critical systems. Carl Frey and Michael Osborne explored the fact that jobs that usually require high cognitive ability are being replaced by an automated solution. They say, "Text and data mining has improved the quality of legal research as constant access to market information has improved the efficiency of managerial decision-making" (Frey & Osborne, 2017). This means that in the near future, tasks believed to require a human may become automated. Frey and Osborne specifically mentions such tasks as legal

writing and truck driving may be taken over by computerization (Frey & Osborne 2017). Darrell West from The Center of Technology Innovation at Brookings says, "Telemarketers, title examiners, hand sewers, mathematical technicians, insurance underwriters, watch repairers, cargo agents, tax preparers, photographic process workers, new accounts clerks, library technicians, and data-entry specialists have a 99 percent chance of having their jobs computerized" (West, 2015). This does not necessarily mean that more complicated jobs such as those in the medical and legal fields can be computerized. In fact, West says that these jobs have a less than one percent chance of being replaced (West, 2015). If phased out by robots then the workforce potentially gains efficiency and accuracy but loses the human element.

Another concerning factor is the potential breach of algorithms that dictate AI for critical systems. In these situations, a real person would be unaffected by such malicious attacks on critical systems. These types of attacks may become more probable as time goes on. Researchers from Stanford and Georgetown dissected the fact that making viruses has never been easier. They state, "To complicate matters, writing malicious programs has become easier: There are virus kits freely available on the Internet. Individuals who write viruses have become more sophisticated, often using mechanisms to change or obfuscate their code to produce so-called *polymorphic viruses*" (Kolter & Maloof, 2006). Surely, the security on critical systems which house essential AI would be strong. This however, has never stopped determined hackers from trying to crack through every firewall and security protocol. The computerization of certain jobs is coming and being prepared for such a future would be beneficial for the whole world.

Security Concerns

The potential dangers and pitfalls of machine learning are vast, and include potential attacks on algorithms themselves that are deliberate and destructive. In a paper from scholars at the

University of California, Berkeley, researchers explore the potential dangers of machine learning and its uses in modern technology. They say, “Use of machine learning opens the possibility of an adversary who maliciously ‘mis-trains’ a learning system in an IDS” (Barreno, Nelson, Sears, Joseph & Tygar, 2006). An Intrusion Detection System (IDS) will monitor network traffic and identify potential threats. The authors identify some real dangers of unchecked machine learning algorithms, and this shows why the technical community cannot sit idly by and let potentially dangerous technology run rampant. This fear of a potentially dangerous AI may seem farfetched and even impossible given the current level of technological advancement. This however, may be more feasible than once expected. Two researchers from the University of Louisville explored a way to intentionally create a malevolent AI. They say, “Just like computer viruses and other malware is intentionally produced today, in the future we will see premeditated production of hazardous and unfriendly intelligent systems” (Pistono & Yampolskiy, 2016). This leads to a world where the average person can manufacture these unsanctioned malevolent AI’s that eventually compromise vital systems and databases. Even if someone were to make a secure machine learning algorithm that cannot be exploited, there could easily be someone deliberately making an algorithm that nullifies the good actions of ethical programmers. The ethical issues associated with compromising machine learning algorithms and making malevolent AI’s from scratch are monstrous. Both sets of authors seem convinced that the possibility of malevolent AIs are worth some level of concern. Security should always hold a top priority, but the potential creation of an AI which has no inherent conscience could be very destructive. Being aware that there could be ways to specifically target algorithms dictating AI’s becomes essential in preparing certain systems for the future.

Malicious AI

Malicious AI has been a topic of science fiction since the inception of the concept of an autonomous artificial intelligence. Artificial intelligence could eventually completely overtake some areas of labor as the need of a human becomes negligible. The potential for an AI to become malevolent is not an immediate problem, but with machines taking over there is a real potential for this sort of thing to happen. A researcher from Louisville University says, "Just because developers might succeed in creating a safe AI, it doesn't mean that it will not become unsafe at some later point. In other words, a perfectly friendly AI could be switched to the 'dark side' during the post-deployment stage" (Yampolskiy, 2015). The potential for malevolence is a concern to a professional environment with large amounts of sensitive data. A single AI which was deemed safe may suddenly "go rogue". This prompts the question if these AI can be regulated and what implications such regulations would bring.

Researchers from Stanford explored the possibility of certain regulations on algorithms. They state, "On the one hand, overlooking ethical issues may prompt negative impact and social rejection,' but 'on the other hand, overemphasizing the protection of individual rights in the wrong contexts may lead to regulations that are too rigid, and this in turn can cripple the chances to harness the social value of data science" (Floridi & Taddeo, 2016). This shows that there may need to be certain restrictions, but individual rights are jeopardized by the implementation of these regulations. One individual however can throw things into chaos. Stephen DeAngelis, CEO of Enterra Solutions, says, "It only takes one 'evil genius' to undo the best laid plans that more ethical scientists put into place" (DeAngelis, 2014). There will always be that one evil genius. There are currently no ways to truly regulate algorithms created by people with malicious intent.

These issues will always be around and the emerging field of artificial intelligence may need heavy regulation in an ever changing world.

Conclusion/Discussion

All of these factors combined lead to a world where AI could truly take over. Robots are taking over jobs soon, people can make intentionally malicious AI's and regulations for algorithm construction are almost nonexistent. The potential impact for this study could bring about greater awareness to the ordinary computer scientist of the dangers of AI if not handled properly. For individuals outside of the disciple, it will also lead to greater awareness that the world is changing. Change is not necessarily a bad thing, but understanding the change and its purpose is important to live in an ever changing world. People may have to be prepared to be replaced by robots and accept that while the robots may be able to do their jobs more efficiently does not mean that they are necessarily better workers. Looking at the potential for infiltration of algorithms is something that needs to be further researched and studied. The potential positive impacts advanced artificial intelligence can have on the future may outweigh the negatives. This however does not mean that the potential dangers can be ignored because the the good may seem more important the potential bad. Awareness is half the battle and knowing how to combat problems before they flare up is an important skill. Being aware that new technology can have alarming consequences is important because oversight of such consequences could lead to disaster. Overall, there need to be regulations within the field to temper the impacts of malicious individuals. Professionals and the common person alike need to be aware of the quickly shifting technological climate and the potential impact that the shift may have in the workplace and overall security.

References

Barreno, M., Nelson, B., Sears, R., Joseph, A. D., & Tygar, J. D. (2006). Can machine learning be secure? *Proceedings of the 2006 ACM Symposium on Information, computer and communications security - ASIACCS '06*. doi:10.1145/1128817.1128824

DeAngelis, S. F. (2014). Machine Learning: Bane or Blessing for Mankind? Retrieved from https://www.wired.com/insights/2014/06/machine-learning-bane-blessing-mankind/

Frey, C. B., & Osborne, M. A. (2017). The future of employment: How susceptible are jobs to computerisation? Technological Forecasting and Social Change, 114, 254-280. doi:10.1016/j.techfore.2016.08.019

Floridi L, Taddeo M. (2016) What is data ethics? *Phil. Trans. R. Soc.* A 374: 20160360.

Kolter, J. Z., & Maloof, M. A. (2006). Learning to Detect Malicious Executables. Advanced *Information and Knowledge Processing Machine Learning and Data Mining for Computer Security*, 47-63. doi:10.1007/1-84628-253-5_4

Munoz, A. (n.d.). Machine Learning and Optimization. Retrieved from https://www.cims.nyu.edu/~munoz/files/ml_optimization.pdf.

Pistono, F., & Yampolskiy, R. V. (2016). Unethical Research: How to Create a Malevolent Artificial Intelligence. Retrieved from https://arxiv.org/abs/1605.02817.

West, D. M. (2015). What happens if robots take the jobs? The impact of emerging technologies on employment and public policy. Retrieved from https://www.brookings.edu/wp-content/uploads/2016/06/robotwork.pdf.

Yampolskiy, R. V. (2015). Taxonomy of Pathways to Dangerous AI. Retrieved from https://arxiv.org/abs/1511.03246.

Matthew Gary Booth
Mechanical engineering at Missouri University of Science and Technology

AUGMENTED APPROACHES TO ENGINEERING

Abstract

This paper presents the results of research into the integration and application of augmented reality (AR) and virtual reality (VR) systems into the fields of engineering and engineering education. The research discusses the current iterations of these systems, and the programs that are being developed to run on them. Also being discussed is the potential benefits that implementing these systems can give to engineering education by improving spatial skills for use in engineering education and engineering design. This paper also touches on the current state of the AR and VR markets, and their current focus on entertainment based consumer electronics. The data on spatial skills in engineering education was first reported by Jorge Martín-Gutiérrez's research on AR and its effects on spatial awareness in first year engineering students. This paper follows this research and that of others in this field to report on the future impacts that these technologies can have as well as the reasons behind implementing them.

Acronyms:

Computer Assisted Design (CAD)

Augmented Reality (AR)

field of View (FOV)

Virtual Reality (VR)

American Society of Mechanical Engineers (ASME)

Augmented Approaches to Engineering

Engineers are constantly working on and innovating new ways to improve our everyday lives. Computer Assisted Design (CAD) has become an integral part of an engineer's everyday life, defining the new standard for how drawings and designs are made. However, CAD itself has several binding limitations such as the platforms that it is currently able to run on and the complexity of the user interfaces, which impede CAD's abilities to be fully utilized by all users. Most industrial level CAD software must be used on high-end workstation-based computers that are expensive to manufacture, and are stationary to one desk or office. This research will explore the possibilities that integrating virtual reality based systems into the fields of engineering can bring, the limitations that are currently inhibiting the use of these technologies, and some steps towards resolving these drawbacks. This research also covers the basic workings of the various technologies that go into making AR, Virtual Reality (VR), and CAD possible.Overall, adapting these technologies into the field of engineering could help to improve the design process.

Aside from simply expanding the engineer's creative assets, Augmented Reality (AR) is also helping to train young engineering students, as was reported in Jorge Martín-Gutiérrez's study of freshman engineering students that underwent a remedial course utilizing AR as a learning asset. Through Gutiérrez's study, AR has even been found to improve the spatial skills that are paramount in working successfully as an engineer. Research was conducted by searching the Scopus, ASME, and Google Scholar databases for past research on this subject matter and other relevant information from the websites and biographies of some of the sources' authors. This research is limited only to the papers that are accessible with the clearances given by the Missouri University of Science and Technology's library database subscriptions. The press

releases of several key hardware and software developers such as AutoDesk, and Microsoft also supplied a lot of relevant information on this topic.

Software

Most fields that involve creating a physical product (e.g. engineering, architecture, etc.) used to require the designer start the concept with traditional drafting and design. But in the last handful of decades, technology has begun to replace the need to start drafts by hand with a pencil and paper. Now the standard for many design based industries is to apply CAD systems to create and improve upon their products. With modern computational power, a product or assembly can undergo low level testing before it is even fabricated. Unfortunately, due to the heavy system requirements that many CAD programs require, only expensive workstation-based desktops can run them. While there are laptops that can run some of these programs, they are typically large, expensive and have a short battery life. But the integration of CAD to AR and VR would allow for a practical and cost effective means to bring these programs into the field.

While there are many different engineering CAD programs available, from SOLIDWORKS to AutoDesk's Inventor, not many of these programs are natively supported on current VR or AR headsets. However, some companies, such as AutoDesk and Microsoft, are investing in the development of CAD based AR. The program that AutoDesk is developing for Microsoft's Hololens headset is called ENTiTi, and it hopes to combine many of the key aspects of desktop CAD and the portability of headset based augmented reality. This program allows the user to project a model or models from a series of file formats, and edit them in real time, seemingly in real space. Programs like this are the first real step towards integrating AR as a proper platform for engineering.

Hardware

For the hardware involved in AR and VR, most think simply of the headsets that have started to spring up in consumer electronics over the past few years; however, there is far more to this technology than just the headsets, as AR can also be a camera's feed being interpreted by a computer and outputting a virtually generated image on the screen that appears as though it is in the camera's line of sight. It was through this type of AR that the spanish researcher Jorge Martín-Gutiérrez conducted his research on the effects of AR in assisting engineering students with spatial reasoning. According to Martín-Gutiérrez:

> An engineer should be capable of creating a mental image of an object and see mentally the different perspectives of it for finding out the relations between this object and another one or any other person in space. These skills are very important in the whole process design since the starting phase until the final prototype so improvement of spatial abilities and their successful application is an important research theme on engineering education. (Gutiérrez et al., 2012, p.1).

This concept brings to light the importance that spatial skills can have on the AR and VR user experience. Gutierrez states how one of the key concepts to engineering is an engineer's spatial skills and spatial understanding. This is an idea that he focused his research on, working to show how the implementation of AR systems in engineering education can improve the results of spatial skills tests that students take. Spatial skills are known to be an important contributor to an engineer's success, and AR based systems have been shown to improve these. however, the results of this study could possibly be improved upon using AR that takes the more ubiquitous first person view method. The AR device can "give feedback to the user, [and] allows to close the interaction loop originated by the visual information captured and interpreted by the camera."

(Betancourt, A., 2015). This method allows for the user to interact more intuitively with the models being displayed through more relevant input styles versus the traditional mouse and keyboard approach.

Current VR and AR inputs differ from device to device, but there is an increasing trend to move towards a dual handed controller setup. This allows for a more natural interaction in a three dimensional work plane. However, some devices, such as Microsoft's Hololens, require only your hands to interact with the device, as it tracks your hands without any external sensors. This technology's potential to further engineering's design future grows with every year, and it is only a matter of time before its use is as ubiquitous as the modern computer is today.

Conclusion/Discussion

VR and AR have been in the spotlight as the most promising upcoming consumer electronic, with just about every tech giant placing their bids into one iteration or another. From Facebook's Oculus to HTC's Vive headsets, VR is spreading across the market like wildfire. However, each piece of hardware runs its own operating system, making it nearly impossible to move software from one device to another. Companies do this to maintain a competitive edge, but it is just an obstacle to the developers, whose programs could benefit from cross platform compatibility. cross platform compatibility is one of the obstacles that CAD developers such as AutoDesk need to overcome. because of this the most promising headset for implementation in engineering is Microsoft's Hololens.

The future of VR/AR is not simply bound to that of entertainment, as it can also be a tool of the modern designer. By using VR/AR, designing could be brought out to the field, allowing for more mobility and design accommodations on the fly. This technology still has a way to go before it is ready to be implemented in everyday engineering, and engineering education fields.

This as well as the improvements to input methods allowing for more people to be able to use and benefit from the use of CAD.

This research highlights the importance of integrating these technologies. However,most AR, VR and the software they will run are just starting to make their way into the world. Much research and development is still needed until AR and VR are up to the levels of practicality that modern computers and CAD based systems are. It is in engineering's best interest to integrate these systems into their careers, improving on a several decades old technology, bringing it into more modern times.

References

Betancourt, A., Morerio, P., Regazzoni, C. S., & Rauterberg, M. (2015). The evolution of first person vision methods: A survey. *IEEE Transactions on Circuits and Systems for Video Technology, 25*(5), 744-760. doi:10.1109/TCSVT.2015.2409731

Eadicicco, L. (2017, January 25). Virtual Reality: How VR Will Improve in 2017. Retrieved February 18, 2017, from http://time.com/4645723/virtual-reality-2017-inside-out-tracking/?iid=sr-link2

Kosowatz, J. (2012, September). Augmented Reality Not Quite Real for Engineers. Retrieved February 11, 2017, from https://www.asme.org/engineering-topics/articles/design/augmented-reality-not-quite-real-for-engineers

Martín-Gutiérrez J, Roca González C, García Domínguez M. Training of Spatial Ability on Engineering Students Through a Remedial Course Based on Augmented Reality. ASME. International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Volume 7: 9th International Conference on Design Education; 24th International Conference on Design Theory and Methodology ():219-225. doi:10.1115/DETC2012-70593.

Menezes P., Chouzal F., Urbano D., Restivo T. (2017) Augmented Reality in Engineering. In: Auer M., Guralnick D., Uhomoibhi J. (eds) Interactive Collaborative Learning. ICL 2016. Advances in Intelligent Systems and Computing, vol 545. Springer, Cham. Pages 221-228

Rojas, J. -., Contero, M., Bartomeu, N., & Guixeres, J. (2015). Using combined bipolar semantic scales and eye-tracking metrics to compare consumer perception of real and virtual bottles. Packaging Technology and Science, 28(12), 1047-1056. doi:10.1002/pts.2178

Technology trends 2016: Augmented Reality and 3D printing. (2016, April 01). Retrieved March 05, 2017, from http://www.augment.com/blog/technology-trends-2016-augmented-reality-and-3d-printing/

Shannon Griffin
Computer Science and Missouri University of Science and Technology

BIOSENSORS FOR CANCER DETECTION APPLICATIONS

Abstract

Cancer is one of the most deadly diseases, and current detection options are ineffective. Recently, a large amount of research has been conducted for the development of biosensors able to detect cancer biomarkers. Many biosensors have been created for cancer detecting purposes. I examined literature reviews outlining current biosensing methods. These reviews provided an overview of the sensing techniques that are currently in existence as well as evaluations of their effectiveness. I also read experimental reports that outline the construction of biosensors fabricated in laboratories and the results of their testings. These papers help to showcase the feasibility and effectiveness that a biosensor has when detecting cancer. In this paper I discuss signal transduction systems, piezoelectric sensors, carbon nanotubes, quantum dots, and raman signals for use as cancer biosensors. Since cancer is such a deadly disease, an accurate biosensor is needed that can detect cancer earlier than current methods. In this paper I will provide an overview of each method along with an evaluation to determine what cancer detecting system is the best.

Overview of Biosensors for Cancer Detection Applications

Doctors and researchers agree that current cancer detection techniques are ineffective. Cancer is most commonly detected by ultrasound, MRI, or biopsy, but a group of British and Turkish researchers state that these current methods rely on the physical properties, or appearance, of the tumor, rendering them ineffective (Altintas, Uludag, Gurbuz, & Tothill, 2011). Cancer is caused by an accumulation of genetic mutations and therefore needs to be caught early before the disease progresses. Since early detection increases the chances that treatment will be effective, a new method of cancer diagnosis is desperately needed. Many researchers believe that cancer biomarkers, small abnormalities in the body's chemical or genetic composition can be detected in the very early stages of cancer, aiding in early diagnosis. A group of Indian researchers led by Jayanthi (2017) explain that these mutations or abnormalities "can act as nucleic acid-based biomarkers in diagnosis" (Jayanthi, Das, & Saxena, 2017). By looking for small abnormalities, cancer can be detected before the tumor has time to grow. A group of Russian researchers agree that by monitoring these biomarkers, abnormal amounts can be detected, aiding in early detection and effective treatment (Ranjan, Esimbekova, & Kratasyuk, 2017). These researchers believe that biomarkers have great potential to help revolutionize cancer detection. A group of professors at ETH Zurich believe that nanotechnology is a promising solution for sensing diseases [such as cancer] and managing health problems (Grieshaber, MacKenzie, Voros, & Reimhult, 2008). I also believe that these biomarkers have the potential to aid in early cancer diagnosis. Many different methods of detection have been developed. In this paper I will investigate the current sensing methods that exist for the detection of cancer biomarkers, and I will evaluate them on a variety of criteria, such as accuracy, feasibility and safety.

Signal - Transduction Systems

Many devicesfor detecting cancer biomarkers include a biorecognition element within a biosensor system. There are many different ways that a detection system can be configured to work properly. A team of international researchers led by Thevenot (2001) explained that in a system of this nature, the biorecognition molecules interact with a target, which is then converted into a measurable signal by the transducer (Thevenot, Toth, Durst, & Wilson, 2001). Essentially these biorecognition elements, usually an enzyme or antibody, are immobilized on a transducer surface and then interact with a target, the biomarker, to produce a signal that can be interpreted. There are a variety of changes that can be detected, which show the presence of the biomarker. A group of researchers clarify Thevenot's statement, explaining that

> ...the BRE [biorecognition element] often employs antibody, enzyme, short DNA strand or aptamer against specific cancer biomarker in close association to a physical transducer (electrochemical, optical and piezoelectric) which amplifies the signal response manifold after which the data is digitized to give results in form of display readout. (Ranjan et al., 2017)

One such sensor was created using an immobilized peptide, which then interacts with hydrogen peroxide (H_2O_2), a biomarker for breast cancer. This sensor was able to detect much smaller amounts of hydrogen peroxide than sensors that have been engineered previously, with a detection limit of .03 μ□ (Zhao, Yan, Zhu, Li, & Li, 2012). This means that the sensor could detect the presence of the biomarker even when it was only present with a concentration of .03 μ□. A sensor with this degree of accuracy is very important since extremely small concentrations can be detected, allowing for much earlier detection of cancer. While Ranjan Esimbekova and

Kratasyuk acknowledge the potential for BREs, they state that they are unable to last for long periods of time, and are not quick nor easy to assemble (Ranjan et al., 2017). While these are obvious flaws in this form of detection, these signal transduction systems can utilize a variety of compounds or materials for BREs, which makes them especially versatile.

Quantum Dots

Another way to detect cancer biomarkers is through the use of quantum dots. Quantum dots are nanoparticles that manipulate electrons while being resistant to photobleaching[1]. In addition, they are easy to excite but only emit in small ranges, making them accurate and sensitive (Wagner, Li, Li, Li, & Le, 2010). When a quantum dot is excited, internal electrons transform to higher levels. When they go back to lower levels, a photon is emitted, which causes a glow (Wang, Peng, Chen, & Li, 2015). Many scientists believe in the potential of quantum dots. A team of researchers led by Hossain (2017) argue for the great potential of these quantum dots because of the many unique characteristics that they posses, including optical and electrical characteristics (Hossain et al., 2017). Zhou, Liu, and Zhang also cite the optical and electrical properties that make quantum dots a topic of interest along with their stability and size control **(**Zhou, Lui, & Zhang, 2015). While most scientists do agree about the potential for quantum dots, several have health concerns. A team of researchers at the University of Alberta believe that despite the potential that quantum dots offer, they pose too great of a health hazard due to their toxic effects (Wagner et al., 2010). Unless quantum dots can be redesigned to be less toxic they are not a plausible option for cancer detection. A group of doctors in China share these fears about the toxicity of quantum dots. They have many concerns including toxicity, poor biocompatibility, and the lack of accurate analytic systems (Wang et al., 2015). Quantum dots

[1] Loss of colour by a pigment (such as chlorophyll or rhodopsin) when illuminated.

biggest advantage is that they are easily excited, which means that the sensor will react to the biomarker even in extremely small amounts. However, the concerns regarding toxicity make this type of sensor implausible. A device that tests for the presence of cancer should not pose additional health risks to the user.

Capillary Array Electrophoresis and Raman Signals

Another possibility for early cancer detection is the use of capillary array electrophoresis. DNA methylation is an indicator of cancerous cells. The use of capillary array electrophoresis as a way to detect DNA methylation is an important topic in cancer research (Wang et al., 2011). One method is surface enhanced Raman spectroscopy (SERS). A study performed by Wang's team (2011) was able to effectively detect mucin protein, a pancreatic cancer biomarker, using SERS technology when other detection techniques failed (Wang et al., 2011). Hu and Zhang were able to design a SERS chip that can detect methylated DNA in very small amounts, even if only 1% of the DNA is methylated (Hu & Zhang, 2012). They believe that this provides endless possibilities for the future and this can be expanded (Hu & Zhang, 2012). However, Ranjan et al. disagrees that this is effective for the detection of cancer since it takes too long and can affect the sample. In addition, interference can make it difficult to identify the signals (Ranjan et al., 2017). A team of researchers from Bangladesh and Australia led by Hossain (2017) believe that there are many challenges for this type of sensor, including building a device that functions without human assistance and ensuring accuracy. While they have doubts, they do believe that more research needs to be done (Hossain et al., 2017). DNA methylation is one of the most well known markers of cancer, since it is a direct effect of the genetic mutations. However, DNA methylation also occurs in cases other than cancer. Basing a cancer biosensor off of the levels of DNA methylation can be problematic because it could result in false positives. While this does

have the potential to be very effective and detect cancer earlier than most of the other sensors discussed, at its current stage, this type of sensor is not feasible.

Carbon Nanotubes and Graphene

Many researchers believe that carbon nanotubes (CNTs) coupled with graphene have the greatest potential for biomarker recognition. These are the most common materials used in antibiotic detecting biosensors (Lan, Yao, Ping, & Ying, 2017). These materials are so interesting and promising because of the astounding properties that they possess. Kumar and Rao (2017) discuss these interesting properties in their paper. They state that CNTs can behave as semiconductors or metals depending on the situation;, they also have quasi-one dimensional structures, high chemical stability, are strong, and have a large surface to volume ratio (Kumar & Rao, 2017). Their strength and large surface area make them attractive candidates for sensors. A different researcher, Zhu, agrees by saying the special features of CNTs, namely "...their nano dimensions and graphitic surface chemistry, make them extremely attractive for new types of electrochemical, electric, and optical biosensors" (Zhu, 2017). Current CNT research is investigating the electrochemical detection of compounds such as glucose, immunoglobulin and a prostate antigen, a cancer biomarker (Kumar & Rao, 2017). This shows the versatility that CNTs can provide, since they are able to detect a wide variety of molecules. One sensor has been created by a group of Indian researchers that can detect lung cancer within an accuracy range of 5 fg mL^{-1} to 50 ng mL^{-1} (Singh, Choudhary, Kaur, Singh, & Arora, 2016). Zhu believes that CNTs have potential, however, he acknowledges that their largest problem is the high surface energy of CNTs, which makes it more difficult to handle CNTs in a controlled way (Zhu, 2017).

Piezoelectric Sensors

On the other hand, Kumar and Rao (2017) note that nano-transducers make the recognition process more seamless. Instead of separate transducers and bioreceptors, a nano-transducer is able to integrate both of these properties into one processing system. These sensors also have high sensitivity and quick response times (Kumar & Rao, 2017). While this seems like a siginificant difference, this PZ sensor is still very effective, but their uncontrollable nature needs to be addressed if they are going to become a feasible option for cancer detection. A piezoelectric (PZ) sensor interprets small changes in the mass, frequency or other measurable properties of the biorecognition element, often through the binding of molecules to antibodies. Most piezoelectric sensors utilize the signal transduction system explained above. A group of Chinese researchers created a PZ sensor in which an antibody is immobilized on the sensor and then interacts with molecules in the body. When binding occurs, the frequency changes depending on the mass of the antibody(Yang, Huang, Sun, & Xu, 2016). This frequency change points to the presence of the specific molecule being tested for. In a study conducted by these same researchers, a PZ sensor was created to detect cervical cancer; it had a fairly quick analysis time and was able to effectively detect the biomarker in ranges of 50 to 1200 ng mL^{-1} (Yang et al., 2016). Several different groups of researchers believe that this type of sensor is a good option for cancer detection and have created sensors that utilize piezoelectric crystals. A group of Chinese researchers created a sensor that aids in the detection of ovarian cancer. Interaction of the cancer antigen with the cancer cells created a mass change which led to a change in frequency from 1080 Hz to 282 Hz (Chen, Huang, Chen, & Shi, 2013). This change in frequency indicates that a cancer biomarker is present. Both groups of researchers were able to demonstrate the potential for PZ biosensors through their respective studies. Fracchiolla, Artuso, and

Cortelezzi believe that biosensors based on the recognition of antigens and antibodies have many advantages compared to other methods, including cheaper and faster production in addition to being more flexible (Fracchiolla, Artuso, & Cortelezzi, 2013). The CNTs and graphene sensors discussed are less effective than the PZ sensors. A PZ sensor is able to detect the marker at 100 million times lower concentrations. Piezoelectric sensors are dependent on a change in the sensor that can then communicate the presence of the biomarker. PZ sensors are stable and are able to detect minute concentrations of the biomarker, which makes them a reliable option for effective cancer detection.

Conclusion

Many different biosensors have been created and tested for cancer detection. Since there are many different forms of cancer and each form is going to have a different biomarker, versatility is the most important aspect of a biosensor. While all of the sensors discussed are effective in detecting cancer biomarkers, I believe that versatility and safety are the most important criterion for a sensor. For that reason, I propose that a piezoelectric sensor is the best option. A sensor of this type is cheap and easy to produce while also being able to detect a biomarker in very small concentrations. In addition, it is an application of signal transduction systems, making it very versatile, since a variety of compounds or molecules can be utilized as the biorecognition elements. Sensors of this type are safe since most utilize biological compounds or molecules as the biorecognition element. While sensors of this type are in existence, more research needs to be done to create more PZ sensors for other types of cancer.

References

Altintas, Z., Uludag, Y., Gurbuz, Y., & Tothill, I. E. (2011). Surface plasmon resonance based immunosensor for the detection of the cancer biomarker carcinoembryonic antigen. *Talanta,* 86, 377-383. http://doi.org.libproxy.mst.edu/10.1016/j.talanta.2011.09.031

Chen, Y., Huang, X. H., Chen, H., & Shi, H. S. (2013). A novel immobilization method for piezoelectric immunosensor with high sensitivity and good stability. *Proceedings of the 2013 Symposium on Piezoelectricity, Acoustic Waves and Device Applications, SPAWDA 2013.* Doi: 10.1109/SPAWDA.2013.6841138

Fracchiolla, N. S., Artuso, S., & Cortelezzi, A. (2013). Biosensors in clinical practice: focus on oncohematology. *Sensors,* 13(5), 6423-6447. doi: 10.3390/s130506423

Grieshaber, D., MacKenzie, R., Voros, J., & Reimhult, E. (2008). Electrochemical biosensors-sensor principles and architectures. *Sensors,* 8(3), 1400-1458. doi:10.3390/s8031400

Hossain, T., Mahmudunnabai, G., Masud, M. K., Islam, M. N., Ooi, L., Konstantinov, K., Hossain, M. S. A., Martinac, B., & Alici, G. (2017). Electrochemical biosensing strategies for DNA methylation analysis. *Biosensors and Bioelectronics,* 94, 63-73. http://doi.org.libproxy.mst.edu/10.1016/j.bios.2017.02.026

Hu, J., Zhang, C. (2012). Single base extension reaction-based surface enhanced Raman spectroscopy for DNA methylation assay. *Biosensors and Bioelectronics,* 31(1), 451-457. http://doi.org.libproxy.mst.edu/10.1016/j.bios.2011.11.014

Jayanthi, V.S.P.K., Das, A. B., & Saxena, U. (2017). Recent advances in biosensor development for the detection of cancer biomarkers. *Biosensors and Bioelectronics.* 91, 15-23. http://doi.org.libproxy.mst.edu/10.1016/j.bios.2016.12.014

Kumar, D.R., S., & Rao, P. V. (2017). A comprehensive assessment on nano biosensor to detect

cancer cells. *Microsystem technologies,* 23(4), 821-827. doi: 10.1007/s00542-016-3173-z

Lan, L., Yao, Y., Ping, J., & Ying, Y. (2017). Recent advances in nanomaterial based biosensors for antibiotics detection. *Biosensors and Bioelectronics,* 91, 504-514. http://doi.org.libproxy.mst.edu/10.1016/j.bios.2017.01.007

Ranjan, R., Esimbekova, E. N., & Kratasyuk, V. A. (2017). Rapid biosensing tools for cancer biomarkers. *Biosensors and Bioelectronics,* 87, 918-930. http://doi.org.libproxy.mst.edu/10.1016/j.bios.2016.09.061

Singh, A., Choudhary, M., Kaur, S., Singh, S.P., & Arora, K. (2016). Molecular Functionalization of Carbon Nanomaterials for Immuno-diagnosis of Cancer. *Materials today proceedings,* 3(2), 157-161. doi: 10.1016/j.matpr.2016.01.050

Thevenot, D. R., Toth, K., Durst, R. A., & Wilson, G. S. (2001). Electrochemical biosensors: recommended definitions and classification. *Biosensors and Bioelectronics,* 16, 121-131. http://doi.org.libproxy.mst.edu/10.1016/S0956-5663(01)00115-4

Wagner, M. K., Li, F., Li, J., Li, X. F., & Le, X. C. (2010). Use of quantum dots in the development of assays for cancer biomarkers. *Analytical and bioanalytical chemistry,* 397(8), 3213-3224. doi: 10.1007/s00216-010-3847-9

Wang, G., Lipert, R. J., Jain, M., Kaur, S., Chakraboty, S., Torres, M., Batra, S. K., Brand, R. E., & Porter, M. D. (2011). Detection of the potential pancreatic cancer marker MUC4 in serum using surface-enhanced raman scattering. *Analytic chemistry,* 83(7), 2554-2561. doi: 10.1021/ac102829b

Wang, L. W., Peng, C. W., Chen, C., & Li, Y. (2015). Quantum dots-based tissue and in vivo imaging in breast cancer researches: current status and future perspectives. *Breast cancer research and treatment,* 151(1), 7-17. doi: 10.1007/s10549-015-3363-x

Yang, L., Huang, X., Sun, L., & Xu, L. (2016). A piezoelectric immunosensor for the rapid detection of $p16^{INK4a}$ expression in liquid-based cervical cytology specimens. *Sensors and Actuators B,* 224, 863-867. http://doi.org.libproxy.mst.edu/10.1016/j.snb.2015.11.002

Zhao, J., Yan, Y., Zhu, L., Li, X., & Li, G. (2012). An amperometric biosensor for the detection of hydrogen peroxide released from human breast cancer cells. *Biosensors and Bioelectronics*, 41, 815-819. http://doi.org.libproxy.mst.edu/10.1016/j.bios.2012.10.019

Zhou, H., Lui, J., & Zhang, S. (2015). Quantum dot-based photoeletric conversion for biosensing applications. *TrAC trends in analytic chemistry*, 67, 56-73. http://doi.org/10.1016/j.trac.2014.12.007

Zhu, Z. (2017). An overview of carbon nantubes and graphene for biosensing applications. *Nano micro letters*, 9, 25. doi:10.1007/s40820-017-0128-6

Grant VonderHaar
Chemical Engineer at Missouri University of Science and Technology

EFFICIENCY OF SOLAR CELL DESIGN AND MATERIALS

Abstract

Fossil fuels have dominated the energy world ever since their introduction in the Industrial Revolution, and the world has grown more dependent on them in the Postmodern Era. However, the limited amount of fossil fuels in the world poses a problem for future generations; solar energy is the solution to this potential future energy crisis. The purpose of this study is to provide a comprehensive review of solar panel materials so that solar panels can be refined until they can replace fossil fuels entirely. In this study, I have researched designs for solar cells and determined the most efficient design for commercial and residential use while finding the most cost-effective materials to produce these cells. I delved into previous research studies on solar cell production and efficiency and current research updates on the materials involved in high-efficiency cells, and I gathered sources that discussed the different materials involved in solar cell manufacturing. This study has allowed me to determine that gallium arsenide compounds combined with crystalline silicon cells are the most effective at absorbing and storing solar energy. I have also determined that factors such as multi-junction cells and the concentration of light increase the cell's efficiency. These advances in solar research will allow for more efficient cells to find their way into neighborhoods everywhere in only a matter of time.

Efficiency of Solar Cell Design and Materials

Since the Industrial Revolution, fossil fuels have made their mark on the world in both positive and negative ways. Coal has dominated the energy equation, producing approximately 33% of the world's energy, and it quickly began to replace the previous primary source of energy: biomass. In the nineteenth century when coal was in seeming abundance, "it very quickly made industrial and economic sense to use coal to supply the rapidly increasing energy demand" (McLamb, 2010). However, with the increasing population and decreasing coal deposits, it became apparent that another form of energy would have to eventually take coal's place as the world's primary source of energy. Luckily, research into using the sun's power to generate electricity began, marking the introduction of solar power as a clean, alternative type of energy. Unfortunately, coal is being consumed faster than ever before, yet it still remains the world's primary energy source. Therefore, a replacement for this fossil fuel has become even more necessary, and solar energy offers a solution. In the last decade, research into solar energy has allowed for the development of solar cells that can reach an average of near 20% energy conversion efficiency when sold commercially and at least double that while being tested in laboratories. By using typical crystalline silicon solar cells in combination with gallium arsenide compounds, solar cells have the potential to reach upwards of 50% conversion efficiency. By also utilizing design techniques, such as a light concentrator in conjunction with multi-junction cells, cells with theoretical efficiencies of close to 80% are created. By implementing this technology into the commercial production of solar cells, solar energy is a plausible replacement for coal as the world's primary source of energy.

The scope of my research, however, is limited. Since my research was directed to find the highest efficiency solar cells I primarily researched experiments and studies done on the

materials and designs that have consistently increased energy conversion efficiency and electrical output. I did not delve into research on the worst possible solar cell materials, rather, I focused on studying what makes a solar cell more efficient from its base form of a single-junction cell with no external influence to allow more sunlight to enter the system.

Solar Cell Design and Light Concentration

The efficiency of solar cells is partially dependent on their design as a whole, taking into consideration a variety of factors such as the intensity of concentrated sunlight and the stacking of multi-junction cells. In a study conducted by Massachusetts Institute of Technology (MIT), a new system was created that uses sunlight to heat an absorber-emitter device that is placed over the photovoltaic cells (PV). The absorber "includes an array of multi-walled carbon nanotubes that efficiently absorbs the light's energy and turns it into heat," while the emitter consists of "a bonded layer of silicon/silicon dioxide photonic crystals...engineered to convert the heat back into light that can then be captured by the PV cells" (Giges, 2014). This system also includes a light concentrator, consolidating the light introduced into the system so that it can be absorbed and transformed into solar energy with less wasted light. This concentration of light that MIT implemented in their design allows for a smaller solar cell to have the same effectiveness as larger ones that rely solely on having small acceptance angles and reflection of light in nature to produce energy.

In order to measure the efficiency and effectiveness of solar cells, one must consider the incident flux of the cell, its area, and its maximum potential power output. Maximum efficiency is measured as the maximum power output divided by the product of the incident flux and the area of the cell (*Measuring PV Efficiency*). Therefore, concentrating the light gives a solar cell

the same incident flux across a smaller area, increasing the maximum potential efficiency of the cell.

However, concentrating light is not the only way to increase efficiency inside of a solar cell. Engineers at the University of New South Wales developed a particular solar cell configuration that achieves a similar maximum efficiency without the use of concentrators. Led by Dr. Mark Keevers, the team utilized a multi-junction system embedded in a prism that splits "the incoming rays into four bands, using a hybrid four-junction receiver to squeeze even more electricity from each beam of sunlight" (University of New South Wales, 2016). This allows for each individual receiver to specialize in absorbing a certain band of light, giving the cell a higher sunlight to electricity conversion, therefore letting the cell produce more energy than a typical single-junction cell.

Since the multi-junction cell does not use concentrators to consolidate the sunlight entering the prism, however, this approach alone does not reach the total possible maximum energy output that solar cells will one day reach. Dr. Stephen Bremner and Professor Martin Green address this issue through their experiments with solar cells, claiming that "Increasing sunlight concentration increases efficiency limits...A maximum of 86.0% is possible when the lowermost cell bandgap approaches zero" (Green and Bremner, 2016). Their experimental results prove that by combining these two approaches to achieving maximum solar cell efficiency, scientists may be able to develop Creating a multi-junction solar cell supported with solar concentrators is the next step insolar cell technology, and it is ultimately taking the next step towards a cleaner world and a more effective replacement for fossil fuels.

Materials of Solar Cell Production

The other major contributing factor to the efficiency of solar cells and the cost-effectiveness of their designs is the materials involved in their creation and development. According to the Department of Energy, "Crystalline silicon PV cells are the most common solar cells used in commercially available solar panels, representing more than 85% of world PV cell market sales in 2011. Crystalline silicon PV cells have laboratory energy conversion efficiencies over 25% for single-crystal cells and over 20% for multicrystalline cells" (Department of Energy). In terms of efficiency, crystalline silicon cells neither excel nor fail in their energy conversion effectiveness, but there are more factors to consider when it comes to choosing which materials to use in a solar cell, especially when marketing to consumers outside of the laboratory.

Crystalline silicon is the second most abundant resource in the Earth's crust, and it can be divided into two separate purities: monocrystalline silicon and polycrystalline silicon. According to Mathias Maehlum, an energy and environmental engineer, the purer silicon is, "the more perfectly aligned the silicon molecules are, [and] the better the solar cell will be at converting solar energy into electricity" (Maehlum, 2015). Monocrystalline silicon typically has a 5% higher efficiency than that of polycrystalline silicon, but with it comes an increase in price. Because monocrystalline has a more precisely aligned molecular structure, it costs more to produce than polycrystalline silicon, but it is a more viable replacement to fossil fuels.

However, studies conducted by Dr. Stephen Bremner and Professor Martin Green have shown that silicon is not the most efficient cell core. They have deduced that there is a positive correlation between energy conversion efficiency and external radiative efficiency (ERE). The "fraction of net recombination when the cell is open-circuited that is radiative," meaning that it does not waste as much energy when the circuit is opened (Green and Bremner, 2016). Through

their studies, gallium arsenide has a higher ERE than crystallized silicon and therefore has a higher energy conversion efficiency.

This is not the first time that gallium arsenide has been included in solar cell testing either. A team of researchers from MIT, and the Masdar Institute of Science and Technology led by Professors Ammar Nayfeh and Eugene Fitzgerald, have been experimenting with gallium arsenide phosphide coatings for silicon cells. They have found that its easy production, as well as the increase in efficiency that it brings, makes it a feasible addition to the future of solar technology. Professor Fitzgerald explains:"adding that one layer of the gallium arsenide phosphide can really boost efficiency of the solar cell but because of the unique ability to etch away at the silicon germanium and reuse it, the cost is kept low because you can amortize that silicon germanium cost over the course of manufacturing many cells" (MIT News Office, 2016). This coating layer acts as a step cell; the light encounters the gallium arsenide phosphate before it reaches the silicon germanium. Because the two materials bonded together, replacing and reusing the silicon germanium greatly reduces production costs while maintaining theoretical efficiencies of upwards of 50%. Introducing gallium arsenide to the commercial solar cell world will increase cell efficiencies across the world, allowing for a cheap alternative to fossil fuels, helping to make the world cleaner and save the environment.

Discussion

Research into the plausibility of solar cells as a replacement for fossil fuels has made decent progress over the last few years, and it is possible to see a future where solar energy becomes the world's primary energy source. Through the recent work of researchers, I have discovered that crystallized silicon is the most cost effective and most plausible base for the cores of solar cells, but by introducing a multi-junction cell with the inclusion of gallium arsenide materials, solar

cells will experience an increase in their energy conversion efficiencies. This will produce more energy with little financial drawback. If a concentration of light is also introduced to these cells, efficiency can increase even further and produce more power than they could without. However, even with these additions to current solar cells, maximum theoretical efficiency only reaches close to 80%. Therefore, further research into material interactions with solar activity as well as solar cell design should be initiated. I believe that science can bring solar cells to an even higher efficiency, and with a higher conversion efficiency, the fewer fossil fuels will be consumed. Further research will allow for a cleaner future and a cleaner world, allowing solar energy to replace fossil fuels.

References

Department of Energy, U. (n.d.). *Crystalline Silicon Photovoltaics Research*. Retrieved from https://www.energy.gov/eere/sunshot/crystalline-silicon-photovoltaics-research

Giges, N. S. (2014, April). *Making Solar Panels More Efficient*. Retrieved from https://www.asme.org/engineering-topics/articles/renewable-energy/making-solar-panels-more-efficient

Green, M. A., & Bremner, S. P. (2016, December 20). *Energy conversion approaches and materials for high-efficiency photovoltaics*. Retrieved from http://um9mh3ku7s.search.serialssolutions.com.libproxy.mst.edu/?url_ver=Z39.88-2003&ctx_ver=Z39.88-2003&ctx_enc=info:ofi/enc:UTF-8&rft_id=info:doi/10.1038%2fnmat4676&rft_val_fmt=info:ofi/fmt:kev:mtx:journal&rft.genre=article&rft.aulast=Green&rft.aufirst=M.A.&rft.issn=14761122&rft.volume=16&rft.issue=1&rft.date=2016-12-20&rft.spage=23&rft.epage=34&rft.pages=23-34&rft.artnum=&rft.title=Nature+Materials&rft.atitle=Energy+conversion+approaches+and+materials+for+high-efficiency+photovoltaics&rfr_id=info:sid/Elsevier:Scopus

Maehlum, M. A. (2015, May 18). *Which Solar Panel Type is Best? Mono-, Polycrystalline or Thin Film?* Retrieved from http://energyinformative.org/best-solar-panel-monocrystalline-polycrystalline-thin-film/

McLamb, E. (2010, September 15). *The Secret World of Energy*. Retrieved from http://www.ecology.com/2010/09/15/secret-world-energy/

Measuring PV Efficiency [PDF]. (n.d.).Retrieved from http://www.pvpower.com/assets/Measuring-PV-Efficiency-Solar-Panels.pdf

MIT News Office (2016, August 29). *New solar cell is more efficient, costs less than its counterparts.* Retrieved from http://news.mit.edu/2016/new-solar-cell-more-efficient-costs-less-its-counterparts-0829

University of New South Wales. (2016, May 17). *Milestone in Solar Cell Efficiency Achieved*. Retrieved from https://www.sciencedaily.com/releases/2016/05/160517121811.htm

Adam Bateman
Computer Science at Missouri University of Science and Technology
DEFINING CONSCIOUSNESS

Abstract

A researcher trying to develop a conscious artificial intelligence or examine consciousness in plants would be completely unable to do so without first obtaining a clear, concise, and global definition. This idea is what originally inspired my research. The main method of research to be used will be to thoroughly examine scholarly articles pertaining to consciousness and different theories of the mind. After gathering data and different ideas, I will create a definition that is plausible, and is optimized in terms of being useful to researchers. Currently, the issue is that there are an incredible amount of mental features that certain organisms have that may contribute to making them conscious. However, these features, such as emotion, thought, and willpower, have yet to be accumulated into a definition. Consciousness should, at the very least, involve a being's awareness, ability to think, and ability to feel. The main reason this research is important is due to the exponential growth rate of technology. Heading into the direction of sentient machines, we must know whether what we create is conscious or not, and how conscious it may be, in order to determine whether it may be dangerous or not.

Defining Consciousness

There has been an incredible amount of research done over thought processes and awareness over the last 10 years. Almost all of it makes some sort of conclusion as to how people think and feel, and why they think and feel those ways. However, when it comes to consciousness, most of the research that has been conducted is just a small part of the much bigger idea. Without obtaining a definition that benefits research, mankind heads towards a dangerous area of uncertainty in technology. Imagine a futuristic world where members of the Robot's Rights Activists Club (RRAC) advocate for their rights, and issues take 20 years to settle because the robots cannot be defined as conscious or not. Aside from saving time, this research would also improve decisions regarding ethical ramifications of mistreatment of organisms whose current consciousness levels cannot be determined. Consciousness needs to be defined, it must be useful, accurate, and measurable, and it must involve, at the very least, a being's awareness, ability to think, and ability to feel.

Awareness

The idea of consciousness is often closely related to awareness. While the definition of awareness is certainly a part of it, the concept of consciousness branches much further beyond simply being aware of one's existence and surroundings. "Most scientists accept that attention can occur in the absence of awareness. But evidence for the opposite idea, that conscious awareness can exist without attention, has been less clear" (Sanders). The idea here is that for most of mankind's history, awareness and attention have gone hand in hand in regard to their definitions and their usage. It is only recently that researchers have had to differentiate the two. The concept of being able to focus on a particular object and being aware of the existence of an object are two separate areas. It is theorized that one can focus on an object, or an idea, without

really knowing what the object is, or if it even exists. Alternatively, attention without awareness is a feature of everyday life. The differentiation that Sanders makes between "awareness" and "conscious awareness" is the fact that conscious awareness most likely cannot exist without the attention of the person. It can then be theorized that one's ability to focus may have an impact on determining whether one can be defined as conscious. Similarly, one's ability to focus on themselves may have a significant impact on one's level of consciousness. "Self-consciousness comes in varying degrees of self-awareness. Sometimes it merely involves a *non-conscious thought awareness* of one's own mental states, and, sometimes, it comes in the form of *conscious meta-psychological thoughts*"(Gennaro 17).

Gennaro is acknowledging the idea that one's consciousness can be measured based on their knowledge of their own existence. These levels may range from a very basic knowledge of one's emotions, to the ability to conceptualize thoughts that may not be empirically verifiable. Whether this spectrum of self awareness represents one's level of consciousness, however, is still unclear. If not, it would be very easy to define a robot as fully conscious if it can express some sort of emotional response to a stimulus, or a plant as fully conscious if it can be proved that it feels pain. Applying the self-awareness spectrum would increase motivation to reach what might eventually defined as 100% consciousness in man-made machines. Attention and awareness are very important parts of consciousness. The very core of one being conscious is for one to be aware of themselves and their surroundings. In order for one to be aware of these things, one must also have even the slightest ability to pay attention and maintain focus, in order to firmly grasp ideas and truly have self-awareness.

Thought

In order for an organism to be described as conscious, it must be able to know, and to think. Thinking, however, is a very difficult area, as it is impossible to determine whether a plant, a machine, or other living organisms are capable of thought. "We are still unable to explain why human beings think a precise way at a certain moment; however, thought is known by certain neurological mechanisms"(Turenne 15). Thinking is an incredibly complex human capability. Humans know the reasons that they have to think, whether it's for reasoning, recollection, debate, etc. There is, however, a theoretically infinite number of factors that affect why people think *exactly* the way that they do. These factors can range from something as large as a recent traumatic event, to something as small as a slight gust of wind impacting the way a person's neurons fire. This brings up the question of whether or not succumbing to these environmental factors is a necessary part of thought, and therefore, consciousness. That would then affect the implementation of random events provoking unrelated thoughts in the creation of an artificial consciousness.

Thoughts are not the only human feature that can be very slightly altered by a theoretically infinite numbers of factors. The way people feel is also incredibly flexible, and the slightest change in temperature or even shifts in things as small as sand can cause the smallest changes in how one feels. "When we are in conscious states we are often not *consciously* thinking about our own [mental] states, but we are nonetheless thinking of having 'thought awareness of' them". (Gennaro 19) This extract is tying one's ability to think with one's ability to feel emotion. Humans are always aware that they are constantly in some form of mental state, however, are almost never directly thinking about it. There is, however, something inside each person's head that connects their current mental state with the way that person would respond to

stimuli. This demonstrates a sort of “ambient awareness” of one’s specific mood. This ambient awareness certainly has a place within the definition of consciousness, in the sense that only conscious beings can contain thoughts without directly thinking about them. For one to be defined as conscious, one must have the ability to think and to feel. The depth at which both external and internal stimuli affect one’s thoughts and emotions can be connected to the what can be defined as a person’s consciousness level. In order for these slight changes in mental processes to be proven, the person must also demonstrate an ambient awareness of emotions that they are not directly thinking about.

Measurability

In order for the understanding of consciousness to be most valuable to researchers, it must first be determined whether consciousness exists in binary states (i.e. something is either conscious or it isn’t), or if there are grey areas in which organisms can achieve certain levels of consciousness. This would allow researchers to more accurately gather data on objects and then use that data to gain a better understanding. “Input to each eye’s retina holds steady, while perception—whether an image pops into awareness—flips back and forth. Scientists can measure brain activity to track this perceptual switch”. (Sanders) In this experiment, it was proven that awareness of an object either exists in a being or does not exist, and the idea of being “somewhat aware” of something is impossible. Therefore, awareness can be thought of as the bare minimum amount of knowledge that one might have about something, after knowing of its existence. The measurability of consciousness then becomes slightly more complex, under the idea that awareness is a binary state of mind. It is, however, still possible to use one’s capability level of thinking, as well as the strength of their ambient self and environmental awareness in order to measure the degree at which one is conscious. These, however, are not the only determining

factors of one being conscious. It has been speculated that one's willpower may also play an important role in determining whether one can be defined as conscious or not. "The strength of our will is the measure of the manipulation of power we enjoy over our selves [sic]; so it is a measure of this *internalized authoritarianism*" (Paglieri 161). Here, Paglieri is relating consciousness to willpower, and willpower to a person's control over their own state of mind and thoughts. The idea of willpower plays a crucial role in defining consciousness, as it brings up a very interesting idea. In order to be conscious, one must also have to want. The ability for one to have internal goals to set towards is very relevant, as willpower is an ambient emotion that can be measured in terms of intensity. It can be safely assumed that if one is imbued with the willpower to control their own life, that being must have some degree of consciousness. Consciousness can, and should be measured, but not based on awareness. Rather, it should be determined by the existence of awareness and ambient awareness, as well as the strength of that person's willpower and their ability to react to infinitely small stimuli.

Discussion

Every one of the features of mentality that has been discussed is a key feature in what makes humans, human. Looking at a person who lacks thought, emotion, or willpower, they are clearly in a state of unconsciousness. Applying these characteristics to a machine would make for a very accurate representation of a conscious human. Researchers could also look for these characteristics in other things they think may be conscious, such as plants. Therefore, an object can be defined with consciousness under following five characteristics:

1. The object must be aware of its own existence, as well of the existence of things that surround it.

2. The object must be able to feel emotion, as well as accurately respond to stimuli while feeling emotion.
3. The object must be able to think.
4. The object must have the ability to “want”. The degree at which the object can feel desire shall correspond with the object’s level of consciousness.
5. The emotions of the object must be a result of external and internal stimuli. The degree at which the object can react to smaller, less relevant external stimuli shall correspond with the object’s level of consciousness.

References

Baars, B. J. (2015). Consciousness. Retrieved from http://www.scholarpedia.org/article/Consciousness

Gennaro, R. J. (1996). Consciousness and Self-Consciousness. Philadelphia: John Benjamins Publishing Company. Retrieved from https://ebookcentral-proquest-com.libproxy.mst.edu/lib/umr-ebooks/detail.action?docID=622349

Paglieri, F. (2012). Consciousness in Interaction. Amsterdam: John Benjamins Publishing Company. Retrieved from https://ebookcentral-proquest-com.libproxy.mst.edu/lib/umr-ebooks/detail.action?docID=979716

Sanders, L. (2012, February 16). Consciousness emerges: Somewhere along a tangled path, sights, sounds and insights pop into awareness. Retrieved from http://onlinelibrary.wiley.com/doi/10.1002/scin.5591810419/abstract

Sejnowski, T. J. (2015). Consciousness. Retrieved from http://www.mitpressjournals.org.libproxy.mst.edu/doi/pdf/10.1162/DAED_a_00321

Singh, G. (2014, April 9). Consciousness. Retrieved from http://www.msmonographs.org/article.asp?issn=0973-1229;year=2014;volume=12;issue=1;spage=161;epage=162;aulast=Singh

Tononi, G. (2012). Integrated Information Theory of Consciousness: An Updated Account. Retrieved from http://www.architalbiol.org/aib/article/viewFile/15056/23165867

Turenne, N. (2013). Knowledge Needs and Information Extraction. Hoboken: John Wiley &

Sons, Incorporated. Retrieved from https://ebookcentral-proquest-com.libproxy.mst.edu/lib/umr-ebooks/detail.action?docID=1124004

Michael Todd Herman Jr.
Aerospace Engineering at Missouri University of Science and Technology

ASSESSMENT ON FOOD AND WATER COLLECTION ON MARS vs. HUMAN SURVIVAL

Abstract

This research focuses on the possibility of farming and water collection on Mars to determine if enough food and water can be gathered to support sustained human life. The inspiration for this comes from the plans to put a human on Mars and create a sustained colony, such as Mars One. This colony can become the basis for a multi-planetary civilization that will substantially reduce future overcrowding problems (the population in 2050 is projected to be 11 billion and is expected to continue to grow exponentially) and promote additional research on space travel that can aid in the reduction of the space debris that will eventually cover the planet if its current growth rate is left untouched. The problems that arise in building a colony on another planet are food and water collection. On Mars specifically, the soil is dry compared to that of Earth and there are no nitrogen fixing bacteria that are necessary for plant growth, making it very hostile to crops. Additionally, liquid water is not existent the planet's surface, and the planet's existing water is difficult to access and is highly contaminated In order to properly assess sustained human survival on Mars, it must first be determined whether farming and the collection of pure water on Mars is possible under the given conditions. If food and pure water can be obtained on Mars, it is then necessary to determine if enough food and water can be acquired to support sustained human life. The research conducted for this paper consisted heavily on lab reports and write ups on studies about water collection methods, farming methods, water purification, and Martian soil composition with a few articles from National Aeronautics and Space Administration (NASA) on Martian ice and farming off of Earth.

Assessment on Food and Water Collection on Mars vs Human Survival

Ever since Aristotle and the ancient Greeks, humans have been fascinated by outer space and what lies within. They have worshiped suns and moons as gods and goddesses, studied planets and galaxies with curiosity and wonder, and have even set foot on another world. Now, the quest to conquer space continues as plans to put a man on Mars permanently begin to unfold. The urgency to colonize Mars stems greatly from the fear of becoming trapped on an Earth that's coated with a thick layer of space debris that increases its numbers with each rocket launch, eventually trapping humankind on an Earth that is rapidly warming and running out of space. If a Martian colony can be established and become sustainable, it will greatly aid in the issues of overcrowding while the promotion of space travel will bring spacecraft to the forefront of technological development and induce more research that will help reduce the number of space debris orbiting the Earth. The most basic issues of this Martian colonization mission is whether man can obtain the most basic necessities of survival, food and water, in the barren Martian environment. In order to properly assess sustained human survival on Mars, it must first be determined whether farming and the collection of pure water on Mars is possible. If this can indeed be done, it is then necessary to determine if enough food and water can be acquired to support human life.

There are limits to the project's scope. The most substantial limitation presented in this paper is that no human has ever been to Mars to test the methods of farming and water collection. These methods have only been tested under Martian like conditions (temperature, light intensity, and atmospheric pressure) and have yet to be exposed to the full score of the Martian environment. Furthermore, this paper operates on the pretense that the proper facilities consisting of current technology are provided, such as pressurized living quarters and a

greenhouse. In the current plans to permanently send a person to Mars, these facilities are included (Mars One, 2017) and this paper is solely examining survival in terms of food and water.

The research for this paper consisted largely of keyword searches on Google Scholar and the Missouri S&T library databases. The keywords included hydroponics, Martian water, water purification, hydroponics under Martian conditions, hydroponics yield, Mars drilling, Martian soil composition, water collection Mars, and Mars water composition. Additionally, the Farmer's Almanac online and the Mars One website were used. The searches turned up scholarly essays and experiments on water collection methods, farming methods, Martian soil and water composition, and water purification. The information gathered was then used to determine the possibility of farming and water collection on Mars and then the yield of food and water to assess the potential of human survival.

Farming Methods

There are two prominent ideas on Martian farming methods. The first method is collecting opaline silica on Mars and combining it with Martian topsoil and bacteria brought from Earth inside a greenhouse. Opaline silica deposits are found in volcanic areas on the planet’s surface. When silica from these deposits is combined with the topsoil, it creates a microenvironment similar to bacterial ecosystems found on Earth.This means that the nitrogen fixing bacteria that are vital for the survival of crops can live on Mars and can be used to create a thriving greenhouse ecosystem (Squyres, 2008). Although the notion of combining silica and topsoil seems like an easy and effective way to create a sustainable microenvironment, there are many roadblocks. First, a great amount of energy would have to be consumed to break down the andesitic rocks to harvest silica, which could deplete other important systems, like oxygen

filtration. Next, the most prominent location of volcanic silica deposits is the northern plains. The northern plains present challenges to survival because there is not much water there. If a silica/topsoil farming method is chosen, the base site would undoubtedly be the northern plains, and dehydration would become a more substantial concern than it is elsewhere on the red planet (McLennan, 2003). Lastly, silica is a well known human health hazard and extended contact with crops could result in the uptake of silica through the roots and its spread throughout the entire plant. A silica uptake of even 0.01% would present a significant human health hazard and result in the decimation of all crops (Miloy and Williams, 2002). The silica/topsoil farming method presents too many health hazards and limitations, so it must be ruled out as a potential method of farming on Mars.

The other method of farming is hydroponic farming. Hydroponics is the process of growing plants by adding nutrients to water, instead of using soil (Dyck, 2016). This is how current astronauts grow plants in space and how crops will be grown during their journey to Mars (Dyck, 2016). Under hydroponic conditions, nitrogen fixing bacteria are able to attach to the roots of plants and survive to produce nitrogen to the plant on Earth. According to a study and paper published by O. J. Macintyre, hydroponic conditions in a Martian (low pressure) environment also support nitrogen fixing bacteria, but not as well as it does on Earth. In this study, the bacteria lost 22% of its population in the first few days but maintained constant numbers for the remainder of the study. In other words, as far as bacteria are concerned, hydroponic farming is sustainable on Mars (Macintyre, 2011). Gathering the nutrients such as potassium, nitrogen, calcium, and water that are required for hydroponics is another issue for this method of farming. NASA plant physiologist Dr. Ray Wheeler believes that all the resources necessary for hydroponic farming can be either recycled from those initially used on the journey

to Mars, acquired on the surface of the planet, or made on site, a process known as in-situ resource utilization. A major source of recycled materials would be wastewater and urine collected and processed by the Environmental Control and Life Support System found aboard all spacecraft (Herridge, 2016). Other required nutrients, like iron, can be found in the soil and on the surface of Mars (Herridge, 2016). The briney ice water located in subsurface pockets also contain nutrients that can be harvested, like calcium (Fischer, 2014). Dr. Wheeler conducted a study using hydroponics and in-situ resource utilization on potatoes in 2014 which simulated deep space conditions. The potatoes harvested from the study were on par with those grown in normal Earth conditions in terms of nutrient content, taste, and size. The results of this study indicate that a hydroponic farm system will work with materials found and brought to Mars (Herridge, 2016). Thus, hydroponic farming is a feasible and sustainable way to effectively grow crops during the journey to and on the surface of Mars, making it method of choice to feed humans on Mars.

Water Collection and Purification

Water exists on Mars as both a liquid and a solid. However, it is both impure and located within the planet, meaning that the water's current state is useless. First, it is necessary to focus on the extraction of water from the planet by the two prominent methods. The first of which is to pull water directly out of the soil using a microwave radiation oven developed by a team of engineers from Colorado School of Mines. This device is powered by silicon solar cells on top of the device so that it needs no outside fuel. This microwave oven works by exposing soil placed inside of it to high levels of microwave radiation in order to vaporize ice crystals located within the soil. Once the ice is heated to a temperature greater than 200^{o}C it turns into water vapor. It is then collected in the water transport system where it is condensed into a liquid due to high

pressure inside the chamber. The transport system can then be removed and the liquid water can be collected. This system is capable of producing 200g of water per hour and can operate on a 12 hour on/off cycle under Earth's temperature and atmospheric pressure (Wiens, 2001). It has yet to be tested under Martian conditions due to a lack of funding (Wiens, 2001). This lack of funding leads to the only downside to this device which is that a full prototype has yet to be built and the team has been limited to crude models and parts of a whole prototype, meaning that it is not practically able to collect water. However, the fact that it is theoretically able to collect water means that at some point it could become a way to obtain water on Mars.

While the microwave oven is theoretically an efficient way to collect water from Mars,the University of California at Berkeley has developed a drill bit that has been proven to effectively extract water from the Martian subsurface. The water in the Martian subsurface is located in shallow pockets that contain a briney ice water mixture. The area that contains subsurface water ranges from the polar regions to the midlatitudes of the planet at a depth of approximately 100 meters below the surface (Fischer, 2014), which is shallow enough for a drill to reach. Drilling under Martian temperatures and atmospheric pressures (-62.2^{o}C and .6 kPa) is very different from drilling on Earth. This is because typical methods used on Earth involve cleaning the drill bit with a pre-prepared gas or liquid flow (Zacny, 2004), but pre-compressed air is not readily available on Mars and liquid water is not stable under these conditions. In order to effectively clean the drill bit on Mars, the team created a drill that uses the surrounding air. The drill takes in 1 L of the surrounding air and uses a low power compressor to compress the air inside the machine. This compressed air is then stored in a reservoir also in the drill and is used to provide intermittent blasts to clean the drill bit (Zacny, 2004). When tested in a lab under Martian conditions, the results were "encouraging" (Zacny, 2004). When exposed to California

limestone, the drill ejected the cuttings with “considerable speed...and [they] fell some distance away from the hole in a completely dry condition” and the drill’s penetration rates were twice of the typical measured value on the same rock while using half the power at 100 W (Zacny, 2004). This proves that the compressed surrounding air is effective in cleaning the drill bit while it is in use. When the drill encountered ice, there was no melting and refreezing during the drilling process which demonstrates that the drill can effectively pass through/extract ice under the Martian surface without getting stuck (Zacny, 2004). This study shows, try to avoid using the word “prove” that water collection on Mars is possible using the technology demonstrated above.

In order for any of the water collected on Mars to be usable, it must be purified. The impurities of the water are predominantly perchlorates such as calcium perchlorate [$Ca(ClO_4)_2$] and sodium perchlorate [$NaClO_4$] (Fischer, 2014). The main methods for removing perchlorates on Earth is ion exchange and reverse osmosis (Hernandez, 2015). Ion exchange involves swapping the ions in the water, like perchlorates, with other ions of the same charge. Reverse osmosis uses pressure to push only water molecules through a selectively permeable membrane. Both of these methods will work on Mars (Hernandez, 2015), but ion exchange is the less practical method because it is relatively expensive on a world without easy access to the ions necessary for this method of purification. This means that it is possible to collect and purify the water located on Mars.

Food and Water Collection: Quantification

Since it has now been determined that food and water can be produced on Mars, it is now necessary to determine if enough can be collected to support human survival. In a study on the effects of a soilless environment on fruit quality, water consumption, and mineral composition of plants under greenhouse and hydroponic conditions, it was determined that hydroponic farming

has a higher overall yield than conventional farming (Rouphael, 2004). This study's data showed that hydroponic plants exhibited a higher yield in fruit number and water efficiency than those planted in soil. The hydroponic plants also exhibited a slightly higher uptake in nitrogen (N), Magnesium (Mg), Sodium (Na), Iron (Fe), Copper (Cu), Manganese (Mn), and Zinc (Zn) than those grown in soil. After 73 days of solution recycling, N, Fe, Mn, Potassium, and Phosphorous were all depleted by 26, 92, 25, 16, and 40 percent respectively. In soilless plants, however, Calcium, Mg, Na, Cu, and Zn all increased by 6, 69, 113, 360, and 981 percent respectively (Rouphael, 2004). Finally, the hydroponic plants produced more carbohydrates and sugars than the soil bound ones while maintaining similar levels of protein (Rouphael, 2004). The results show that using hydroponic farming allows growers to improve control of water and nutrients as well as fruit yield and quality. Considering humans need an average of 1500 calories per day to survive and maintain health and the average potato (a crop easy to grow on Mars) contains 110 calories, it would be necessary to eat approximately 13.6 potatoes a day (Farmers Almanac, 2010). Potatoes have ten week harvest cycle meaning 952 potatoes must be grown per person per harvest, although less would be required with the hydroponic method due to the better quality of crops produced. As long as the proper facilities to produce 1500 calories or about 13.6 potatoes per day are provided, greenhouse hydroponics is a viable way to support human life on Mars.

A human needs 64 oz (1814.37 grams) of water per day to survive. There are two viable methods for obtaining water on Mars, but the methods vary in the amount collected per day. Assuming after full development and simulation under Martian conditions, the theoretical microwave oven maintains its extraction rate 200 grams of water per hour from Martian soil, it would extract 2400 grams of water per day (Wiens, 2001). At this rate, a single oven would be enough to support one person and have water left over to use in other tasks. While the

hypothetical oven extraction method produces a consistent amount, pulling water from subsurface pockets is not so. Subsurface water can range from ice sheets the volume of Lake Superior ($3.1965*10^{15}$ gallons or $1.21*10^{16}$ L) (NASA Jet Propulsion Lab, 2016) to pockets the size of a puddle. This inconsistency leads to a lack of specific data on the volume of subsurface pockets. However, considering the Lake Superior sized ice sheet is more than large enough to support human life, the best drill for extraction is not nearly large enough to pull enough water to support a human, even though it is possible to pull water from the subsurface (Zacny, 2004). This means that in order to support human life on Mars, the technology for collecting water must be improved upon as in its current state, it cannot collect enough water to support a human life.

Conclusions and Need for Additional Research

At this moment, the data conclusively demonstrates that humans can not survive on Mars given the proper facilities of today's technology because it is not possible to collect enough water on the planet to support human life. In order to make survival possible, further research must be conducted on the microwave water extractor and drilling technology or other methods must be found/discovered/invented. Both of these methods should be improved upon and made readily available to use on Mars. More funding and time should be devoted to the microwave oven, which can be used as the main source of water collection for daily human consumption where research on increasing the drill's harvesting power would allow for more water to be collected for side tasks and emergency water. The evidence does suggest, however, that human survival on Mars is possible in the future. Considering that greenhouse hydroponic farming can feed humans on Mars and the Mars One plan has been building the proper facilities to host human life on Mars, all that needs to be finished is water collection tools.

References

Daniel, Dyck. (2016, April 8). *Development of Micro-Hydroponic Systems for Space Travel.* Retrieved from http://commons.erau.edu/pr-discovery-day/2016/posters-and-demonstrations-presentations/13/

Farmers Almanac. (2010). *Potatoes.* Retrieved From http://www.almanac.com/plant/potatoes

Fischer, E., Martinez, G., Elliot, H., Renno, N. (2014, July 7). *Experimental Evidence for the Formation of Liquid Saline Water on Mars*. Retrieved from http://onlinelibrary.wiley.com/doi/10.1002/2014GL060302/full

Hernandez, Daniela. (2015, October 2). *What it would take to drink the water on Mars.* Retrieved from http://fusion.net/story/205189/water-mars-future-human-habitats/

Herridge, Linda. (2016, February 17). *NASA Plant Researchers Explore Question of Deep-Space Food Crops*. Retrieved from https://www.nasa.gov/feature/nasa-plant-researchers-explore-question-of-deep-space-food-crops

MacIntyre, O. J., Trevors, J. T., Dixon, M. A., Cottenie, K. (2011) *Application of Plant Growth Promoting Rhizobacteria in a Hydroponics System for Advanced Life Support in Space.* Retrieved from http://agris.fao.org/agris-search/search.do?recordID=US201400112037

Mars One. (2017). *Permanent Settlement.* Retrieved from http://www.mars-one.com/mission/technical-feasibility

McLennan, Scott M. (2003, April). *Sedimentary Silica on Mars.* Retrieved from file:///C:/Users/Michael%20Herman/Downloads/315.full.pdf

Meloy, T.P., and Williams, M.C. (2002) *The moon then Mars: Minerals Engineering.* (v. 15, p. 115–121).

NASA Jet Propulsion Laboratory (NASA JPL). (2016, November 22). *Mars Ice Deposit Holds as Much Water as Lake Superior.* Retrieved from https://www.jpl.nasa.gov/news/news.php?feature=6680

Rouphael, Y. Colla, G. Battistelli, A. Moscatello, S. Proietti, S. & Rei, E. (2004, July 29) *Yield, water requirement, nutrient uptake and fruit quality of zucchini squash grown in soil and closed soilless culture.* Retrieved from http://www.tandfonline.com/doi/abs/10.1080/14620316.2004.11511784

Squyres, S. W., Arvidson, R. E., Ruff, S., Gellert, R., Morris, R. V., Ming, D. W., Crumpler, L., Farmer, J. D., Des Marais, D. J., Yen, A., McLennan, S. M., Calvin, W., Bell III, J. F., Clark, B. C., Wang, A., McCoy, T. J., Schmidt, M. E., de Souza Jr. P. A. (2008, May 23). *Detection of Silica-Rich Deposits on Mars.* Retrieved from http://science.sciencemag.org/content/320/5879/1063

Weins, J., Bommarito, F., Blumenstein, E., Ellsworth, M. Cisar, T. (2001, January) *Water Extraction from Martian Soil.* Retrieved from http://www.lpi.usra.edu/publications/reports/CB-1106/csm01.pdf

Zacny, K. A., Quayle, M. C., Cooper, G. A., (2004, July 22). *Laboratory Drilling Under Martian Conditions Yields Unexpected Results.* Retrieved from http://onlinelibrary.wiley.com/doi/10.1029/2003JE002203/abstract

Joshua Eiswirth
Nuclear Engineering at Missouri University of Science and Technology

NUCLEAR FUSION AS A PRIMARY ENERGY PRODUCTION METHOD

Abstract

In this paper, the possibility of using nuclear fusion as a primary energy producer will be analyzed. A brief overview of nuclear fusion is given as well as the drawbacks of nuclear fusion today. The human species, need to find a more abundant and renewable means to produce energy, because the non-renewable resources relied on today will be completely used up in as little a 100 years. Nuclear fusion, if perfected, offers a reliable and extremely abundant energy source. With commercial nuclear fusion plants more energy would be available than ever before. While no efficient fusion reactor design exists today, many steps are being taken towards efficient fusion and a few will be outlined in this research paper. The sources used come from accredited academic sites written by the organization as a whole or individual authors with degrees that pertain to the information collected. Nuclear fusion is often described as “always 15 years away”, but many innovations exist today that were often thought of as impossible. Any given day a breakthrough could occur in one of the many fields related to nuclear physics that serves as the missing piece to efficient fusion power generation.

Nuclear Fusion as a Primary Energy Production Method

The world's biggest producers of electricity in 2013 were China, with 5422.2 billion kWh, and the United States, with 4286.9 billion kWh produced (The World Bank). This

accounted for 41.6% of the entire world's electricity production, and both of these super-powers rely on non-renewable resources as their main sources of power. If no alternative energy sources are adopted, in 110 years the world's coal supply will run dry according to the World Coal Association. If this happens, over 40% of the world's energy production means will disappear along with it. The best way to fix this problem is to avoid it altogether. It is crucial that a clean, reliable energy source be developed to replace the non-renewable sources relied so heavily on and cut back on the carbon emission that are proven to hurt the environment. There are many options when it comes to renewable energy production; however, none are without their drawbacks. Solar energy can only be collected when the sun is shining, wind turbines require a windy day, and nuclear fission leaves behind fission fragments that take years to decay and require special storage. The biggest drawback to nuclear fusion is that it cannot be done efficiently at this point in time. Nuclear fusion is a strong contender for the world's primary energy source if mastered. Efficient fusion power may still be impractical, but any day a major breakthrough could catapult the world into an age of cheap, plentiful energy for all.

Methods

As a student in the Nuclear Engineering field much of the information presented in the following research paper falls under "general knowledge", meaning that a source was not necessary as the information is taught in fundamental Nuclear Engineering classes. While attending the American Nuclear Society national student conference, I was able to speak with many student researchers about my research proposal. Unfortunately, it is not possible for me to give credit to these people because the presentations given at the conference are not publically available. However, all statistics and numerical data are properly cited and come from accredited sources, either organizations in the energy production field or authors with degrees pertaining to my research.

Because the topic of this paper is theoretical in nature, some information is estimated. using mathematical formulas or computer simulations.

Basics of Nuclear Fusion

Nuclear fusion is the process of combining the nuclei of two lighter atoms to create a heavier atom. During this process a small amount of mass is converted into a large amount of energy, by the famous equation E=mc^2. This energy must either be contained by strong magnetic waves generated with a superconductor, or by compression forces generated by a powerful laser (Carlton, 2017). A massive amount of energy is needed to force two atoms close enough to fuse, as well as a temperature in excess of 180 million degrees Fahrenheit (Carlton, 2017). With current methods, much more energy is required to achieve fusion than is obtained from the reaction. However, scientists all over the world are working to make this process more efficient in hopes that one day fusion will be what powers the world.

Commercial fusion will most likely use deuterium and tritium, two isotopes of hydrogen, as fusion components. The fusion cross section between these two atoms is high, so they are easy to fuse. The product of the fusion reaction is a helium nucleus and a 14 MeV neutron. Deuterium can be distilled from seawater making it readily available. Tritium however, is not naturally occurring and must be produced by other means. A major problem which stood in the way of fusion research was finding a way to deal with the extremely powerful neutrons that are produced during the Deuterium-Tritium (D-T) reaction. Fortunately, the problem concerning the extremely powerful neutron can be used to solve the problem that tritium is not naturally occurring. The fast neutrons produced from the D-T reaction can be directed towards and absorbed by lithium, which can also be distilled from seawater, resulting in the reaction n + Li6 -> He4 + T + 4.8 MeV where T is tritium and n is the neutron from the D-T reaction. Essentially,

everything needed for fusion can be obtained from seawater, making it an extremely abundant energy source.

The State of Fusion Today

Major efforts in the fusion power production field are being made by people all over the world, from research labs at MIT, to multi-billion dollar projects. The direction fusion research is heading in right now is a good starting point, but research must continue. As other technologies improve, they may be able to be applied to fusion. The International Thermonuclear Experimental Reactor (ITER) is multi billion dollar international project that looks to build a massive fusion reactor. In theory, the reactor will output more energy than is put into it. Until concrete data is collected from the reactor, it is unknown how well it will truly perform, but it is likely that ITER will be the closest thing to efficient fusion ever achieved. This is a huge step towards making fusion an effective energy producer. However, there are some issues with the ITER. The production cost has nearly tripled since proposed in 2006 and some countries are no longer as optimistic about the success of the project. For example, the US is considering retracting financial support for the project after estimated contribution raised by nearly $3 billion (Lucibella, 2014). Backing out now could mean even further setbacks to the project and may doom it entirely. Regardless of the costs, the ends will always justify the means if the secrets to fusion are discovered and fusion power can be shared throughout the world. ITER should be looked at as a stepping stone towards commercial fusion and template for smaller, more efficient, reactors in the future. The two easiest ways to make fusion more efficient are to decrease the amount of energy that is required to start the fusion reaction, and increase the amount of energy obtainable from the reaction.

A World Powered by Fusion

Once perfected, the Department of Energy estimates that "One gallon of seawater would provide the equivalent energy of 300 gallons of gasoline; fuel from 50 cups of water contains the energy equivalent of two tons of coal." According to the U.S. Department of the Interior 97% of all of the water on the planet is seawater. The volume of all water would be about 332.5 million cubic miles, and every cubic mile is more than 1.1 trillion gallons. This means that there is 3.548*10^(20) gallons of seawater on the planet. If every 50 cups (3.125 gallons) of water contains the energy equivalent of two tons of coal, the energy equivalent of all of the seawater in the oceans is around 454,144,000,000,000,000,000,000 pounds of coal. Having energy production means on this scale would mean energy for countless years, and the ability to get power to places in the world that have never had power before.

According to The World Bank, 15.4% of the population did not have access to electricity in 2012. For some, life without electricity is something that is impossible to even imagine. In many places readily available electricity is something that is taken for granted, but there are over 1 billion people on the planet who do not know this luxury. A world with fusion power is a world that is capable of providing energy to every single person; once the stigma of nuclear energy is no longer an impediment, scientists could devise a plan for rolling it out globally. Fusion promises a means to produce zero-carbon emission energy cheaply and abundantly, andshould be looked at as a way to get power across the globe.

Conclusion

Matthew J Moynihan, a so called “fusion expert” with a PhD in Inertial Confinement Fusion, has made many attempts to explain fusion to the masses. Moynihan started a Wikipedia page called “Teaching Fusion to the Public” and has written many articles on fusion for magazines.

Moynihan made an comparison in an article written for *Forbes Magazine* saying "I argue that fusion development is about where human powered flight was in the early 1890's". The author argued that when human powered flight was first being discussed there were many similarities in the way people view fusion power today. Fusion is often considered impossible or improbable, but considering the current state of human powered flight , humanity should not give up on trying to make fusion realistic. Even if it takes 100 years to perfect fusion power generation, the results will be well worth the wait. Energy costs could drop to all time lows, everyone on the planet could have access to power and clean drinking water, and scientists could turn their focuses to other applications of fusion.

References

Nordhaus, T. (2014, June). How To Make Nuclear Cheap. Retrieved April 17, 2017, from https://thebreakthrough.org/images/pdfs/Breakthrough_Institute_How_to_Make_Nuclear_Cheap.pdf

Carlton, P. S. (2017). Harnessing the Energy of Nuclear Fusion Reactions with Superconductors and Lasers. Retrieved April 19, 2017, from http://www.cas.org/news/insights/science-connections/nuclear-fusion

The World Bank. (n.d.). World Development Indicators: Electricity production, sources, and access. Retrieved April 13, 2017, from http://wdi.worldbank.org/table/3.7

Lucibella, M. (2014, September). Congress Divided Over Future of U.S. ITER Contributions. Retrieved April 13, 2017, from https://www.aps.org/publications/apsnews/201409/iter.cfm

Perlman, U. H. (n.d.). How much water is there on, in, and above the Earth? Retrieved April 19, 2017, from https://water.usgs.gov/edu/earthhowmuch.html