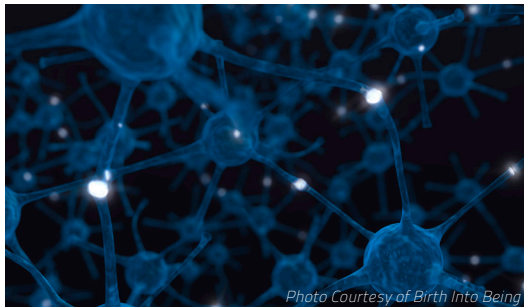


DISCUSSIONS

Undergraduate Research Journal of CWRU

Table of Contents



Faculty Spotlight: Gary Landreth

3

Research

Phase Cancellation in Ultrasonic Measurements due to Misalignment of Receiving Transducer

5

The Remittance Effect: Do Remittances Help Development?

11

Review

How Electrical Activity & Synaptogenesis of Neurons Contribute to the Efficiency of Neurofeedback Therapy

17

The Arcane and the Rational: Lovecraft's Development of a Unique Mythos

22

Letter from the Editor

Dear readers,

Since 2006, Discussions has celebrated and promoted undergraduate research at Case Western Reserve University and other universities all over the world. As a continuance of our tradition and mission, it is my pleasure to introduce the newest issue of Discussions to you.

By taking the time to read this journal, you are promoting Discussions and, in turn, the long hours of research conducted by undergraduates, often without herald or pay. And, in today's society of fluid information and constantly evolving knowledge, taking the time to inform oneself about current research is paramount. In choosing to read the papers of Discussions, you are stepping into an oft-overlooked niche of research, learning about topics to which you may not have been exposed.

The papers within these pages were selected from yet another all-time high in submissions from students across the country. Each article was carefully chosen by a team of peer reviewers before receiving final approval from the editorial board.

If you would like to see your research published in Discussions, visit our website at case.edu/discussions or our Facebook page for submission guidelines and more details. Feel free to contact us on our website with any questions.

As we continue to grow in size and prestige, I encourage anyone interested in research or the publication process to find ways to get involved with our publication. We accept submissions from around the world and distribute around the country; our organization's success has increased exponentially in recent years. Reach out to askdiscussions@case.edu to learn how to get involved.

Finally, I would like to thank Sheila Pedigo and the entire SOURCE office for their continued support.

Thank you for taking the time to read our journal, and I hope you enjoy the fantastic articles within.

Sincerely,

Jack Behrend

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Editor-in-Chief, Discussions Research Journal

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Faculty Spotlight

An Interview with

GARY LANDRETH

Conducted by Karbi Choudhury

INTRODUCTION

Case Western Reserve University has been at the forefront of scientific research for many decades now, particularly in its search for novel biotechnologies in order to treat disease and illness. In recent years, the Department of Neurosciences has made stunning advancements regarding Alzheimer's disease, a degenerative disorder of the central nervous system that involves a buildup of plaque in ventricular and cortical areas of the brain. There are also a variety of behavioral deficits that come with this physiological abnormality. Patients living with the disease typically experience a severe form of dementia and exhibit a wide range of mood swings. Because Alzheimer's disease involves interactions between behavioral and physiological deficits, scientists at Case Western Reserve University have sought to target both in all possible future treatments. At the head of this team is Dr. Gary Landreth, a professor of neurosciences at the Case Western Reserve University School of Medicine and Principal Investigator of his own laboratory. In 2012, Dr. Landreth and his team from institutions all over the country discovered the current leading skin cancer drug bexarotene to be effective in reducing morphological as well as behavioral symptoms of the disease in adult mice. Recently, I sat down with him to discuss the experiment and the significance it holds today for future treatments of Alzheimer's disease.

[We] sought to study the drug bexarotene...as a way to reduce Alzheimer's symptoms in mice.

1. Tell us a little bit about yourself. What is the main research topic of your lab?

I am a professor of neurosciences and a Neurology Director at the School of Medicine at Case. I am also the founder of our very own Alzheimer's Research Laboratory. I received my B.A. in Chemistry and Biochemistry at the University of Kansas in Lawrence, my Ph.D. at the University of Michigan in Ann Arbor, and completed my



Photo Courtesy of Gary Landreth

Post-Doctorate in Neuroscience at Stanford University. Over the past decade, my lab has researched the role of microglia and inflammation in the Alzheimer's pathway. Our goal is to increase the amount of Apo E to clear up beta-Amyloid plaques in Alzheimer's patients. In addition to Alzheimer's, we study ERK kinase knockouts, which mimic a broad range of autism spectrum disorders.

2. In a few sentences, could you describe the overall methods of your experiment and how they are significant to neuroscience?

The article was published in Science Magazine in February of 2012 by a team from many top institutions in the nation, including Case Western Reserve University, Washington University in St. Louis, New York University, and the University of Pennsylvania. Our group sought to study the drug bexarotene, currently a treatment for skin cancer, as a way to reduce Alzheimer's symptoms in mice. Now, Alzheimer's disease is widely believed to be the cause of the formation of clumps of plaque in the brain cells known as beta-Amyloid. Usually, beta-amyloid is cleared by the alipoprotein E, or Apo E. So, we deduced that through oral administrations of bexarotene, we would increase the levels of Apo E and see more clearance of beta-amyloid than ever before. We were right – after only one dose of

Faculty Spotlight

bexarotene, levels of beta-amyloid were rapidly lowered after only 6 hours, and they sustained at a 25% reduction for 70 hours. Not only did we reverse the physiological impairments of Alzheimer's in mice, but we also reduced their behavioral impairments. We saw an overall reduction in cognitive, social, and olfactory deficits.

3. This experiment was conducted in mice. What are the discrepancies you will have to overcome in order for this to be as effective in a human model?

The research is still very preliminary, and it is too early to be making a leap from an animal experiment to a human experiment, simply due to the differences in morphological characteristics. Though we are heading in the general direction of a potential therapy for patients with

We saw an overall reduction in cognitive, social, and olfactory deficits.

Alzheimer's, it is important that people do not try this at home. We are currently preparing clinical trials on a small group of people to see the drug's effect on humans.

4. Upon which prior publications and research did this paper improve?

This research is unprecedented partially because previously, the best existing treatment for Alzheimer's required many months in order to decrease beta-amyloid plaque formations. The 2011 Chin paper talks about selecting the proper mouse model in which to conduct the Alzheimer's experiment.

5. Was the process of getting your work published a challenging one?

Getting published is always quite an experience. There are multiple drafts of a paper before it is even considered for publication, and after that the publishing committee has their own recommendations and suggestions of how it should be written. The overall process takes several months to a year.

6. What kind of press attention did this paper receive upon its publication?

We were very grateful and optimistic about

the reception and ramifications of this paper. We were interviewed by BBC, the Cleveland Plain Dealer, Scientific American, the Wall Street Journal, and NPR, to name a few.

7. Let's talk about Case. How has Case's neuroscience research really developed in the last few years?

There is a lot of good work being done in Case's neuroscience department, and I am positive that there will be more good work to come. We have the implementation through passionate graduate students and faculty members, and funding for more research has been successful. We have attracted many Ph.D. candidates to our Department due to our highly specialized and narrowed-down interdepartmental focus. Each lab has its own specific topic it focuses on – mine, for instance, focuses on Alzheimer's disease. This really allows the students to find for themselves which aspects of neuroscience interest them.

8. What advice do you have for Case undergraduate students interested in neuroscience and looking to conduct research in an area similar to Alzheimer's?

Be proactive. Don't be afraid to put yourself out there and actively look for research opportunities. Whether that is here, in the Cleveland Clinic, or anywhere else, there is a lot of great work being done that requires the aid of motivated undergraduate students. If you find a lab with an area of focus that interests you, contact the professor who is running the lab. You never know who may offer you a position until you reach out.

...one step closer to finding a treatment for Alzheimer's disease.

9. What are future routes for Alzheimer's disease that we can now test because of your discovery?

This study has put us one step closer to finding a treatment for Alzheimer's disease. Just recently, a group at Yale has found yet another drug that is virtually 100% effective against Alzheimer's behavioral and physiological deficits in mice, and I am confident that soon we will find the key to making this treatment applicable to humans.

Phase Cancellation in Ultrasonic Measurements due to Misalignment of Receiving Transducer

Photo Courtesy of Mikael Altermark, Flickr, 2006

Yu Tao Li

INTRODUCTION

Bone sonometry is an established modality for the characterization of potentially osteoporotic cancellous bone. The ultrasonic field propagated through the heel bone (calcaneus) is subject to diffraction effects that complicate the acquired data. The immediate goal of this work is to examine the consequences of diffraction on phase cancellation at the face of a single-element piezoelectric transducer. The long-term goal of this research is to develop mechanisms that compensate for the effects of diffraction. As an approach to understanding the physics underlying this complex phenomenon, in the present study spatial variations in the phase of the ultrasonic signal are induced by systematic rotation of the face of the receiving transducer.

BACKGROUND

A. Phase cancellation

Phase cancellation across the face of a receiving transducer can be defined as the cancellation between positive and negative voltages across different locations on the surface of a receiving transducer. The different signs in voltage reflect the different signs of the velocities of particles in contact with the surface of the receiving transducer, which is a consequence of wavefront distortion as the ultrasonic wave approaches the receiving transducer.

The concept of phase cancellation should not be confused with the concept of interference of wave fronts. In interference, the ultrasonic fields present at a particular point in space may add in a destructive or constructive manner. However, the total energy of the field is conserved. In contrast, phase cancellation across the face of a receiving transducer results in dissipation of energy in resistive losses in the electrodes of the transducer (Holland, 1989).

In medical applications of ultrasound, phase cancellation is a very common phenomenon in through-transmission detections involving inhomogeneous media, such as segments of bone or heart. For homogenous media, phase cancellation can also happen by misalignment of the surface of receiving transducer, thus creating phase differences, or wave front distortions

B. Introduction to phase sensitive and phase insensitive detection

The distinction between phase sensitive and phase insensitive detections is very important in ultrasonic measurements. In *phase sensitive* (PS) detections, signals received at each location across the face of the receiving transducer are combined before further procession, which may result in phase cancellation across the face of the transducer. Further analysis (such as computing the power spectrum) is based on this summed signal. In *phase insensitive* (PI) detections, analysis is first carried out of the power spectrum at each location across the face, and the total power is obtained by combining power at all locations. Phase insensitive detection does not involve the possible cancellation between positive and negative voltages, so it is not subject to the effect of phase cancellation. Phase insensitive detection analyzes power locally. Power is always a nonnegative quantity, so cancellation across different locations cannot occur. As a result, phase insensitive detection correctly estimates the amount of power that reaches the receiving transducer and in this regard it is the preferred detection method. On the other hand, phase sensitive detection, which is often susceptible to phase cancellation effects, underestimates the power that reaches the receiving transducer.

In an experimental setting, phase sensitive detection only requires a single receiving transducer with an aperture on the scale of one centimeter. In contrast, phase insensitive detection, which analyzes signal at numerous specific locations across the face of the receiving transducer, requires an array of point-like receiving transducers, each with an aperture on the scale of one millimeter for wavelength typical of low megahertz frequency ultrasound. As a result, phase sensitive detection, which is usually cheaper and less technically challenging, remains widely used both in laboratories and in bone sonometry and related applications of ultrasound, despite its susceptibility to phase cancellation.

C. Power spectra of phase sensitive and phase insensitive detection

A useful representation of an ultrasonic field is its frequency-domain power spectrum. A substantial amount of useful information for the characterization of an ultrasonic field can be obtained from its frequency content.

Suppose the receiving transducer consists of an array of N hydrophones. If the digitalized wave form received by the n th hydrophone is defined as $v_n[t_k]$, the phase sensitive power spectrum can be found with the following formula,

$$P_{PS}[f_k] = \frac{|FFT[\frac{1}{N} \sum_{n=1}^N v_n[t_k]]|^2}{R} \quad (1)$$

The corresponding phase insensitive power spectrum is obtained as

$$P_{PI}[f_k] = \frac{1}{N} \sum_{n=1}^N \frac{|FFT[v_n[t_k]]|^2}{R} \quad (2)$$

In both formulas, FFT stands for Fast Fourier Transform, and R is the appropriate impedance of the system (Holland, 1989).

D. Zero-padding of time domain signal

In Fast Fourier Transform, a digitalized time-domain signal with m data points and resolution dt is converted into a digitalized frequency-domain signal with m data points and resolution df . The following equation relates dt , m and df :

$$df = \frac{1}{m dt} \quad (3)$$

An approach for interpolation can be used to improve the resolution of power spectra by making df smaller. From (3) we see that this can be achieved by either increasing m , the number of points in the digital signal, or increasing dt . However, an increase in dt means worse resolution of time domain signal, which is undesirable. Therefore, the only feasible method is to increase m by appending values of

zero on both ends of the time domain signal. This technique is called “zero-padding” and is employed in this study.

E. Brief introduction to FOCUS

FOCUS (Fast Object-Oriented C++ Ultrasound Simulator) is a free cross-platform ultrasound simulation tool that calculates pressure fields generated by single element transducers and phased arrays (McGough, 2013). Developed by Professor Robert J. McGough and his colleagues from Michigan State University, FOCUS is capable of running both continuous and transient ultrasonic simulations. FOCUS is able to perform transient calculations quickly with less demand on computer memory by using Time-Space Decomposition (Kelly & McGough, 2009) (Kelly & McGough, 2006) (Chen & McGough). In this study, a combination of FOCUS Version 0.796 and MATLAB R2012a were used to run the simulations.

SIMULATIONS

A. Setup of FOCUS simulation

In this study, the effects of rotating receiving transducers for two different ultrasonic measurement systems are investigated with the help of FOCUS simulation. Each system consists of a transmitting transducer and receiving transducer of the same dimensions and frequency, both fully immersed in water. A broadband pulse propagates from the transmitting transducer, to the receiving transducer, where the time-domain waveform is recorded.

To perform transient wave simulations in FOCUS, a transducer object must be defined and the propagation medium, which was water in this case, must be specified first. FOCUS also requires an input waveform to be specified. Then a 4 dimensional coordinate system with 3 spatial dimensions (x,y,z) and 1 time dimension (t) needs to be defined. FOCUS will calculate the particle velocity field generated by the transducer as a function of (x,y,z,t). Because the transmitting transducer has a circular surface and can be reasonably assumed to be cylindrically symmetric, the resulting velocity field can also be assumed to be cylindrically symmetric, so

only 3 dimensions (r,z,t) where $r = \sqrt{x^2 + y^2}$ are needed.

Phase Cancellation in Ultrasonic Measurements

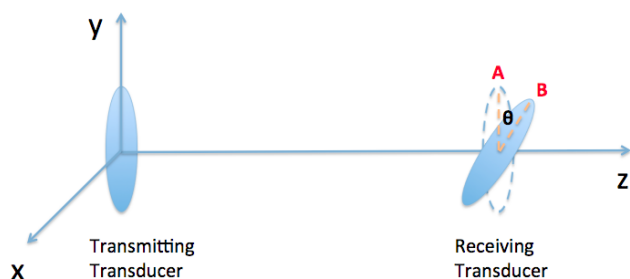


Figure 1: Configuration of the ultrasonic system. An ultrasonic wave propagates from the transmitting transducer through water to a receiving transducer. The receiving transducer can be rotated about the x-axis by a certain angle θ , typically between 0 and 10 degrees (exaggerated for the ease of viewing). To make sure that the waveforms calculated at $\theta=0$ and $\theta=\theta'>0$ are significantly different, a high resolution on the z-axis is needed so that there can be enough points in the z direction separating A and B. In the case of $\theta'=1^\circ$ the number of such points is defined as the “degree of fineness” (DOF) and it is expected to be >10 .

The receiving transducer is modeled to be composed of N receiving transducers (sometimes known as hydrophones). For each rotation angle θ (Figure 1), each hydrophone is located at position (x,y,z) , which can be further simplified into (r,z) as described above. Given the (r,z) coordinates and the velocity field calculated by FOCUS, we can find $v_n[t_k]$, the digitalized time-domain signal received at the n th hydrophone. A further application of formulas (1) and (2) gives the phase sensitive spectra $P_{PS}[f_k]$ and the phase insensitive power spectra $P_{PI}[f_k]$ respectively.

Choosing a suitable resolution of the (r,z,t) grid is important. On one hand, we cannot make the resolution so high that the memory available in our computer is inadequate. On the other hand, we cannot make the resolution too low so that: 1) a very low resolution in time could fail to meet the Nyquist sampling criterion, resulting in a distorted waveform, or 2) a very low resolution in r and z dimensions (especially z) could mean that there is little or no difference between the waveforms acquired at $\theta=0$ and $\theta=\theta'>0$. The first issue can be addressed by setting dt , the time difference between two neighboring points on the time axis, to be no bigger than the Nyquist value. The second issue can be tackled by requiring that DOF, as defined in the Figure 1, to be greater than a certain value, which is chosen to be 10.

Table 1. Parameters of the two sets of ultrasonic transducers being investigated and the resolution in (r,z,t) space used in FOCUS simulations.

Transducer set	Diameter (mm)	Center frequency (MHz)	Distance between transducers (mm)	Focal length
1	28.6	0.5	88.9	planar
2	14.7	5	127	planar

Transducer set	dr (mm)	dt (μ s)	dz (mm)	DOF
1	0.010	0.1	0.015	16.9
2	0.018	0.05	0.010	10.7

The hydrophones should be placed throughout the face of the receiving transducer with even density. A way to accomplish this is to imagine a square grid covering the face of the receiving transducer, and hydrophones are placed at all the grid points lying inside the boundaries of the face of the receiving transducer, as shown in Figure 2.

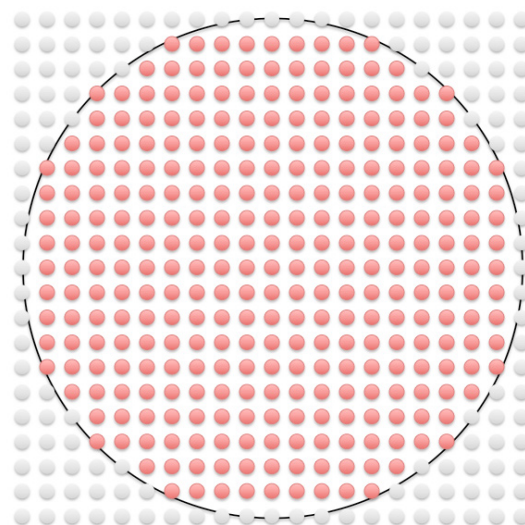


Figure 2: Location of hypothetical point-like ultrasonic receiving transducer. A 21x21 square grid is superimposed onto the face of the receiving transducer (shown as a black circle). Red dots that lie inside the circle are the sites where a hypothetical hydrophone is placed and $v_n[t_k]$ is taken. There is a total of 305 dots, or $N=305$.

B. Results of FOCUS simulation and comparison with results from laboratory work

Figure 3A shows the FOCUS simulated phase sensitive power spectra of transducer set 1 for $\theta=0^\circ$ to $\theta=10^\circ$ in increments of 1° . Figure 3B shows the power spectra of the same transducer calculated from actual laboratory data. In our laboratory a single circular transducer, instead of an array of hydrophones, is used as the receiver, so the laboratory data are results of phase sensitive detection.

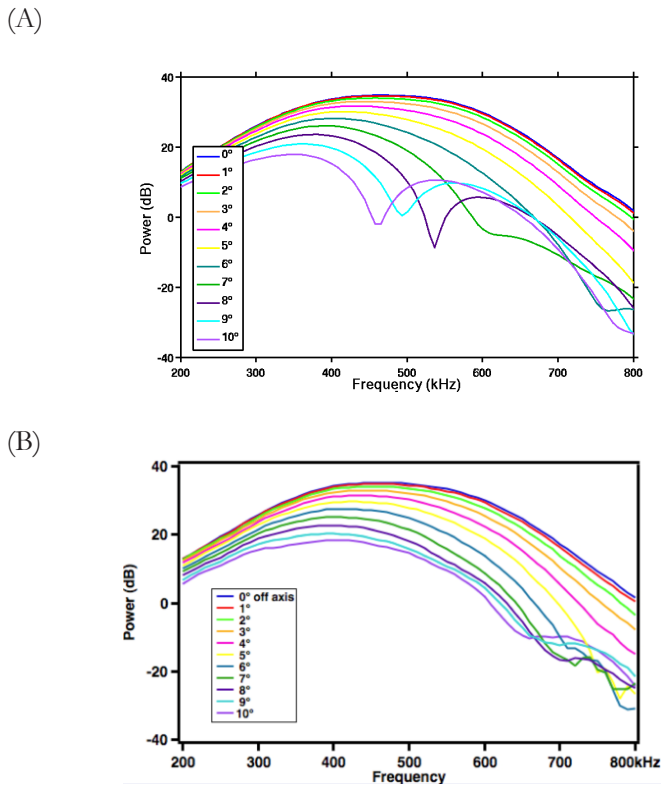


Figure 3: (A) Plot of phase sensitive power versus frequency at different values of θ for transducer set 1 based on FOCUS simulations. (B) Plot of phase sensitive power versus frequency at different values of θ for transducer set 1 based on laboratory data. Apart from minor disagreements in higher values of θ , these two plots agree with each other extremely well. A nonzero value of θ can significantly weaken the power received by a receiving transducer in the case of phase sensitive detection.

Figure 4A shows FOCUS simulated phase sensitive normalized power change as a function of rotation angle θ at three different frequencies for transducer set 1. Figure 4B is similar to Figure 4A but uses laboratory data instead. It is clear that more and more power is lost as the rotation angle of receiving transducer increases. For the same rotation angle, a higher frequency is correlated to more power loss.

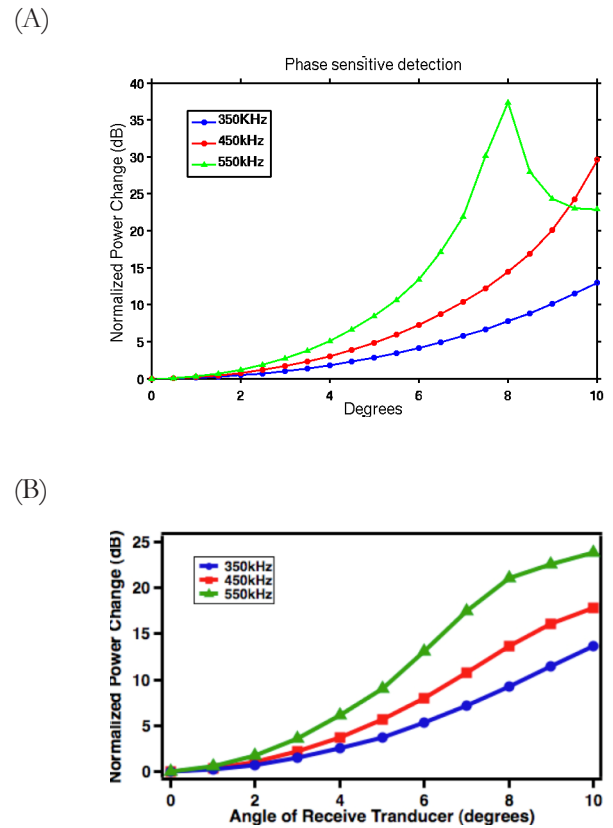


Figure 4: (A) Plot of “normalized power change”, the power loss due to misalignment at three different frequencies as a function of θ based on FOCUS simulation results. (B) Same as (A) but based on laboratory data. For both (A) and (B), transducer set 1 is used.

Figure 5 shows the FOCUS simulated phase insensitive power spectra of transducer set 1. Notice that the power spectra for different angles are very similar.

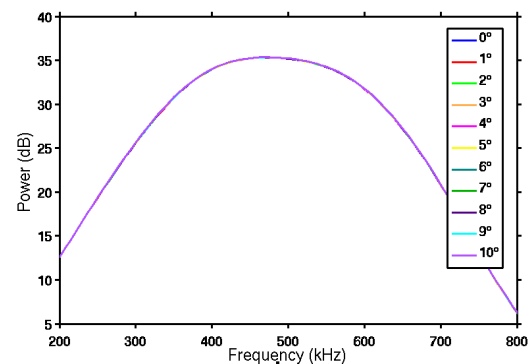


Figure 5: Plot of phase insensitive power versus frequency at different values of θ for transducer set 1 based on FOCUS simulations. The power spectra for different values of θ are very similar, which is proof that phase insensitive detection is not susceptible to power losses caused by phase cancellation. Laboratory results are unavailable as it is very difficult to do phase insensitive detection in a laboratory setting.

Phase Cancellation in Ultrasonic Measurements

Figure 6A shows the FOCUS simulated phase sensitive power spectra of transducer set 2 for $\theta=0^\circ$ to $\theta=5^\circ$ in increments of 1° . Figure 6B shows the power spectra of the same transducer calculated from actual laboratory data, which is also phase sensitive.

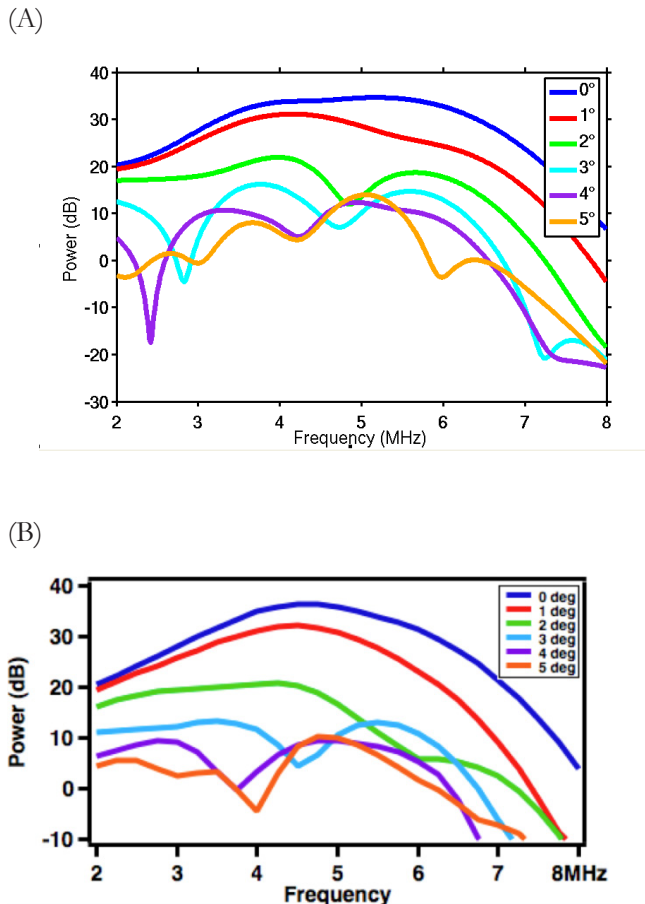


Figure 6: (A) Plot of phase sensitive power versus frequency at different values of θ for transducer set 2 based on FOCUS simulations. (B) Plot of phase sensitive power versus frequency at different values of θ for transducer set 2 based on laboratory data. Apart from minor disagreements in higher values of θ , these two plots agree with each other extremely well. A nonzero value of θ can significantly weaken the power received by a receiving transducer in the case of phase sensitive detection.

Figure 7 shows the FOCUS simulated phase insensitive power spectra of transducer set 2. Notice that the power spectra for different angles are very similar.

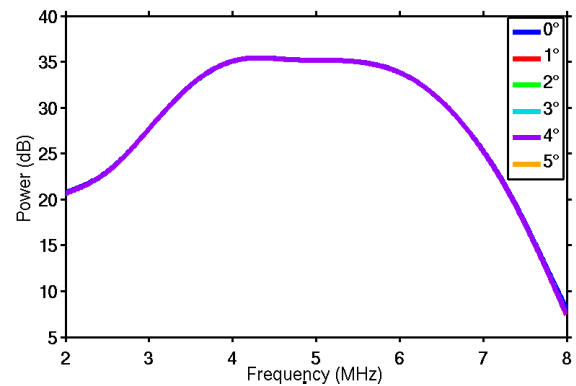


Figure 7: Plot of phase insensitive power versus frequency at different values of θ for transducer set 2 based on FOCUS simulations. The power spectra for different values of θ are very similar; a proof that phase insensitive detection is not susceptible to power losses caused by phase cancellation. Laboratory results are unavailable as it is very difficult to do phase insensitive detection in a laboratory setting.

DISCUSSIONS

Issues associated with the diffraction of ultrasonic waves as they propagate through inhomogeneous media present challenges for quantitative determination of material properties of specimens such as potentially osteoporotic bones. In order to investigate some of the physics underlying the diffraction of propagating ultrasonic waves, this investigation made use of a homogenous medium (water) to investigate the impact on quantitative measurements of phase variation across the face of a receiving transducer. Systematic variations in phase were achieved by rotation of the plane of the receiving transducer relative to the direction of propagation of the ultrasonic beam. Such small variations in angle would not be expected to alter significantly the power spectrum of the received ultrasonic signal. However, results of this investigation indicate that the apparent magnitude of the power as a function of frequency varies dramatically in the case of phase sensitive reception. In contrast, with the use of phase insensitive detection, the power spectrum is quite stable over the entire range of angles investigated. These results suggest the potential benefit of employing phase insensitive detection in the investigations of material properties.

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The Remittance Effect: Do Remittances Help Development?

Photo Courtesy of Jason Rogers.

Sabrina Singh

ABSTRACT

In 2013, developing countries were expected to receive \$414 billion in remittances – money sent back home by migrant workers. Remittances have been extolled in academic literature for having a substantial positive impact on development and poverty reduction. This paper will explain the link between remittances and development and argue against a quick, causal link between the two. There are three crucial factors that affect the development potential of remittances: Firstly, the literature suffers from a lack of remittance data in developing countries. Secondly, domestic and international politics mediate and curtail the positive impacts of remittances, which may result in adverse effects, such as public moral hazard. Finally, micro-level studies show that remittances can lock in existing household inequalities. Since development includes not only economic growth, but also includes equitable human welfare and poverty reduction, the impact of remittances on development are complex and may be adverse. Policy makers must not perceive remittances as a panacea for the poorest of the world; instead, they

need to be cognizant of how remittances interact with particular socio-cultural and political economy factors.

THE REMITTANCE EFFECT: DO REMITTANCES HELP DEVELOPMENT?

A rapid increase in global migration has led to an average of nine percent annual growth of remittances¹ globally (“Migrants,” 2013). For countries like Tajikistan, the Kyrgyz Republic, Lesotho, and Nepal, remittances constitute as much as 20 to 40 percent of national GDP (“Migrants,” 2013) and, in many other developing countries, remittances outstrip official development assistance as well as foreign direct investment (Gabel, 2009, p.87). Remittance literature has extolled this rising volume of remittances for having a substantial positive impact on development and poverty, especially in comparison to the impacts of official

¹ This paper uses the definition of ‘remittances’ that the World Bank uses: namely, monies comprising of workers’ remittances, migrant transfers and compensation of employees. “Migrant transfers” arise from change of residence for at least one year and “compensation of employees” are funds sent back by temporary workers. See Devesh Kapur, “Remittances: The New Development Mantra,” pg. 2.

development assistance (“Impact of Remittances,” 2011). This paper will argue against the establishment of a quick, causal link between remittances and development. Insofar as development includes not only economic growth, but also quality of life and human welfare, remittances can have no effect or even detrimental effects on development. The first section will employ Jeffrey Sachs’ development model to explain why many studies have shown that remittances are beneficial for countries’ development. The second section will problematize these optimistic remittance studies on three grounds: basic methodological problems, the interaction of remittances with domestic and international politics, and, finally, the masking of unequal effects on human capital in the household level.

Studying remittances has become very important because they are steadier and more reliable than development assistance and foreign direct investment. Indeed, the \$414 billion worth of remittances expected to be received by developing countries in 2013 is truly the bread and butter for many people (“Migrants,” 2013). However, remittances and development are not so simply linked; remittances have developmental potential, but their effects on development should be considered in particular socio-political-economic contexts.

REMITTANCE OPTIMISTS: THE CASE FOR REMITTANCES-AS-DEVELOPMENT

Much economic research shows a link between remittances and poverty reduction, but these studies do not explain how exactly remittances help reduce poverty. Jeffrey Sachs’ model of development can be used as a framework to understand the argument of remittance optimists. Sach’s model shows how remittances help in savings, investment, overall GDP, and how they act as a buffer against adverse productivity shocks. Sachs’ theory does not directly address remittances – what is central to his development model is foreign aid. However, his theory can be used to understand how remittances fit with popular development paradigms today, as well as to help understand flaws in remittances.

For Jeffrey Sachs, development is consubstantial to breaking out of the poverty trap² via GDP growth. ‘Growth’ is obtained by a combination of high savings, development of human capital, and technology and trade, among others.³

² For Sachs, poverty trap is the mechanism due to which the poorest of the world are unable to lift themselves out of poverty. A person in the poverty trap has to use all of his/her income to merely survive, and thus is unable to save, invest, or develop human capital. Jeffrey Sachs, *The End of Poverty* (New York: Penguin Press, 2005), pg. 56.

³ Sachs also includes geography as a key factor in development. He argues that poor countries are poor often because of a geography curse. Remittances, at first, seem to be

There is evidence that remittances are fulfilling some of Sach’s prerequisites to development: Yero Baldé, for example, found that a 10% increase in remittances increases household savings by 7% and investment by 6.5% (Balde, 2011, p. 247). Other studies show that remittances raise household consumption as well as increase household investment in education and health care (Nallari and Griffith, 2011, p.126).

Moreover, Sachs identifies a potential setback in development—“adverse productivity shock” (Sachs, 2005, p. 55)—against which remittances can protect national economies. Adverse productivity shocks are unexpected occurrences, like natural disasters or financial crises. Remittances seem apt to buffer against these shocks because they are countercyclical (Ratha, 2007): Remittances tend to rise during economic crises, natural disasters, or political conflicts. For example, the number of remittances rose during financial crises in Mexico in 1995 and Indonesia and Thailand in 1998, acting as buffers during those times (Ratha, 2007). Therefore, remittances not only seem to help overcome poverty but also act as a buffer against adverse productivity shocks.

Studies have indeed documented a reduction in poverty due to remittances. After surveying 7,276 households in Guatemala in 2000, Richard J. Adams found that international remittances decrease the squared poverty gap by 21.9%.⁴ Even more convincing effects on poverty are shown by Richard H. Adams and John Page’s study of 71 low-income and middle-income developing countries. They conducted an analysis of the effects of remittances on poverty headcount, poverty gap, and squared poverty gap⁵, and showed that official international remittances have a statistically significant negative impact on all three poverty measures.

However, remittances are not this generation’s panacea for the poor to “gain a foothold on the ladder” of development (Sachs, 2005, p.73). There are flaws and caveats to the idea of remittances as a cure for lagging development.

a balm even to this problem, since migrants are transgressing geographical constraints to send money home. However, most remittances received by developing countries go to lower middle-income countries. Regions like Latin America and South Asia get a significantly larger volume of remittances than Africa despite its large rate of migration. See Devesh Kapur, “Remittances: The New Development Mantra,” pg. 10.

⁴ Squared poverty gap is the square of the distance of the poor from the poverty line; as such, it measures the severity of poverty. See Richard H. Adams, Jr., “Remittances, Poverty, and Investment in Guatemala,” pg. 68.

⁵ Poverty headcount is the proportion of the population that is counted as poor. Poverty gap index is the total cost of bringing each poor member of a society up to the poverty line. See Raj Nallari and Breda Griffith, *Understanding Growth and Poverty: Theory, Policy, and Empirics* (Washington, D.C.: World Bank, 2011), pg. 23.

FLAWS AND CAVEATS IN REMITTANCES-AS-DEVELOPMENT

Most remittance research is plagued by sample omissions and a shallow definition of 'migrant.' Furthermore, remittances are embedded in social and political economy contexts that constrain their development potential.

i. Methodological Shortcomings

One of the easiest criticisms of the 'remittance-as-development' discourse is sample omission. Many economic analyses suffer from a lack of remittance and migration data across countries and time. For example, although Adam and Page's study showed an attractive reduction in all three measures of poverty, there are grave data omissions. For example, India, densely populated and a recipient of a large volume of remittances, is included in the study, but some of the countries with highest absolute poverty headcounts (\$1.25/day) in 2005, like Congo and Niger, are excluded due to unavailability of poverty and remittance data. Furthermore, a large volume of remittances are transferred from informal sectors like 'hawala' in Pakistan and 'hundi' in India, and these are omitted from official remittance data (Orozco, 2011, p.63). This lack of data should caution researchers against deducing policy recommendations from such studies, because the countries where remittances matter the most are often the ones with the least data, and thus, the most excluded or underrepresented in samples (Kapur, 2003).

Furthermore, the effects of remittances on poverty is compounded by the narrow operational definition of 'migrant.' Most remittance-optimistic studies do not consider socio-political characteristics of migrants like education level and income level prior to migration. This is a crucial missing piece in the puzzle: Studies have shown that skills and education of migrants do matter for remittance determination and usage. In Bangladesh, for example, the poorest families with little to no education tend to produce temporary migrants (Zaman and Mashfique, 2013, p.111). The average education levels of migrants tend to be higher than the average education levels of their home countries (Kapur, 2003). Studies that ignore socio-political characteristics of migrant families are reductive, and thus, we must not be quick to extol those that show an increase in education and health investments due to remittances.⁶ This result could very well be due to socio-political characteristics of migrants before they migrate, and might be abetting transient poverty

⁶ In fact, almost half of all remittances received by developing countries go to lower-middle income countries (like Guatemala). See Devesh Kapur, "Remittances: The New Development Mantra," pg. 8. Hence, although Adams and Page found poverty reduction in terms of poverty gap and squared poverty gap, this might be reflecting a reduction of poverty in low middle income countries or those that are just below the poverty line.

as opposed to long-term structural poverty. Ultimately, these studies are inconclusive about abject structural poverty.

ii. Politics of Remittances

Unlike the studies on other international capital flows, like developmental assistance and foreign direct investment, academic literature has downplayed the political economy context of remittances (Grabel, 2009, p.86). Like Sachs, some researchers assume that development needs governments "oriented toward development" (Sachs, 2005, p. 59), but do not examine how governments can be incentivized to underdevelop a country or a neighboring one.

A powerful reason why remittances might not lead to development is because their flow and effects depend on bilateral relations and geography between countries. As such, remittances can be a powerful foreign policy and economic warfare tool. Devesh Kapur identifies what he calls a "source-destination dyad" (2003) in a remittance economy whereby two countries have longstanding unidirectional remittance flow. Examples include Mexico as a source of migrants and USA as a destination, and Burkina Faso as a source of migrants and Cote d'Ivoire as a destination. Because of this dyad, a civil war between 2001 and 2004 in Cote d'Ivoire "rapidly reverberated" into Burkina Faso (Kapur, 2003): Burkinabe remittances took a deep plunge during the civil war in Cote d'Ivoire. Similarly, in the aftermath of the September 11 terrorist attacks in New York, the US government put global pressures on diasporic remittances going to countries like Pakistan and Somalia for fear of terrorist funding. In Somalia, where remittances were being controlled by a single firm, the effects of the United States shutting down that firm in 2001 were an economic and humanitarian disaster (Kapur, 2003). As the cases of Burkina Faso and Somalia show, remittances still depend on geography in terms of migrant flows and on bilateral relationships in terms of the amount and effects of remittances. A civil war or change in foreign policy in destination countries can severely diminish the amount of remittances received and their macroeconomic impacts.

Developmental effects of remittances not only depend on international diplomatic relations but also on domestic politics – for example, the public moral hazard problem. This refers to the possibility that, because remittances are countercyclical, they incentivize governments to shirk their responsibility to provide basic public goods and maintain citizens' welfare. This effect might be most pronounced during natural disasters and crises when the countercyclical nature of remittances can relieve the

government of its responsibility of providing social programs and institutional support to the public (Grabel, 2009, p.94). Moreover, the moral hazard might also extend to the household level: As Ralph Chami et al. put it, “Compensatory remittances that insure the public against adverse economic shocks ... reduce households’ incentives to pressure the government to implement reforms to facilitate economic growth” (Chami, 2008). Households that expect and depend on remittances can also be de-incentivized to participate in the labor market, thus slowing economic productivity (Grabel, 2009, p.97). Far from helping development, remittances have a dangerous potential to exacerbate domestic political problems and hamper the economy.

Thus, it is important to remember that remittances operate in a context of political economy. They are not only affected by politics, like source-destination dyads, but they also affect politics, like public moral hazard. Their development capacity relies not only on the economics enumerated in section one, but on these powerful, political factors as well.

iii. Development: Beyond Economic Growth

Remittances do not lead to development if we take, in Amartya Sen’s words, a “foundational view of development” (Sen, 1999, p.5) that moves away from defining development as economic growth and instead foregrounds people’s capabilities, welfare and quality of life.

Micro-level studies of remittance workers and their families show that a rise in income does not necessarily lead to human welfare. In fact, it may instead lock in existing gender and family inequalities. Madeline Wong identified “intrafamily politics around remittances” with respect to female Ghanaian remittance workers (Wong, 2006, p.368). Taking into consideration the culturally entrenched obligations of motherhood, she documented the stress and constant unhappiness Ghanaian woman remittance workers experienced — a factor in ‘development’ that “the literature often fails to recognize.” Similarly, Vogel and Korinek used household surveys in Nepal to show that, although remittances result in a higher propensity to invest in education, the investment is disproportionately spent in boys’ education, particularly in low-income households relying on male remitters (Vogel and Korinek, 2012, p. 87). In both cases, although there is a rise in income and an investment in human capital, this investment is not happening on an equitable basis.⁷ If the definition of development is extended

to foreground quality of life (not merely GDP growth), then remittances do not necessarily lead to development but rather lock in existing socio-cultural inequalities.

Furthermore, the tendency of remittance studies to take households, not individuals, as their unit of analysis adds to this problem by conflating people’s welfare with household welfare. Researchers are most inclined to examine remittances in households such that a resulting increase in household consumption and investment is taken to be a right step towards development. These studies tend to overlook the inequality and power dynamics within households. Leisy Abrego, for example, points out that mothers are expected to willingly self-sacrifice, and that female workers tend to send a high percentage of remittances, even when they earn meager wages (Abrego, 2009, p.1078). Indeed, Vogel and Korinek point out something that remittance-optimists hardly take into account: “the family is also a gendered institution” (Vogel and Korinek, 2012, p.70). Locating the remittance-and-development nexus in the household, albeit useful and efficient, comes at the expense of conflating an increase in household consumptions and savings as an increase in every family member’s welfare. Therefore, one should consider whether remittances might be institutionalizing or even exacerbating existing inequalities in the household.

CONCLUSION

Although remittances bring economic potential, policy makers need to not only take a careful look at the methodological shortcomings of research, but also place the results in a political economy and socio-cultural context. The lack of remittance data and omission of socio-cultural characteristics of migrants shows an unrealistically positive picture of the impact of remittances on household consumption, investment, and poverty reduction. Source-destination dyads between countries means that geography and bilateral relations matter for the volume and impact of remittances. Although the countercyclical nature of remittances is perceived to be mostly positive, in reality, it can create a public moral hazard problem whereby governments shirk their public responsibilities. Furthermore, remittances can exacerbate existing inequalities rather than ameliorate them, which can be seen in gender inequality within households.

Hence, policy makers must carefully consider how ‘development’ is conceptualized and under what circumstances remittances can have negative effects on human welfare, government responsibility, and economic growth. Policy makers need to be cognizant of how these capital flows interact with particular socio-cultural and

⁷ Plus, gender is not the only social factor: Devesh Kapur (2004) notes that remittances to Cuba have a strong racial bias since the Cuban diaspora is mostly white, while the island is majority black. See Devesh Kapur, “Remittances: The New Development Mantra,” pg. 21.

political factors. Despite the claims of remittance optimists, remittances have a more complex and sometimes harmful effect on development. This less-than-optimistic conclusion is more pragmatic for the development policies of those low-income countries that rely on remittances the most.

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DISCUSSIONS

Undergraduate Research Journal of CWRU

ENGINEERING & SCIENCE REVIEW

Case Western Reserve University's Engineering and Science Review (ESR) was a student magazine that brought cutting-edge research news to campus. Established in 1958, ESR's mission was to highlight the work of top researchers from across the country primarily through review, human-interest pieces, and news articles. They did so in an exemplary fashion for over 55 years before joining Discussions to bring the work of undergraduates to the campus community and abroad.

In honor of their storied history, Discussions presents a new review section. The following pages will contain the work of undergraduates who have formulated holistic reviews of various topics through extensive study. Using the research of others, these authors will present new theses, new directions, and new ideas on relevant issues.

How the Electrical Activity and Synaptogenesis of Neurons Contribute to the Efficacy of Neurofeedback Therapy

Sabrina Perry

Photo Courtesy of Allan Ajifo, Flickr, 2014

ABSTRACT

Neurofeedback Therapy (NFT) is a type of biofeedback therapy specifically targeting the brain and nervous system. According to the Mayo Clinic, biofeedback is defined as a technique one can use to learn to control the body's functions, done usually by connecting one's body (bio) to electrical sensors that help you receive information about it (feedback). This can help people focus on making subtle changes in their bodies, such as relaxing certain muscles to achieve certain results, such as pain reduction. Subsequently, the Task Force on Nomenclature specified that the presentation of information on the functioning of one's brain partnered with changes in thinking, emotions, and behavior, support desired physiological changes. By examining a variety of studies, from ones that sought to quantify the changes in white and gray matter after NFT to those that examined the increased neurogenesis of mice living in enhanced environments to those that tried to understand the neural activity underlying brain waves, this review seeks to elucidate the quantifiable evidence that may underlie, and thus explain, the emerging efficacy of neurofeedback therapies. These studies led to the conclusion that there are biological changes taking place during NFT, though only a few have yet come to light. Of these, synaptogenesis and the varied electrical activity of neurons appear to explain how some of this brain modification, or neuroplasticity, occurs.

INTRODUCTION

This paper aims to explore the biological substrates underlying the therapy of neurofeedback, which already has

demonstrated to have therapeutic and clinical implications for ailments ranging from Attention Deficit Disorder (ADD) to Carpal Tunnel. According to the International Society for Neurofeedback Research, Neurofeedback Therapy uses monitoring devices to provide individuals with information on the state of their physiological functioning, specifically focusing on the nervous system and the brain (Figure 1). Discovering how neurofeedback works is significant because the better understanding of it there is, the more precisely it can be used therapeutically. However, though current understanding of it is not very extensive, neurofeedback therapy (NFT) has already been shown to be clinically efficacious. In previous studies using subjects with ADD, it has been shown that NFT aiming to increase beta brainwaves (those associated with concentration and focus) while trying to minimize theta brainwaves (daydreaming, inattention), can lead to a reduction in impulsivity and hyperactivity, thus contributing to an improvement in attention (Monastra, 2002). While the effects of pharmaceuticals are typically short lived and it can often take weeks for a patient to experience results, NFT can last for months after the training takes place, depending on how intensive the training. It is also much less invasive than any form of surgery. So, though it takes a number of neurofeedback training sessions to see results, it is less invasive, longer term, and has significantly fewer side effects than either pharmaceuticals or surgery.

However, for this type of therapy to be taken seriously, its mechanisms of action need to be understood. Not only should this lead to more accurate and specific usages, but also it should make it more easily accepted as a form of therapy. Firstly, this paper will discuss the methods

of recording neural activity and imaging the brain, and how they apply to neurofeedback therapy. The methods included are electroencephalography (EEG), magnetic resonance imaging (MRI), functional MRI (fMRI), diffusion MRI (dMRI), and Diffusion Weighted Imaging (DWI). While EEG and fMRI are used to record more “real-time” data, MRI is usually used to form images and view the internal anatomy of parts of the body (Hollingworth, et al). It is of great utility for measuring volumes in certain areas of the brain, since it can distinguish between white and gray matter and its images are 3-D, measured in units of voxels (like a pixel, but three dimensional). dMRI is typically used to examine white matter (Hagmann et al, 2006), while DWI is more commonly used for gray matter (Le Bihan, et al. 1986).

Secondly, brainwaves and the distinctions between the different types will be explained. Because alpha and beta brainwaves are primarily used in the neurofeedback therapies examined, these will be focused on. These two brainwaves are observed and used more extensively because alpha activity is thought to reflect attentional demands (Basar, 1997) and beta activity is thought to reflect cognitive processes, so they both have clear implications in disorders such as ADD (Cole and Ray, 1985) and general improvement of mental processing.

Lastly, but perhaps most importantly, this article will examine how electrical activity of neurons and synaptogenesis influence the neuroplasticity that underlies the clinical efficacy of neurofeedback therapy (NFT). The term electrical activity refers to the speed of action potentials, or electrical conduction, and the rates at which they occur (Ghaziri, 2013), both factors that influence the type of brainwaves EEGs detect and record. On the biological

side of things, it has been shown that changes in electrical activity can influence the myelination of axons (Ghaziri, 2013). Synaptogenesis refers to a positive change in synapse number, and sometimes includes changes in morphology (Markham and Greenough, 2004). Because neurofeedback can be seen as a way of enhancing ones environment, it makes sense that there would be increased neuroplasticity, as previous studies have repeatedly shown that mice placed in “enriched environments” containing paper, toys, and nesting materials, had more hippocampal neurons than those who were housed in empty cages (Kempermann, 1997). Both changes in axon myelination and synapse formation have been found as a result of neurofeedback therapy, and thus provide quantifiable evidence that supports the idea that it induces long-term neuroplasticity that is essential to the clinical effects.

Methods of Neurofeedback Therapy

Electroencephalography works through strategically placing electrodes on parts of the scalp and recording electrical activity and quantifying it in terms of brainwaves, the type of which depends on the frequency of the electrical activity. These voltage fluctuations result from the ionic current flows within the neurons of the brain (Niedermeyer, 2004). Magnetic Resonance Imaging (MRI) uses magnetic fields and radiowaves to form images of and examine the anatomy of different parts of the body. It allows for the diagnosis and treatment of many conditions in the medical field, however, neurofeedback therapy is most concerned with its ability to provide contrast between white and gray matter (Hollingworth, et al). fMRI takes the technology of normal MRIs, and adds a real-

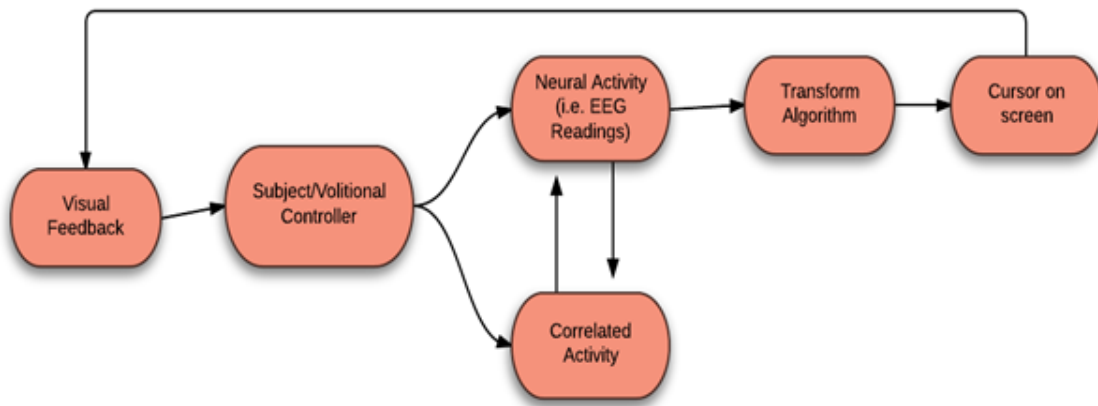


Figure 1 The basic components and processes of a neurofeedback paradigm. The transform algorithm is part of the brain-computer interface that transforms neural signals into visual feedback on a screen, such as moving a cursor.

Electrical Activity and Synaptogenesis of Neurons

time functional capability to it; it measures brain activity by detecting changes in blood flow to different regions of the brain. This technique is based upon the fact that blood flow in the brain and neuronal activity are correlated and that the blood oxygen level changes in areas in which it is being used (Huttel, 2009). However, the unit of measurement of the fMRI, a voxel, is 3mm x 3mm x 3mm, which is quite large compared to the size of a neuron, and it records data every 1-2 seconds, which is also very slow compared to the speed of electrical transmission along axons and between neurons. For these reasons, it is not a very specific form of measurement, though it has proven successful in some brain training methods (deCharms, 2007). Diffusion MRI (dMRI) is used to provide images of white matter structure and models of brain connectivity by mapping the diffusion process of various molecules, such as water, in-vivo and non-invasively (Hagmann, et al, 2006). This form of imaging allows researchers to view the changes in white matter by measuring the volume at the beginning and end of experimental trials. Diffusion weighted imaging (DWI) is similar, except that it is primarily used for measuring gray matter (Le Bihan, et al. 1986). So, to record activity of the brain and conduct neurofeedback therapy, EEG is used. By connecting the EEG electrodes placed on the scalp to technology that monitors the electrical output and sends it to brain-computer interface software that transforms the neural activity into some form of visual feedback, such as a moving cursor, patients can view and attempt to manipulate their brainwaves and investigators can study the recording patterns (Fetz, E.E., 2007). To record the brain volume in order to measure changes in it, MRI, dMRI, or DWI, are typically used. These methods allow neurofeedback therapy to happen, and for its neuronal effects to be measured and quantified.

Brainwaves: What are they and what do they mean?

Currently there are five types of brainwaves known: these are delta, theta, alpha, beta, and gamma. Each represents different frequencies of electrical activity, which are recorded by EEG machines. Gamma waves are the highest frequency waves, usually recorded around 20-80Hz (Bressler, S.L. 1990), while delta and theta are the slowest, at 0-3Hz and 4-7Hz respectively. However, most neurofeedback therapy targets beta brainwaves, which are recorded at 16-25 Hz and dominate focused waking states when attention is aimed at cognitive tasks and problem solving. When the brain is awake and alert, but not problem solving, alpha brainwaves, between 8-12 Hz, dominate (Cole

and Ray 1986). Not much is known about brainwaves, aside from the fact that they are due to the electrical activity of neurons and that, as previously stated, certain ones correlate to certain mental states. However, by focusing on targeting the brainwave associated with whatever mental state one hopes to practice maintaining (i.e. Beta for paying attention and problem solving), it is possible to use neurofeedback to ameliorate conditions such as ADD.

Electrical Activity of Neurons and Synaptogenesis

Synaptic interactions as well as their respective strengths and input signals contribute to setting the conditions necessary for oscillatory neuronal behavior, more commonly known as brainwaves, to occur. According to Lopes da Silva's observations, where neurons had synergistic oscillations in the beta frequency range, there were patches of enhanced correlations. Because oscillatory effects appear to be a highly effective manner of activating large populations of neurons (Lopes da Silva, 1991), it can be reasoned that, along the lines of Hebb's postulate, these neurons "fire together" and "wire together", thus facilitating the pattern of electrical conductance in the future.

It has been shown that electrical activity within an axon can modulate its myelination over a period of weeks (Ghaziri, et al, 2013), so it can be theorized that focusing on achieving a particular brainwave, for prolonged periods of time, the most common of which is around 30-40 minutes for NFT (Ghaziri, et al 2013), can induce an increase in white matter. Ghaziri, et al. used an NFT protocol that called for three sessions per week, at 30 minutes each, for 13.5 weeks. By comparing the results of the con group (no neurofeedback, and no guidance from researcher), sham group (fake neurofeedback, and guidance from researcher), and experimental group (accurate neurofeedback and guidance from researcher), it was found that NFT led to a significant increase in both white and gray matter. EEG was used for the neurofeedback, while MRI was used to image both white and gray matter volume, and dMRI was used to more specifically examine the white matter.

The idea that the electrical activity of neurons within the CNS affects the myelination of axons, and thus the volume of white matter, is further supported by studies that show that myelin can be inhibited or enhanced by either blocking the action potentials of neighboring axons, or by enhancing their electrical activity. Administration of tetrodotoxin (TTX), and action potential inhibitor, can also induce a dramatic inhibition of the level of myelination, and its subsequent removal allows for recovery of electrical

activity that allows myelination to proceed again (Demerens, 1996).

Any type of sensory experience alters the brain in some way. However, it has been shown that experiencing repeated neurofeedback therapy can induce measurable, morphological changes. Alterations in gene expression and the physiology of the associated neurons often accompany environment-induced reorganization of brain connectivity. This all goes hand in hand with the evidence supporting that electrical activity influences neuroplasticity. Because action potentials cause the release of neurotransmitters, and these neurotransmitters often trigger second messenger cascades within the cell that ultimately affect gene expression, it is very possible that changing patterns of electrical activity can alter genes. In fact, several activity dependent axon signals have been proposed to initiate myelination, including ATP and the neurotransmitters glutamate (Butt and Tutton, 1992).

The results that show increases in both white and gray matter from Ghaziri et. al. support that neuroplasticity remains possible well into adult life – a relatively new concept given that not too long ago people believed the brain to be analogous to a computer and unable to change. The change observed in gray matter is thought to be due to synaptogenesis, or the formation of new synapses. It has been shown that experience can modify the morphology of synapses and contribute to the formation of new ones or loss of old ones (Marham, 2004), so neurofeedback therapy could very well function in this way. Furthermore, changing the shape of dendritic spines can often influence a change in their conductive properties (Markham, 2004), which could ultimately tie into the subsequent modification of myelination. This possibility implies that changes in gray matter can influence changes in white matter.

Brain-derived neurotrophic factor (BDNF) also likely plays a role in the neuroplasticity accompanying NFT. Referring back to the brains of the mice housed in enriched environments, along with their increased numbers of hippocampal neurons, it has been found that these rats also showed increased levels of BDNF. Though the correlational relationship has been found, the causal relationship between BDNF and neurogenesis is still being determined. However, Markham and Greenough found that BDNF is critical for use-dependent synaptic plasticity, and Mizuno et al have found that it regulates both short and long-term potentiation (Mizuno, 2007). This data all support the idea that neurofeedback therapy works by causing changes in white and gray matter that are due to neuroplasticity, which

is generated by a myriad of biological mechanisms.

CONCLUSION

The neuroplasticity thought to underlie the clinical efficacy of neurofeedback therapy is likely due to synaptogenesis and varied electrical activity of neurons. This review intended to analyze the relationship between how neurofeedback therapy is conducted and the neural substrates underlying how and why it works. By examining a variety of research articles, it can be concluded that NFT has concrete biological underpinnings that are slowly but surely becoming elucidated. A more thorough understanding of how this therapy works should lead to an increase in its popularity, and hopefully an increase in precision of treatment methods. The implications of this type of therapy are vast and appear highly beneficial in clinical settings. The risks are much lower and the benefits much longer-term than pharmaceutical or surgical therapies. The brain has an amazing ability to adapt and change itself to environmental demands, and NFT aims to utilize this. Research in this field should continue towards gaining a deeper understanding of how neurofeedback works in the brain and how to accurately use it to manipulate neuroplasticity. It should also examine how pharmaceuticals might be able to enhance the effects of NFT, and how NFT can enhance pharmaceutical use or recovery after surgery. By doing so, the amount of clinical therapies to choose from when faced with ailments of the brain will be greatly expanded.

Electrical Activity and Synaptogenesis of Neurons

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The Arcane and The Rational: Lovecraft's Development of a Unique Mythos



Photo courtesy of Dave Heuts, Flickr, 2009

Dale Allen Crowley

ABSTRACT

The early 20th century saw the rise of a unique sub-genre of science fiction and horror literature known as weird fiction. H.P Lovecraft, one of its more prolific and lasting contributors, is rightly considered one of the fathers of the genre. Like the rapidly modernizing world around him, Lovecraft developed his own universe and mythos that was itself a unique mix of old and new. He created monsters that would have been at home in fairy tales or the ancient mists of folklore. At the same time, these ancient, mythic evils were at odds with Lovecraft's 20th century protagonists – men of education, breeding, and science. The inevitable result of their clash was death and madness on the part of the protagonist.

Prior to Lovecraft, literature portrayed ancient religions and gods as benevolent protectors of mankind and the devout. Lovecraft subverted this and instead argued that the cosmos, and the god-like beings that reside there, are indifferent to the plight of man. Tempered by his own rationality and atheism, he created a world that was unique only in its insignificance. An avid reader, Lovecraft

understood the prior works of writers like Milton and Dante, and the concept of higher and lower worlds that bookend our own place in the universe. Heaven, hell, and the earthly world were places of equal size and influence. However, Lovecraft's writing rejected this and instead minimized the human realm to a sliver, sandwiched between the pitiless depths of an indifferent underworld below and an infinite, cold, and remorseless cosmos above.

This paper studies how, through stories like "The Call of Cthulhu," "At The Mountains of Madness," "The Shadow Over Innsmouth," and others, Lovecraft redefined both weird and traditional fiction. While perhaps unintentional, he nevertheless established new perspectives on science fiction and horror.

THE ARCANES AND THE RATIONAL: LOVECRAFT'S DEVELOPMENT OF A UNIQUE MYTHOS

In the early 20th century, a unique sub-genre of fiction emerged on the pages of magazines with titles like *Weird Tales* and *Astounding Stories*. The stories found therein were lurid tales of space exploration, alien monsters, ancient horrors, and strange worlds that bore an eerie and uncanny similarity to our own. These stories laid the basis for what would become the genre known as weird fiction. A mongrel mix of science fiction, fantasy, and horror – and sometimes all three – the stories contained within these “pulp” magazines laid the groundwork for the work of later writers, and some of them were the precursor to what would become a widely accepted subgenre of horror literature. It was amidst this exploration of unique fantasy and horror that one eccentric, bookish writer rose above his contemporaries. Through his writing, Howard Phillips Lovecraft, a reclusive descendant of New England's founding fathers, created a unique mythos that remains an indelible part of horror writing and popular culture.

Much has been written of Lovecraft – of his introversion, his quaintly anachronistic Victorian principles, and his reluctance to publish his work – and his legacy remains an undeniable part of American literature. The period during which weird fiction arose was unique, and Lovecraft and his fiction represented that uniqueness. Lovecraft was a patrician: a man born out of his time who lived his life as an English gentleman. At the same time, he was a rationalist, an atheist, and a learned man of scientific bent, with a love for astronomy and the hard sciences. These seemingly incongruous worldviews, rather than hindering him creatively, were what made him so powerful a writer.

Lovecraft's writing can be divided into three distinct periods. The first two consisted of less original works, pastiches of his two greatest influences: Edgar Allan Poe and Edward John Moreton Drax Plunkett, the 18th Baron of Dunsany (De Camp, 1975, p. 151). It was during his final period, however, when Lovecraft grew into his own as a writer and contributor to horror fiction. Commonly referred to as the *Cthulhu mythos* period in reference to his story and creature of the same name, this latter part of Lovecraft's life – beginning roughly around 1925, after the dissolution of his marriage to Sonia Greene and his return to Providence from New York – is when his literary mastery reached its zenith (Joshi, 1997, p.6). To be precise, however, it should be noted that there is some

overlap in the periods and that he composed literature indicative of the Cthulhu mythos period throughout his life, but the lion's share of the works that are now considered as classic Lovecraft were mostly written after 1925.

In the early 20th century, there was a powerful amalgam of science both at odds with and in reconciliation with the “old” and mythical. It was also a time of exploration, as there were still unexplored swaths of wilderness or barren locale and empty places on the map – places of mystery, wonder, and, possibly, terror. Likewise, Lovecraft's monsters were beings of science, but also mythical in proportion. The people populating his universe were exemplary of this dichotomy as well – Lovecraft's tales feature men of science, scholars who find solace in their knowledge and comfort in their modernity, as well as the backwoods voodoo of the uneducated and illiterate. Lovecraft's heroes were reflections of himself – quiet, reposing, scholarly gentlemen who face the incomprehensibly backwards myths of a world long gone. The result of this irreconcilable mixing of the old and new was invariably madness and death for the protagonists and supporting characters.

While there are three distinct traits that make Lovecraft's Cthulhu mythos unique, the focus in this paper will be on the Cthulhu mythos, the development of Lovecraft's unique literary mythology, and the role that location played on the development of his unique vision. Specifically, this paper will explore how Lovecraft's worldview, his atheism, and his rationality subverted the standard archetypes of classical literature to create a distinctly different universe – a modern take for the 20th century, as it were.

Prior to Lovecraft, the gods were looking out for us. Literary heroes were likely to survive because the gods were benevolent. Lovecraft changed that – he wrote of the indifference of the cosmos and the insignificance of man. Despite several thousand years of religious belief and the inherent hubris of humanity, Lovecraft posited that humankind, instead of being unique and the masters of all we see, was, in fact, insignificant when compared to the backdrop of the larger universe.

Religious writings have argued that we are the center of the universe, but science has argued otherwise, and Lovecraft's fiction falls squarely on the side of science. To Lovecraft, we are not the center of the universe; our impact on a cold and unforgiving universe is infinitesimal. Lovecraft said as much himself when he wrote to Farnsworth Wright, editor of *Weird Tales*, in July 1927:

Now all my tales are based on the fundamental

premise that common human laws and interests and emotions have no validity or significance in the vast cosmos-at-large. To me there is nothing but puerility in a tale in which the human form – and the local human passions and conditions and standards – are depicted as native to other worlds or other universes. To achieve the essence of real externality, whether of time or space or dimension, one must forget that such things as organic life, good and evil, love and hate, and all such local attributes of a negligible race called mankind, have any existence at all (Joshi, 2012, p.102).

Lovecraft was aware that he was developing his own unique mythology. He was a voracious reader, self-educated, and amazingly literate, and was undoubtedly aware of earlier explanations of the universe. The order and makeup of the world had been written about before in myths, but Lovecraft was moving in a different direction.

The mythological world, and the plane where humans exist, has been explored numerous times throughout written history. However, there has been some commonality to the structure. At its simplest, the world is divided into realms: heaven, hell, and the central realm where humanity dwells – what was known in Old English and ancient Norse mythology as Midgard. This same Midgard, which J.R.R. Tolkien would put to use in the 1930s as Middle Earth in his own opus, *The Hobbit* and *The Lord of the Rings*, is a special place between the celestial bookends of the upper and lower worlds. This motif has resonated throughout literature, whether in the medieval concept of the hierarchal Chain of Being, or the delineated worlds of Milton in **Paradise Lost**. As Northrop Frye (2009) explained,

...the physical world has usually been not only a cyclical world but a “middle earth” situated between an upper and lower world... The upper world is reached by some form of ascent, and is a world of gods, or happy souls.... The lower world, reached by descent through a cave or underwater, is more oracular and sinister (p. 58).

In other words, this particular mythological view has been divided between a higher plane of good, where gods and angelic beings reside, a lower plane, Hell, where torment and demons await, and the middle ground, where we toil and strive to ascend. Earth and natural life reside in Middle Earth. There is also the underground, or underwater world, which is a place of punishment and darkness. It

is from here that we must ascend – as Virgil wrote, “It is easy to go down into Hell; night and day, the gates of dark Death stand wide; but to climb back again, to retrace one’s steps to the upper air – there’s the rub, the task.”

Lovecraft, while undoubtedly aware of this historic literary view, altered it to better match his own worldview. The changes, while subtle, were powerful in their implications. Lovecraft’s view of the mythological world was tempered by his own love for science and his own atheism; thus, Lovecraft did not have an upper level: There was no heaven. To Lovecraft, humanity is sandwiched between the dead, forgotten underworld and the cold, uncaring cosmos or higher level. As Fritz Leiber observed, “[Lovecraft] ... altered the focus of the supernatural dread from man and his little world and his gods, to the stars and the black and unplumbed gulfs of intergalactic space” (Joshi 2012, p. 103).

Examples of this worldview can be found in Lovecraft’s preference in the Cthulhu mythos for abandoned, forgotten places and the chance encounters his characters have with the cold and uncaring universe. In “At The Mountains of Madness,” a scientific expedition to Antarctica uncovers a monstrous mountain range and the remnants of an ancient city. There, amidst the unforgiving ice, the expedition discovers the corpse of a resident of the ancient city, a barrel-shaped and winged creature known as an “Old One.” The narrator, Professor William Dyer, and another member of the expedition arrive at the newly-established camp after the discovery only to find their comrades and their sled dogs dead, horribly mutilated by the Old Ones who were not dead, only frozen. The scientists, in their zeal for knowledge, had thawed them.

Left to their own devices, Dyer and Danforth explore the city and discover through the study of the ruins and bas-reliefs in the Old Ones’ city that the Old Ones themselves were not the greatest threat. The Old Ones, as horrible as they were, were destroyed by their own creations, slaves and beasts of burden called shoggoths. Dyer and Danforth go deeper and deeper into the ruins, only to find a shoggoth. They flee the city, pursued by the creature, a horrifying, unnatural, insanity-causing “formless protoplasm” (Lovecraft, 2010, p. 312).

In “At The Mountains of Madness,” we see some of the hallmarks of established mythology. In fact, while the Antarctic was a frequent location for pulp fiction of the era, Lovecraft went beyond the normal representation of it as a barren locale devoid of humanity. Elizabeth Leane (2005) observed in her article about the Antarctic as an alien space that Lovecraft, in placing “At The Mountains

of Madness” where he did, centered his classic story on ideas and images that link the story “...with earlier literary and mythological constructions” (p. 227). Not only is there the earth and its inhabitants, represented by the scientific expedition, but there is also the labyrinth beneath the Old Ones’ city, representative of the underworld and a place of darkness and terror. However, Lovecraft altered the standard by giving the location a cosmic origin. The Old Ones came to Earth millennia ago from the stars. They were not of this earth, nor from heaven. They had God-like powers in their ability to manipulate genetics and create another race, much as God did with Adam and Eve. However, the creation of the shoggoths was less a matter of divinity and more one of practicality. The shoggoths were simply a ready-made workforce that rose up and threw off its masters.

The idea of tombs and underground catacombs that hide ancient secrets is replete throughout Lovecraft’s fiction. Whether it is the underworld of the city of the Old Ones in “At The Mountains of Madness,” or the forgotten tombs beneath the Australian desert in “The Shadow Out of Time,” or the horrifying catacombs beneath the Exham Priory in “The Rats in the Walls,” Lovecraft created an underworld of mind-boggling antiquity and decidedly inhuman origin. The underworld and the things found there supersede and deny human religions.

It is this denial of religion for the cold logic of science that separates Lovecraft’s fiction from the earlier representations of the Chain of Being. Lovecraft was an unrepentant atheist. He was a disciple of science, with a special love for astronomy and chemistry. As Joshi observed, “The entirety of Lovecraft’s philosophical (and perhaps even literary) career can be seen as a gradual weaning away from the dogmatism, positivism, and optimism of the late nineteenth-century science, art, and culture to the indeterminacies of relativity and modernism” (Joshi, 1997, p. 5). In other words, Lovecraft was a man of the 20th century. His writing style and political views were anachronistic and Edwardian, but his scientific and religious bent clearly leaned towards the darker and more pragmatic realism of the day.

This realism and denial of religiosity was reflected in the mythology Lovecraft created. In his decidedly areligious mythology, Midgard is a thin precipice, a tiny island of humanity occupied by chance. Instead of being the center of the universe and the beloved of a benevolent God, we are here solely at the whim of the ‘others’ – monstrous creatures to whom we are inconsequential. To these creatures, we are, at best, ants scurrying about, and, at worst, a food source. On the other side of this equation, for us there is no reward

for good behavior. The closest we come to Paradise in Lovecraft’s vision is through his Dunsanian-like Dreamlands from earlier in his writing career, which he abandoned as pretentious later in life as he developed his Cthulhu mythos.

Further support for the idea of an underworld or underwater world where the horrors of the cosmos lurk hungrily can be found in the sea-related stories of the Cthulhu mythos, specifically, “The Call of Cthulhu.” The most well-known example of Lovecraft’s unique mythology, this story was built gradually throughout his writing career. There are images of it in the earlier story, “Dagon,” and there are echoes of both stories in “The Shadow Over Innsmouth.” “Dagon,” while preceding the accepted beginning of the Cthulhu mythos era of Lovecraft’s writing, was the genesis for the mythology he would later be credited with creating. Though written at the onset of his career, it has been observed that:

“Dagon” plants the seeds for not only the nature of his mythos creatures, modes of narration as in the epic journeys and telling pre-history via archaeological remains, “Dagon” even hints at the cosmic view which underlines the later developments in the mythos and which has been averred to be the true nature of the nebulous link between what are known as the mythos stories” (St. Pierre, 2004, p. 17).

“Dagon” was, in other words, the seed that grew into “The Call of Cthulhu.”

“The Call of Cthulhu” represented a seismic shift in Lovecraft’s writing and the mythology previously discussed here. As Joshi observed in his lecture *Poe, Lovecraft, and the Revolution in Weird Fiction*, “The Call of Cthulhu” changes everything because it introduces to Lovecraft’s work a “... coherent and plausible use of the theme that would come to dominate his subsequent tales: alien races dwelling on the underside of the known world (Joshi, 2012). In “The Call of Cthulhu,” Lovecraft uses the ocean and its black, unfathomable depths as a stand-in for the tombs, catacombs, and underground hells in which we find his loathsome alien creatures.

“The Call of Cthulhu” is a study in perfection in terms of Lovecraft’s mythology. The story builds slowly and the mysterious evil of the sea stands as a surrogate to the cold expanse of outer space. Cthulhu is a being that came to Earth before history and that still lives, sleeping beneath the waves. As he occasionally turns, coming close to wakefulness, his dreams cause madness and terror around the world. The narrator, Francis Waylon Thurston,

recounts the story of having become the executor of his late great-uncle, Professor George Gammell Angell of Brown University. It is in the late professor's papers that the narrator discovers and resumes a quest begun by his great uncle. The story builds with a methodical pace and we learn that Cthulhu – Lovecraft's greatest creation – is an alien worshipped by voodoo tribes in the steamy swamps of Louisiana, and by degenerate Esquimaux tribes in the Arctic north. Thurston eventually learns of a harrowing, terrifying encounter between the creature and a crew on a merchant ship. This story contains many of the elements for which Lovecraft is well known: the *Necronomicon*, the mad Arab, Abdul Alhazrad, and Cthulhu himself, a creature that embodies all that Lovecraft hated about the ocean.

Lovecraft's hatred for the sea was well known. He hated seafood in all of its forms, and that hatred extended to its source. De Camp (1975) observed that Lovecraft "often used the sea, along with the cold, wet, and darkness as a symbol of evil in his stories" (p. 78). Indeed, Lovecraft himself once said to Donald Wandrei, "I have hated fish and feared the sea and everything connected to it since I was two years old" (p. 78). It is this hatred that makes the sea-related Cthulhu mythos stories so wondrously chilling. "The Shadow Over Innsmouth," while less a Cthulhu mythos story than others mentioned, still manages to capture the horrifying, alien quality of Lovecraft's demons. The demons of his mythology, as opposed to the fallen angels of classical literature, are outside of human understanding and definition. The croaking, bleating Cthulhu, or Dagon-spawned monsters of this and Lovecraft's other sea stories, only further reinforce this mythology. We now have the yawning chasm of an uncaring cosmos above us, and the dark depths of earth below us. Add to that the forbidden, cold waves of monster-filled oceans that surround us, and Lovecraft has effectively bound us on all sides by evil and horror. Midgard, classically a place of light and human residence, is suddenly a sliver in an indifferent universe.

In almost all of Lovecraft's stories, the narrator or protagonist is a scholar, someone of high education, good social breeding and standing, and possessor of a healthy skepticism. In other words, the characters are, in many cases, reflections of Lovecraft himself. His rationalism and disdain for religion in all its forms built upon established classical mythology and resulted in something new and revolutionary. The reflectiveness of his narrators only scratches the surface. Lovecraft's mythology is also a reflection of his own worldview, his own feelings of alienation. It is a profound recognition of the changing face of horror

literature in the early part of the 20th century. As Joshi remarked, "The previous century's stories of the ghost, the vampire, the werewolf, the sorcerer, the haunted house, and so on... had simply become too implausible in the wake of advancing human knowledge" (Joshi, 2012, p. 103).

At the time when weird fiction was growing and becoming a literary sub-genre on its own, Lovecraft was redefining both it and what had come before. While he may not have meant to do so, he established a new way of looking at science fiction and horror. He may have been simply looking to tell a good story, but his encyclopedic knowledge of classic and contemporary literature was such that he developed a new view of our place in the universe. As Lovecraft himself said in *Supernatural Horror in Literature* (2012), "The one test of the really weird [story] is simply this – whether or not there be excited in the reader a profound sense of dread, and of contact with unknown spheres and powers; a subtle attitude of awed listening, as if for the beating of black wings or the scratching of outside shapes and entities on the known universe's utmost rim."

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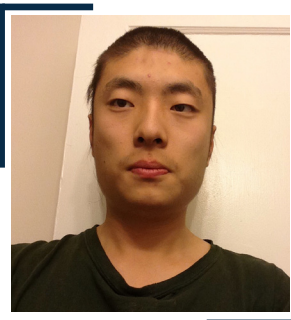
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BIOGRAPHY

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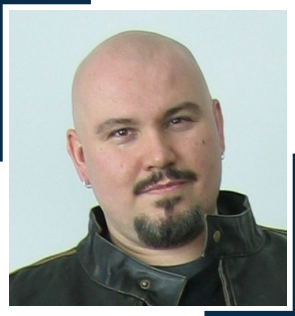
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Dale Allen Crowley graduated summa cum laude from Baldwin-Wallace University with his Bachelor of Arts in English in December of 2014. He is a member of the Sigma Tau Delta English Honor Society and plans to pursue a Master of Arts in English Literature in the fall of 2015. His planned area of study focuses on American and British horror, science fiction, and fantasy literature. He has published two novels- "North Coast Gothic: A Grim Fairy Tale" and "A Darkness Within" - as well as several short stories and poetry in both print and online magazines.

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