Diagnosis of Autism using resting-state fMRI

Analysis of the impact of psychology in combination with technology on society through behavioral microtargetting

A Thesis Prospectus Submitted to the

Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements of the Degree

Bachelor of Science, School of Engineering

,

Technical Project Team Members

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

Autism is a developmental disorder characterized by challenges with social skills, repetitive behaviors, speech, and nonverbal communication. The CDC estimates that as of 2020, autism spectral disorder affects around 1 in 54 children in the United States. This prevalence is not evenly distributed among all groups of people, as boys are 4 times more likely to be identified with Autism Spectrum Disorder than girls (CDC, 2020b). Although autism diagnosis is becoming more evenly prevalent in disadvantaged communities, there is still a large disparity in the resources available to properly diagnose and care for individuals with ASD. Current methods of diagnosis include a wide variety of diagnostic screens heavily dependent on the knowledge and involvement of both the attending physicians and the patient's parents (CDC, 2020a). Thus, the accuracy of diagnosis can range heavily from case to case and disproportionately affect those with less resources. Also, since most diagnostic tools used involve behavioral screening, it is often difficult to properly diagnose due to patient age and outside influences. The goal of this research is to design an algorithm to classify ASD using data from resting-state fMRI scans.

The STS project is focused on analyzing the impact of the combination of psychology and technology on society through behavioral microtargeting and using the LTS framework to model and predict the future direction of the field. It is expected that the research will reveal the lack of public knowledge on the applications of the field relative to the increasingly large impact the field has on most members of the developing world's everyday lives. The future prediction will be that the influence of the field will only increase with time, and best practices for minimizing the negative impact of the new developments, while maximizing the potential for positive impact will be explored and presented.

Technical Topic

To overcome some of the problems that arise with current methods of ASD diagnosis, many researchers have focused on using various methods of brain scans to create a more accurate tool for diagnosis. One of the prevailing methods being explored is the analysis of fMRI data to diagnose and better understand ASD. Functional MRIs measure the use of oxygen in different regions of the brain by taking advantage of the different magnetic properties of oxygen-rich and oxygen-poor blood. The two major types of fMRI scans are task-based and resting-state. Task-based fMRI scans follow the patient's change in brain activity as they try to complete a task. For example, patients may be asked to respond to a variety of prompts or simply watch a slideshow of images. For the diagnosis of a behavioral disease like ASD, one would think that task-based fMRI would be the preferred method of scanning. However, some major issues with task-based fMRI include high heterogeneity among studies and the need for active patient compliance, which is often difficult when working with young patients. Resting-state fMRI scans involve measuring the activity of different areas of the patient's brain when they are not in a task. Thus, the goal is to explore the way that the different regions of the brain interact with each other independent of outside influence. For ASD diagnosis, the idea is that the human resting-state connectome will be different for people with ASD than control samples. Although resting-state data is less heterozygous and thus more likely to have clinical potential, the data can still vary in multiple ways mainly scanning parameters, such as MRI machine, scanning time, and scanning time intervals. Since resting-state fMRI analysis has a higher probability of clinical applicability, most attempts at ASD classification use it instead of task-based fMRI.

Machine learning has revolutionized a wide variety of fields in the past decade and has the potential to increasingly dominate tasks once deemed computer impossible. Machine vision saw its largest innovation with the development of the convolutional neural net. Convolutional neural nets allow computer algorithms to learn to detect patterns within a certain spatial area. For most machine vision tasks, this mostly involves detecting object borders or proximal spatial patterns, such as texture. A comparable innovation was more recently developed in the context of Natural Language Processing. The Transformer model architecture has allowed computer interpretability of language to extend far beyond previous NLP technologies (Vaswani et al., 2017). Many researchers are focusing on the use of novel Machine learning techniques to analyze fMRI data.

Most applications of machine learning in the analysis of biomedical scanning data fall safely within the domain of Machine Vision. These applications can vary from organ segmentation to disease diagnosis. However, most of these tasks simply require the training of contemporary machine vision algorithms, sometimes with slight tweaks, to achieve cutting edge performance on these biomedical tasks. The field of fMRI analysis differs greatly in this regard. One of the largest hurtles with fMRI analysis is the dimensionality of the data. Function MRI data is inherently 4 dimensional, 3 spatial dimensions and one temporal. Most machine vision algorithms are focused on the analysis of two-dimensional images. The analysis of 3-dimensional data is becoming more prevalent in the machine vision, but the analysis of 4-dimensional data is still largely rare. As well, the goal of fMRI analysis is not only to find spatial

patterns within the brain at given time points, but it is to find temporal-spatial patterns throughout the scan.

To tackle the problem of dimensionality within the data, researchers have looked to a wide variety of techniques. To reduce the data spatially, many algorithms focus on the utilization of brain atlases to map voxels (3D pixels) to functional areas of the brain. These atlases are often automatically generated through unsupervised machine learning techniques, such as clustering, but can also be manually generated based on functional brain studies. Then, the spatial component of the brain can be summarized by the activation of different areas of the brain, which are often represented in a graph. Another approach commonly taken by researchers is to reduce the temporal dimensionality of the data through decomposition techniques, such as Independent Component Analysis (Khosla et al., 2019). Once a dimensionality reduction technique has been implemented, a modeling algorithm is applied. Common approaches include the use of standard machine learning classification algorithms, such as support vector machines with kernels. Researchers are beginning to utilize neural networks for this step of the analysis due to their ability to extract meaningful features from complex data (Dekhil et al., 2019; Heinsfeld et al., 2017; Hull et al., 2017; Khosla et al., 2019; Lau et al., 2019; Thomas et al., 2020).

Despite a lot of progress within the field, automatic ASD diagnosis using resting-state fMRI data is still far from achieving the accuracy required to implement diagnosis in a clinical setting. State of the art accuracy on the ABIDE dataset, which is the largest dataset of ASD vs. control patients, is around 70%. Many algorithms are able to achieve higher accuracies on smaller datasets, but they fail to generalize when applied to other datasets. To overcome this overfitting of data, this research is focused on the exploration of the Transformer architecture to assist resting-state fMRI classification. The power of the Transformer comes from a novel machine learning technique called attention. Attention allows the meaning of an input to a follow up algorithm (classification in this case) to change based on the other inputs given at the same time (Vaswani et al., 2017). For Natural Language Processing, an input is commonly a word and the change due to attention is based on the context (other words) in which the word is given. For resting-state fMRI analysis, an input will be the activation of a brain region and the context will be the entire state of the brain activity at that given time. The Transformer embeddings are able to be learned on a generic dataset and then applied to a more specific downstream task. In this case, a Transformer will be trained on the tasks of predicting if a brain state is the correct next brain state and predicting the activation of masked brain regions within a brain state for a wide variety of patients (mostly control) with the most frequent scanning parameters. This will allow the Transformer to create brain region embeddings that carry temporal and spatial information as well as adaptability to differing brain states. Once the Transformer is trained, the embeddings will be used to classify ASD vs. control resting-state brain scans from the ABIDE dataset.

The success of this machine learning tool will not only increase the accuracy of ASD diagnosis, but will also improve the analysis capability of fMRI data for a wide variety of tasks. This technology will allow researchers to further interpret the resting-state connectome with increased generalizability and resistance to scanning artifacts.

STS Prospectus

Introduction

New developments in many technical fields throughout the decade have revolutionized the way people live and empowered people to accomplish tasks never thought possible before. This cannot be seen any clearer than in the field of machine learning. New machine learning tools have allowed developers to not only automate systems previously thought only human accomplishable, but they have also given developers the resources necessary to build systems way beyond the scope of human capability. The possibilities of applying these technologies to solve real world problems seem endless. However, just as quickly as these technologies increase in their ability to improve the world around us, their power to harm us increases. This research is specifically focused on the capabilities of new technology combined with increasingly developing psychological knowledge to affect individuals through behavioral microtargeting.

It is vital that the current and potential future effects of these developing fields be analyzed to ensure that proper regulation and public knowledge exist to prevent widespread human harm whether intentional or accidental. Current applications of this crossover field range heavily and impact almost every person in the developed world. The largest current application of the field is targeted online advertising. Whether the advertising is commercial or political in nature, it likely is implemented using a combination of emerging technologies and knowledge of human psychology. Most of these advertisements are largely harmless and do not greatly impact the targeted individual's life. However, targeted advertising has the power to make large influences on the public, especially when looking at the public as a whole instead of individual participants. The ex-political consulting firm Cambridge Analytica played a major role in influencing hundreds of elections globally. They did this through acquisition of Facebook user data and individual psychological targeting. Although Cambridge Analytica does not exist anymore, many companies, such as Auspex International and Emerdata, have risen to take advantage of the hole the fall of Cambridge Analytica left. The power of such tools is only going to increase as knowledge of the human psyche is learned and our lives become increasingly digital.

Research Question

The goal of this research will be to explore different questions to help bring light to the current ways in which psychology is used in combination with emerging technologies to influence people's lives through behavioral microtargeting and to explore future potential applications. This knowledge will help make people more aware of the largely unknown influences that they experience on a daily basis. Exploring the future direction of the field will help individuals and governing bodies properly address this newly arrived danger without limiting the potential for good. The questions that will be investigated are:

1. How is behavioral microtargeting to influence people's actions?
2. What groups of people are most susceptible to the influences of this technology?

3. How can individuals reduce their susceptibility to influence from this technology?
4. What is the public knowledge and perception of these emerging technologies and their impact on society?
5. What are the largest potential impacts of the field given the current direction of development?
6. Who are the most powerful stakeholders when deciding the direction of the field?

The answering of these questions will help show the current influence of the field and some possible ways the field may develop. I hypothesize that this research will show that the influence of this field is far reaching and personally invasive in many regards. As well, the influence of the technologies will not be evenly distributed among different demographics. Most people are not sufficiently knowledgeable about the field to truly consent to the influences it has on their thoughts and actions. The most powerful stakeholders are likely large corporations that design and run the majority of the applications of this field. However, there are many more stakeholders than just those corporations, and the power dynamics of the technological development system are likely to change over time.

Literature Review

The recent growth in the use of psychology in combination with technology has drawn interest from a wide variety of researchers. Most of the research is concerned with the psychological affects that technology has on individuals instead of the way psychology is utilized. In many cases the technology having the largest psychological impacts also utilizes psychological techniques to improve engagement of their users. In *The Emerging Nature of Psychology of Technology*, Kool et al. look at the new reality created by technology and criticize the lack of knowledge surrounding the psychological impact of this augmented reality (Kool & Agrawal, 2016; Montag & Diefenbach, 2018). Many other researchers share similar concerns for the lack of knowledge within this newly emerging field. G. Soldatova utilizes a variety of data sources to study the impact technology has on a developing person's features of cognitive and personal development, relationships with the outside world, social, and cultural practices in *Digital socialization in the cultural-historical paradigm: a changing child in a changing world* (G.u, 2018). While these authors are mostly focused on the psychological impacts of technology, other researchers focus on an ethical perspective of these newly emerging technologies (Aizenberg & van den Hoven, 2020; Rességuier & Rodrigues, 2020). Both of these works study the numerous human rights issues produced by recent developments in Artificial Intelligence. Both of the authors share a concern for the lack of ethical based control in the current field. In *Emotional AI, soft biometrics and the surveillance of emotional life: An unusual consensus on privacy*, Mcstay addresses the rising issue of data on the emotional states of individuals. Current practices require the anonymization of such data, but Mcstay expresses concern for the lack of regulation surrounding the privacy of this individual emotion information (McStay, 2020). This data could prove to be extremely useful for psychographic analysis. Thus, it is very important that proper practices and regulations exist to ensure that it does not fall into the wrong hands.

Although most researchers are focused on minimizing the negative psychological impacts of current technological practices, some researchers are working to create new systems to improve overall impact on society. In *Contesting algorithms: Restoring the public*

interest in content filtering by artificial intelligence, Elkin-Koren starts by analyzing the potential impacts of automated content censorship on the general public (Elkin-Koren, 2020). The paper specifically focuses on the black box nature of most of these approaches and the public's increasing distrust of such systems. Finally, a new contesting algorithm is proposed as a potential solution to maintain the benefits of automated content filtering, while restoring the societal power to deliberate and determine social tradeoffs. The powerful influence of technology in our everyday lives does not need to have a negative impact on our psyche. This is the perspective of researchers who are dedicated to utilizing technology and psychology to improve overall human psyche (Muñoz, 2019; Villani et al., 1 C.E.). Muñoz emphasizes the never before seen widespread global influence that technology has on the psyche of people in their everyday lives. While this influence is largely negative currently, the authors analyze the potential positive psychological influence of technology arguing that psychology and technology can be harnessed together to contribute to making health care a universal human right.

Current public concern regarding the use of psychology in combination with technology is largely focused on political advertising. In *Political Advertising as a Factor of Socialization in Modern Society*, Yaneko gives a general overview of the creation of targeted political advertisements (Yanenko, 2020). The overview focuses on the modeling of expected audience behavior using socialization patterns to predict the audience's views of the future and properly tailor the presentation political messages to be best received by the audience. The most notable instance of public outcry within this field of technological development was the Facebook-Cambridge Analytica data scandal. Cambridge Analytica was a British political consulting firm that was involved in hundreds of elections globally, including working with the Trump campaign. The scandal not only brought to light data privacy concerns, specifically within the Facebook API framework, but also more general concerns regarding behavioral microtargeting and its impact on the ability of people to participate as informed citizens and consumers (*Cambridge Analytica and Our Lives Inside the Surveillance Machine | The New Yorker*, n.d.; Isaak & Hanna, 2018). In *Cambridge Analytica, independent research and the national interest*, Laterza argues that the role of Cambridge Analytica in the influencing of elections has been downplayed by U.S. government officials and British academia due to the Western military and security funding sources of much of the psychological research at Cambridge that led to the founding of Cambridge Analytica. He also argues that the influence of Cambridge Analytica in African, Middle Easter, and Asian elections has been downplayed to further coverup the Western exploitation of these regions largely by European countries.

Although the capabilities of current user behavioral modeling techniques are incredible, development within the field is only speeding up. Kotras takes a comprehensive look at the current field of personalized marketing algorithms by revealing how consumers are modeled by different companies (Kotras, 2020). It is also discussed how pre-existing consumer information is best utilized to optimize marketing within this new mass personalized marketplace in ways that were previously infeasible. One attempt at personalized neural representations called DimensionRank focuses on creating an optimized search tool for both general search and social media products (Coppola, 2020). The technology works by creating a vector representation of each individual user that can be utilized to predict best online feed content. This neural representation technology has many potential applications than just search, such as insurance and political modeling. While this literature review has largely focused on technical developments that have driven the applications of psychology, there have also been significant psychological research developments that have the potential to greatly revolutionize the way

humans are algorithmically modeled. In his book *Thinking, Fast and Slow*, Kahneman models the human brain as having two separate functional parts (Kahneman, 2013). These parts dominate in different instances and determining the participation of each part in contributing to our actions can result in more accurate predictions of human behavior in many edge scenarios. Psychological developments such as the ones presented by Kahneman have the potential power to improve individual behavior prediction and highjack human subliminal consciousness to result in non-logical decision making.

STS Framework and Method

The Large Technical System framework will be used to analyze the research topic presented in this proposal. This framework was chosen to model the development of the field so far with hopes of utilizing this model to predict future developments within the field. The LTS framework's focus the incremental impact of system builders will prove vital for modeling the technological progress and direction. As well, modeling the general consuming public as a system builder will help represent the impact that public opinion has on the technology and the way the technology is presented to increase the social adaption of the technology.

The majority of the research will be done through document analysis. The two main goals will be analyzing the current applications of the field and evaluating potential future applications based on emerging technologies and new psychological developments. The second source of data for the research will be a survey and interviews. The goal of these data collection methods will be to gauge the public knowledge and opinion of the research topic. One possible technique to gauge public knowledge will be asking factual questions regarding current applications of the field. The interviews will be targeted towards collecting public opinion on the subject from a variety of perspectives.

Timeline

Since the majority of the research is literary review and online research, the main time constraints involve the survey and interviews. The first milestone will be completing the survey and sending it out by February 22nd. This will ensure plenty of time for analysis of the data and a follow-up survey if necessary. The second major milestone will be completion of the interviews by March 29th.

Conclusion

The STS project is focused on analyzing the impact of the behavioral microtargeting on society and using the LTS framework to model and predict the future direction of the field. It is expected that the research will reveal the lack of public knowledge on the applications of the field relative to the increasingly large impact the field has on most members of the developing world's everyday lives. The future prediction will be that the influence of the field will only increase with time, and best practices for minimizing the negative impact of the new developments, while maximizing the potential for positive impact will be explored and presented.

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