deStigma

deStigma is an AI-powered application that aids psychiatrists in the pre-emptive detection of Autism Spectrum Disorder in children, as well as follow-up monitoring and diagnosis sessions. It leverages Microsoft Azure Cognitive Services and Natural Language Processing to conduct speech analysis, as well as Attentional Convolutional Network to perform facial expression recognition. deStigma equips psychiatrists and therapists with empirical statistics and analysis on their patients, empowering them to make data-driven decisions.

About Us

We're an interdisciplinary team of 4 students from Singapore's Nanyang Technological University who aspire to utilize technology to solve challenges in the mental health sector.

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Problem statement

General information

A mental disorder is a clinically significant disturbance in an individual's cognition, emotional regulation, or behavior. It is usually associated with distress or impairment in critical areas of cognition.

Being one of the critical mental disorders, autism is a pressing point within the mental health industry. It is considered a neurodevelopmental disorder, which inhibits the ability to learn and communicate with other people. Autistic children face difficulties following social cues and display unusual responses to stimuli and interactions, which leads them to be perceived as "strange" in many cultures.

Autism Prevalence

There are no official statistics or studies regarding autism demographics in Singapore, with most studies extrapolating on global and foreign data. In 2021, the Centers for Disease Control and Prevention (CDC) reported that approximately 1 in 44 children in the United States is diagnosed with an autism spectrum disorder (ASD). Assuming a similar proportion worldwide, this translates to 125 thousand Singaporeans and 181 million individuals that have autism in varying severities. Diagnosing ASD can be challenging with the absence of a reliable test, such as a blood test. Doctors usually observe the development and behavior to make a diagnosis, which can be visible as early as two years of age. However, many did not get a proper diagnosis and intervention, which can cause detrimental effects on the children as they grow older.

Challenges Faced by Psychiatrists

Around the world and in Singapore, an alarming trend emerges where the need for psychiatric experts is becoming higher, and mental health consultation has progressively been destigmatized yet the workforce of psychiatrists is continuously shrinking. While most of the medical workforce is increasing, psychiatry has been stagnant(Johnson, 2022). This led to longer waiting times as well as shorter and less comprehensive sessions. In Singapore, patients can expect up to 4 weeks on average to see a psychologist without using a helpline. This egregious waiting time primarily rises from the low ratio between doctors and patients, which for Singapore is just 44 psychiatrists and 83 psychologists for every million citizens (Ong, 2020).

Mental disorder care and diagnosis - especially autism - is a field within healthcare that benefits from prolonged contact and careful consideration, yet is also the one suffering the worst workforce crisis. The effects are exacerbated in the case of children's care. Insofar as shortage ensues, experts require either decentralization or assistance in early diagnosis, which may cut waiting time and consultation time, respectively. This enables experts to provide greater care and more in-depth diagnosis within the same constraint without compromising their expertise.

Target Audience

Target Audience & Implementation

Our main target would primarily be special needs students. More specifically, we targeted and studied the needs of students with autism. Students that are conventionally categorized as requiring special needs are disproportionately prone to mental illnesses (McMillan & Jarvis, 2013). This phenomenon is partly due to their isolation and marginalization within the academic world. Furthermore, as mentioned earlier, children with ASD also have a higher risk of injury and self-harm than neurotypical children.

The product may also be implemented at mental health clinics and special needs schools. At these institutions, individuals requiring further diagnosis and treatment can be referred to experts who can confirm the early diagnosis made by the application.

Benefits of early intervention

Early intervention can help diagnosed children improve learning, communication, and social skills, as well as underlying brain development. Children affected by autism can benefit from interventions such as speech and occupational therapy if it is detected early. Furthermore, it enables caretakers to take special attention to monitoring the growth and development of the child to ensure the safety of the child. Ultimately, the risk of autistic children being marginalized, isolated, or abused may decline with earlier detection and intervention.

Moreover, exposing young children to awareness efforts of mental conditions - as well as further steps to be taken - potentially increases their empathy towards individuals with such conditions and realize its normativity. This can supplement our ultimate goal to nurture a culture where individuals with autism and other mental conditions are destigmatized.

Common symptoms of autism

Through extensive research, we compiled a list of symptoms for detection in at-risk children that have a high degree of certainty within our technological capabilities. The following are the indicators of autism, which our initial software will detect to provide a pre-emptive diagnosis:

- Avoidance of eye contact
- Hyperactivity, impulsive or inattentive behaviors
- Repetition of words/phrases
- Stress or excessive anxiety
- Intense fear
- Lack of meaningful language (eg. delayed odd first words)

Although the list above is adequately comprehensive, these symptoms still fall short in precisely pinpointing the severity of autism within the wide spectrum. Thus, we aim to further integrate the following symptoms for detection within our product in the future:

- Hand flapping, body rocking, and spinning in circles
- Lack of communicative gestures
- Not subconsciously mimicking the behavior of the conversant (e.g.lack of social smiling, mirroring)
- Unusual reactions to a situation
- Epilepsy and seizure
- Repetitive behavior and actions
- Under- or over-reaction to sounds

Technological Implementations

The main aim of our product is to provide early detection of autism in children and preliminary analysis of their condition through a customized summary report.

Our product leverages the video and audio monitoring of its users for its analysis. Using both Computer Vision (CV) and Natural Language Processing (NLP), users' emotions and speech can be detected and analyzed efficiently. Subsequently, with the aid of data analysis, an individual's behaviors can be evaluated and identified accordingly. Our solution provides targeted suggestions and remedies for the mental health symptoms identified.

<u>Data collection</u>

To collect real-time video data of users' facial expressions and motions, we will be utilizing Raspberry Pi (RPi) and a camera module. First, we can control the camera module directly from the command line with the native *raspicam* command line tools, which include *raspistill* to take still images and *raspivid* for videos. These provide a wide range of recording options, including the possibility to preview the camera stream, adjust the camera settings (e.g. contrast, brightness, saturation, ISO, shutter speed), and set exposure mode and white balance. Then, send the frames over the network to a centralized processing server via *ImageZMQ*. Lastly, the

video will be analyzed using *OpenCV* and Facial Expression Recognition modules. (Rosebrock, 2019)

RPi boards are also capable of recording stereo audio using an interface called the inter-IC sound (I2S) bus.The I2S standard uses three wires to record data, keep track of timing (clock), and determine whether an input/output is in the left channel or right channel. First, the RPi needs to be prepared for I2S communication by creating/enabling an audio port in the RPi OS system. This audio port will then be used to communicate with MEMS microphones and consequently record stereo audio (one left channel, one right channel). Python is then used to record the 2-channel audio via the Python audio library *pyaudio*. Finally, the audio data will be visualized and analyzed in Python with simple digital signal processing methods that include Fast Fourier Transforms (FFTs), noise subtraction, and frequency spectrum peak detection. (Hrisko, 2022)

Symptoms Analysis

Below are the symptoms we've identified that are most prevalent in children with autism. We will collect data based on these symptoms.

Repetition of words/phrases can be detected through NLP. As the speech of the child surveyed will be recorded and subsequently converted into text, the text can be analyzed. The number of times a certain word is mentioned will be counted and ordered. Words that have higher than normal counts will be flagged and the original raw text will be retrieved to analyze if these words were spoken concurrently. This enables us to determine if the child shows this symptom.

Stress or excessive anxiety can be detected through NLP. Phrases that people with anxiety say can be detected, which include (Quinn, 2020)

Phrases	What they actually mean
"I'm sorry"	People with anxiety are anxious about whether they did something to hurt someone's feelings or they did something wrong.
"I'm exhausted"	People with anxiety often have a lot on their minds. Their minds don't stop racing and the feeling of exhaustion is constant.
"Stop!"	People with anxiety often get very hyper-vigilant, they cannot connect to the situation, even when the other party has already reacted.

Avoidance of eye contact can be detected through CV. The time taken for lack of eye contact can be measured, and if it exceeds a threshold, avoidance of eye contact can be flagged.

Hyperactivity, Impulsive, or Inattentive behaviors can be detected through motion analysis. We can analyze the upper torso motion and flag out excessing twitching and fidgeting.

Intense fear can be detected through the facial expression recognition model. The intensity of fear will be denoted on a numeric scale.

Lack of meaningful language such as delayed response to a question asked or odd first words used as the response to a question can be detected through NLP's sentiment analysis. The time taken for the child to answer after the question is posed can be analyzed and determined if it is within normal response time.

Speech Analysis

Speech patterns of people are known to be indicators of mental disorders. In comparison to other behavioral indicators, an individual can rarely hide their symptoms through speech. Through the language content, emotions are expressed directly which reflects the person's thoughts. Stuttering or repeating words can be detected through NLP and these are early indicators of mental illnesses. Sentiment analysis will be conducted in NLP. This is done to extract the subjective qualities of the individual sampled, allowing us to determine whether a given text contains negative, positive, or neutral emotions.

Firstly, we collect raw audio recordings of the target audience which then will be processed and transcribed into words. This is done using Microsoft Azure Speech-to-text feature (a part of Microsoft Azure Cognitive Services) that accurately transcribes spoken audio to text. Following this process, the data is cleaned and placed in a corpus form and further analyzed. During the cleaning process, punctuations are removed and words are made all lowercase with the aid of the python module Regular Expression (RE). Words that are constantly repeated are also flagged. The data is placed into a document-term matrix, whereby the text is tokenized. At the end of the analysis, a detailed report containing the word count and the subjectivity of the individual's words will be produced for further analysis by the system.

Facial Expression Recognition

Facial expressions are an essential tool to communicate emotions nonverbally in social interactions. (Ekman P, 1993) Being able to understand as well as to generate these expressions is crucial to the exchange of inner states with others. When people are experiencing basic emotions, their faces will display a variety of expression patterns, each with its own set of characteristics and distribution scale.

We will develop a facial expression recognition model capable of detecting and analyzing users' emotions using facial expressions. The trained model is capable of detecting faces and interpreting different facial expressions in real-time, and related potential symptoms can be identified and flagged. The facial expression recognition system utilizes an end-to-end deep learning architecture based on Attentional Convolutional Network (Minaee & Abdolrashidi, 2019).

In this project, we collect the raw video recordings of our users. The video is then sent frame-by-frame to the Microsoft Azure backend server. The data is later cleaned by performing noise reduction, color correction, image scaling, and cropping. Then, facial detection, feature

extraction, and image classification is performed by fitting the data into our deep-learning pipeline. Lastly, facial expressions can be identified for further analysis.

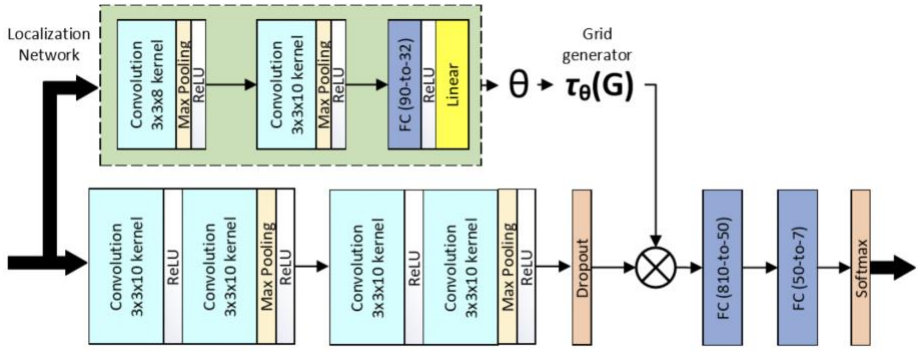

Figure 1: Attentional Convolutional Network Model

User Interface

The software leverages Azure app service to create a mobile application for the end user to generate the analysis report and also manage the monitoring hardware system.

Each analysis report will be generated for an individual, which is usually a psychiatrist or practitioner. This report will be inclusive of details of the language usage of the individual and the main few prominent emotions detected by the individual. This provides empirical evidence and comprehensive analysis which can be used to enhance the psychiatrist's diagnosis.

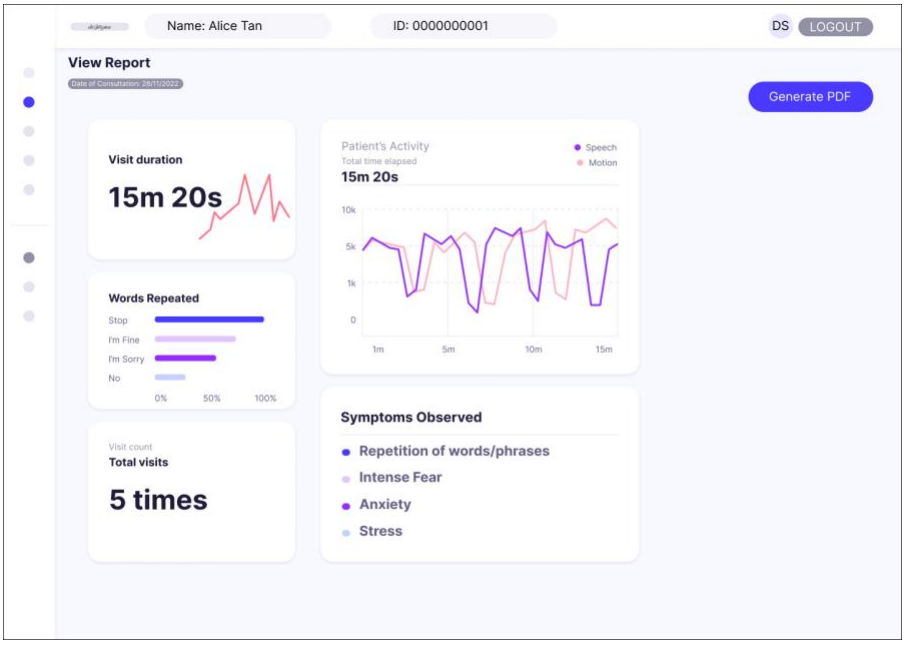

Figure 2: User Interface of Analysis Report generated

Software Architecture

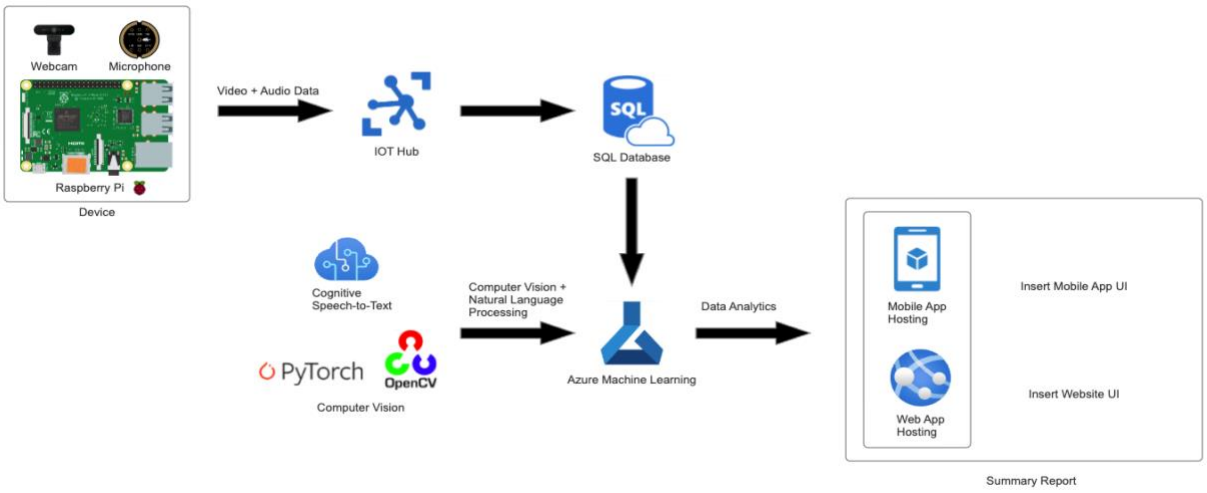

Figure 3: Software Architecture of deStigma

Diagnosis Procedure

The device will be placed in the diagnosis room when collecting audio and video data of the patients during consultation. The application will provide experts or pediatricians the valuable second opinion on any symptoms they might overlook as well as assist them in making more nuanced and comprehensive decisions on the patients, complementing their own personal diagnosis. For regular control patients, the detection program provides the experts with a quantifiable measure of any improvements, in addition to the aforementioned benefits.

Privacy concerns

Since our main target audience are minors, privacy rights are relinquished to the institutions and guardians. For example, a clinic using our technology will only use the application during a diagnosis or consultation session and will not detect symptoms passively. This active detection approach ensures parties whose children's personal data will be analyzed are made aware and may retract their consent at any given time. Furthermore, since such institutions are non-public areas, the application cannot collect data on individuals who do not explicitly express their consent.

The RPi and any other hardware used will not store and retain any of its collected data. Any collected data will be encrypted before being strictly used for analysis. The developed application will also be in compliance with Singapore's Personal Data Protection Act 2012, the law concerning the collection, storage, and use of personal data where the application will be developed and trained. The application can be modified to comply with the prevailing laws in other countries where applicable - insofar as they allow the anonymous and consented collection and analysis of facial features and speech recognition.

We can set up encryption for the Root File System (RFS) encryption that can be set upon the RPi module for client-side encryption. This prevents sensitive data such as the frames captured from being stolen. The initial ramdisk (*initramfs*) will be set up that will prompt for the password,

decrypt the partition, and resume boot during the boot-up of the module. This ensures that only authorized users will be able to access the module.

Azure provides numerous server-side encryption services that we will leverage in the development of our product, namely the customer-managed keys. This allows institutions to have more flexibility on access control protocols. Azure also provides encryption for data at rest. This ensures that the analysis report generated together with the frames from the client will be secure.

Business Model

An innovative idea must be supported by a robust plan to become a successful venture. Hence, we have developed a comprehensive business model canvas to visualize our inner workings. We begin by conceptualizing the minimal viable products at autism care institutions and perfecting our algorithm to be commercially implemented through multiple iterations of upgrades.

Value Proposition

To set us apart from our competitors, the key value proposition that we provide to our customers is the monitoring and detection of Autism Spectrum Disorder through the detailed reporting of at-risk children using facial emotion recognition and speech analysis. We have provision for detecting atypical neurological development of the children throughout the treatment, notifying the concerned authorities and guardians.

We add value to psychiatrists and doctors through our software-based evaluation services, streamlining their diagnosis processes by assisting in symptom detection. It also creates value for patients and their caretakers as it helps them in understanding the severity of the condition and get reassurance in data.

Customer Relationship

We intend to build a strong relationship with our customer base through a friendly user interface and easy-to-interpret data for psychologists and patients' families. As the mental healthcare industry highly values ethical communication for the good of the mentally challenged, we will establish communication with customers valuing the transparency of processes. deStigma enshrines its core value of normalizing autism and making society more accepting of the mentally challenged. We continuously work to reflect this in our product through a feedback loop with all the stakeholders towards making our product accepting of all special needs.

Critical Partnership

deStigma works in the mental healthcare industry, which is quite sensitive in nature and requires experience to gain expertise in the segment. Thus fostering partnerships with experienced institutions such as the Institute of Mental Health (IMH), the Autism Resource Centre, and the Autism Association of Singapore will be hugely beneficial. We can leverage their experience to gain valuable insight into the industry while adhering to applicable regulations efficiently. In return, our technology will be implemented in their centers for better

evaluation and streamlining diagnosis and treatment, reducing the workload on the workforce which is severely understaffed.

Due to its humanitarian nature, privacy concerns naturally arise in the mental health industry, which is strictly regulated by the government. It is critical to form partnerships with institutions experienced with autism, where our products can be tested and data can be collected to develop and improve our machine learning model. One such institution we are currently in talks with is Asian Women Welfare Association (AWWA) which has daycare facilities for mentally challenged children. Our product will make their programs more data-oriented and technology-driven.

Our goals align with the government in regard to achieving the betterment of the lives of the mentally challenged, which would be optional but game-changing nonetheless. One such critical partnership will be with the Ministry of Social and Family Development of Singapore (or other similar bodies in other countries), which actively encourages innovation in the socially conscious segments, distributing grants and offering facilities - reducing administrative and financial burdens for research and development of our product.

Competitor Analysis

The field of mental health throughout time has been a neglected and underfunded field for research and technological advancement. However, with increased awareness and sensitivity, various big firms and startups are venturing into this field, and the industry is currently going through a revolution. We intend to become a major player in the mental healthcare sector by innovating the existing processes of autism detection through technology. We have identified a few direct and indirect competitors of our firm:

Direct Competitors

The Health Screening tests and similar surveys developed by Hospital Management Asia (HMA) and similar organizations are currently leading the market specific to autism evaluation. In these tests, patients have to complete the provided tests and assignments. We aspire to completely revolutionize the market through the application of AI by providing detailed and comprehensive analysis to assist psychiatrists and assurance to patients' families.

Indirect Competitors

Kintsugi Mindful Wellness, *WinterLight Labs,* and *Ellipsis Health* are some companies working on developing an AI model for evaluating mental health. However, their technology is focused on the psychiatric evaluation of research participants and their surface-level evaluation lacks details to diagnose mental disorders akin to autism or provide feedback to psychiatrists. Therefore, we serve a completely different market segment than the mental health modeling companies operating in the current healthcare ecosystem.

Financial Projection

The measurement of the success of a venture is its financial viability. Strong financial projections indicate the growth prospects of the firm. Hence it is of utmost importance to

maintain a decent cash flow for the company so that we can sustainably fulfill our core mission of helping children under the autism spectrum. Our prospective revenue stream and cost structure are drafted below to showcase our financial sustainability plan.

Revenue Streams

Our main revenue stream will be the sale of the monitoring hardware setup to psychiatry offices and organizations. It would be accompanied by an annual subscription-based model to utilize our data analytics software which provides a comprehensive analysis of the patient. To reach out to the majority of our core customers, we will launch our product at a low price before becoming the market leader, only after which exponential profit can be expected.

An additional source of income is research grants from the government or mental health research institutions. We would also offer our technological expertise for consultancy for autism and other mental disorder-related firms.

Cost Structure

We expect to have high costs for the initial investment in the development of our product as extensive research is required, as well as administrative and infrastructural costs incurred by setting up a company. After initial costs, we would have dynamic recurring costs of software, infrastructure maintenance, and continuous research and development. Additionally, setting up connections with the industry and gaining a reputation would require us to spend heavily on our marketing channels (i.e. Events and Networking).

All in all, we project to operate at losses within the first few years of operation to be covered by our investors. Then as our product becomes a fully-fledged and reputed analytical tool, gains offsetting our losses are to be expected. The profits will be further reinvested in research and development, expansion, and launching of related mental health services.

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