Post-Disaster Aid Distribution

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Abstract

The goal of this project was to design a system to match volunteer mental health care providers with individuals seeking care after experiencing a natural disaster. This was done through developing an optimization model for matching based on volunteer and client preferences and availability and an application prototype for users to input the information used for matching. After developing our matching model, we evaluated its performance by running it with different sets of synthetic data. We found that the model performs best when the ratio of clients to volunteers is less than 10:1. When the model was tested with various ratios below this threshold, we found that more than 70% of clients were matched to volunteers after two rounds of matching. Our application prototype was evaluated at three different stages by mental health experts and potential client users. We received feedback that we implemented during our final revisions to improve the clarity of information throughout the application. Overall, it was found that our application prototype was effective in communicating objectives to the sample of potential users we evaluated. With the prevalence of natural disasters increasing around the world, these tools could be used to support individuals who experience disasters and mitigate the chance of them developing PTSD.

Executive Summary

With the increased frequency of natural disasters in recent years, there has been an increase in the number of individuals and communities impacted by these tragic events. While humanitarian aid organizations around the world exist to provide food, water, and other material goods to people during these times, there are few free resources available for providing mental health care to people impacted by natural disasters. Disaster research has found that individuals who experience natural disasters are at a greater risk of developing PTSD or related symptoms (Al Jowf et al., 2022). The goal of this project was to design a system for matching volunteer mental health care providers with individuals seeking care after experiencing a natural disaster, which can ultimately be implemented to mitigate the potential for people to develop PTSD. Our proposed system combines a matching model for pairing clients and volunteers with an application prototype for the system interface. When developed to be fully functional, the application will serve as a medium for volunteers and clients to be matched to each other based on their availability and preferences. This would include prompting the users for data and storing said data before using the matching model to find optimal groups of pairs.

To accomplish our goal, we concurrently developed our mathematical model and application prototype. For our application prototype, we used principles of user-centered design and developed our prototype over three iterations of designing, prototyping, and evaluating, increasing the prototype fidelity at each stage. The first iteration was focused on identifying the features necessary to develop a matching platform, and we created a Qualtrics form. The second iteration was focused on developing a user interface that allows the collection of the features from multiple user types, and we created a Figma prototype. The third iteration was focused on operationalizing the user interface to assess the utility of the proposed solution, and we created a semi-functional HTML-based prototype. Our fourth and final iteration was carried out utilizing mendix, this stage prioritizes different user interfaces, with the inclusion of an administrative view.

The features included in each iteration of the prototype were informed by feedback and recommendations we received from experts in the mental health care field. For example, we learned that having clients complete a set of questions screening them for PTSD and providing volunteers with their results would help them provide more tailored care during a consultation. They also informed us that asking volunteers for the state they are licensed in along with their license number and expiration date would be sufficient to confirm their credentials.

For our math model, we drew upon existing models for matching and consulted with domain experts to determine how much information we would need to collect from clients and volunteers to appropriately match them. Based on the feedback we received, we developed our model to match users based on the information collected from the application prototype. Specifically, we considered the availability of the clients and volunteers and what languages they speak as hard constraints for the model. For our objective functions, we first sought to maximize the number of clients matched weighted by their severity level, which was calculated based on how many of the PTSD screening questions to which they answered “Yes”. For our second objective, we maximized the number of patients matched weighted by the patient-volunteer compatibility score. The compatibility score was calculated based on how many of the client’s

preferences their provider meets. Our third and final objective maximized the number of patients matched without any weighting, which is also known as max cardinality weighting. After evaluating our model's performance, we made improvements before conducting our final tests.

Through the evaluation of our math model, we found that the model performs best when the ratio of clients to volunteers is less than 10:1. When the model was tested with various ratios below this threshold, we found that more than 70% of clients were matched to volunteers after two rounds of matching. The best result achieved was an unmatched rate of 2% when run with a 4:1 ratio of clients to volunteers. Out of all the scenarios we evaluated, the worst performance came from a client to volunteer ratio of 20:1, which yielded an unmatched rate of 50.5%.

Through our evaluations of our application prototype, we received feedback pertaining to various areas of the application. During our first two iterations the feedback mostly pertained to the phrasing of the questions we were asking. The primary concerns were whether the information was inclusive, and whether the information being collected was sufficient to effectively match the users. We incorporated this feedback into our revisions leading up to our third and then our final prototype iteration. At this stage, the feedback we received was mostly related to the flow of the application and the clarity of the information presented.

Due to the complex nature of the problem we are trying to solve, we have multiple recommendations for future work to further increase the accessibility of this system. For example, we recommend developing plans for how this system could be implemented in other U.S. states or even outside of the United States. Developing these plans would require the consideration of the need for this kind of system in that area, as well as potential cultural implications surrounding disasters and mental health care. In addition to potential expansion, we outline our recommended considerations for fully developing the back-end portion of this application. It is necessary to ensure that when volunteers and clients are using this system, their data is being stored securely. Through the course of this project, we were able to utilize insight from experts in the mental health care field along with new combinations of existing approaches to matching algorithms to develop a system that has the potential to make post-disaster mental health care accessible to people who may not have access to traditional modes of therapy.

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1. Introduction

Disasters have devastating impacts on affected communities worldwide. Communities face a massive struggle during these times, not just finding the resources to live but also the strength to rebuild. Even in the face of such immense hardships, there still exists the determination of individuals, communities, and nations that come together and extend a helping hand. According to Lan et al. (2021), in 2019 alone, there were nearly 400 mass natural disasters, resulting in almost 95 million victims and $130 billion in economic losses worldwide. Additionally, climate scientists suggest that the number and severity of natural disasters will increase as greenhouse gas emissions rise (Boustan et al., 2020).

As disasters become more frequent, the number of people impacted will only grow. This is especially true in the United States as more economic activity clusters along the coasts, putting more of the population at risk of exposure to disasters such as hurricanes (Boustain et al., 2020). The adverse effects of disasters can spread well beyond the initial area of devastation in today's highly connected world. Humanitarian aid is a crucial response to earthquakes, wildfires, and hurricanes.

Aid organizations, governments, and communities can unite and provide support more efficiently by using online resources and communication. Bhuvana & Arul (2019) found that apps like Facebook and WhatsApp were critical components of post-disaster management during the 2015 Chennai floods in India. In this case, many individuals used social media to connect members of affected communities and reveal resource needs and gaps in distribution.

While these groups routinely provided physical assistance such as first aid supplies, food, and water, there is less emphasis on distributing resources for mental health care after a disaster. However, studies have found these post-disaster resources to be very important. People who live through natural disasters or other catastrophic events are known to be at risk of developing post-traumatic stress disorder (PTSD) or related symptoms, in the weeks and months following the disaster (Green & Lindy, 1994, Madakasira & O'Brien, 1987).

PTSD affects around 6-8% of the general population and increases to 25% among groups who have experienced psychological trauma (Ressler et al., 2022). PTSD is characterized by symptoms that fall into three main categories: reminders of exposure, activation (such as insomnia or agitation), and deactivation (numbing, avoidance, or withdrawal) (Sherin & Nemeroff, 2011). For most of the population, these symptoms are uncomfortable but lead to minimal functional impairment. For the small population of people who develop post-traumatic stress disorder as a more long-term syndrome, they often face "devastating functional impairment" (Sherin & Nemeroff, 2011).

To address this unserved need for mental health care, we developed a system for matching qualified volunteers with people suffering from PTSD and related symptoms after experiencing a disaster. While online mental health providers exist, most offer a paid model that may not be accessible to those without health insurance. Our system would operate as an emergency mental health service, aiming to refer patients to more long-term care options after assessing their needs.

When conducting our background research, we reviewed the current literature on matching algorithms for various applications, including healthcare and mental health services. We also explored existing online mental healthcare applications and methods of maintaining successful volunteer programs. We developed a math model and a prototype that efficiently and effectively matches volunteers to patients to help aid people with PTSD and related symptoms in the wake of disasters.

We developed our prototype application over three iterations of the user-centered design process. We started with a prototype of just survey questions and after consulting with experts were able to expand it into a semi-functional full application prototype. At each stage we designed, prototyped, and evaluated our application and revised based on the feedback we received. In addition to a survey for collecting data used to match users, our application also included a home screen where volunteers and clients can see their matches and upcoming appointments.

Alongside the prototype application we developed a mathematical model to match volunteers with clients. After consulting with experts, we were able to determine what features to match users on, which determined our objective functions and constraints. Clients and volunteers had to speak the same language and be available at the same time to be able to be feasibly matched, and the model will prioritize matching clients with high severity level. The model will also prioritize matches that have a high compatibility, which is based on the client's preferences, but only if client severity is already maximized. Based on our literature review of existing matching models, we decided on a multi-objective approach. Our first objective maximizes the number of clients matched weighted by their severity. Our second objective maximizes the compatibility-score weighted number of matches of client-volunteer pairs, and our third objective maximizes the number of clients matched without any weights. After we developed our model, we evaluated its performance on numerous scenarios, and made revisions accordingly.

2. Background

The effects of natural and artificial disasters have spread well beyond the initial area of devastation in today's world. Disasters can ruin lives, demolish infrastructure, and cause great turmoil. Whether the cause of these effects is earthquakes, hurricanes, pandemics, armed wars, or other devastating catastrophes, they leave behind populations coping with significant difficulties. Some people struggle with finding clean water and a place to live while dealing with the intricate web of psychological, emotional, and sociological effects.

In recent years, the world has witnessed a series of devastating disasters, each leaving a trail of destruction and despair in its wake. From the troubling scenes in Syria (*U.S. Assistance to Emergency Earthquake Response Efforts in Türkiye and Syria*, 2023), communities already grappling with conflict were further burdened by unforeseen tremors. As seen in 2023 on the shores of Maui, in our own United States, wildfires engulfed the surrounding areas (The White House, 2023). Yet, even in the face of such immense hardships, there still exists the determination of individuals, communities, and nations that come together and extend a helping hand.

Humanitarian aid is a crucial response following disasters. These disasters can cause significant devastation, displacing communities and leaving them in need of assistance. Humanitarian aid organizations, governments, and communities come together to support those affected. To date, $185 million in U.S. humanitarian aid has helped with the earthquake response in Turkey and Syria, providing emergency medical assistance, food, clean water, shelter, and hygiene supplies to the affected communities (*U.S. Assistance to Emergency Earthquake Response Efforts in Türkiye and Syria*, 2023). Similarly, FEMA sent the county administration in Maui 50,000 meals, 75,000 liters of water, 5,000 cots, 10,000 blankets, and shelter materials for distribution (The White House, 2023). While there is a necessity for material aid, it is also incredibly valuable, it is also important to provide disaster survivors with emotional support.

Although there is less emphasis on distributing resources for mental health care, studies have found that this can be very important following a devastating disaster. People who live through natural disasters or other catastrophic events are known to be at risk of developing post-traumatic stress disorder (PTSD) or related symptoms, both in the weeks following the disaster and months later (Al Jowf et al., 2022). A paper by Green & Lindy (1994) discusses the impact of the San Francisco Bay Area earthquake of 1989 and cites findings from a convenience sample of graduate students impacted by the earthquake. This research found that these students self-reported symptoms of derealization, depersonalization, time distortions, and alterations in cognition and memory within the first week following the disaster. They also noted that people's ability to process a traumatic event successfully depends on personal characteristics such as coping methods and a history of trauma or psychological problems. It also depends on the community's response to the event and the availability of social networks and support systems.

Historically, the primary focus of allocating resources in the wake of disasters has largely overlooked resources for mental health. Existing telehealth resources for mental health, such as BetterHelp, TalkSpace, and Calmerry, are modeled as convenient replacements for traditional therapy and require payment or insurance coverage. In this chapter, we will review existing options for providing online mental healthcare and how to maintain a successful volunteer system, as well as current optimization applications in healthcare and mental healthcare, along with existing matching methods for two-sided platforms.

2.1. Post-Traumatic Stress Disorder (PTSD)

Post-Traumatic Stress Disorder (PTSD) is a mental health condition that can develop in those who have experienced or seen a traumatic event (Mayo Clinic, 2022). Natural catastrophes, accidents, physical or sexual assault, combat, and other life-threatening scenarios are examples of traumatic events that can lead to PTSD (Al Jowf et al., 2022). A person may perceive these events as being emotionally, or physically life-threatening, which impacts their mental, physical, social, or spiritual health (Mayo Clinic, 2022).

PTSD has formerly gone by various labels, including "shell shock" during World War I and "combat fatigue" following World War II, however it affects more than only combat veterans (American Psychiatric Association, 2020). Any person of any race, nation, or culture, and at any age, may experience PTSD. Approximately one in eleven people may receive a PTSD diagnosis over their lifetime. According to the American Psychiatric Association, every year, 3.5% of adult Americans experience PTSD, and for adolescents aged 13 to 18, the lifetime prevalence of PTSD is 8%. In addition, it is stated by the National Center for PTSD that within the United States, 50% of women and 60% of men experience trauma at some point in their life; however, women are twice as likely as men to suffer and manifest PTSD from those traumatic events.

Long after the traumatic incident has passed, people with PTSD may continue to endure intense, unsettling thoughts and sensations related to their experience. A loud noise or an unintentional touch may be enough to trigger significant adverse reactions in those with PTSD, who may avoid circumstances or people who remind them of the traumatic occurrence (American Psychiatric Association, 2020). Flashbacks or dreams may cause them to relive the incident, experience sadness, fear, or rage, and feel distant or estranged from other people. Although it takes time for PTSD to manifest fully, with the exact length varying per person, assessing individuals on a case-by-case basis will be necessary.

2.1.1. PTSD Severity

It is essential to understand the severity of PTSD to pair the client with the appropriate course of treatment. The severity levels of PTSD are like the severity levels defined for general stress, as PTSD is associated with high levels of stress. According to BetterHelp, the five stages of stress are normal stress, acute stress, uncomplicated PTSD, complex PTSD, and comorbid PTSD.

Normal stress is the stage before PTSD begins. It is normal to have some stress levels as a response to life events such as accidents, injuries, or discomfort towards a situation. This feeling often goes away within a few weeks, with tension being low (*5 Types of PTSD and How to Treat Them | BetterHelp*, 2023).

Acute stress disorder occurs in people who have experienced life-threatening events (*5 Types of PTSD and How to Treat Them | BetterHelp*, 2023). This may include natural disasters such as a hurricane, the death of a family member, friend, or pet, or losing a job. All can be major triggers in a person's life. Acute stress is slightly more severe than normal stress. If left untreated, it can develop into PTSD.

Major traumatic events cause uncomplicated PTSD. This is the lowest level of PTSD and, if caught earlier, can be treated quickly through a combination of medication and therapy. People experiencing this level of stress show signs of irritability and mood changes. These people may feel discomfort visiting areas that remind them of this trauma and often get reminded of it in dreams or flashbacks. These mood changes affect their behavior and relationships with other people both mentally and physically (*5 Types of PTSD and How to Treat Them | BetterHelp*, 2023).

Unlike uncomplicated PTSD, multiple traumatic events can cause complex PTSD. These events are often recurring, such as domestic violence, war, or other violent events. Although symptoms of complex PTSD are like those of uncomplex, treatment is more intensive. Many patients are diagnosed with personality disorders and show major behavioral issues. They tend to have more extreme behavioral responses with more aggression and anger. This can lead to various abuse such as substance abuse, sexual abuse, and aggression towards others as the individuals' feelings intensify. Eventually, one's emotions fill with rage and anger, but can also be more depressed and more worried (*5 Types of PTSD and How to Treat Them | BetterHelp*, 2023).

Lastly, comorbid PTSD is a term used to refer to a combination of co-existing disorders. A person experiencing comorbid PTSD are more likely to experience substance abuse to combat their mental issues. Often, people experiencing the four stress levels mentioned above try to treat stress by themselves. Sometimes, self-care is not enough. It is crucial to reach out when needed.

Not getting the proper help can lead to the development of comorbid PTSD. Self-induced medications, in combination with increasing likelihood of destructive tendencies, can cause patients to spiral and find themselves in this vicious loop as they try to numb the pain. The goal is to break this cycle by stopping stress from getting to this point in the first place by providing them guidance (*5 Types of PTSD and How to Treat Them | BetterHelp*, 2023).

2.1.2. Stages of PTSD

The journey through post-traumatic stress disorder can be challenging and complex, often characterized by several stages that individuals may experience. These stages can vary from person to person, but they provide a framework for understanding coping and recovery.

According to the Transformations Treatment Center, there is first the Impact Stage or the Emergency Stage. This stage occurs immediately after the traumatic event, when the person is still reeling from shock and disbelief. Emotions can be overwhelming, and some may experience guilt, hypervigilance, or confusion. Survivors may grapple with guilt for surviving when others did not. Someone who survived a major natural disaster may experience these emotions, even if they suffered losses or injuries. Following this is the Denial Stage. Not everyone with PTSD goes through this stage, but it can present unique challenges for those who do. In this stage, individuals may have strong emotions related to the trauma but attempt to distance themselves from the event. Some may engage in numbing behaviors like substance abuse to cope with their feelings. Thirdly, there is the Short-Term Recovery Stage. During this stage, individuals with PTSD try to return to everyday life. Two scenarios may play out: They either seek help and support or become more discouraged and disheartened. Some may experience intrusive thoughts and nightmares during this phase, making the recovery process challenging. Lastly, we arrive at the Long-Term Recovery Stage. In this stage, individuals continue to live their lives while managing the effects of PTSD. Seeking treatment and support from loved ones or professionals can help mitigate the symptoms and improve overall well-being. Some individuals may still experience adverse symptoms, such as nightmares, flashbacks, or anxiety, but they learn to cope and function better daily (*What Are the Four Stages of PTSD? - Transformations Treatment Center*, 2021).

It's important to recognize that everyone's journey through PTSD is unique, and not everyone will follow these stages in the same way or order. Additionally, seeking professional help and a support system of friends and family can significantly aid individuals in their recovery process. Understanding these stages can provide insight into the challenges faced by those with PTSD and the importance of ongoing support and treatment for their well-being.

2.1.3. Communication

Arguably, the most crucial step in getting help for PTSD is communication. A potential patient coming forward and stating that they may need help is essential for helping them treat the symptoms of their PTSD. Regardless of the severity of their symptoms, receiving assistance from others can often help mitigate symptoms. While receiving help, communication between the patient and a provider goes a long way. A patient stating all emotions and a provider communicating ways to help can help accelerate the process. Additionally, communication can help set a patient up with additional resources that may better help their problems.

Communication can help a patient and provider to develop a relationship. Relationships are so meaningful in life, and in times of disaster, the importance of relationships becomes exponentially beneficial as they can provide support to ones that need it before it could potentially get worse. PositivePsychology states, “positive outcomes from therapy and counseling rely on the strength of the relationship between the mental health professional and the client.” (Sutton, 2022). People helping others in need can go a long way, and without communication, those relationships may not be formed, and post-disaster recovery would not be possible.

2.2. Telehealth and Online Mental Health Care

One way people can receive support and treatment for their PTSD and symptoms is through telehealth. Telehealth is “the use of telecommunications and information technology to provide access to health assessment, diagnosis, intervention, consultation, supervision, education and information across distance" (Nickelson, 1998). Telehealth is an effective alternative to face-to-face therapy as it does not fundamentally change the face-to-face interaction between a provider and a patient. Telehealth can also expand provider and patient access to health care (Stamm & Perednia, 2000). In the wake of a disaster, it is often hard to get resources into the geographic location of the victims. Therefore, telehealth can be a viable option for treating potential PTSD patients after disasters.

There are four types of clinical applications of telehealth: Store-and-forward, video teleconferencing (VTC), Remote patient monitoring, and mHealth. Email is the simplest form of store-and-forward as emails can contain diverse data stored in a computer on the sender and recipient end. Since data gets stored on both sides of this interaction, both parties do not need to be present simultaneously. When practicing store-and-forward, the platforms must encrypt and protect shared personal data (Stamm & Perednia, 2000, Haque & Hayden, 2022).

Remote patient monitoring includes using devices to monitor patients from a distance. This allows providers to give and change care plans without seeing the patient in person. An example of this can be seen in continuous glucose monitors, as providers can receive information on the patient from a distance and change the care plan if needed from a distance (Haque & Hayden, 2022).

MHealth, also known as mobile health, uses smartphones and patient-facing applications to facilitate care and provide education to patients. Examples of this form of telehealth could include patient-generated health information, such as health information on an Apple Watch or notifications to remind patients to take medications (Haque & Hayden, 2022).

VTC sends real-time audio and visual data from provider to patient and vice versa, resulting in a technologically mediated face-to-face therapy session (Stamm & Perednia, 2000). VTC saw a considerable uptick due to the COVID-19 outbreak in 2020 and is also an effective mode of therapy for ex-military personnel experiencing PTSD, people who have trouble leaving their homes, people living in remote areas, prison inmates, and geographically dispersed members of migrant populations (Thomas et al., 2021). Also, this paper showed that delivery by videoconferencing is non-inferior to in-person therapy in reducing PTSD symptoms in most studies examined. The authors also state that all studies showed no significant difference in dropout or satisfaction between VTC and in-person therapy. There are many benefits to telehealth over traditional therapy methods, such as lower costs, flexibility, and ease of access. Also, recent legislative initiatives have advocated for advancing telehealth in the future (Gajarawala & Pelkowski, 2021).

Various platforms are available online for mental health care, such as BetterHelp, TalkSpace, and Calmerry. In 2023, BetterHelp is one of the most popular online mental health platforms, home to nearly 2,000,000 clients and 33,000 licensed therapists. BetterHelp's Mission is "Making professional therapy accessible, affordable, and convenient — so anyone who struggles with life's challenges can get help, anytime and anywhere" (Fair, 2023). BetterHelp has new patients fill out a survey that collects multiple attributes such as age, gender, and sexual orientation. It also asks users if they have been displaying behaviors such as fidgeting, poor appetite, or tiredness. These screening questions are essential for BetterHelp as they provide their model with data to match patients with qualified and optimal therapists. BetterHelp offers both store-and-forward and VTC telehealth options for its patients. Since BetterHelp is an online therapy service, they also store a lot of personal data online. Personal and health data is confidential data meant to stay between the patient and therapist. BetterHelp marketed its service as trustworthy and safe from data breaches; however, in 2023, BetterHelp violated this trust by selling client data to organizations such as Facebook, Snapchat, Criteo, and Pinterest. Because of this breach in data, the FTC proposed a settlement to BetterHelp, including $7.8 million for partial refunds to BetterHelp patients.

To provide care to patients, these applications employ therapists and pay them for their time working with patients through their website. While we want to develop a similar application that provides online mental health care, we aim to enlist volunteers. This opens additional considerations and implications distinct from these existing telehealth providers.

2.3. Volunteer Care Providers

Volunteers agree to do a particular task or provide a certain service at their discretion. Our model will utilize volunteers to provide patients with mental health care. When searching for volunteers, it is essential to use professional volunteers for the most distressed patients as they have more significant experience than their paraprofessional counterparts (Armstrong, 2009). Armstrong (2009) suggests that paraprofessional volunteers should undergo additional training to better tailor their knowledge towards treating patients. Having a high volunteer retention rate is essential for a volunteer backed organization to succeed. Gaber et al. (2022) say that "volunteer programmes should communicate positive programme impacts that could enhance volunteers' development, communicate any client impacts to volunteers to reinforce volunteers' purposes for volunteering (thus reinforcing that their work is meaningful), and ensure logistical aspects of volunteer role work well." All these factors make volunteers more likely to stay as they are more likely to feel a sense of pride and accomplishment in their work. Volunteers having positive experiences during their time, such as gaining new skills or knowledge, meeting like-minded people, enhancing one's status, or even volunteering for the cause of a family member, fuels volunteer retention (Forbes & Bussell, 2003). On the other hand, many factors may cause volunteers to leave a certain organization. Forbes and Bussell (2003) present the volunteer life cycle, which shows the points at which volunteers may enter or leave an organization. The 'volunteering determinants' stage involves attracting potential volunteers and understanding their motivation for the specific cause. During this stage, the organization needs to market the volunteering opportunity to raise awareness and interest during this stage.

The second stage of the Volunteer Life Cycle is the 'decision to volunteer' stage, which includes more marketing from organizations to differentiate themselves to attract volunteers. During this stage, volunteers must be matched to an appropriate volunteer activity, as it will increase the odds that they move on to the third phase of the Volunteer Life Cycle: Volunteer Activity. Volunteers need to be active and not stagnant so they can continue feeling valued within the program. The goal of the Volunteer Life Cycle is to be a committed volunteer. A committed volunteer can grow within the organization and will act as an asset until it is their time to exit. *Figure 1* displays a diagram of the volunteer life cycle. To provide high-quality care to a diverse group of people, one must consider the needs of both the patients and the volunteers. This creates a variety of limitations that need to be incorporated into the model to match patients with the appropriate volunteer(s).

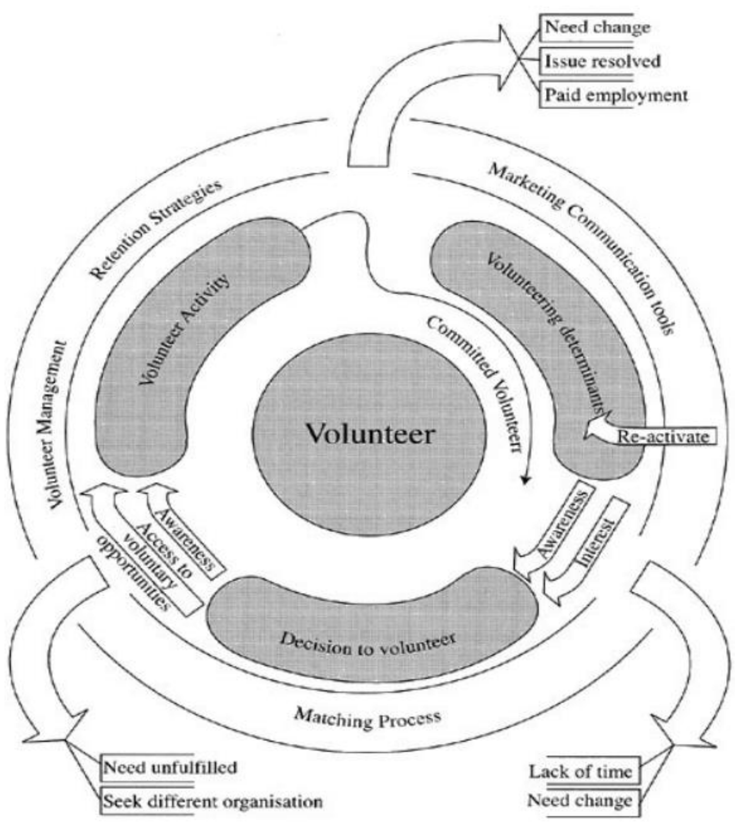


Figure 1. Volunteer Life Cycle

2.3.1. Volunteer Considerations

Volunteers are essential to helping patients recover from PTSD and monitoring symptoms in the wake of a disaster. Many factors go into organizing and maintaining a successful volunteer program. ICMA.org states, "the most often cited measure of volunteer programs tends to be that x number of volunteers gave y hours and that time spared the organization adds up to z dollars. Although those numbers show an important perspective, other key indicators of volunteer program efforts should be carefully considered." (ICMA, 2010) This statement is considered when modeling to create an efficient process, often using the least number of volunteers to help the most people possible. According to Şentürk and Turan Tüylüoğlu (2022), a key component of volunteerism is that volunteers are acting out of their free will, and not being forced to perform actions that they are unwilling to. Because of this, it is essential for volunteers to have an option to opt-out of volunteering services if they no longer have desire to volunteer. The desire and intrinsic motivation of volunteers oftentimes determines how long and often they will volunteer. The following section looks at different components of volunteer programs and how to manage them.

2.3.2. Risk Management

Risk management is vital in establishing a volunteer mental health counseling program. Some considerations include considering investigating all the legal and outside factors before a mental health counseling program starts. A person may first consider risk when setting up a volunteer program. During a meeting with WPI Professor Brenton Faber, one of the risks he mentioned was the safety of volunteers. Could a volunteer suffer physically and or mentally from volunteering in post-disaster relief? Volunteer Hub notes, "How your nonprofit goes about handling risk can make all the difference in potential threats impact on the organization." *What Is Volunteer Risk Management and Why Is It Important?* (2017). Risk possibilities are endless. A volunteer may inflict self-harm, enter a state of depression, or experience anxiety from dealing with patients. Another risk comes with acquiring volunteers. While many volunteers may want to help for the greater good of the people who may be dealing with PTSD, some of these volunteers may not be qualified. Lack of qualifications may hurt the situation. Not knowing how to help someone may hurt the patient and the volunteer program. This can escalate the PTSD a patient is having and may even lead to the downfall of the volunteer program.

Some volunteers may want compensation for volunteering. This compensation could be money, some voucher, or any other gift. This situation can be a risk as volunteers may only be volunteering for compensation rather than serving out of free will. Volunteer effort, length of shifts, and potential for being overworked can weaken the effectiveness of the program. It is important to consider these risks when creating a volunteer program. Some people may be forced to volunteer and not give their best efforts in helping the situation. Sometimes, people won't volunteer in their free time because of the length of shifts. People will not want to give up entire days of their time, and overworking volunteers can hinder the program's effectiveness. This is a cause for concern, and considering all of these potential risks when creating a volunteer program is vital.

2.3.3. Matching Skill Set with the Right Patients

As important as having exemplary volunteers is for a volunteer program, pairing the patients with qualified volunteers is equally important. Volunteers should be matched with a compatible patient to reach their full potential. Scientific Reports suggest one way to do this. “The objective here was to implement a machine learning classification modeling workflow for delineating individuals with PTSD from trauma-exposed, matched control participants using MEG-derived functional connectomes based on neural synchrony.” Zhang et al. (2020). This machine-learning algorithm is very efficient in optimizing compatibility. Further, a document by Olli Miettinen gives a blueprint for the beginnings of patient volunteer matching. The document states “the one-to-one individual matching principle of the matched pairs design is generalized to R-to-one individual matching in the case of all-or-none responses and fixed sample size procedure” (Miettinen, 1969). These references truly highlight the importance of proper pairing, which can especially be brought to practice in times after a disaster.

Another way to do this is by using multi-objective optimization. ScienceDirect states “Multiobjective optimization (also known as multiobjective programming, vector optimization, multicriteria optimization, multiattribute optimization, or Pareto optimization) is an area of multiple-criteria decision-making, concerning mathematical optimization problems involving more than one objective function to be optimized simultaneously” (Chang, 2015). This method helps optimize multiple objectives, which can be especially useful in a healthcare or mental healthcare context. This is because in these contexts there are many important variables to consider, such as the severity of a patient, how long a patient has been waiting for care, what their needs are, that all need to be considered in your model. Multi-objective optimization is one way to handle possible instances while also maximizing the total number of patients that can be handled.

Using ideas from optimization, one can also create an algorithm working to make strong patient and volunteer pairs. If a person has an anxiety issue, pair them with a volunteer who knows how to deal with anxiety. If a person is dealing with anxiety, do not put them with a person with depression. Matching patients appropriately can help them resolve symptoms better and ultimately help with the volunteer program's success. This may also help a former patient develop skills to help future patients.

2.3.4. Creating Proper Training Programs

Creating a proper training program is vital for the volunteers to help the patients. Many volunteers who may not be trained professionals have little to no skills in helping these patients, or their skills are very raw. Having weak skills will not help patients and will ultimately affect the credibility of the volunteer program. Creating a training program can help these newer volunteers know what the volunteer program is about and how to best serve within it. These training programs can help the volunteers find their interests and learn the necessary skills to be successful volunteers for an organization. Trainingmag.com mentions, “Setting objectives for your volunteer training program keeps your planning process focused and on target. When you have a clear goal, it’s easier to decide what you want to prioritize in your training.” (Fellman, 2023). Setting this up for the volunteers will help them focus and find their passion. The volunteers knowing their interests can help them help patients in need. This will ultimately help patients recover and allow the volunteers to develop a network to help them volunteer for other disasters down the road.

Volunteer programs need qualified volunteers to help lead a successful and helpful program for patients. Gettingattention.org states, “Volunteers are vital to your nonprofit’s ability to fulfill its mission.” (Getting Attention, 2021). More volunteers are not always the best option. The quality of volunteers is more important than the quantity of volunteers, and mathematical optimization is one way to manage a small group of volunteers as efficiently as possible. Risk management, communication, matching skill sets, and proper training programs are enormous factors that play a role in this mathematical model and drive results in post-disaster relief efforts.

2.4. Mathematical Modeling for Patient and Volunteer Matching

Mathematical modeling can effectively facilitate pairing volunteers with patients, making this process go smoothly. Different mathematical approaches such as machine learning and linear programming (or optimization) could be considered in this situation. IBM states “Machine learning is a branch of artificial intelligence (AI) and computer science which focuses on the use of data and algorithms to imitate the way that humans learn, gradually improving its accuracy.” (IBM, 2023) BYJUS then states “linear programming is a method of optimizing operations with some constraints” (BYJU’S, 2020). The mathematical model we will use is integer linear optimization because it is effective in helping match patients and volunteers, given both parties' preferences. Linear programming and optimization are mathematical methods designed with multiple equations where the objective is to find the assignment of values to variables that attains the absolute maximum or minimum value of the objective function given the constraints. In this situation, we must first identify what our constraints are. There are all sorts of constraints to consider when setting up post-disaster relief. Other factors that may impact the program in the area are the magnitude of the disaster, the time since the disaster, the number of people impacted, the costs associated with the disaster, and the type and severity of PTSD a patient may be suffering from. Utilizing integer linear optimization to match patients to available volunteers is a method of doing such.

Mathematical Optimization or Integer Linear Optimization is a type of constrained optimization that involves minimizing or maximizing an objective function representing a measure of interest to a decision-maker (Crown et al., 2017). The objective function is the function that is to be optimized, either maximized or minimized. Variables are subject to constraints, and functions consist of variables. Constraints help determine which actions can and cannot be taken. Decision variables represent these actions that can or cannot be taken. In the case of providing care to patients in need, these constraints come from patient characteristics as well as the limitations of the healthcare systems or volunteers. Without constrained optimization, problems with the presence of more constraints get increasingly complex, even for small hospitals or clinics. Utilizing constrained optimization methods is one way to solve these problems efficiently and effectively. Not having constraints gives infinite possibilities on resources that can be allocated, which is unrealistic. Having constraints forces a program to find the best way to optimize helping a patient, given the limitations of the program.

To model a constrained optimization problem, it is critical to follow several steps. The first step is problem structuring, which involves specifying the objective function, decision variables, constraints and declaring any assumptions made. Next is the mathematical formulation, which involves presenting the objective function and constraints in mathematical notation using the decision variables and parameters decided during the structuring of the problem. Mathematical formulation and model development develops the optimization problem. This involves representing the objective function and the constraints in mathematical notation. Once mathematically representing each component of the model, it is essential to validate the model and ensure it is appropriate for evaluating all scenarios.

Succeeding in the problem being modeled and validated, the optimization process can begin. The first step is to select an appropriate optimization method based on the problem's characteristics. Once there is a choice of a method, it will be used to search for the optimal solution. Once we have the solution, it is interpreted and reported to determine if its performance is reasonable and can be helpful in decision-making.

Constrained optimization can be applied to numerous existing healthcare applications. A study by Crown et al. published in 2017 discusses many of these applications, and the following section reviews some of their findings. Resource allocation across different departments is one way to use constrained optimization. Some specific examples include allocating donated organs and allocating personal protective equipment (PPE) and other resources for infectious disease management.

Constrained optimization can also be applied to workforce planning and shift template optimization for staffing. In this case, the decision-makers are hospital managers and department heads, and the decisions are how many staff members to schedule at different hours of the day. The objective is to increase efficiency and maximize the utilization of staff. The constraints considered are staff availability, other human factors, and state laws regarding nurse-to-patient ratios and budget. For large hospitals, especially, this technology has the potential to improve their efficiency significantly and when applied to inpatient and outpatient scheduling to minimize waiting time and maximize staff utilization.

When using methods of constrained optimization for health care, the idea of fairness may be questioned. A paper by Stinnett and Paltiel (1996) presents methods for incorporating ethical constraints into the resource allocation problem. They discuss adding constraints to ensure that a certain portion of resources are allocated for a particular disadvantaged group within the population or to ensure that net health benefits or the amount invested meet a certain threshold. Stinnett and Paltiel recommend applying this by explicitly identifying the cost of equity by comparing the model results with and without equity constraints. On top of this paper, another paper by the national library of medicine states “optimization models typically seek to maximize overall benefit or minimize total cost. Yet fairness is an important element of many practical decisions, and it is much less obvious how to express it mathematically.” (Violet Xinying Chen & Hooker, 2023). Incorporating all of these ideas and considerations and applying them in a constrained optimization model can help the decision-makers determine what benefits to sacrifice for the cost of equity.

2.4.1. Matching for Two-Sided Platform

Constrained optimization can also be applied to problems involving matching. Matching patients to care providers is an example of a two-sided platform since constraints come from both sides. The patient has specific needs that the provider must meet, and the providers have limited time availability and expertise depending on their training. One approach to two-sided matching is the Two-sided Online Bipartite Matching (TOBM) problem. In this context, online refers to the matching being done gradually as information enters the system, rather than requiring the entire dataset all at once (Karande et al., 2011). This is one way that the matching of patients and care providers can be modeled, since people on both sides may decide to join the system when the time is right for them, so people would be gradually entering the system and looking to be matched. The TOBM problem aims to maximize the total number of tasks performed by matching as many as possible to compatible workers. In the case of our application, the "workers" would be care providers, and their "tasks" would be providing care to a particular patient.

A paper by Li et al. (2019) explores multiple implementations of the TOBM problem and compares their performance. The authors also note in their paper that while these problems are commonly discussed and analyzed in academia, some important evaluation methods are often ignored in these studies, those being average response time and the long-term performance and stability of matches. In the context of mental healthcare, these are two crucial metrics. In many cases, patients may benefit the most if they receive care as soon as possible, and it is important that the quality of matches between patients and providers does not decrease over time. The paper looks at multiple implementations of the TOBM problem, those being Greedy, Batch-GR, Batch-LLEP, Batch-NNP, Random, ext_ranking, and POLAR-OP. Their research aimed to fairly compare each method and report on the results they found. To assess their performance, they used the metrics of matching size (the total number of assigned pairs), the average response time of tasks, the running time of the algorithm, and memory usage. The first two metrics are important to determine the quality of the matches, while the second two are important to assess the efficiency of the matching, which affects the user experience and how quickly patients can receive care. The authors found that in the short-term and long-term tests, Batch-GR outperforms other algorithms in terms of matching size. However, regarding average response time, Greedy and Random outperformed the other algorithms for the short-term tests, with Batch-LLEP achieving the lowest for the long-term tests. They recommend Batch-GR for applications where the average response time does not have a strict requirement and Greedy or Random when the requirement is more stringent.

Another approach to managing resources with dynamic arrivals was outlined in a paper by Cinar et al. in 2022. The authors consider its use in the context of a public health emergency, which may have similar levels of urgency as a natural disaster scenario. They formulated a mixed-integer programming (MIP) model and set predetermined optimization times to account for patients gradually entering the system. They evaluated the effectiveness of the optimized schedule by looking at the number of patients whose visits are postponed, the waiting time of urgent patients, and required overtime. They compared their MIP-based approach to two heuristics and found that their model correctly prioritized more urgent patients when selecting which patients to postpone, whereas the heuristic approaches selected based on arrival time without considering urgency.

In providing mental health care online, the priority may change depending on the patient or group of patients. Some may require more immediate care, while others would not benefit much more from being matched marginally earlier. However, we will not always know when patients need more immediate care, but we can try to determine this through thorough screening questions.

To effectively match volunteers and patients, there must be meaningful and relevant data from both groups to determine which matches are optimal. In addition to recruiting and retaining volunteers, it is essential to consider how to manage the quality of patient-volunteer matches within the system.

Historically, the primary focus of allocating resources in the wake of disasters has largely overlooked resources for mental health. We propose developing a web application for matching qualified volunteers with people suffering from PTSD and related symptoms after experiencing a disaster. Existing telehealth resources for mental health, such as BetterHelp, TalkSpace, and Calmerry, are modeled as convenient replacements for traditional therapy and require payment or insurance coverage. We envision an application that operated as an emergency mental health service, aiming not to retain customers but to find alternative long-term care options for their specific needs without requiring payment. This would make it more accessible to people without insurance than BetterHelp or traditional therapy services.

3. Methodology

This chapter outlines the procedures we took to complete this project.

3.1. Defining Project Scope

Defining the scope of our project allowed us to make more informed choices about the model based on the potential users of our application. The calculations made in the pairing process are transferable from location to location but will vary based on the needs and preferences of different populations. Choosing one location to study keeps more factors consistent while examining other fluctuating factors. After initially tailoring our solution to one location, we provide recommendations for how it can be expanded.

We decided to focus on the United States specifically, before expanding our application. From there, we considered more densely populated states as there would be more information on the demographic information. Some states we considered were Florida, Massachusetts, New York, Texas, and California. After further research it was determined that not all these locations would benefit equally from this application. Massachusetts was ruled out as they had a lack of frequent natural disasters within the past ten years (*Massachusetts | Fema.gov*, 2023). Similarly, same can be said about New York (*New York | FEMA.gov*, 2023). Residents are accustomed to the naturist weather patterns present within New England. Florida was ruled out because of their laws pertaining to mental health care. Florida has a mental health act known as the Baker Act. The Baker Act forces services on individuals with mental illness in the case that they need medical attention. Although people need medical attention, it does not mean they necessarily want it. This act allows loved ones to seek medical attention from those in need, regardless of whether they want it or not (*Baker Act - UF Health*, 2023). This act contradicts the scope of our project, as we want to pair people with help on voluntary terms. Based on factors such as population, geographic location and law regulations, we ruled out states until we settled in Texas.

Texas within the last five years has had several unexpected disasters, in particular, weather fluctuations. Texas is prone to natural disasters because of its proximity to the water, tectonic plate boundaries, and the equator. Texas has had many occurrences of flooding, hurricanes, tornadoes, and, most recently, winter storms. Texas tends to be warmer, and the recent winter snowstorm caught residents by surprise, causing a sudden change in their daily lives.

Due to the points mentioned above, our groups decided to initialize the scope of our project in Texas to develop synthetic data for our system. Texas has a large population, with a favorable legal environment. In addition, this state would benefit from this protype with the number of natural disasters over similarly comparative states (NCEI.Monitoring.Info@noaa.gov, 2023).

3.2. Employing User-Centered Design for Prototype Development

In addition to developing a mathematical model for matching patients and volunteers, we created a functional prototype of an application for both user groups to view their matches. The following section outlines the steps taken to develop our functional prototype using principles of user-centered design. User-centered design refers to the process of involving intended users in the design process (Chamberlain et al., 2022). While there are many ways to include users in the design process, research has found that certain principles are important to apply to successfully conduct user-centered design (Leavitt & Shneiderman, 2006, Chamberlain et al., 2022). *Figure 2* from Leavitt & Shneiderman outlines the general phases of the user-centered design process.

Figure 2. User-centered design (UCD) process diagram

Once a need has been identified, the next step is to specify the context of use. This involves identifying the people who will use the product and what they will use it for. Users can be involved in this stage through interviews and focus groups, and by looking at examples of existing applications that were designed for a certain set of users. The second step is to specify the requirements or identify any business requirements or user goals for the product to succeed. Third is producing design solutions, which involves prototyping multiple versions of the application. Before iterating the cycle over again, the last step is evaluating the designs through usability testing (Leavitt & Shneiderman, 2006, Chamberlain et al., 2022). For our project, we split the components of this diagram into three main stages, each with its own set of steps to take toward the end goal of an effective application design. These stages are the design stage, which will encompass "Specify Context of Use" and "Specify Requirements", the prototype stage, which will encompass "Produce Design Solutions", and the evaluation stage (Hasani et al., 2020).

This process repeats iteratively until the final product is achieved, as shown in Figure 2 (Leavitt & Shneiderman, 2006). Our project involved three iterations of the user-centered design process. The first iteration was focused on identifying the features necessary to develop a matching platform. The second iteration was focused on developing a user interface that allows the collection of the features from multiple user types. The third iteration was focused on operationalizing the user interface to assess the utility of the proposed solution. This section outlines the steps we took to complete these three iterations.

3.3. Iteration 1: Developing Feature Lists

It was important to employ user-centered design in the process of developing our feature lists, as it helped us ensure that the users of the application, both patients and volunteers, are comfortable with the level of personal information that they are providing us. For this first iteration, we followed the steps of designing, prototyping, and evaluating our proposed feature lists before using them to develop our optimization model and wireframe prototype.

3.3.1. Iteration 1: Specify Requirements

For our first iteration, we utilized ideation and task analysis to design a list of patient features to collect for our application. Before we began our own brainstorming, we conducted a review of existing online mental healthcare services, specifically BetterHelp (BetterHelp 2023) and Calmerry (Calmerry 2023). Our goal was to identify the methods and features that they use to match their patients with therapists. As we conducted our review, we answered the following questions:

1. What methods do existing telehealth applications use to screen and categorize their volunteers or paid care providers?
2. What characteristics or skills do they look for to determine volunteer qualifications?
3. What skills do they look for to determine volunteer compatibility with patients?

Our group developed a list of features to collect from patients or volunteers based on the methods currently used by existing platforms.

The next stage of the design process was identifying the various goals of our feature lists and matching those goals with potential features. It is important that each feature that we collect from patients or volunteers is backed by a reason for needing that data, so that only necessary data was collected. This is one way user privacy was considered while also making our matching algorithm more efficient.

We reviewed the notes we took during our brainstorming session, and for each potential feature, identified a goal or reason behind obtaining that information. Each feature could have multiple, or no reasons associated with it. Some features may achieve the same goal. For features that have no reason associated with them, we removed them from our data collection stage. With these considerations, we developed our prototype list of features.

3.3.2. Iteration 1: Produce a Design Solution

We used Qualtrics to prototype our first design solution. We developed two questionnaires. One questionnaire is to collect data from patients. Another is to collect data from volunteers, using the features we identified during the design stage.

3.3.3. Iteration 1: Evaluate Design

We evaluated our prototype surveys through a series of consultations with expert users. We reached out to two professors at UMASS Chan Medical School, Professor Rachel Davis-Martin and Professor Celine Larkin, to ask for their expertise from the perspective of potential care providers. During our consultations, we asked the following questions about our prototype surveys:

1. Do you think that the data being collected from volunteers in this prototype is sufficient to effectively match them with patients? Can you think of other information that may be effective to ask at this stage, or some information that is not necessary?
2. Do you think that volunteers will be comfortable with providing this information in the application knowing that it will be used to match them with patients? Note: Some demographic questions allow for people to not disclose this information if they do not wish to.

We also reached out to Professor Brenton Faber at Worcester Polytechnic Institute to gain perspective from a potential user. He is a volunteer EMT and researcher, and he provided us with background insight into the unique mental health challenges that emergency responders often face. Instead of looking for people actively seeking mental health care to evaluate our design, we consulted with Professor Faber, as he is familiar with the needs and opinions of this portion of our target user population. Since first responders play such an important role in post-disaster aid, it was important that we consider their perspectives as potential users seeking mental health care.

During our consultation with him, we asked the following questions about our prototype patient feature list:

1. Do you think that the data being collected from patients in this prototype is sufficient to effectively match them with volunteers? Can you think of other information that you would want your provider to know going into a first-time consultation?
2. Do you think that patients will be comfortable with providing this information in the application knowing that it will be used to match them with volunteers? Note: Some demographic questions allow for people to not disclose this information if they do not wish to.

Once we received feedback on our feature lists, we developed a list of changes that needed to be implemented in the next iteration. We were also able to begin developing our mathematical model now that we knew what features to collect from our users.

3.4. Iteration 2: Developing a Wireframe Prototype

As we were working on our optimization model for matching patients and volunteers, we also began to develop a wireframe prototype of our application. Our second prototype was developed in Figma as a wireframe that incorporates all the functions a potential user would need to use the application.

3.4.1. Iteration 2: Specify Requirements

For our second iteration, we utilized ideation in a similar way to what we did in the first iteration. Our goal was to identify what tasks users will need to do when using the application, as well as how to create an interface that allows for all these tasks to be implemented. We looked again at Calmerry (Calmerry 2023) and BetterHelp (BetterHelp 2023), this time looking more at their website's interface and what features they included for volunteers and patients. We developed a list of webpage features that when implemented, would support the tasks users would need to complete. As we began thinking about how our prototype would appear in Figma, we also used existing application templates as inspiration for our layout and navigation, which served as a starting point for us to customize the prototype to meet the needs of our potential users.

3.4.2. Iteration 2: Produce a Design Solution

We used Figma to prototype our second design solution. We modified an existing template for a mental health application and incorporated pages and functions that we brainstormed in the previous step. To ensure that we were able to conduct a thorough evaluation of our prototype, we represented all the features of the prototype with varying levels of functionality.

3.4.3. Iteration 2: Evaluate Design

We evaluated our wireframe prototype through consultations with relevant users, like our evaluation stage for Iteration 1. We followed up with Dr. Rachel Davis-Martin from UMASS Chan Medical School, to gain feedback on the prototype. In addition to reflecting on the overall flow of the application, and following up on the feedback we implemented since our first meeting, we asked the following questions:

1. Do you feel that the options presented for each question adequately represent the potential needs of the volunteers who would be filling out this form?
2. As a potential volunteer, would the depth of questions asked put you off for signing up for a program like this? If yes, do you have any suggestions for simplifying the questionnaire?

Once we received feedback on our wireframe prototype, we developed a list of changes that needed to be implemented in our final iteration.

3.5. Iteration 3: Developing a Functional Prototype

After evaluating our wireframe prototype, we revised it based on the feedback we received. This marked the start of our third iteration of the user-centered design process, and our goal was to develop a semi-functional prototype that supports all the tasks outlined in our wireframe prototype with more complete functionality.

3.5.1. Iteration 3: Specify Requirements

To design our functional prototype, we used the feedback we received on earlier stages as a basis for brainstorming improvements for the final version of the application. We also brainstormed which non-functional features of the wireframe prototype needed to be converted into functional features to best encompass the vital parts of the application. We followed the same brainstorming process as the previous iterations.

3.5.2. Iteration 3: Produce a Design Solution

We utilized the Figma plugin Anima to convert our Figma prototype into HTML and CSS code. Additional development was required to make the prototype features work as intended. We hosted our prototype using GitHub pages.

3.5.3. Iteration 3: Evaluate Design

We evaluated our functional prototype by recruiting various representatives of the intended users. We found people to evaluate our prototype from the perspective of potential volunteers and potential clients. This included six professionals and ten WPI students. Students were from a multitude of backgrounds to ensure we covered as many demographics as possible. We received approval from the WPI Institutional Review Board to conduct our prototype evaluations. Our approval letter can be found in Appendix 1.

For both sets of evaluations, we created user scenarios to help us test our design. Our user scenarios can be found in Appendix 2. Across both groups of testers, we created four total user scenarios, one for each primary use case of the application. Of the total four, two were tested by the volunteer group, and the other two were tested by the client group. These were created by considering all the possible flows users may take when using the application, and discussing the reason why each user would take that path. Each user scenario is comprised of a brief paragraph to establish the context of the client's reasoning for using the application, along with a set of tasks for each user to complete. Some of the user scenarios come with a user biography, which has all the information the tester will need to fill out if they are filling out the create account survey.

It was important for us to provide each tester with a user bio when they were filling out the surveys to assure them that we were not collecting any of their data. Particularly, due to the sensitive topic of mental health, we wanted to instill in our volunteers that the goal of the evaluation was not to collect their data but to test our application's quality.

3.5.3.1. Recruiting Test Volunteers

To conduct our test, we recruited volunteers to represent the two types of users. These users include possible volunteers and possible patients. First, we look at potential volunteers mental care providers.

To recruit test volunteers who could be potential volunteer mental health care providers, we reached out to staff members at the Student Development and Counseling Center (SDCC) at WPI. We provided them with a brief description of our project and a timeline for conducting evaluations, and asked if anyone would be interested in signing up to help us evaluate our prototype. We received six responses and conducted evaluations with each of these people.

To recruit test volunteers who could be potential patients or people seeking mental health care, we recruited people who could see themselves using this program if they were in the position of having experienced a natural disaster or other traumatic event. We sampled from the WPI community to find test volunteers for this category. We were able to conduct ten evaluations with potential client users from the WPI community.

Each test volunteer, regardless of which user group they are representing, was required to sign an informed consent form. The form will describe the evaluation process and how data will be collected and then used. See Appendix 3 for a copy of the informed consent form.

3.5.3.2. Evaluation Procedures

Each volunteer had the instructions read to them and was reminded that they can leave the study at any time. A team member also walked them through the informed consent form's contents before having them sign. They were reminded that the only data collected would be observation notes that would not be attached to their name or any other identifying information.

Once the details of the study had been discussed, and the volunteer expressed consent to continue the study, a team member would read the introduction to the user scenarios and ask the volunteer to complete the tasks outlined on the page. Once the volunteer completed each task, the team members observing would ask any questions about the user's behavior and give them a chance to give suggestions. At this point, the study concluded.

Evaluating our functional prototype design was one of the last steps of our third iteration of the user-centered design process. Before finalizing our prototype, we implemented feedback we received during our evaluations, while ensuring we did not change any aspects of the design that people found effective. Screenshots of our final application prototype can be found in Appendix 4.

3.6. Developing a Mathematical Model to Match Patients and Volunteers

The following section outlines our mathematical model, including the sets, parameters, and variables used. The input data for the model is synthetic data during testing. The synthetic data is representative of the population demographics of Texas.

The sets and parameters of our mathematical model are based on the data that would be collected from each client and volunteer based on our prototype application. When using the application, clients and volunteers are asked to provide their availability for the coming week. The goal is to match clients with a volunteer that can meet with them sometime within that week. If there are insufficient volunteers in the system, the client will be added back into the pool of clients needing a match and be given the opportunity to update their availability.

3.6.1. Model Definitions

Set Definitions:

Let P be the set of patients with index p
Let V be the set of volunteers with index v
Let T be the set of 1-hour time blocks for the week with index t
Let S be the set of severity levels with index s

Subset Definitions:

Let $T_v \subseteq T$ be the set of 1-hour time blocks for the week that volunteer v is available
Let $T_p \subseteq T$ be the set of 1-hour time blocks for the week that patient p is available
Let $P_s \subseteq P$ be the set of patients with each severity level s for $s \in S$; $\bigcup_{s \in S} P_s = P$

Parameter Definitions:

Let m_{pv} be the matching scores between a pair of patient $p \in P$ and volunteer $v \in V$
Let l_{pv} be the binary language match score, 1 if patient $p \in P$ and volunteer $v \in V$ speak the same language, 0 otherwise
Let c_s be the objective coefficient for severity level $s \in S$

Variable Definitions:

$$x_t^{p,v} = \begin{cases} 1 \; if \; volunteer \; v \; is \; assigned \; to \; patient \; p \; during \; timeblock \; t \\ 0 \; otherwise \end{cases}$$

$$y_p = \begin{cases} 1 \; if \; patient \; p \; has \; been \; assigned \\ 0 \; otherwise \end{cases}$$

Constraints:

Subject to

$$y_p \leq \sum_{v \in V} \sum_{t \in \{T_p \cap T_v\}} x_t^{p,v} \leq k \; y_p, \quad p \in P, \; where \; k \; is \; a \; constant \qquad (1)$$

Constraint set (1) ensures that if patient p has been assigned, then they receive between 1 and k assignments of volunteers and time slots.

$$\sum_{p \in P} x_t^{p,v} \leq 1, \; v \in V, \; t \in T_v \qquad (2)$$

Constraint set (2) ensures that each volunteer is not matched to more than one patient at the same time.

$$\sum_{v \in V} x_t^{p,v} \leq 1, \; p \in P, \; t \in T_p \tag{3}$$

Constraint set (3) ensures that each patient is not matched to more than one volunteer at the same time.

$$\sum_{t \in \{T \setminus T_p\}} \sum_{v \in V} x_t^{p,v} = 0, \; p \in P \tag{4}$$

Constraint set (4) ensures that no matches are made for all volunteers when a patient is unavailable.

$$\sum_{t \in \{T \setminus T_v\}} \sum_{p \in P} x_t^{p,v} = 0, \; v \in V \tag{5}$$

Constraint set (5) ensures that no matches are established for any patient at any time when a volunteer is not available.

$$\sum_{t \in T} x_t^{p,v} \leq l_{pv}, \; \forall p \in P, \; \forall v \in V \tag{6}$$

Constraint set (6) ensures that every patient-volunteer match must have at least one language in common, or else cannot be matched.

$$x_t^{p,v} \in \{0,1\}, \; \forall p \in P, \; \forall v \in V \tag{7}$$

$$y_p \in \{0,1\}, \; \forall p \in P \tag{8}$$

Lines (7) and (8) contain the variable domains for the two decision variables.

3.6.2. Multi-Objective Optimization

We chose to model our matching problem using multi-objective optimization. We opted for this strategy to maximize the number of matches while prioritizing patient severity and volunteer compatibility. Through multi-objective optimization, we may divide our objective into more manageable components and arrange them in order of significance.

There are existing approaches to optimization problems in the healthcare field, such as the one in Azizi et al., 2023, that utilize a hierarchical objective function to maximize patient priority while also minimizing cost (in the case of this approach, distance). The severity or priority of patients is an important component of healthcare optimization problems, and many multi-objective or hierarchical approaches to optimization in this field will maximize severity first with other components coming second. In addition to the paper cited earlier, we found three other papers that implemented multi-objective functions to optimize distribution of healthcare and incorporated patient severity or priority into their first objective function (Aringhieri et al., 2022, Cinar et al., 2022, Meersman & Maenhout, 2022). Similarly, to these papers, we chose to maximize matches weighted with patient severity as our first objective, and maximize matches weighted with matching score secondarily.

To prioritize all clients with the highest severity above lower severity clients, we developed the following algorithm to calculate coefficients to ensure that any number of lower-severity clients will never outweigh even one client with a higher severity.

Objective coefficient derivation algorithm

Input: List of the number of clients with each severity level [num_0, num_1, … num_6]
Output the coefficients list $[c_0, c_1, c_2, c_3, c_4, c_5, c_6]$

1) *Initialize coefficients list with the first element (index 0) as the value 1*

2) *For each index i from 1 to 6:*

   a. *Initialize current_coefficient to 1*
   b. *For each index j from 0 to i-1:*
      i. *Update current_coefficient += num_j * coefficients[j]*
   c. *Append current_coefficient to coefficients list*

The coefficients calculated using this algorithm were used in our first objective function to maximize the number of matches of high severity patients. Our objective functions for this model are outlined below.

Objective Functions:

$$f_1(.) = \max \sum_{s \in S} \sum_{p \in P_s} c_s \; y_p$$
$$f_2(.) = \max \sum_{p \in P} \sum_{v \in V} \sum_{t \in T_v} c_{pv} \; x_t^{p,v}$$
$$f_3(.) = \max \sum_{p \in P} y_p$$

The primary objective function (f_1) maximizes the total number patients matched weighted by the severity level of the patient. The secondary objective function (f_2) maximizes the total number of matches between patients and volunteers weighted by the matching score between the patient and the volunteer. The third objective function (f_3) maximizes the total number of patients matched without any weights.

3.6.3. Creating Synthetic Data

To test the performance of our model, we created synthetic data and modified it to test various edge cases. We used Gurobi Optimizer in Python to run our model after generating synthetic data. We needed to create data corresponding to all sets, subsets, and parameters for our input data, which also correspond to the questions asked in our prototype application.

To create the sets and subsets, we created dictionaries in Python for the sets of patients, volunteers, and time blocks and for the subsets of the times each patient is available and the times each volunteer is available. In the context of our application prototype, this data would come from the number of patients and volunteers who sign up for the program, and how many hours a week they indicated they were available in the form.

To best model how many hours a week each volunteer was available, we used a distribution defined in a paper by Paret et al., 2021, "Assigning spontaneous volunteers to relief efforts under uncertainty in task demand and volunteer availability". The authors of this paper assume that "Spontaneous volunteers arrive at the system according to a Poisson process rate, lambda." The arrival rate lambda for the Poisson process can be considered as the rate per hour. It also assumes that until abandonment, volunteers' time in the system are exponentially distributed with a mean of 1/gamma. We utilized a gamma value of 0.5. A higher gamma corresponds to a shorter average time volunteers will be available.

To best model how many hours a week each patient would be available, we used a normal distribution as there is oftentimes large uncertainty when natural disasters strike leading to variability in predicting patient's schedules. We utilized a normal distribution with a mean of 7, and a standard deviation of 1. We chose a mean of 7 as we have 14 total time blocks from 8:00am – 10:00pm, which would put the center of our distribution at 3:00pm. With regards to patient duration, we utilized a normal distribution with a mean of 2 and a standard deviation of 1, making the average time patients would be available in a day to be 2 hours.

To create data for the model parameters, we randomly assigned patient severity levels from 0 to 6, which correspond to the six screening questions patients are asked when they fill out the form in the application. In our evaluation section we explore other assignments of these scores that are not random.

For the compatibility score parameter, we needed to generate additional data that is not seen by the model to determine the score. We generated demographic information for each patient and volunteer in the dataset and used demographic statistics for the state of Texas to do so (*Religion in Texas 2023, Texas Equality Profile*, 2020, *Texas Population by Gender - 2023 Texas Gender Demographic*, *U.S. Census Bureau QuickFacts: Texas* (2022)). We also used random assignment to assign age groups to patients and volunteers. For the category of religion, we selected the six most prevalent religions in our target population. For the category of language, due to the lack of detail in other languages spoken in Texas besides English and Spanish, we ultimately rounded both values up for the model and only offered a Spanish or English option. Table 1 below shows the categories of demographic data that we generated and the distributions for each.

Feature	Population %
Ethnicity	
Hispanic or Latino	39.8%
American Indian or Alaska Native	0.2%
Asian	5.0%
Black or African American	11.7%
Native Hawaiian or Pacific Islander	0.1%
White	43.2%
Gender	
Agender	0.5%
Man	49.0%
Woman	49.0%
Non-Binary	0.5%
Transfeminine	0.5%
Transmasculine	0.5%
Sexual Orientation	
Asexual	0.13%
Bisexual	2.3%
Gay/Lesbian	1.41%
Heterosexual/Straight	95.9%
Pansexual	0.13%
Queer	0.13%
Religion	
No religious background	18.0%
Christian (all denominations)	77.0%
Buddhist	1.0%
Hindu	1.0%
Jewish	1.3%
Muslim	1.2%
Sikh	0.5%
Age (Randomly Assigned)	
18-35	33.33%
36-55	33.33%
55+	33.33%
Language	
English	65.0%
Spanish	35.0%

Table 1. Demographic Distributions for Synthetic Data

After generating the patient and volunteer demographics, we also randomly assigned patient preferences for the demographics of their providers. We generated responses based on the options presented in our application prototype and coded them to correspond to specific demographics that are associated with a volunteer. During our evaluation of the model, we will randomly assign demographics to both patients and volunteers to see how the model would perform on a larger scale.

To generate a compatibility score associated with each patient-volunteer pair, we compared the patient's response to each of the five preference questions with the volunteer's demographic information for each possible pair, and calculated a score representing the number of preferences that the volunteer meets. Patients are given the option to select their preferences for their provider from the same options for the five demographic questions asked. When a patient did not have a specific preference, they had the option to choose no preference, which calculates as a met preference. These scores are all either 0, 0.2, 0.4, 0.6, 0.8, or 1.

Lastly, to evaluate whether the provider and volunteer would speak the same language, we generated a binary language score. This score is given the value 1 if the provider and volunteer speak the same language and 0 if they do not. This score is used in our constraint for matches as all matches will have to have a score of 1 to be a verified match.

3.6.4. Model Evaluation

After developing and running our mathematical model, we evaluated it to assess its performance. We used the total severity score, total matching score, and number of patients matched as measures of performance. To assess how the model performs under different circumstances, we evaluated it using different sets of synthetic data. Table 2 below outlines the sets of synthetic data that we generated and the various distributions we evaluated.

Set of Data				
Patient Preferences	Randomly Assigned		No Preference for All	
Patient Availability	Uniformly distributed		Normally distributed	
Volunteer Availability	Uniformly distributed		Normally distributed	Poisson Distributed
Demographics	Texas	Randomly Assigned Patients	Randomly Assigned Volunteers	Randomly Assigned Patients and Volunteers
Patient Severity	Randomly Assigned		All Patients Have Severity 0	All Patients Have Severity 5

Table 2. Synthetic Data Distributions Evaluated

For patient preferences, we created data so that no patients have any preferences and patients have randomly assigned preferences for all five preferences. For patient and volunteer availability, we uniformly and normally distributed their availability in addition to using the distribution we described earlier in this section. For demographics, which applied to both the patients and the volunteers, we used data based on the Texas population and also data made by randomly assigned patient and volunteer demographics. Lastly, for patient severity, we randomly assigned the severity levels across all the patients and generated data where all patients have severities between 0 and 6, all patients have severity level 0, and all patients have severity level 5.

After the model runs once, we implemented a process that can automate matches based on the best compatibility score. This process includes three main steps which automate matches for patients and update the patient data so that only unmatched patients are included in the second run. The first step groups the results data frame by Patient ID and finds the index corresponding to the maximum value in the "Matching Score" column within each group. The next step uses the indices obtained in the previous step and the pandas package loc function to retrieve the entire rows from the results data frame, resetting the index in the process. The final step of the automation process initializes a new list called to hold matched patients, loops through the full Patient list P, appending the element to the Matched list if it matches any Patient ID in the Automated Matches data frame. After the loop, a list is created called Unmatched_p, containing the elements of P that are a part of matched using a difference function.

After automating matches, we run the model again with updated data only representing the patients in the Unmatched_p list that were not matched originally. This process ensures that the maximum number of patients are being matched at a given time and that open volunteers' availability is being used up by other patients.

By evaluating our model in this way, we analyzed its performance on a wider application than our baseline model, which is limited by our assumptions about the population of patients and volunteers. To address potential biases and ensure that the model can be applied to a wider audience, it is important that we test these factors.

3.7. Iteration 4: Development of Functional Prototype Utilizing Local Platform

With the conclusion of the development of our final prototype, and the completion of all our rounds of feedback, we looked to integrate the work we have accumulated up until this point by utilizing the low-code application development platform Mendix to deploy our app. The application takes into consideration the flows, inclusive wording, and interface that we have sought after up until this point. The end product is an application that can be maintained and operated by an administrator, and that can be used by both clients and volunteers. Figure 3 demonstrates the data flow diagram of our application with Mendix serving as the front-end system in the context diagram, before being expanded upon with the level-0 diagram.

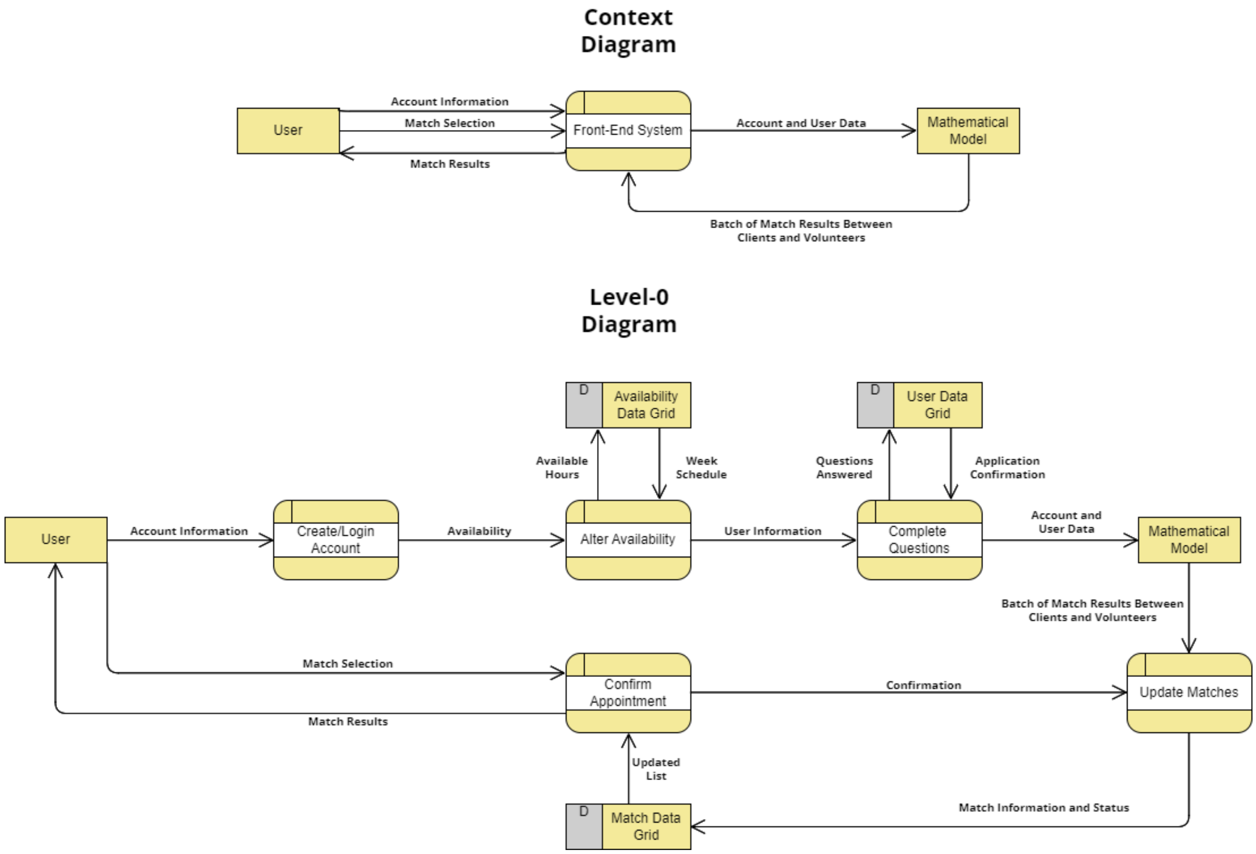


Figure 3. Data Flow Diagram (DFD)

3.7.1 Why Mendix and Local Platform

With just a small amount of manual coding, users can create, launch, and maintain online and mobile applications using Mendix, a low-code application development platform. With the use of a visual development environment, developers may produce applications fast and effectively regardless of their level of programming knowledge (Pietsch, 2023). Given the scope and range of time available for this application and project, Mendix offers a solution in creating a refined interactable application following our final prototype.

Because Mendix was built to be scalable, our application may be expanded in the future to meet demand and need as the scope of the project changes. Whether we are developing a sophisticated application from the ground up or starting small, Mendix can scale with our project without requiring extensive re-development or re-architecting (Pietsch, 2023). Mendix allows teams to collaborate effectively with collaboration tools. It is easy for multiple developers to maintain versions, track changes, and work on the same project at the same time. In addition, Mendix frequently offers industry-standard compliance and integrated security capabilities, assisting developers in building reliable and secure systems from the ground up. This is particularly important for the purposes of our application as we are working with sensitive personal mental health data that must be protected to maintain client and volunteer trust.

3.7.2 Domain Model and Excel Database

Our feature list and optimization model were utilized to create an excel database that served as the framework to be imported into Mendix to establish a baseline application for our users. Once this database had been incorporated, we looked to alter and define the Domain Model or Entity Relationship Diagram, as seen in Figure 4, of the application that closely reflects our vision for the final prototype, which takes into consideration the Mathematical Model.

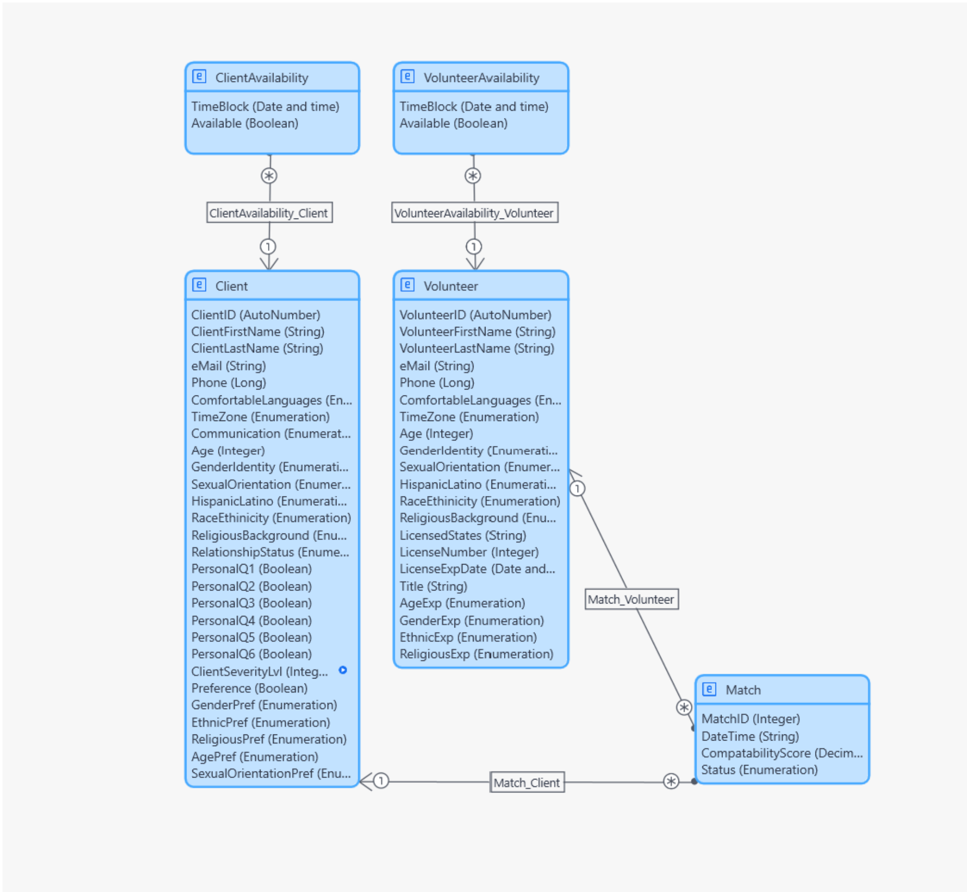


Figure 4. Entity Relationship Diagram (ERD)

Client and Volunteer Entities were implemented with their association of 1-Many to their respective Availability entities. At the same time, both Client and Volunteer share a 1-Many Association with the Match Entity. This reflects how Client and Volunteers each can have many hours of availability in each time frame while also possibly possessing multiple matches to one another. Figure 5 shows that this set up allows us to construct data grids for each entity and incorporate features for the administrators that were previously not present, such as ability to add, delete, modify, import, and export user data.

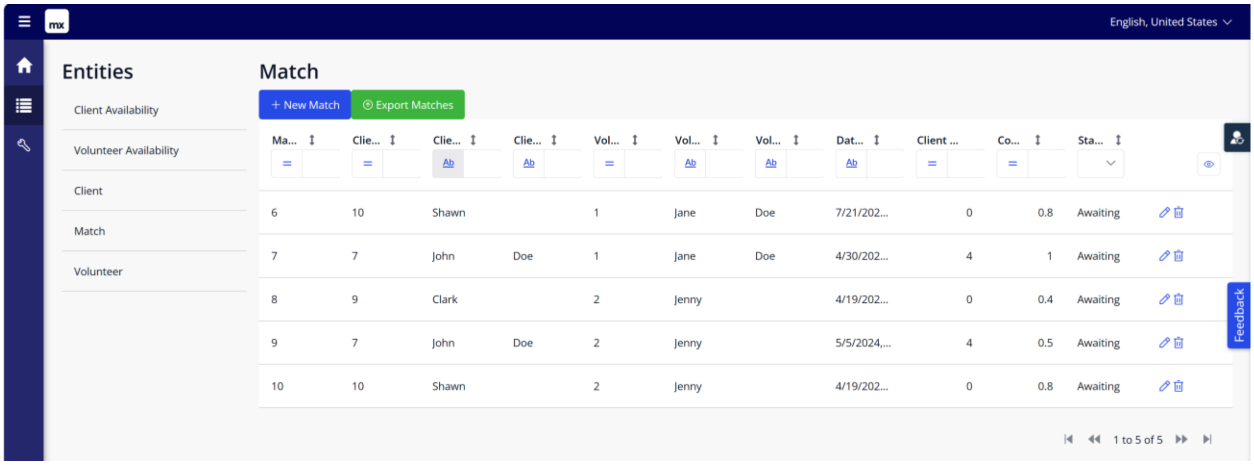


Figure 5. Data Grid View of Matches

4. Results

4.1. User-Centered Design Iteration 1: Feature List Prototype

The first prototypes we created for this project were developed using the prototype lists of features. The list determined what information we planned on collecting from patients and volunteers. These prototypes were made in Qualtrics, and used questions based on the important features we brainstormed. *Figure 6* below shows parts of two pages of one of these prototypes. Creating this prototype allowed us to visualize what our application may look like, and how potential users would interact with it. To improve upon this prototype in our next iteration, we needed to evaluate it through conversation with potential users.

Figure 6. Iteration 1 Prototype

4.1.1. Evaluation of Feature Lists

The first expert we met with was a WPI professor who has experience volunteering with a local clinic as an EMT. During our consultation, he emphasized the importance of keeping the needs of the volunteers in mind and not just focusing on the agency of clients. He also suggested ways that we could be inclusive with our language and prompted us to reach out to the Office of Diversity, Inclusion, and Multicultural Education to review our surveys.

Next, we met with a professor and researcher from UMASS Chan Medical School who also works as a clinical psychologist. She provided us with specific information about whether the questions we were asking were effectively gauging the volunteers' qualifications. One area that this pertained to was volunteer licenses. In addition to license numbers, we would also need an expiration date, and which state they were licensed in. She also provided some insight into what kinds of information volunteers would like to know about their clients prior to meeting and directed us to a set of standardized PTSD Screening questions. She helped us address some areas where the language could be rephrased to be more inclusive and easier to understand for a wide audience of users. She helped us hone our questions so that they were more succinct, without room for interpretation, as it is important that we get consistent information from our users.

The next professor that we met with from UMASS Chan Medical School is not familiar with the clinical side but has experience researching suicide, substance abuse, and depression. When it comes to people seeking mental health help, she emphasized how important it is to be inclusive and welcoming to everyone, especially since patients are going out of their way to seek help. She mentioned the bar of entry for clients as well as volunteers should be low. She also stressed the importance of data security for volunteers and clients. Further, she helped us establish questions for volunteers to gauge their experience working with certain clients. Another point of insight she was able to provide was for us to consider the importance of honesty and transparency with our patients. It is important to not mislead them with our questions and make clear the limitations of the matching algorithm in the application.

Although the experts we consulted with largely represented the volunteer user group, they gave us insight into how to present the information to clients and volunteers. Moving into our next iteration, we knew that we had to adjust the wording of our questions to ensure inclusion and clarity. We also made sure to consider whether each question served a purpose to help lower the bar for entry for both clients and volunteers. Additionally, we improved the accuracy of the information already in the application by including a set of questions to screen clients for PTSD and modifying our volunteer qualifications section.

4.2. User-Centered Design Iteration 2: Wireframe Prototype

The second prototype that we created was a wireframe of an entire application, rather than just the survey portion. We created our prototype in Figma after brainstorming pages that we thought we should include to provide the user with the information they need to complete necessary tasks. We also implemented the list of requirements that we collected during our evaluation of the previous iteration. *Figure 7* below shows a few pages from this prototype. Creating a wireframe prototype allowed us to consider more completely how users would likely interact with the application. Our next step was to evaluate the prototype's contents and the overall flow.

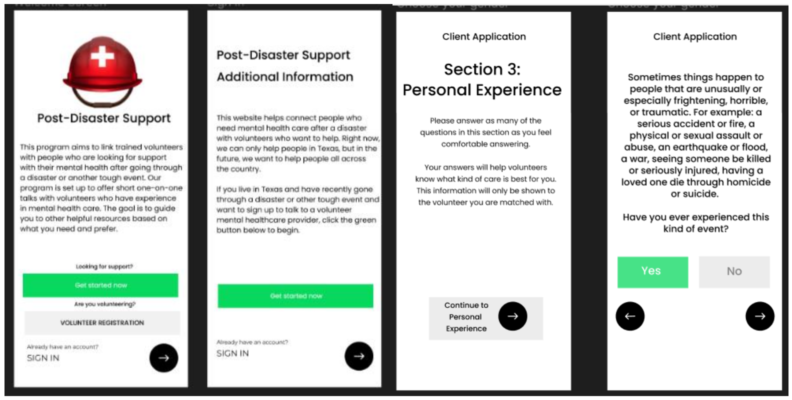


Figure 7. Iteration 2 Prototype

4.2.1. Evaluation of Wireframe Prototype

To evaluate our wireframe prototype, we followed a similar process to our evaluation for the first iteration. This involved collecting qualitative data from conversations we had with the same clinical psychologist. This time, more information was obtained about the flow of information through the application rather than the particulars of the content. We gathered the following feedback during our evaluation:

1. Limit the number of questions volunteers are asked to just be the state they are licensed in, and their license number and expiration date
2. Supplement the qualifications and experience information by allowing volunteers to write a professional bio to convey their specialties to their clients
3. Find a set of five questions to screen patients for PTSD, the original ten questions was too much information, but presenting their client's responses to the five-question screener would be beneficial
4. When you prompt clients to enter their preferences for their providers, make it very clear through the wording and presentation that it is not guaranteed that they will be matched with someone that meets all of their preferences

Moving into our next iteration, we knew that we would have to implement the above requirements during the development process.

4.3. User-Centered Design Iteration 3: Functional Prototype

In our final iteration, we developed a semi-functional prototype of our proposed application to aid in matching clients with volunteers. *Figure 8* below shows screenshots of some of the application pages. The application is based on the Figma prototype we developed for iteration two, with additional changes based on the feedback we received from our evaluations. For the final part of our application design process, we evaluated the quality of our prototype through a series of tests with representative users.

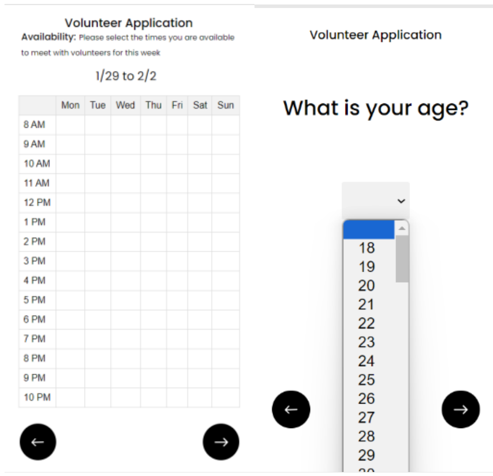


Figure 8. Iteration 3 Prototype

4.3.1. Evaluation of Functional Prototype

In total, we evaluated our prototype with six representatives from the volunteer group, and 10 representatives from the client group. Through our process of observing the testers as they completed tasks, we were able to collect data in the form of observation notes to help us assess the quality of our application. Tables 3 and 4 below outline the feedback we obtained from volunteer and client testers and the associated revisions for each comment.

Scenario Version (1 or 2)	**Page of Prototype**	**Feedback Received/ Observed**	**Revision**
2	Availability and update availability pages	User was unclear if the times for each time block represented the start or end time	Place the numbers corresponding to each time block in line with the top gridline for each square to make this clearer
2	License expiration date page	Sites often have date format guidelines	Add date format guidelines to the date input box rather than using a plain text input

2	Welcome screen	User tried to click on the “Sign In” text rather than the arrow	Make both the text and the arrow clickable
2	Match view page -> account view page	User suggests labeling back arrow “Back to Home/Account”	Label the back arrow to make it clear where the user is going back to
2	Update availability page	User was unclear how they were meant to update their availability, and for what time	Add additional information indicating your availability can be updated for the following weeks as you are matched to more clients
1	Navigate Through Initial Page	User clicked the grey button rather than the black arrow with functionality	Make whole button clickable rather than just Arrow.
2	Thank You Page	User must go to a new tab just to get back to the sign in page	Make the thank-you page have a button that connects to the beginning of application.
1	Create Account	User was confused and thought client button was the only option since it was green	Made both Client and Volunteer option pop out to not emphasize one over the other
1	Home Screen	Wasn’t clear which button was made for volunteer registration	Made clear buttons for volunteer and client registration
1	View Patient Screening Results	Buttons were unclear to view the screening results	Made button clearer for viewing results

Table 3. Feedback Table for Volunteer Prototype

Scenario Version (3 or 4)	**Page of Prototype**	**Feedback Received**	**Revision**
3	First page, also other Section heading pages	Too much text	Split up paragraphs, and rewrite to make shorter
3	Section heading pages	Information feels repetitive	Rewrite section heading paragraphs to be less repetitive
3	Preliminary screening intro page	The amount of information is overwhelming	Reduce the amount of information and split up paragraphs
3	Availability and update availability	You can select the squares with the times and turn them green	Make the label squares unclickable
3	Section header pages	Wording of each page is inconsistent, should follow a more similar pattern	Make the wording of each page follow a similar pattern
3	Screening question pages	Should be paragraph space after “in the past month”	Add paragraph space
3	Screening question pages	There should be an indication of the number of questions	Add number indicators
3	Selecting volunteer demographics	Maybe have people opt in rather than making them fill out the requests if they don't have any	Allow clients to opt in to select demographic details for their volunteer
3	Thank you page	Should have the number of matches	Add number of matches and

		displayed big instead of in the paragraph	reduce amount of text on page
3	Home screen	The navigation bar should have icons, not just text	Add icons to navigation bar
3	Home screen	“View matches” isn’t clearly a button	Make the button look more like a button
3	Sign up Screen	Maybe have the password not appear when typing it in	Make password appear starred out when typing it in
3	All Pages	Spacing should be less/arrows moved up, so user does not have to scroll to click to next page.	Make spacing more consistent across pages
4	Matches Page	You should show times, not just the day of the week when looking at all matches together to better weigh your options. Especially if matches have same day	Add both times and dates to match view page
4	Confirmation Page	Wrong wording “We are recommending logging”	Update wording to be accurate and clear

Table 4. Feedback Table for Client Prototype

Overall, for the volunteer group, we found that most testers had an easy time navigating through the application. During a few tests we encountered areas of the application where users were not clear how to progress, and based on this feedback we were able to make small changes to make the application flow clearer. Usually this involved making sure clickable elements looked like buttons to indicate to users that they could be clicked. In one case, we also added a label to a back arrow to indicate where it was going back to.

For the client group, we found that overall users had a similar experience to that of the volunteers. We noticed users got briefly stuck at similar places where buttons were not as obvious, and arrows were not labeled. We also got feedback from the clients pertaining to the wording on the front page for each section, specifically that the amount of text was overwhelming and at times redundant. We implemented similar revisions to the buttons as we did for the volunteer application and revised the language used to make it more concise and user-friendly.

4.4. Matching Model Evaluation

The math model was tested with synthetic data altered in the ways described in Section 3.6.4. The goal of the evaluation of the math model was to see at what patient-volunteer ratios does the model perform best, when does it perform, and how very rare circumstances and scenarios are being handled by the model. The results of these tests are seen below. When we tested results, all tests in which the patient to volunteer ratio was not being changed were tested on a 150 patient to 15 volunteer ratios. To ensure that results can be replicated in the future, we initialized a constant random seed. This allowed for all randomly assigned and demographically distributed attributes to be repeated if necessary. Additionally, when testing these cases and observing the resulting matches, two Excel sheets were created to contain the matches, one for each round of the matching process.

	Run One			Run Two with Leftover Patients		
Model	**Patients Unassigned**	**Total Severity Score**	**Compatibility Score**	**Patients Unassigned**	**Severity Score**	**Compatibility Score**
After Obj1	88	280	23.8	40	136	16.6
After Obj2	88	280	26.8	40	136	19.6
After Obj3	88	280	26.8	40	136	19.6

Table 5. Results with 150 Patients and 15 Volunteers (10:1 Ratio, 26.6% Unmatched Rate, 12.65s Runtime)

	Run One			Run Two with Leftover Patients		
Model	**Patients Unassigned**	**Total Severity Score**	**Compatibility Score**	**Patients Unassigned**	**Severity Score**	**Compatibility Score**
After Obj1	95	463	36.2	28	147	22.6

After Obj2	95	469	44.2	28	159	33.8
After Obj3	95	469	44.2	28	159	33.8

Table 6. Results with 200 Patients and 25 Volunteers (8:1 Ratio, 14% Unmatched Rate, 17.82s Runtime

	Run One			Run Two with Leftover Patients		
Model	**Patients Unassigned**	**Total Severity Score**	**Compatibility Score**	**Patients Unassigned**	**Severity Score**	**Compatibility Score**
After Obj1	21	295	33.8	3	32	6.0
After Obj2	21	320	44.8	3	32	6.8
After Obj3	21	320	44.8	3	32	6.8

Table 7. Results with 100 Patients and 25 Volunteers (4:1 Ratio, 3% Unmatched Rate, 7.06s Runtime)

	Run One			Run Two with Leftover Patients		
Model	**Patients Unassigned**	**Total Severity Score**	**Compatibility Score**	**Patients Unassigned**	**Severity Score**	**Compatibility Score**
After Obj1	193	503	37.6	114	246	26.6
After Obj2	193	505	51.0	114	246	35.8
After Obj3	193	505	51.0	114	246	35.8

Table 8. Results with 300 Patients and 25 Volunteers (12:1 Ratio, 38.0% Unmatched Rate, 28.46s Runtime)

	Run One			Run Two with Leftover Patients		
Model	**Patients Unassigned**	**Total Severity Score**	**Compatibility Score**	**Patients Unassigned**	**Severity Score**	**Compatibility Score**
After Obj1	291	570	35.8	198	332	30.0

After Obj2	291	564	42.8	198	332	37.6
After Obj3	291	564	42.8	198	332	37.6

Table 9. Results with 400 Patients and 25 Volunteers (16:1 Ratio, 49.5% Unmatched Rate, 39.53s Runtime)

	Run One			**Run Two with Leftover Patients**		
Model	**Patients Unassigned**	**Total Severity Score**	**Compatibility Score**	**Patients Unassigned**	**Severity Score**	**Compatibility Score**
After Obj1	162	190	14.6	134	120	9.2
After Obj2	162	190	15.4	134	120	11.2
After Obj3	162	190	15.4	134	184	11.2

Table 10. Results with 200 Patients and 10 Volunteers (20:1 Ratio, 50.5% Unmatched Rate, 9.21s Runtime)

	Run One			**Run Two with Leftover Patients**		
Model	**Patients Unassigned**	**Total Severity Score**	**Compatibility Score**	**Patients Unassigned**	**Severity Score**	**Compatibility Score**
After Obj1	88	280	62	40	138	48
After Obj2	88	280	62	40	138	48
After Obj3	88	280	62	40	130	48

Table 11. Results with No Patient Preferences (26.67% Unmatched Rate, 8.62s Runtime)

	Run One			**Run Two with Leftover Patients**		
Model	**Patients Unassigned**	**Total Severity Score**	**Compatibility Score**	**Patients Unassigned**	**Severity Score**	**Compatibility Score**

After Obj1	88	310	22.2	41	235	11.2
After Obj2	88	310	33.6	41	235	18.2
After Obj3	88	310	33.6	41	235	18.2

Table 12. Results with All Patients Severity 5 (27.33% Unmatched Rate, 8.19s Runtime)

	Run One			**Run Two with Leftover Patients**		
Model	**Patients Unassigned**	**Total Severity Score**	**Compatibility Score**	**Patients Unassigned**	**Severity Score**	**Compatibility Score**
After Obj1	88	0	22.2	41	0	11.2
After Obj2	88	0	33.6	41	0	18.2
After Obj3	88	0	33.6	41	0	18.2

Table 13. Results with All Patients Severity 0 (27.33% Unmatched Rate, 9.22s Runtime)

	Run One			**Run Two with Leftover Patients**		
Model	**Patients Unassigned**	**Total Severity Score**	**Compatibility Score**	**Patients Unassigned**	**Severity Score**	**Compatibility Score**
After Obj1	33	434	40.6	0	40	11.6
After Obj2	33	509	72.4	0	80	31.4
After Obj3	33	509	72.4	0	80	31.4

Table 14. Results with Volunteer Times Normally Distributed (Same as Patients) (0.0% Unmatched Rate, 8.53s Runtime

	Run One			**Run Two with Leftover Patients**		
Model	**Patients Unassigned**	**Total Severity Score**	**Compatibility Score**	**Patients Unassigned**	**Severity Score**	**Compatibility Score**

After Obj1	45	423	34.0	2	50	16.0
After Obj2	45	423	42.2	2	72	33.8
After Obj3	45	423	42.2	2	72	33.8

Table 15. Results with Patient Times Uniformly Distributed (Arrival 1-14, Duration 1-6) (1.3% Unmatched Rate, 13.44s Runtime)

	Run One			**Run Two with Leftover Patients**		
Model	**Patients Unassigned**	**Total Severity Score**	**Compatibility Score**	**Patients Unassigned**	**Severity Score**	**Compatibility Score**
After Obj1	45	387	37.0	25	44	5.8
After Obj2	45	392	48.6	25	50	14.6
After Obj3	45	392	48.6	25	50	14.6

Table 16. Results with Volunteer Times Uniformly Distributed (Arrival Between 1-14, Duration Between 1-6) (16.67% Unmatched Rate, 17.91s Runtime)

	Run One			**Run Two with Leftover Patients**		
Model	**Patients Unassigned**	**Total Severity Score**	**Compatibility Score**	**Patients Unassigned**	**Severity Score**	**Compatibility Score**
After Obj1	89	296	20.8	42	129	16.4
After Obj2	89	296	25.6	42	129	18.2
After Obj3	89	296	25.6	42	129	18.2

Table 17. Results with Patient Demographics Randomized (28.0% Unmatched Rate, 15.62s Runtime)

	Run One			**Run Two with Leftover Patients**		
Model	**Patients Unassigned**	**Total Severity Score**	**Compatibility Score**	**Patients Unassigned**	**Severity Score**	**Compatibility Score**

After Obj1	90	292	19.4	45	133	14.0
After Obj2	90	292	23.4	45	133	16.8
After Obj3	90	292	23.4	45	133	16.8

Table 18. Results with Volunteer Demographics Randomized (30% Unmatched Rate, 14.18s Runtime)

	Run One			Run Two with Leftover Patients		
Model	**Patients Unassigned**	**Total Severity Score**	**Compatibility Score**	**Patients Unassigned**	**Severity Score**	**Compatibility Score**
After Obj1	90	288	21.4	44	148	17.4
After Obj2	90	288	26.2	44	148	19.8
After Obj3	90	288	26.2	44	148	19.8

Table 19. Results with Volunteer and Patient Demographics Randomized (29.33% Unmatched Rate, 16.763s Runtime)

When considering the differing patient ratios, the ratio of 4:1 with 100 patients and 25 volunteers performed the best with an unmatched rate of 2.0%. In addition, no patient preferences had a 26.67% unmatched rate. All patients with severity level 0 and all patients with severity level of 5 had a 27.33% unmatched rate. The worst performing model was when a ratio of 20:1 patient to volunteers was used, resulting in 50.5% of patients being unmatched. When looking at randomized demographics for just patients, just volunteers, and both patients and volunteers, over 70% of patients were matched in all cases.

In addition to looking at the objective function, the matching results were also held in comma separated value (csv) files. These csv values held the patient ID, volunteer ID, time block and day available, the severity level, their compatibility score and both the patient and the volunteer language. This csv file was created to ensure that the objective functions and constraints were working properly.

To see how the model performed in terms of prioritizing severity level 6 patients, stacked bar charts were created for each of the scenarios except ‘all patient's severity level 0’ and ‘all patients severity level 5’. These charts were created with percentage of matches as the y-axis, severity level as the x-axis, percentage of patients matched by severity level in run 1 as the initial bar and percentage of patients matched by severity level in run 2 as the second bar. Examples of these charts can be seen in Figures 9, 10, and 11. These charts provided great information on what percentage of severity levels were being matched in each run, ensuring that our first objective function was working correctly prioritizing high severity levels before moving onto lower ones. The rest of the charts can be seen in Appendix 5.

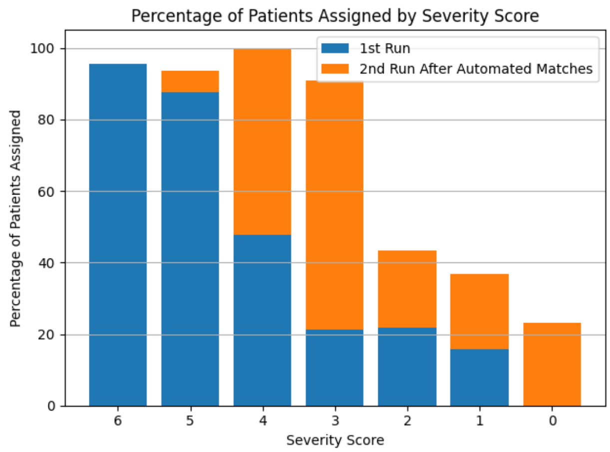


Figure 9. Stacked Bar Chart for 150 Patients: 15 Volunteers

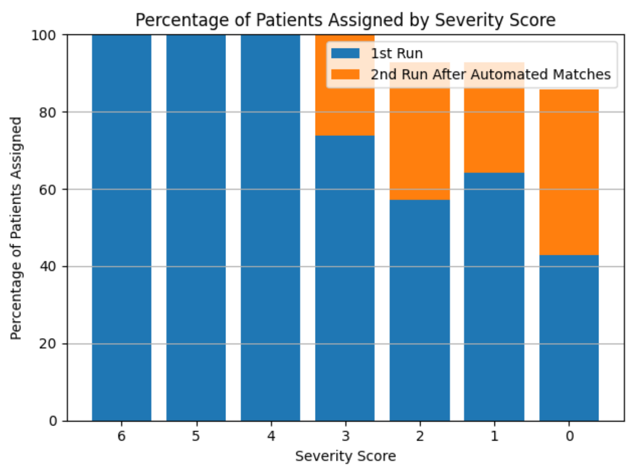


Figure 10. Stacked Bar Chart for 100 Patients: 25 Volunteers

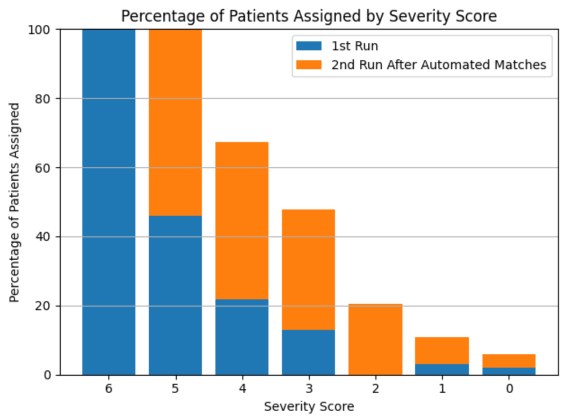


Figure 11. Stacked Bar Chart for 400 Patients: 25 Volunteers

4.5. User-Centered Design Iteration 4: Functional Mendix Prototype

With the last iteration of our functional prototype, we incorporated the feedback and features of the previous iteration and transformed our semi-functional local prototype to a cloud-based platform that can be used to input user data. In this Mendix prototype, we implemented security and role-based authorization for different types of users in the application, including the administrator, the client seeking mental health care, and the volunteer looking to provide care.

4.5.1 Administrative View

The inclusion of an administrative user opens the door to new functions and features that are specific to them that were originally not present in our previous iterations. Figure 12 shows the homepage for an administrator. This page includes access to a list of clients and volunteers, and their associated matches. In addition, administrators are able to view the statistics of the application, including the number of patients and volunteers, matches awaiting to be confirmed, matches selected, and matches that were not selected. Lastly the administrator can access various data grids for each entity of the system. With this they can export client and volunteer information and availability, while being able to import matches that would be produced from our Mathematical Model.

Figure 12. Administrative Homepage

4.5.2 Volunteer View

The volunteer view (Figure 13) follows very similar functionality as the one mapped out by Figma. This includes an overview page of the current matches that the volunteers have been assigned to. Volunteers can view limited information on the client they have been matched to and the date and time of the appointment. This page also includes a button to add and delete the availability of the volunteer for the next matching interval.

Figure 13. Volunteer Overview Page

4.5.3 Client View

The clients can view their associated matches and change their availability. However, unlike volunteers, clients have the option to select and confirm on a specific volunteer/time slot and are led to the confirmation page shown in Figure 14. This results in removal of all matches in the client view that were not selected and updating the match from a status of “awaiting” to “not selected”, with the only match left being updated to “selected”. This in turn changes the statistics that can be viewed by the administrative user to account for the change in status.

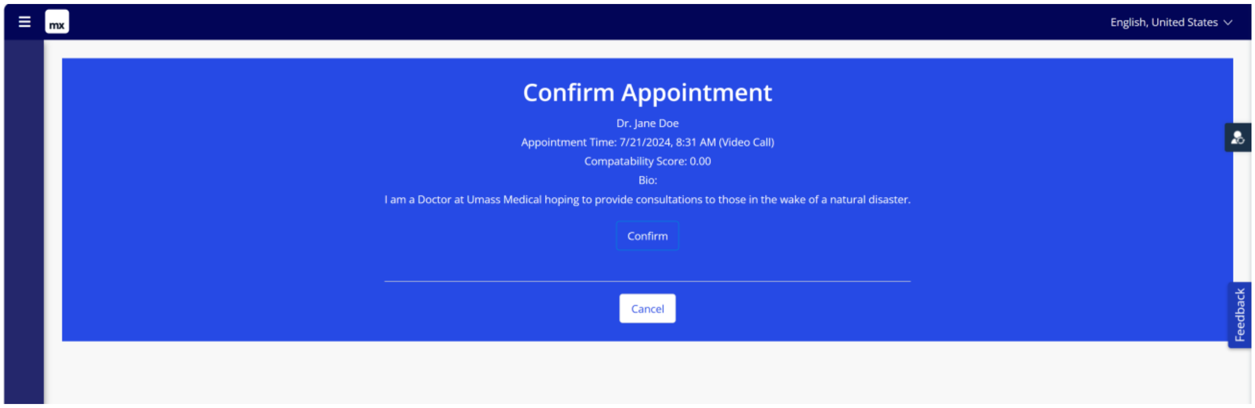


Figure 14. Client Confirmation Page for Match

5. Discussion

The following section presents our discussion of the results detailed above.

5.1. Application Prototype

Over the three iterations of our application prototype, we noticed patterns in the feedback we received from experts and uninformed users. For iterations one and two, we only consulted with experts and noticed they commented on the wording of the text present in each iteration. For iteration one, this was the wording of the survey questions we were asking the clients and volunteers. They commented on the importance of making our language inclusive and our questions robust enough to provide sufficient information for matching. During iteration two, we received a few more comments on the wording of some of the questions, but also received feedback on the phrasing of our section headers and welcome page. These pages were just as important to ensure inclusivity and clarity since they also served as instructions, and it was important that the clients especially were informed about the purpose of the application.

During iteration three, we received fewer comments from experts about wording, however in one case a user was unclear where to progress in the application due to the wording of one of the pages. We also received feedback from our uninformed user volunteers about the wording of the section headers and welcome page. One of the comments was simply “too many words”, and they also observed that some of the wording was repetitive and could be removed for brevity.

Based on the feedback we received, the language used in the application is very important to the user’s experience. Despite the straightforward nature of the application, which was affirmed by comments we received during iteration three, it is important to make sure the language used is as clear and simple as it can be. Throughout the course of the project, we have kept in mind the idea of a user’s agency, particularly due to the potential vulnerability of clients. We have focused significantly on what overall features can be included in the application to promote agency, such as allowing clients to indicate preferences for their providers. After conducting all three iterations, user agency is an element that permeates all aspects of the application.

5.2. Math Model

The results of our evaluation of the math model helped us understand the models' capabilities better. The evaluation of the model also helped us as a group understand what patient-volunteer ratios would perform the best. We found that a 4:1 patient to volunteer (100:25) ratio was optimal in this situation with 2.0% of patients being unmatched after two runs of the math model. In addition, under our standard demographic information we found that the model performed worst when it had a ratio of 20 patients to 1 volunteer (400:25) with 50.5% of patients being unmatched after two runs. This likely is due to the limited volunteers not being able to serve all the patients. When running a model where all the patients had the same severity level (5 and 0), the model still performed well leaving only 27.33% of patients unassigned after both run throughs.

The main limitation when testing the math model is that it is difficult to increase the size of the model past hundreds of volunteers across many time slots. Since the model has many loops, data elements, dictionaries, and constraints, when the size of patients and volunteers exceeds values in the 100s, the model takes a long time to fully run. Also, as the number of patients and volunteers becomes larger, the number of x variables to choose from becomes larger as it is the duct of the size of the index sets. For example, the model with 400 patients and 25 volunteers took the longest to run with a 39.53 second run time as the number of x variables is 400*25*98 or 980,000.

Another limitation while testing our model is that our model could not decide which volunteer the patients would pick out of their group of 3. To overcome this obstacle, we adjusted the code so that matches could be automated after the optimization model had been run once. Matches were automated by picking the patient-volunteer combination that had the highest compatibility score for every patient. After patients were automated, unmatched patients were captured to then be ran through the model again, utilizing timeslots that may have been offered to other patients previously.

Overall, our math model proved to be efficient in matching patients with volunteers when the patient to volunteer ratio was less than 10:1. While testing the model with different ratios less than 10:1, more than 70.00% of patients were matched to volunteers after two rounds of matching as can be seen in Appendix 5. Patients that were not matched often had slight availability or strict preferences, not allowing the model to find a spot for them with a volunteer. Also, the leftover patients after two runs of the model were usually of severity level 0-2, meaning that all patients with higher severity levels are being prioritized for matches, which is what our objective function was built to do.

When looking more closely at changing the availability of patients and volunteers, the model performed better than the base model when looking at volunteers' availability normally distributed, volunteers' availability uniformly distributed, and patients' availability uniformly distributed. This is likely due to these distributions not being as realistic as the Poisson distribution that we used for volunteers and the normal distribution we used for patients. Because there are more available timeslots, the model performed a lot better resulting in over 83% of patients being matched in all cases.

When faced with a high patient to volunteer ratio our models unmatched patient percentage increases. Even during this increase in unmatched patients, over 75% of Severity 6 patients were matched. In fact, besides the 20:1 patient to volunteer Ratio, all other ratio tests with Texas demographics resulted in over 85% of severity level 6 Patients getting a match. In addition, when looking to test randomized demographics for patients, volunteers, and patients and volunteers at the same time, 100% of Severity level 6 patients were matched and at least 70% of all patients were matched at a 10:1 ratio. Like before, many of the patients not being matched in this case were severity level 0-2. This was a promising statistic as it is evidence that our mathematical model can take on a bigger scope if needed. We believed this as the model proved its capabilities to take on randomized demographics and when working with a larger scope, the demographics would start to become more random.

When looking more closely at the math model and at our results of the math model, the third objective function did not appear to have a large impact on the matching process. Although our results were never negatively impacted by our third objective function, this function appeared to not influence the matching process, implying that it may have been unnecessary to have this third function as a part of our model. We ultimately decided to keep the third objective in our model as we believed that it could match patients that weren't matched during the first two objectives and act as a final sweep to fill any patients in time slots that may have opened during the second objective.

5.3. Future Work/Recommendations

This section outlines our recommendations for future work that can be done to improve various aspects of our proposed system.

5.3.1. Additional Model Implementations

We have spent most of our efforts and time translating our math model into Python to reflect the questions asked in our prototype and be successful in producing optimized results. However, there are many assumptions put into place, and ideas that we have had to not include or cut due to our time constraints, and for the overall functionality of our model. Future work on the model can incorporate various constraints and variables that we have chosen to omit but would possibly be able to yield positive results if done correctly. A couple of questions that we could have further asked to have more inputs into our model would include "How familiar are you with therapeutic aid". This will allow volunteers to have even more of a sense of the clients they are working with, being able to adjust their approach to providing aid based on if clients have already had prior experience speaking with therapist.

Our application is targeted towards those that are 18 and older, without the need for a guardian or parental figure. A possible implementation would be to have a feature where teenagers or younger have the option of also having access to the application, provided that the guardian gives consent on their behalf. This can be seen as the case in many states where therapeutic aid is given to adolescents, given that the parent gives permission for the care. This would lead to the creation of a new parameter, such as a_p, to indicate 0 for non-adolescent and 1 to represent that they are. The model can then use this parameter as a constraint to ensure that consent or the acknowledgment of a parental figure was given prior, for the model to be used on them. If we wish to further express this parameter to implement another objective function to maximize the number of adolescent matches, we follow the model:

$$f_4(.) = \max \sum_{p \in P} a_p \; y_p$$

A feature we chose to simplify but can be expanded upon is certification and specialties that volunteers possess, either contributed to compatibility score or considered in other ways. Another area would be the application of multiple time zones to take a patient's availability and convert it to a universal availability dictionary in our model. Our working prototype asks what time zone our clients and volunteers currently reside in, but to simplify the scheduling, our model does not include time zone as an input in our optimization.

We have chosen and incorporated the necessary constraints that complement our objective functions and ensure overall functionality in our model. However, it would be possible to potentially make the objective function constraint flexible, which would allow for a percent decrease in compatibility, but possibly in turn give us more matches overall. An approach to consider would be to relax the compatibility equation itself to perform similar results to that of altering the constraints. Several of our constraints are aimed towards scheduling between patients and volunteers, which have produced positive results in terms of matches for us, and still allows prioritizing the patients that would need it most. By giving the patients as much agency as possible, patients will feel as comfortable as they can and be accommodating to the situation they are in. An alternative would be the option to add further constraints that would give some level of agency to the volunteers, given that it seems to be more ideal or makes sense in the moment. Such as allowing volunteers to choose their method of communication, which would lead to the addition of a constraint that prohibits matching between volunteer and patient without similar forms of communication.

5.3.2. Recruit Medical Student Volunteers

One important consideration when implementing this system will be where the volunteers are coming from. From our consultations with experts early in the project, we learned that medical students could be a target population within the volunteer base for this kind of program. There will likely be many full-time providers volunteering as well, but medical students may be able to use this experience to gain credit towards their program, which would provide a built-in incentive for volunteering.

5.3.3. Backend Upgrade

At the current stage, the prototype system we developed does not include a full-fledged database for storing data from the application and calling upon it when the math model is run. Since we worked with synthetic data to run our evaluations and did not collect any user data through our prototype, our data has been stored in the form of a csv file. During the process of fully implementing this system, a database would need to be created. It is especially important to consider the security of the database that is used, since personal information is being stored about both clients and volunteers, and there would need to be elements in place to protect this information. In addition, the tables in the database should be linked accordingly to help keep relations and organized data. With all of this, the data can be queried for analytics, or matching. It can also help the algorithms developed for the questionnaire. This database's importance stretches further, from keeping up with competitors, to being able to match patients to volunteers to get help. This helps with the overall results and success of the program. Ultimately, there is so much a database could provide to the system, and it is imperative that it is maintained for its future success.

In addition to creating a database to store volunteer and patient data from the prototype, the math model would also need a function to be able to take raw data and convert it into data that can be inputted into the math model. This function would need to be able to take a patient data set including patient demographics, preferences, PTSD screening questions, and availability, as well as a volunteer data set including volunteer demographics, availability, and certification information as inputs. This function would need to compute patient severity level, compatibility score and language score of patient-volunteer combinations and store them in dictionaries. Patient and volunteer availability would also have to be stored in dictionaries for the math model to take it as input data.

5.3.4. Expand Functionality Worldwide

The system that we have proposed was developed to be implemented in the state of Texas. However, envisioning the full potential of this application, its use can be implemented towards various areas of the world as mental health is not specific to any one geographical location. This could lead to further implementation within the United States, or even to other countries around the world. Natural disasters occur all around the world, and the people who experience them face similar mental health challenges. Expanding the scope of this system will require research and insight into the potential impact and cultural implications, which will vary significantly from place to place.

However, while expanding the application, it must be taken into consideration that every location's needs are different. Each place has different cultural norms and access to resources. By extending the reach of this system, the goal is to offer a sense of compassion towards peoples' mental wellbeing.

5.3.5. Connect To Long Term Care

The end goal of our application is to connect patients with volunteers to have a safe space to assess their mental health in one session lasting one hour. The biggest incorporation that we are not able to do is the connection between our services, into a potential long-term care solution if necessary for the patients interviewed. Our application is not a one all be all solution for a lot of the patients that would be signing up. It would be important that an external service be linked to the application and have the volunteers recommend it to the patients after assessing them. This will allow more severe patients to introduce them to therapeutic care before transitioning into full time therapy.

5.3.6. Mendix Mathematical Model Connection

The final iteration of the front-end Mendix prototype is not integrated with our python code due to time constraints. However, Mendix prototype has the ability to export client and volunteer data as an excel sheet for our back-end optimization model to utilize as an input. After the optimization model produces a batch of match results as a .csv file, this file can also be imported back into our Mendix prototype. In the future, we hope to bridge the Mathematical Model with the front-end Mendix prototype to eliminate the need to manage the integration using excel files.

5.3.7. Mendix Future Implementations

Mendix unlocks a plethora of possibilities and functionalities applicable in real-world scenarios. However, the current state of the application presents ample room for improvement. Certain design features introduced and carried over from previous iterations were not seamlessly integrated into Iteration 4. These include the format for entering client and volunteer information, "select all that apply" buttons, and overall layout enhancements to better reflect the feedback received during Iteration 3. We anticipate that this iteration will serve as a steppingstone towards future iterations of the Mendix application that will eventually align with the HTML format we've generated and give greater consideration to user roles.

6. Conclusion

Through our prototype evaluations, we found that members of our sample of potential users could navigate and understand the functional prototype easily. While some users commented specifically on elements that they found effective or confusing, we also gained insight through observing them as they navigated the prototype. By the end of our third iteration of the user-centered design process, we had achieved our goal of operationalizing the user interface to assess the utility of our proposed solution and found that it was effective overall.

When looking at Texas's demographics and our base synthetic data set, the math model performed best when the patient to volunteer ratio was less than 10:1, as over 70% of all patients and over 90% of severity level 6 patients were matched in all these cases. When looking at 3 cases with a 10:1 patient to volunteer ratio that have randomly assigned demographics in just patients, randomly assigned demographics in just volunteers, and randomized assigned demographics in both patients and volunteers, the math model matched over 70% of patients and matched 100% of severity level 6 patients. This is the first step for the math model to take on a larger scope with more randomized demographics compared to Texas. Overall, the math model was found to match clients effectively and efficiently while prioritizing clients with greater severity levels.

The efficiency of the math model is also very important, as speed and efficiency are very important during a crisis or natural disaster. Clients with higher severity levels may be at risk of experiencing more distressing symptoms and developing complex PTSD, so by prioritizing high severity-level patients we can hopefully mitigate these symptoms.

When looking at our proposed system as a whole, the quality and performance of our application prototype is important. We want the application to be accessible to as many people as possible, to increase the likelihood of people receiving the care they need. Employing user-centered design is effective in a variety of applications, but when designing for potentially vulnerable populations it is especially important to involve the users in every stage.

With some additional integration and the development of a completely functional front and back-end, the system we propose has the potential to help provide mental health care to people who otherwise may not have access to it at a time when they may need it most. There are many opportunities to expand this system to other parts of the world, but there must be careful consideration of the cultural ideas and regulations surrounding disasters and mental health care. While this system was centered around the state of Texas, it is not ideal for it to be applied to other countries or even other states without adjusting based on laws for providing mental health care in addition to cultural implications.

Appendices

Appendix 1

WPI Institutional Review Board Approval Letter

WORCESTER POLYTECHNIC INSTITUTE

100 INSTITUTE ROAD, WORCESTER MA 01609 USA

Institutional Review Board
FWA #00030698 - HHS #00007374

Notification of IRB Approval

Date:	26-Oct-2023
PI:	Andrew C Trapp
Protocol Number:	IRB-24-0152
Protocol Title:	Post-Disaster Aid Distribution
Approved Study Personnel:	Trapp, Andrew C~Marcotte, Madelyn K~Vo, Justin V~Lam, Kaycie H~Anderson, Maxime W~Dubey, Brock R~Tulu, Bengisu~Aygul, Ozge~
Effective Date:	26-Oct-2023
Exemption Category:	3
Sponsor*:	

The WPI Institutional Review Board (IRB) has reviewed the materials submitted with regard to the above-mentioned protocol.We have determined that this research is exempt from further IRB review under 45 CFR § 46.104 (d). For a detailed description of the categories of exempt research, please refer to the IRB website.

The study is approved indefinitely unless terminated sooner (in writing) by yourself or the WPI IRB. Amendments or changes to the research that might alter this specific approval must be submitted to the WPI IRB for review and may require a full IRB application in order for the research to continue. You are also required to report any adverse events with regard to your study subjects or their data.

Changes to the research which might affect its exempt status must be submitted to the WPI IRB for review and approval before such changes are put into practice. A full IRB application may be required in order for the research to continue.

Please contact the IRB at irb@wpi.edu if you have any questions.

*if blank, the IRB has not reviewed any funding proposal for this protocol

Appendix 2

User Scenarios

User Scenario 1: First-Time Volunteer Sign Up with Immediate Matches

You are a Licensed Professional Counselor (LPC) working out of Texas (Central Time Zone) and you're looking to provide aid to your community in the wake of a recent natural disaster. One of your colleagues told you about this website for providing online mental health consultations, and you decided to sign up as a volunteer.

To do so, you follow the following steps:

1. Read the information on the home page
2. Click on the "Volunteer Registration" button and read the information provided on the page
3. Click on the "Volunteer Sign Up" button
4. Enter your email and password (found in the user bio) and click "Continue"
5. Navigate Sections 1 – 3 of the application using the user bio provided
6. For section 4, you decide that you are able to work with all patients, regardless of their age, gender, race, or religious affiliation

Once you filled out the form, you were immediately matched to 3 patients who were looking for providers! You decide to hold off on writing a professional bio for now and go back to it later. Now you can:

1. View your appointments to see the patients you matched with and the results of their PTSD screening.
2. Update your availability for next week, as you will only be available 5:00pm – 8:00pm on Mondays, Wednesdays, and Fridays.

Once you have completed these tasks, please let us know!

<u>User Biography – Volunteer</u>

Name: Jane Doe

Email address: jane.doe@gmail.com

Password: password123

General Information (Section 1)

Languages spoken: English

Time zone: Central

Availability: Monday-Friday 5:00 pm – 9:00 pm

Demographic Information (Section 2)

Age: 40

Gender: Woman

Sexual Orientation: Heterosexual/straight

Race: White (not Hispanic or Latino)

Religious affiliation: No religious background

Professional Experience (Section 3)

States licensed in: Texas

Title: LPC

License Number: 07463

License Expiration Date: 5/10/2025

User Scenario 2: First Time Volunteer Sign Up and Returning Log In

Part 1 - You are a Licensed Professional Counselor (LPC) working out of Texas (Central Time Zone) and you're looking to provide aid to your community in the wake of a recent natural disaster. One of your colleagues told you about this website for providing online mental health consultations, and you decided to sign up as a volunteer.

To do so, you follow the following steps:

1. Read the information on the home page
2. Click on the "Volunteer Registration" button and read the information provided on the page
3. Click on the "Volunteer Sign Up" button
4. Enter your email and password (found in the user bio) and click "Continue"
5. Navigate Sections 1 – 3 of the application using the user bio provided
6. For section 4, you decide that you are able to work with all patients, regardless of their age, gender, race, or religious affiliation

Once you filled out the form, you received a notice that there were no clients awaiting matches, but you will receive a notification when more clients enter the system.

You can now switch over to the second tab.

Part 2 - You just received a notification that you have been matched to three clients! You log back into the application to view the details about the consultations.

To do so, you follow the following steps:

1. Sign in to the application as an existing user
2. Make sure you are signing in as a volunteer, not a client
3. Enter your email and password, click continue

Now that you are on the homepage, you can:

1. View your appointments to see the clients you matched with and the results of their PTSD screening.
2. Update your availability for next week, as you will be unavailable all day on Thursday.

Once you have completed these tasks, please let us know!

User Scenario 3: First-Time Client Sign Up with Immediate Matches

You are a Texas resident who recently experienced a natural disaster. One of your family members told you about this website for matching with local volunteers who can provide mental health care to people struggling after experiencing a disaster or other traumatic event. You decided to sign up to be matched with a volunteer.

To do so, you follow the following steps:

1. Read the information on the home page
2. Click on the "Client Registration" button and read the information provided on the page
3. Click on the "Get started now" button
4. Enter your email and password (found in the user bio) and click "Continue"
5. You answer "No" to all the preliminary screening questions
6. Navigate Sections 1 – 3 of the application using the user bio provided
7. For section 4, you decide you do not have preferences for your potential provider's demographics.

Once you filled out the form, you were immediately matched to 3 volunteers who were available to meet with you! Now you can:

1. View your matches to see the volunteers you matched with and their professional bios.
2. Select one of the three volunteers to meet with, based on which one is available to meet sooner.

Once you have completed these tasks, please let us know!

<u>User Biography – Client</u>

Name: John Doe

Email address: john.doe@gmail.com

Password: password123

General Information (Section 1)

Languages spoken: English

Time zone: Central

Availability: Monday-Friday 5:00 pm – 9:00 pm

Mode of communication: Video call

Demographic Information (Section 2)

Age: 40

Gender: Man

Sexual Orientation: Heterosexual/straight

Race: White (not Hispanic or Latino)

Religious affiliation: No religious background

Relationship status: Single

Personal Experiences (Section 3)

Question 1: Yes

Question 2: Yes

Question 3: No

Question 4: No

Question 5: No

Question 6: No

User Scenario 4: First Time Client Sign Up and Returning Log In

Part 1 – You are a Texas resident who recently experienced a natural disaster. One of your family members told you about this website for matching with local volunteers who can provide mental health care to people struggling after experiencing a disaster or other traumatic event. You decided to sign up to be matched with a volunteer.

To do so, you follow the following steps:

1. Read the information on the home page
2. Click on the "Client Registration" button and read the information provided on the page
3. Click on the "Get started now" button
4. Enter your email and password (found in the user bio) and click "Continue"
5. You answer "No" to all the preliminary screening questions
6. Navigate Sections 1 – 3 of the application using the user bio provided
7. For section 4, you decide that you have no preferences for the demographics of your potential provider.

Once you filled out the form, you received a notice that there were no volunteers available to meet with you at any of the times you gave, but you will receive a notification when more volunteers enter the system or when existing volunteers update their availability.

You can now switch over to the second tab and begin **Part 2**.

Part 2 - You just received a notification that there are three potential volunteers you can match with! You log back into the application to view the details about the providers.

To do so, you follow the following steps:

1. Sign in to the application as an existing user
2. Make sure you are signing in as a client, not a volunteer
3. Enter your email and password, click continue

Now that you are on the homepage, you can:

1. View your matches to see the volunteers you matched with and their professional bios.
2. Select one of the three volunteers to meet with, based on which one is available to meet sooner.

Once you have completed these tasks, please let us know!

Appendix 3

Informed Consent Agreement for Participation in a Research Study

Investigators: Max Anderson, Brock Dubey, Kaycie Lam, Madelyn Marcotte, and Justin Vo

Contact Information: Research team email alias: gr-post-disaster-relief-MQP-24@wpi.edu

Phone number: Madelyn Marcotte 603-733-7370

Title of Research Study: Post-Disaster Aid Distribution

Introduction: You are being asked to participate in a research study. Before you agree, however, you must be fully informed about the purpose of the study, the procedures to be followed, and any benefits, risks or discomfort that you may experience as a result of your participation. This form presents information about the study so that you may make a fully informed decision regarding your participation.

Purpose of the study: This is a study about matching volunteers to people seeking mental health care after experiencing a disaster (such as an earthquake or hurricane). It is intended for people who could see themselves volunteering their time to provide care to those seeking it as well as those people who could see themselves seeking out care in the wake of a disaster. Our goal is to make the application used to match providers with people seeking care appealing, intuitive, and user friendly. Your participation will help us achieve this goal.

Procedures to be followed: The evaluation will not take longer than an hour. During the session you will be working with a prototype of our matching application. We'll ask you to perform tasks that a typical user might do, such as creating a profile, inputting your availability into a schedule, or checking for matches. A few members of the team will sit in the same room, observing and taking notes. Once you have completed the tasks, we will ask you a few questions about your approach to navigating the prototype.

Risk to study participants: Given that the subject matter pertains to mental health and disasters, participation in the study may put participants at risk of being reminded of events that they may have experienced, which could be uncomfortable. To mitigate the chance of this occurring, we do not require participants to provide any sensitive information pertaining to their mental health or experience in past disasters. We will also remind participants that if they ever feel uncomfortable, they can leave at any time.

Benefits to research participants and others: While there are no benefits directly to the research participant for taking part in the study, they are helping us design an effective application for providing mental health care to people who have experienced a disaster.

Record keeping and confidentiality: Data will be collected from each evaluation in the form of written notes taken during the tests. Participants will be assigned unique ID numbers so that data can be stored without any identifying information such as names. The results from the evaluations may be published in our report, but all information will remain confidential and anonymous. The data will be stored securely, and only the student group and associated advisors will have access to it. The same is true for this consent form once it is signed and returned. Records of your participation in this study will be held confidential so far as permitted by law. However, the study investigators, the sponsor or it's designee and, under certain circumstances, the Worcester Polytechnic Institute Institutional Review Board (WPI IRB) will be able to inspect and have access to confidential data that identify you by name. Any publication or presentation of the data will not identify you.

Compensation or treatment in the event of injury: Due to the minimal risk associated with the research and the steps being taken to mitigate the effects of said risk, there is no compensation or treatment available in the event of injury. You do not give up any of your legal rights by signing this statement.

For more information about this research or about the rights of research participants, or in the case of research-related injury, contact the research team at the email address or phone number provided at the top of the first page. You can also contact:

IRB Manager: Ruth McKeogh, Tel. 508 831 – 6699, Email: irb@wpi.edu)

Human Protection Administrator: Gabriel Johnson, Tel. 508 831 – 4989, Email: gjohnson@wpi.edu)

Your participation in this research is voluntary. Your refusal to participate will not result in any penalty to you or any loss of benefits to which you may otherwise be entitled. You may decide to stop participating in the research at any time without penalty or loss of other benefits. The project investigators retain the right to cancel or postpone the experimental procedures at any time they see fit. **By signing below**, you acknowledge that you have been informed about and consent to be a participant in the study described above. Make sure that your questions are answered to your satisfaction before signing. You are entitled to retain a copy of this consent agreement.

______________________________ Date: ____________________

Study Participant Signature

____

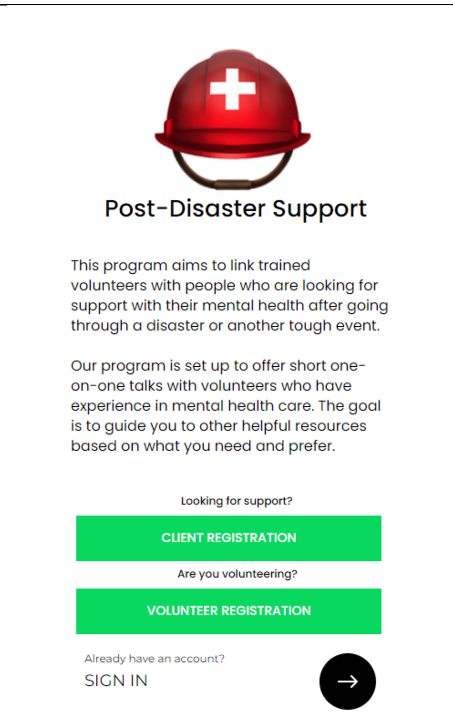
Study Participant Name (Please print)

______________________________ Date: ____________________

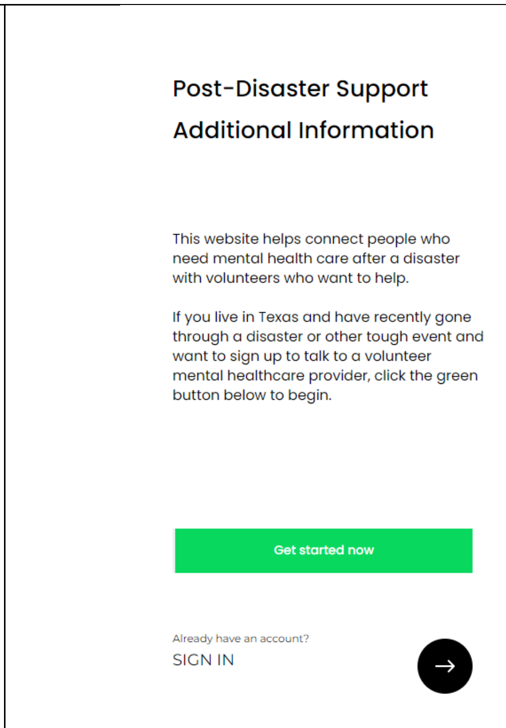
Signature of Person who explained this study

Appendix 4

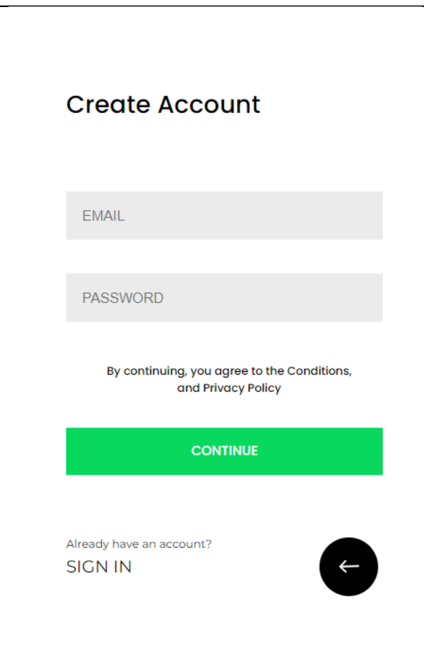
Prototype Screenshots



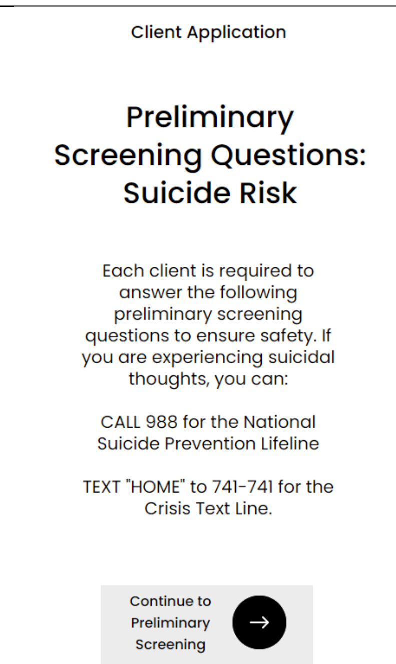
Page 1: Welcome page



Page 2: Client additional information



Page 3: Create account



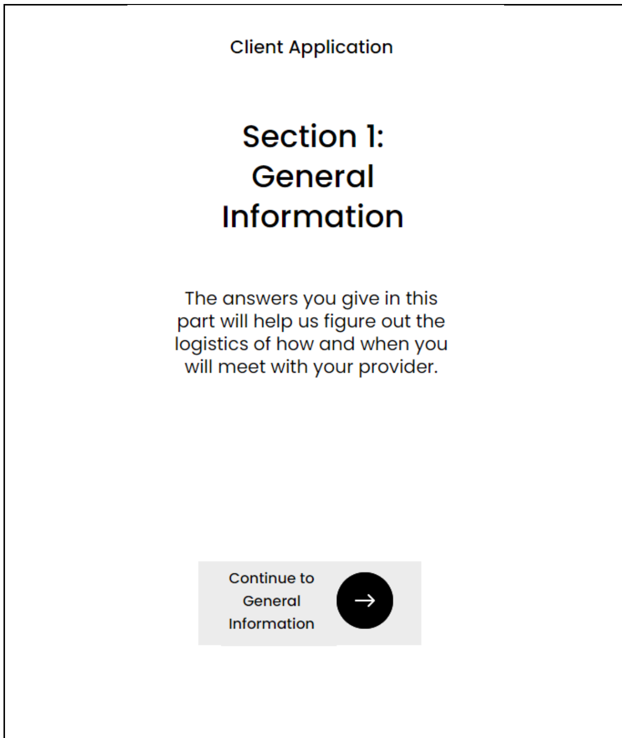
Page 4: Preliminary screening questions

Page 5: Suicide screen 1

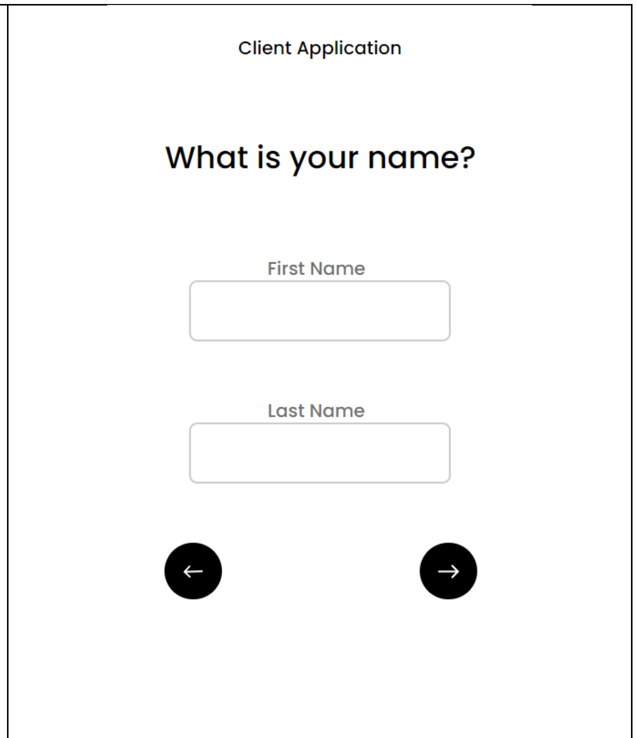
Page 6: Suicide screen 2

Page 7: Suicide screen 3

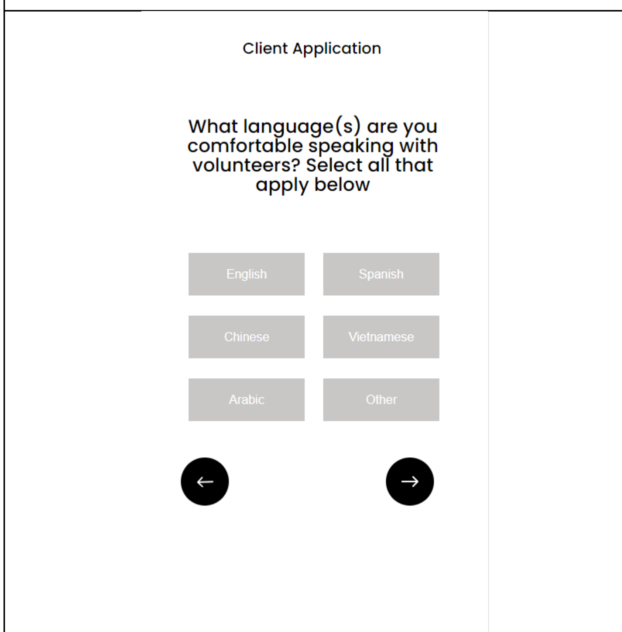
Page 8: Suicide screen 4



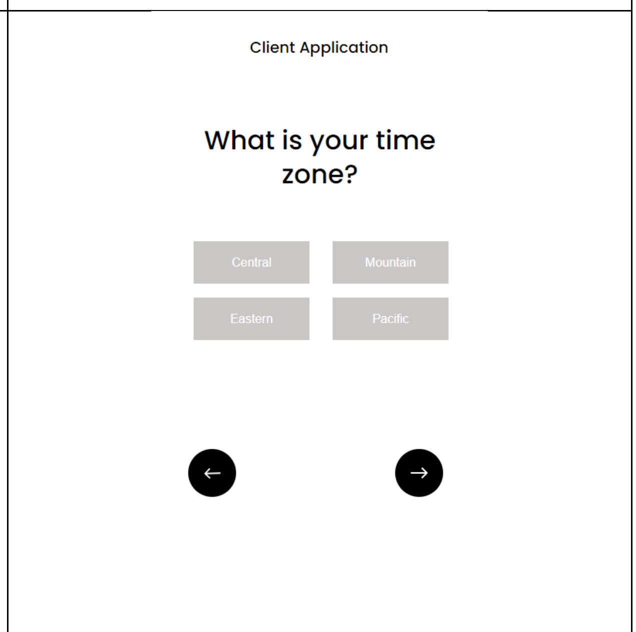
Page 9: Client general information



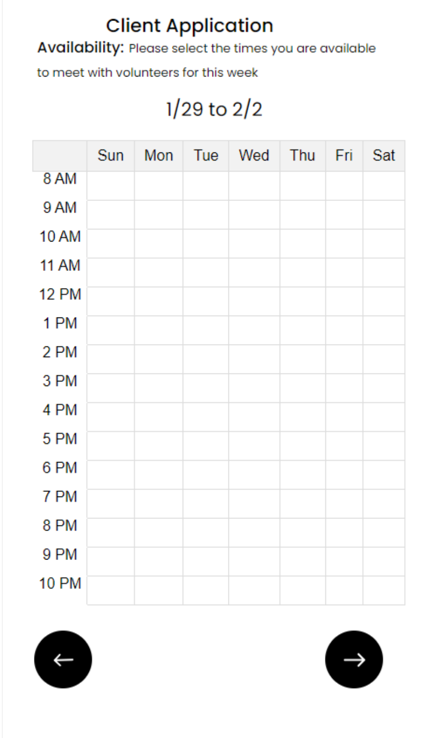
Page 10: Client name



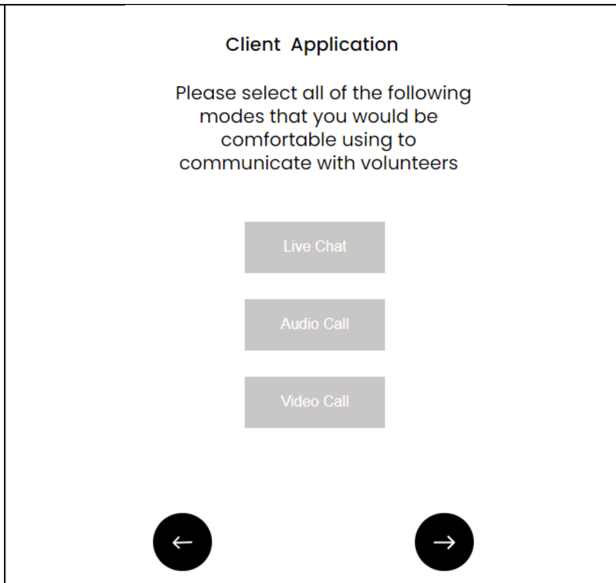
Page 11: Client languages



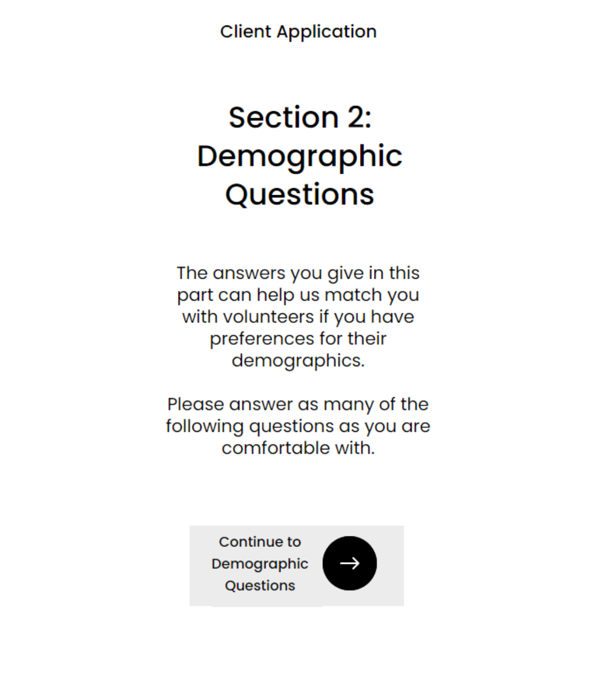
Page 12: Client time zone



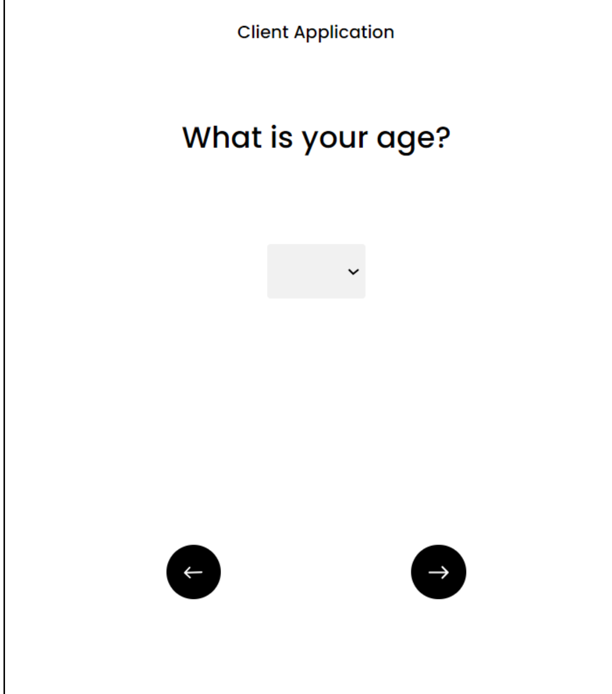
Page 13: Client availability



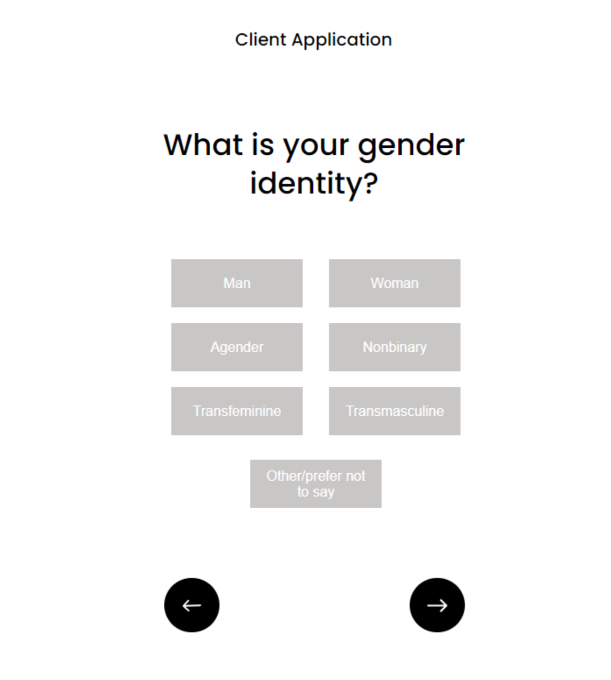
Page 14: Client communication mode



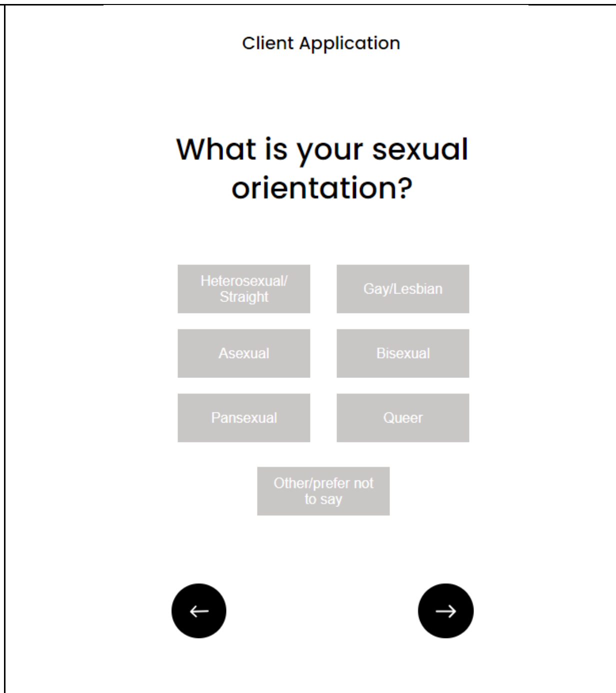
Page 15: Client demographic questions



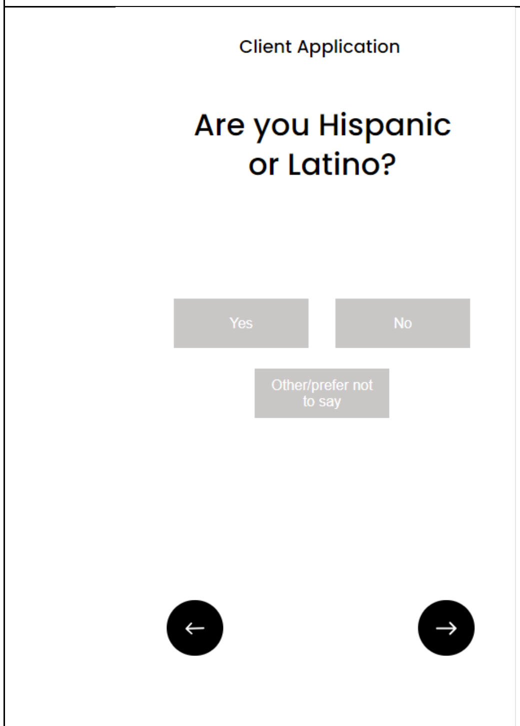
Page 16: Client age



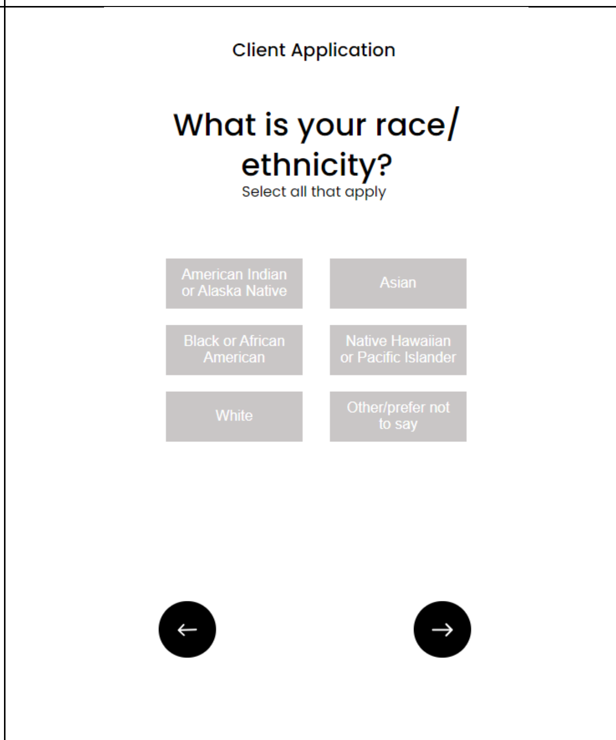
Page 17: Client gender identity



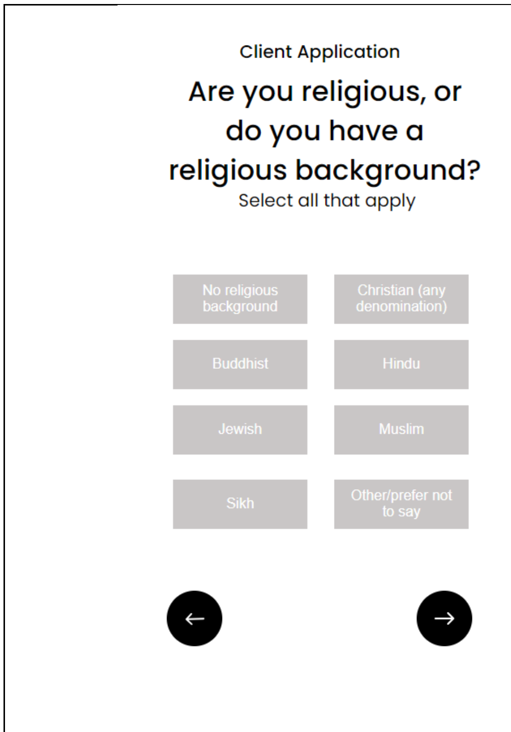
Page 18: Client sexual orientation



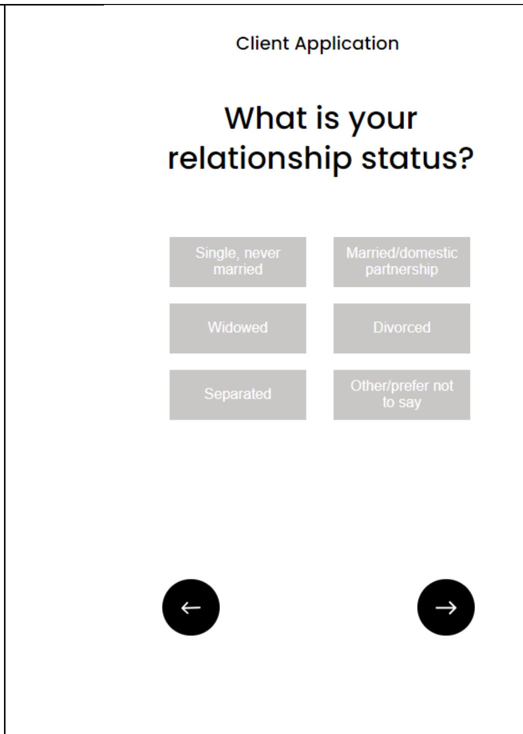
Page 19: Client Hispanic or Latino



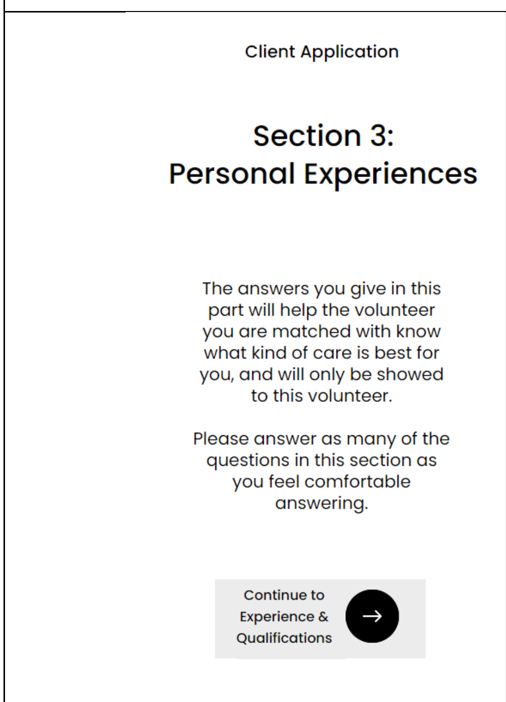
Page 20: Client race/ethnicity



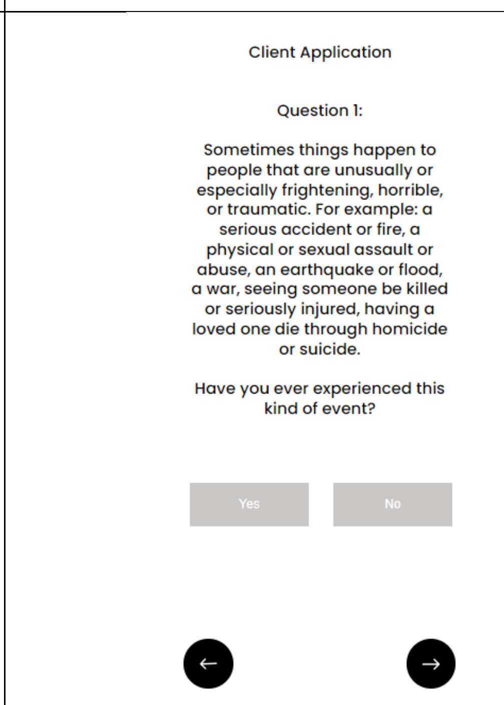
Page 21: Client religious background



Page 22: Client relationship status

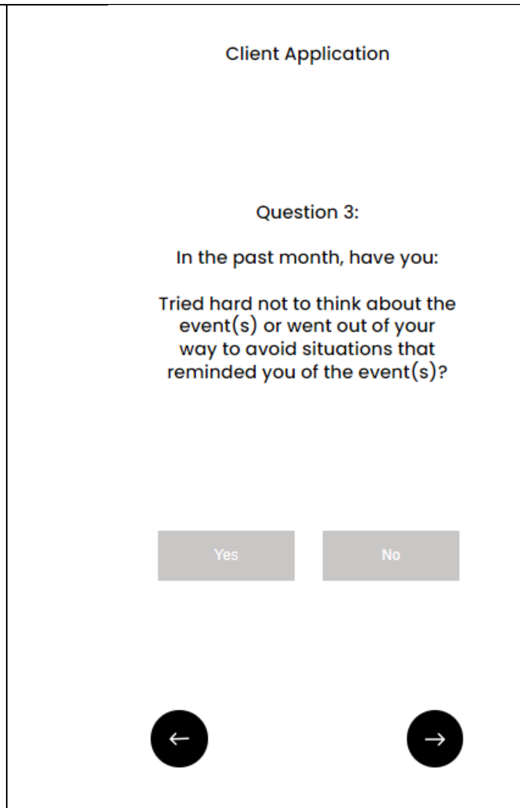


Page 23: Client personal experiences

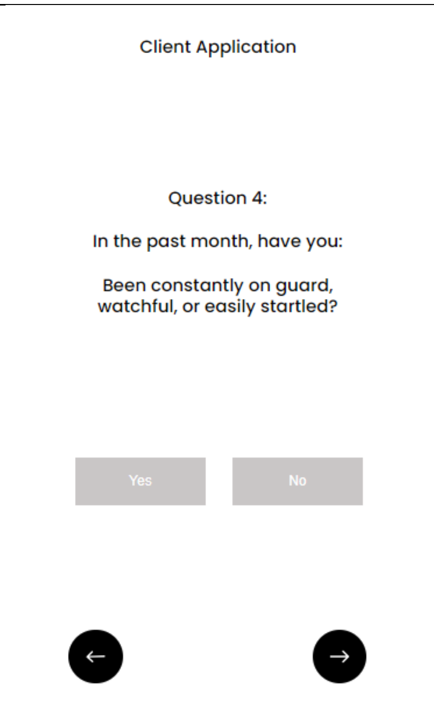


Page 24: Client screening 1

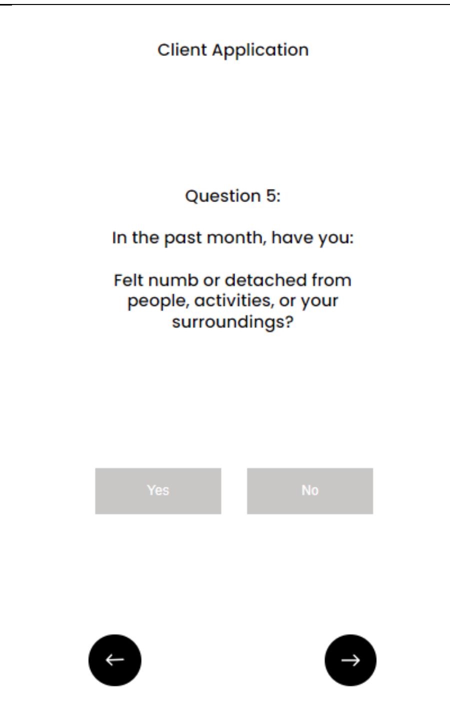
Page 25: Client screening 2



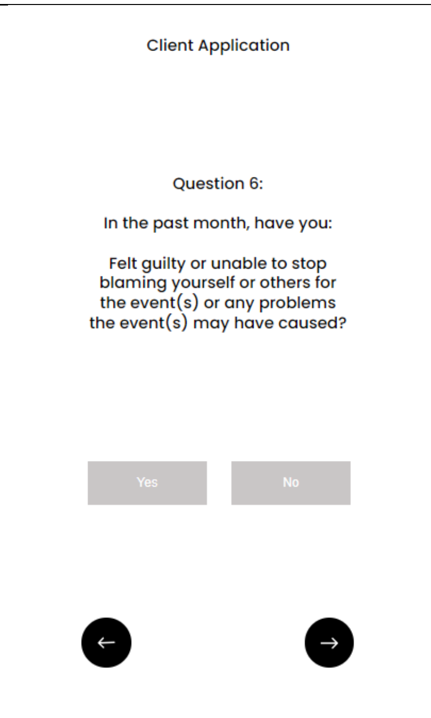
Page 26: Client screening 3



Page 27: Client screening 4

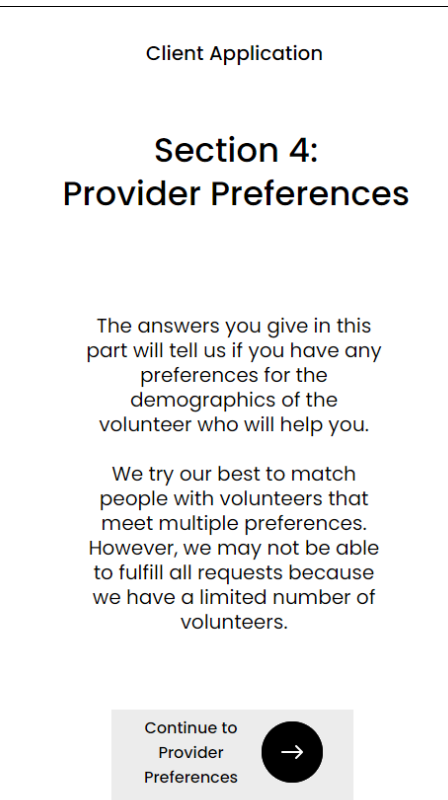


Page 28: Client screening 5

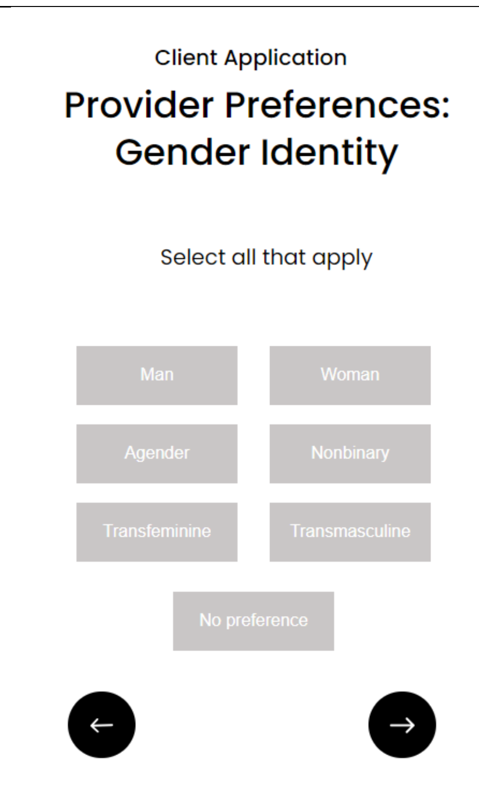


Page 29: Client screening 6

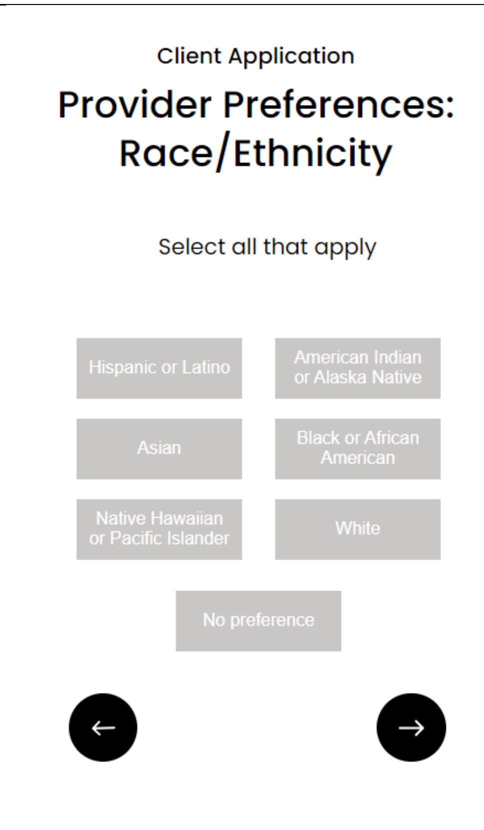
Page 30: Provider preference opt-in



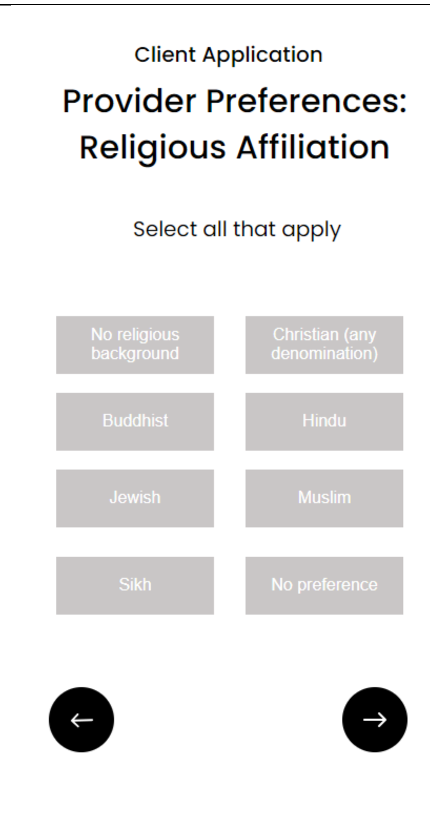
Page 31: Client provider preferences



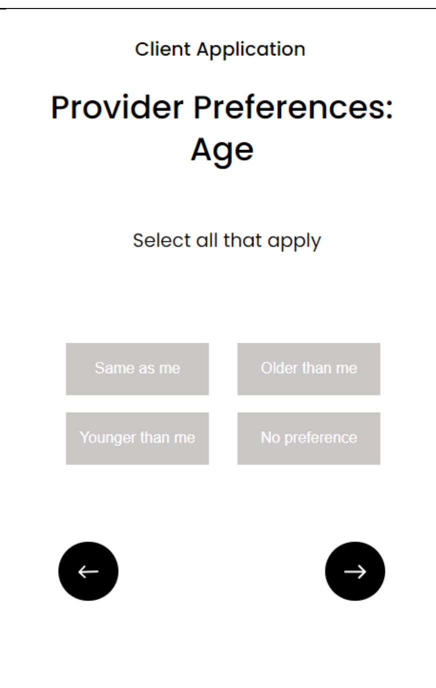
Page 32: Client gender preference



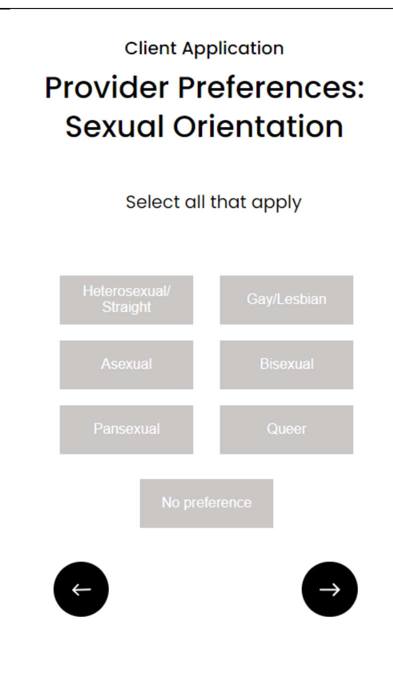
Page 33: Client race/ethnicity preference



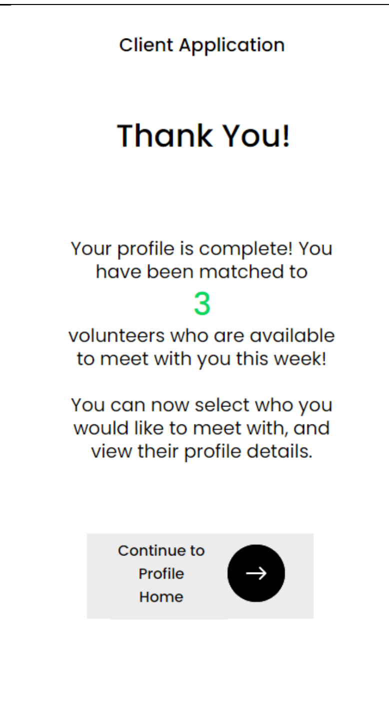
Page 34: Client religion preference



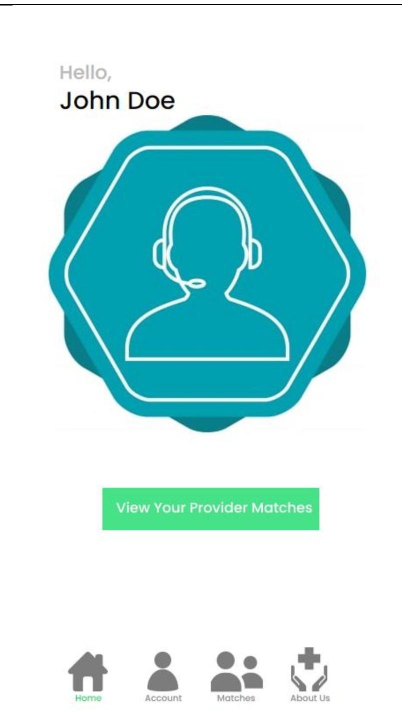
Page 35: Client age preference



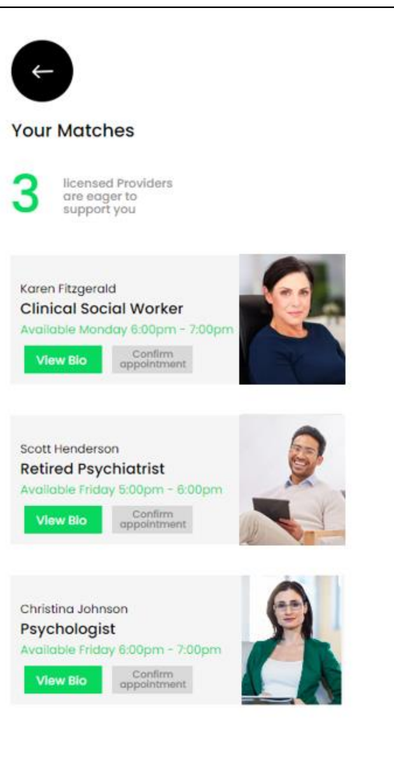
Page 36: Client sexual orientation preference



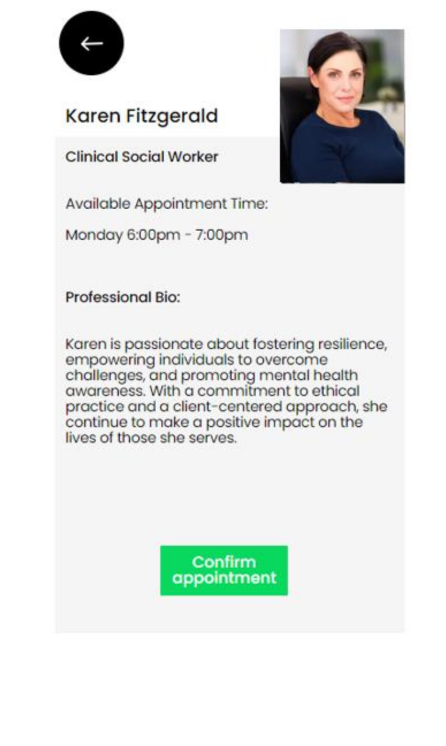
Page 37: Client thank you page



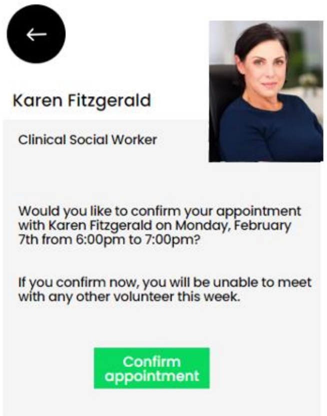
Page 38: Client home page



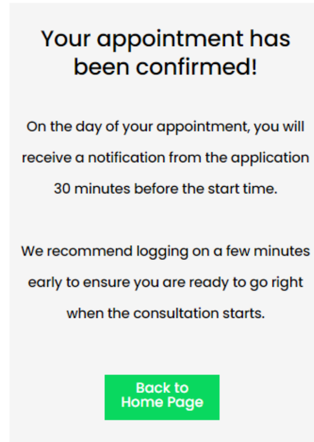
Page 39: Client match view



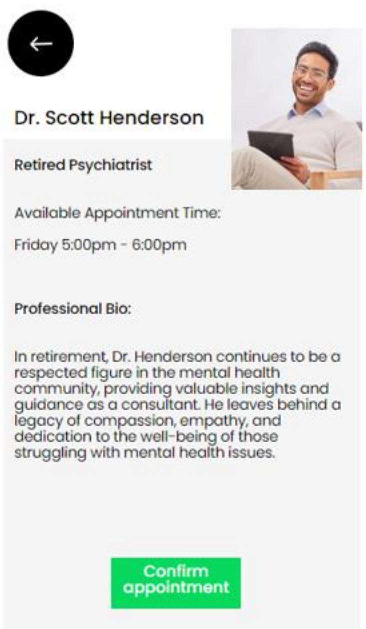
Page 40: Client match Karen



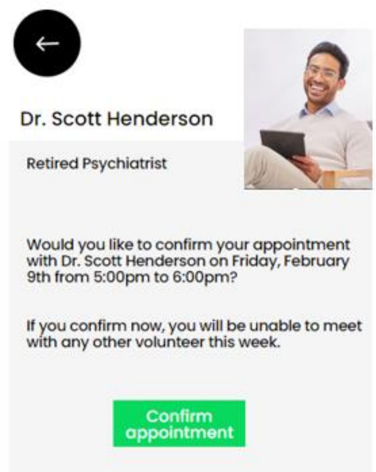
Page 41: Confirm appointment Karen



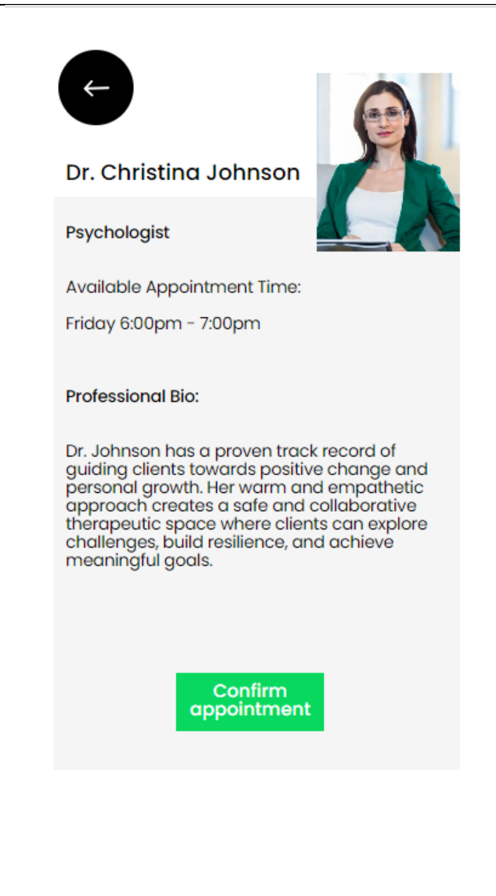
Page 42: Appointment confirmed



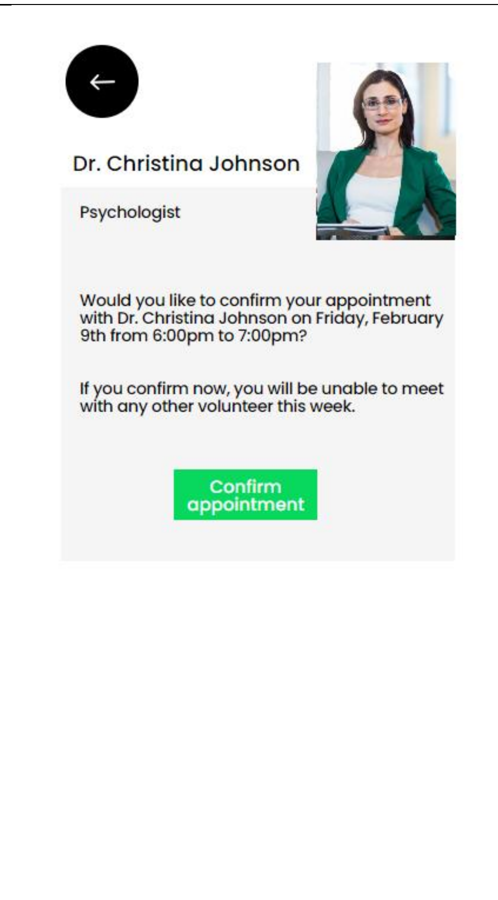
Page 43: Client match Scott



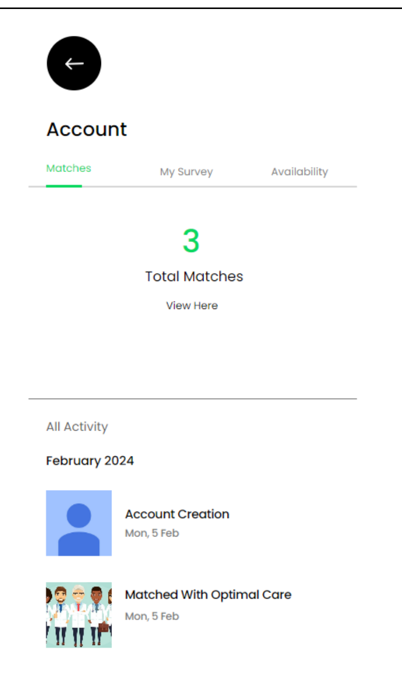
Page 44: Confirm appointment Scott



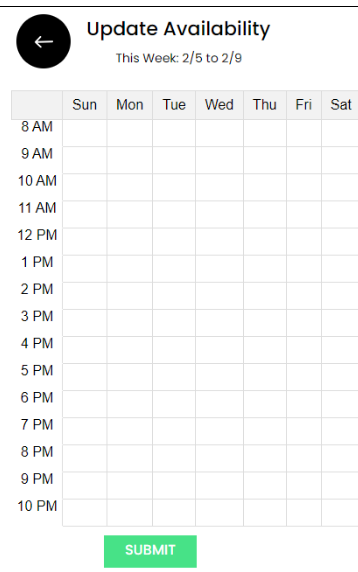
Page 45: Client match Christina



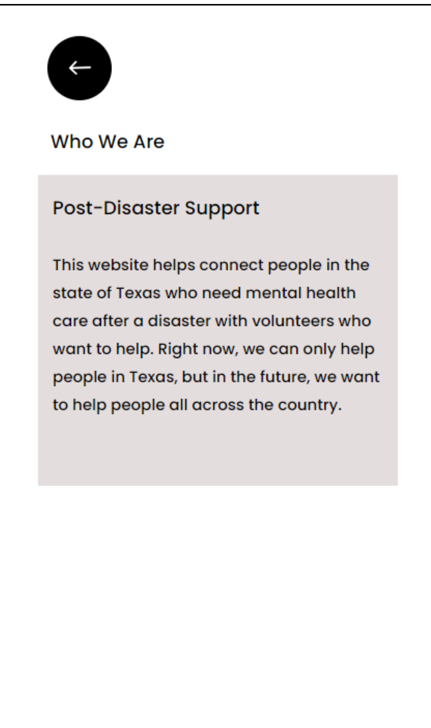
Page 46: Confirm appointment Christina



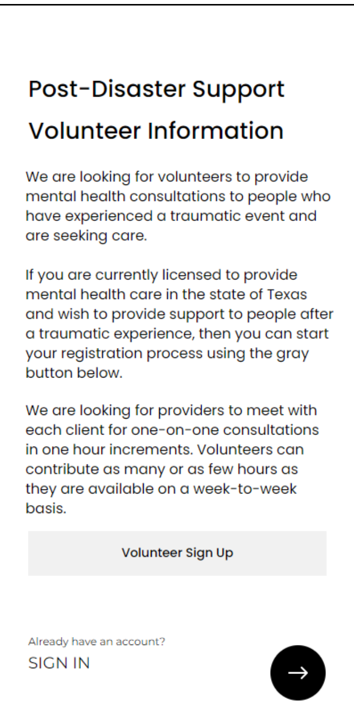
Page 47: Client match page



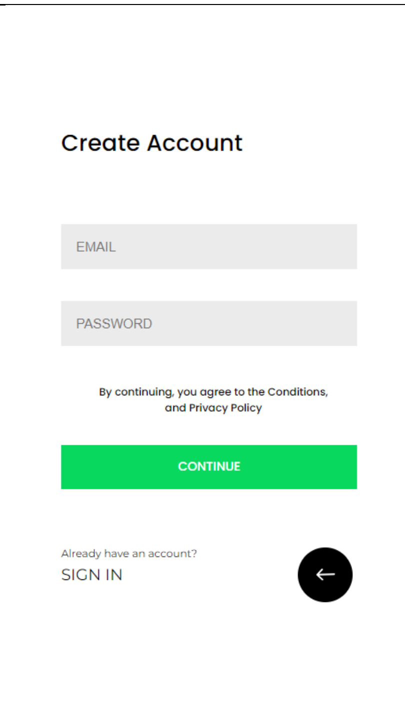
Page 48: Client update availability



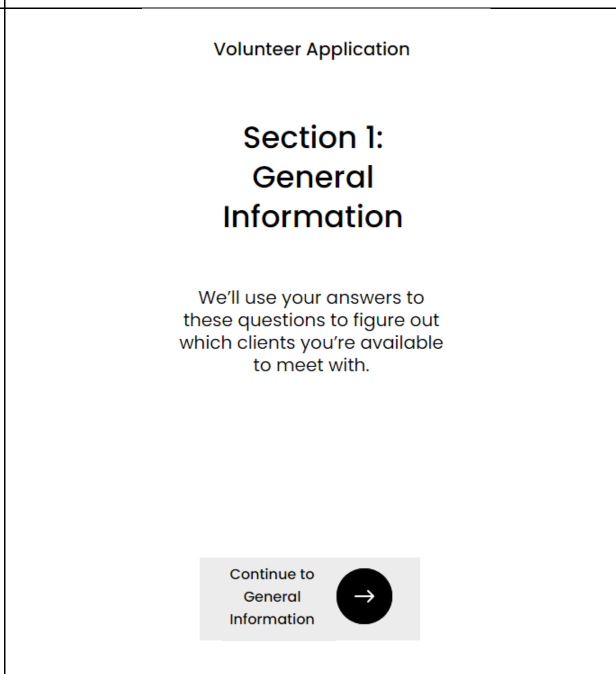
Page 49: Who we are



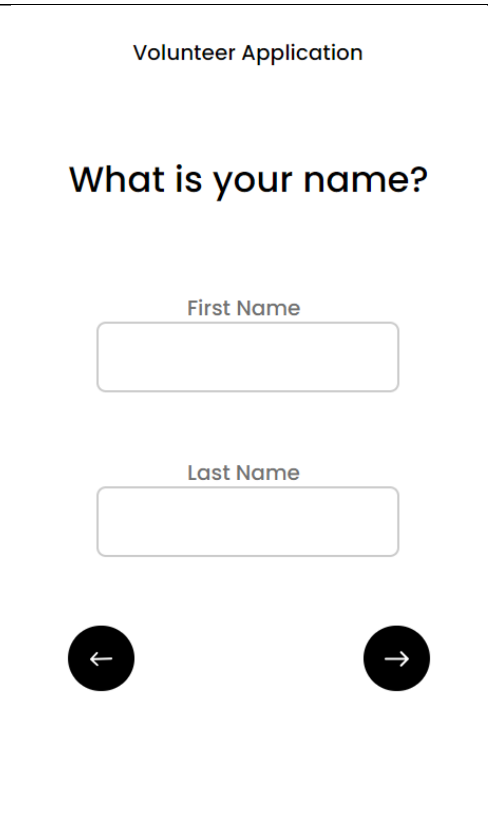
Page 50: Volunteer additional information



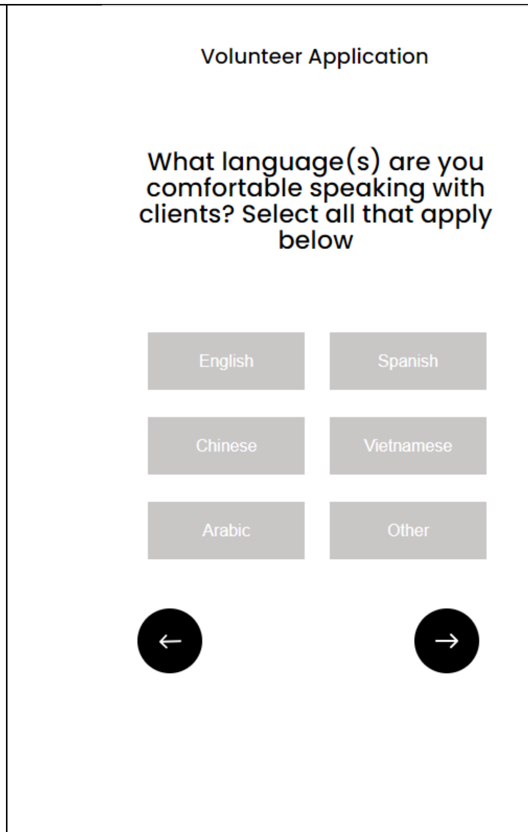
Page 51: Create account



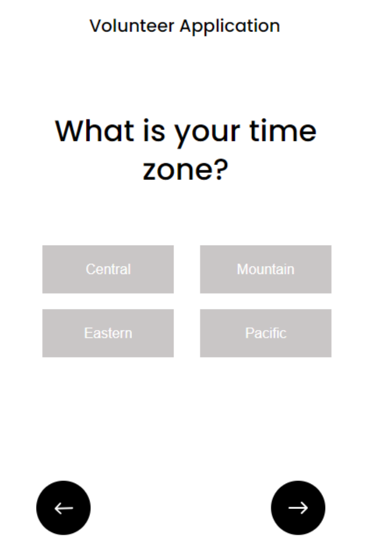
Page 52: Volunteer general information



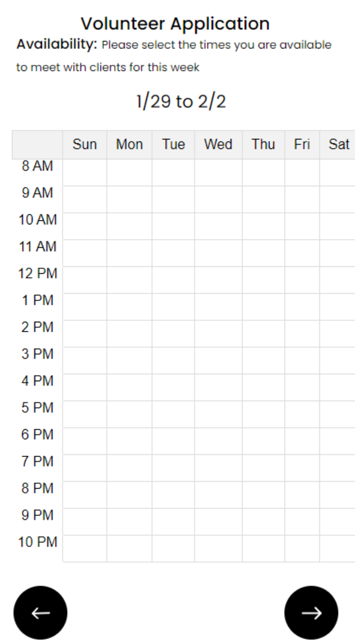
Page 53: Volunteer name



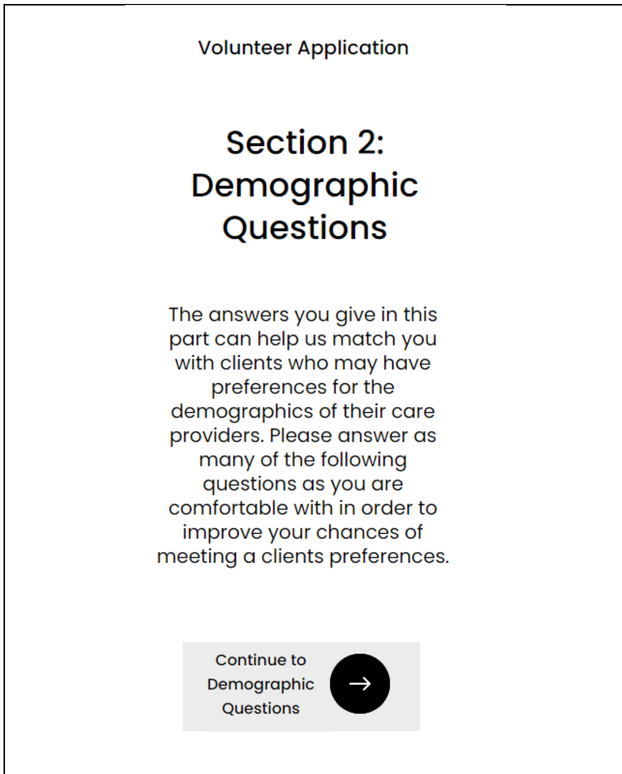
Page 54: Volunteer languages



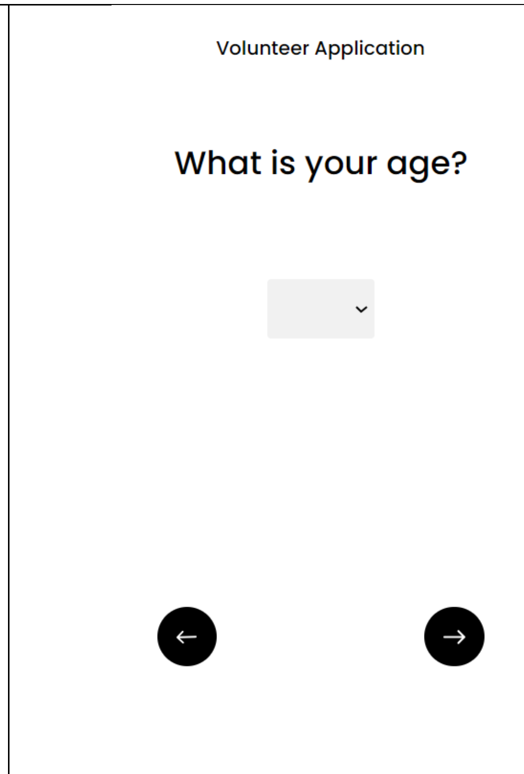
Page 55: Volunteer time zone



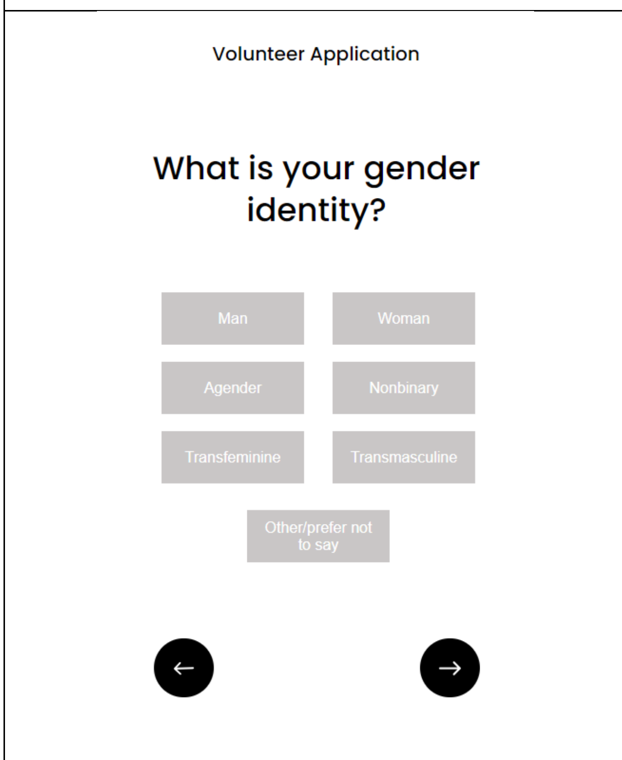
Page 56: Volunteer availability



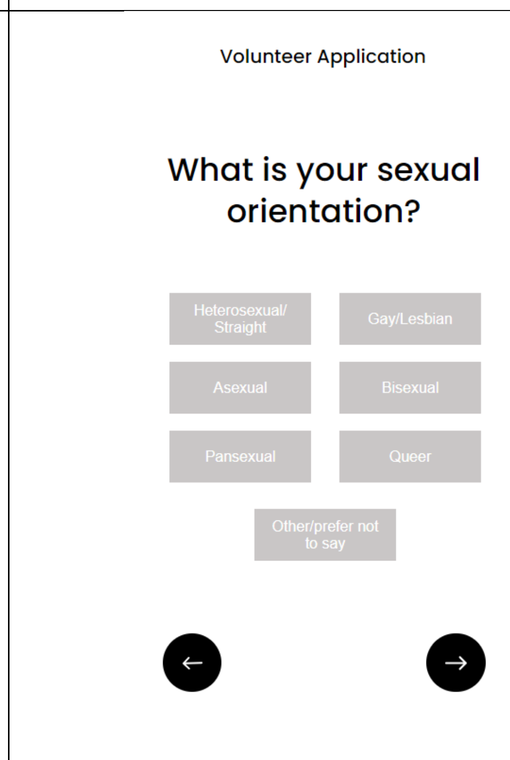
Page 57: Volunteer demographic questions



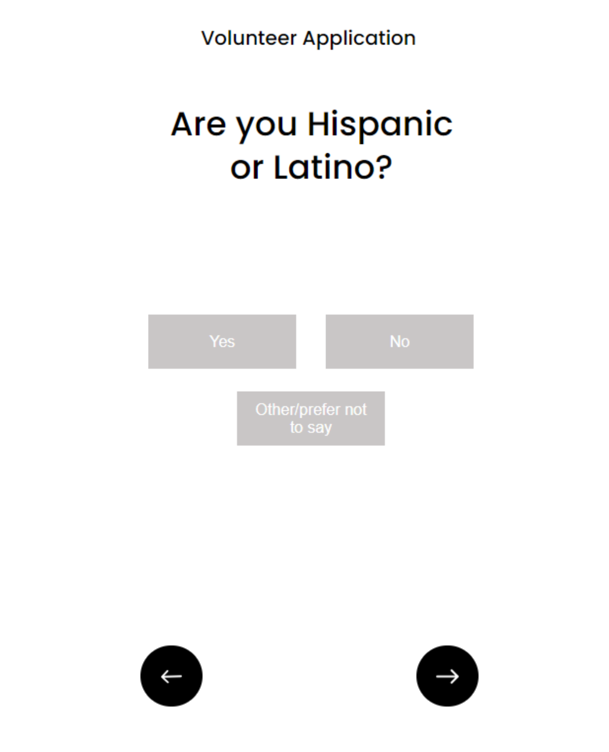
Page 58: Volunteer age



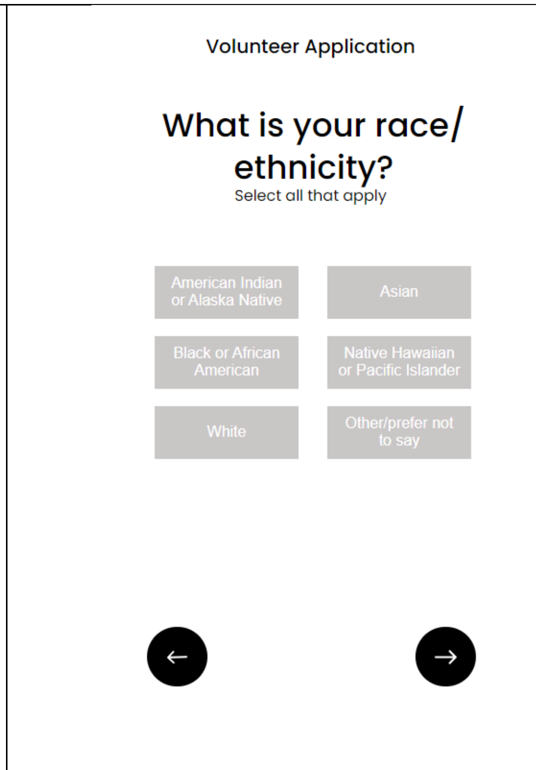
Page 59: Volunteer gender identity



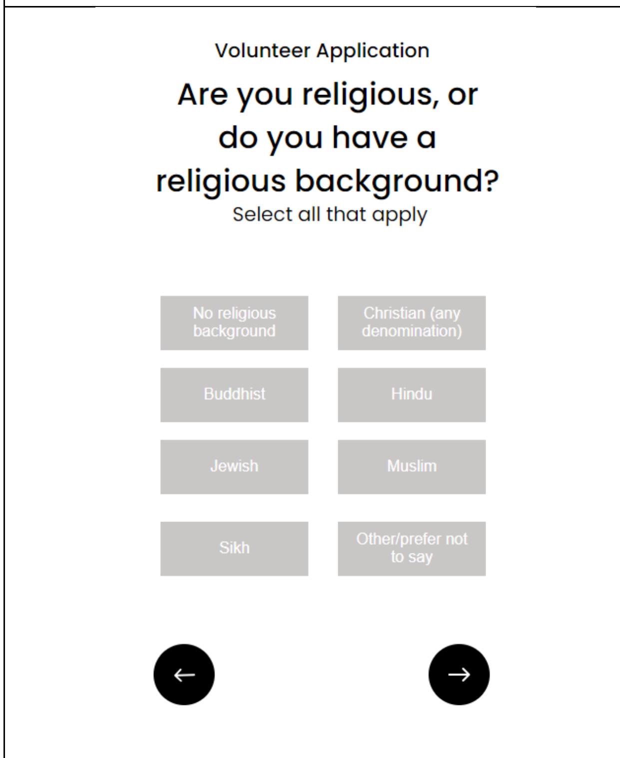
Page 60: Volunteer sexual orientation



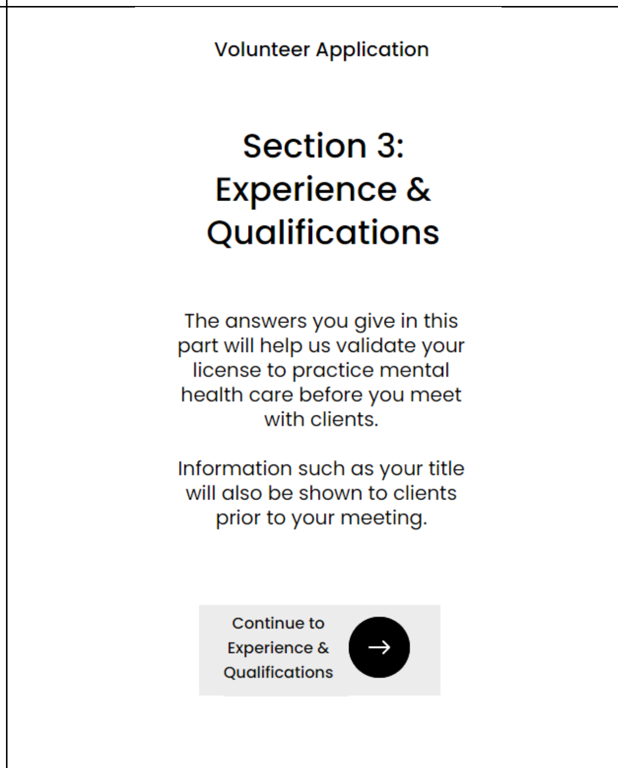
Page 61: Volunteer Hispanic or Latino



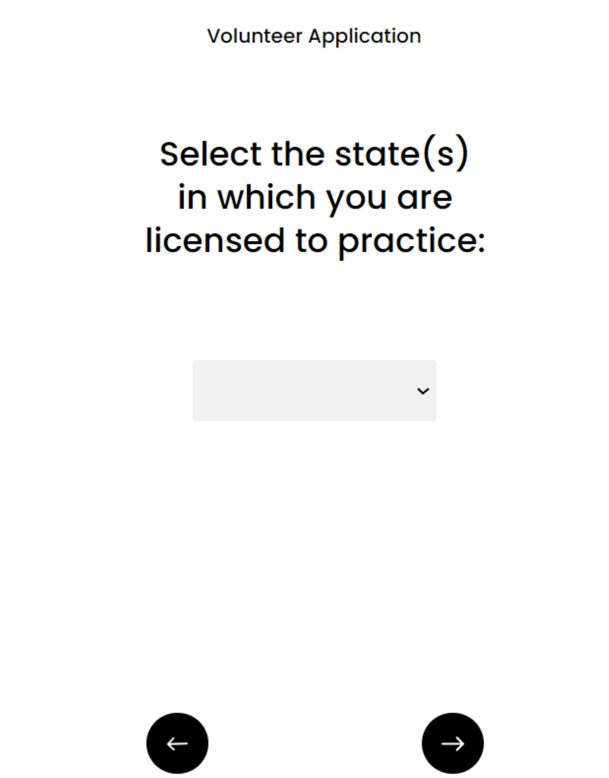
Page 62: Volunteer race/ethnicity



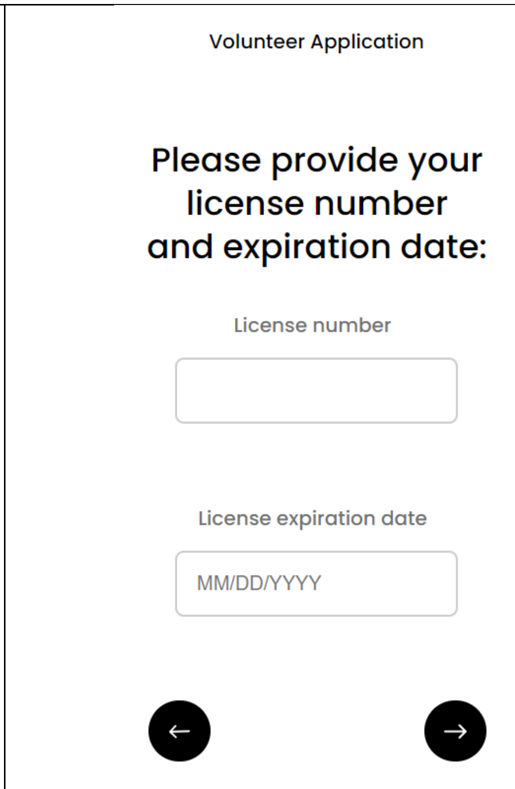
Page 63: Volunteer religious background



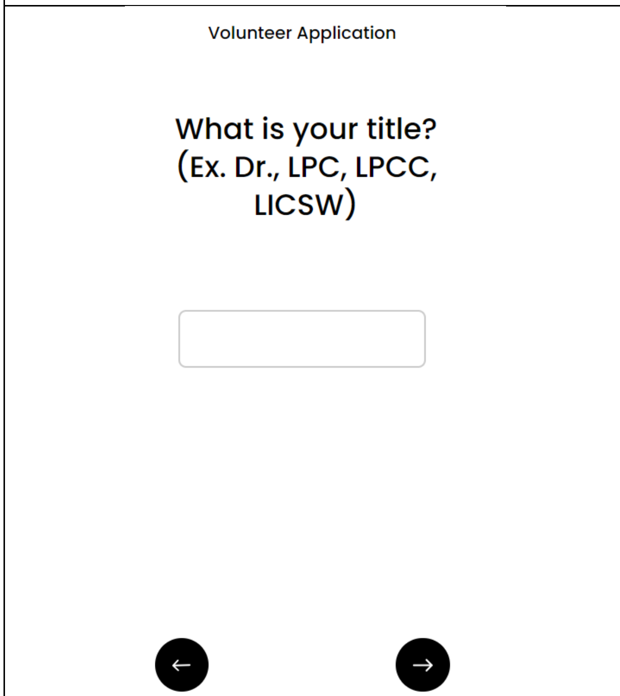
Page 64: Volunteer experience



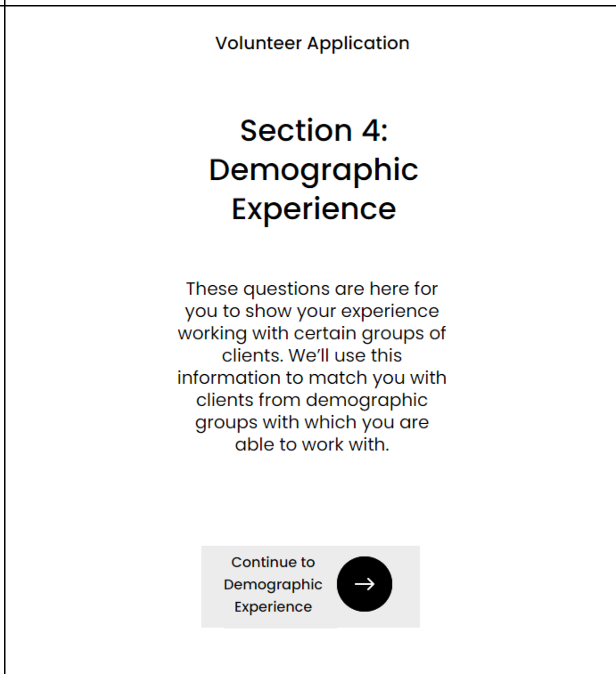
Page 65: Volunteer states



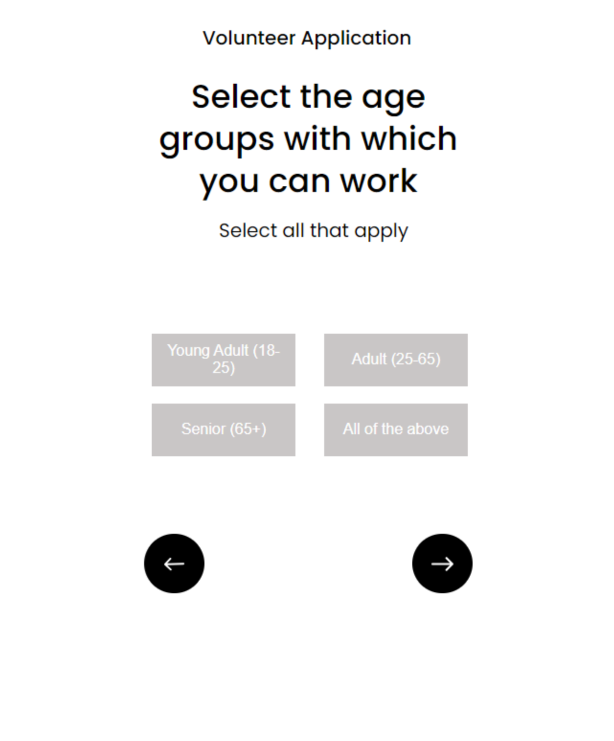
Page 66: Volunteer license



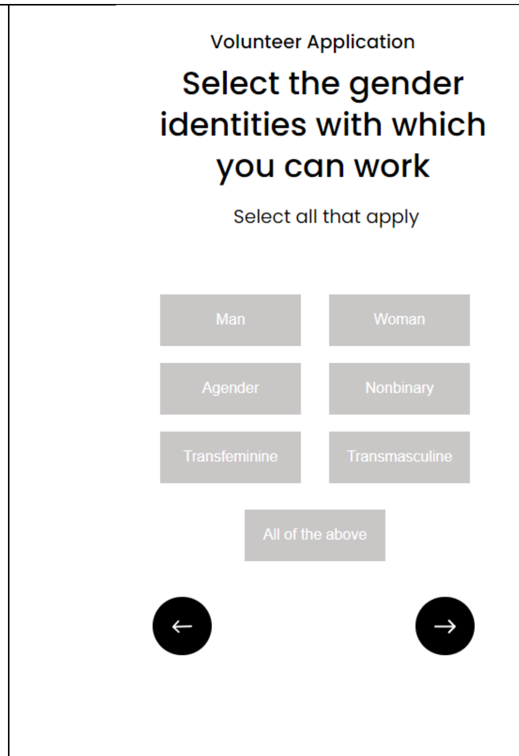
Page 67: Volunteer title



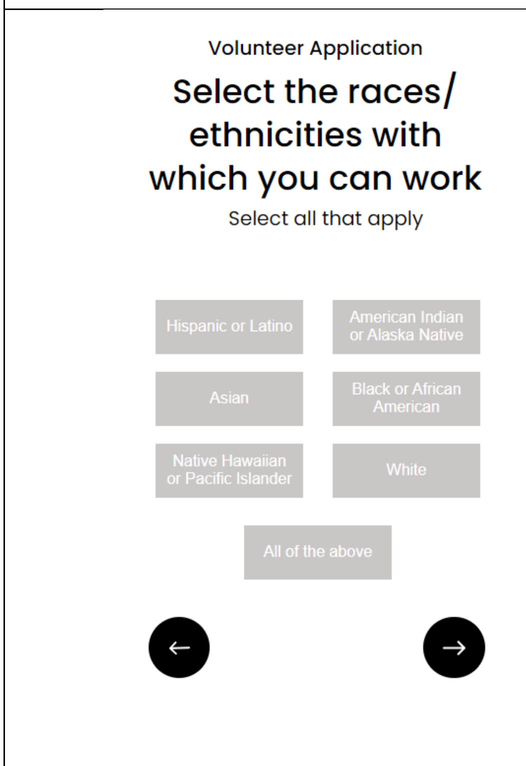
Page 68: Volunteer demographic experience



Page 69: Volunteer experience age

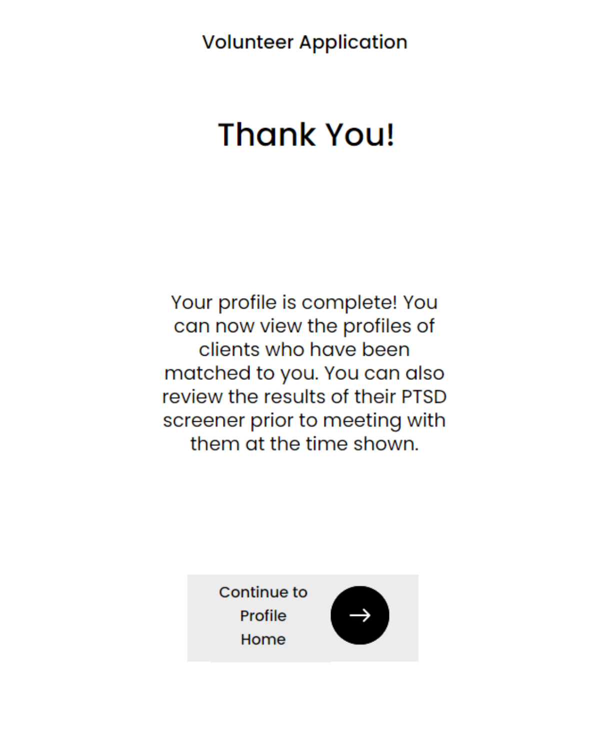


Page 70: Volunteer experience gender

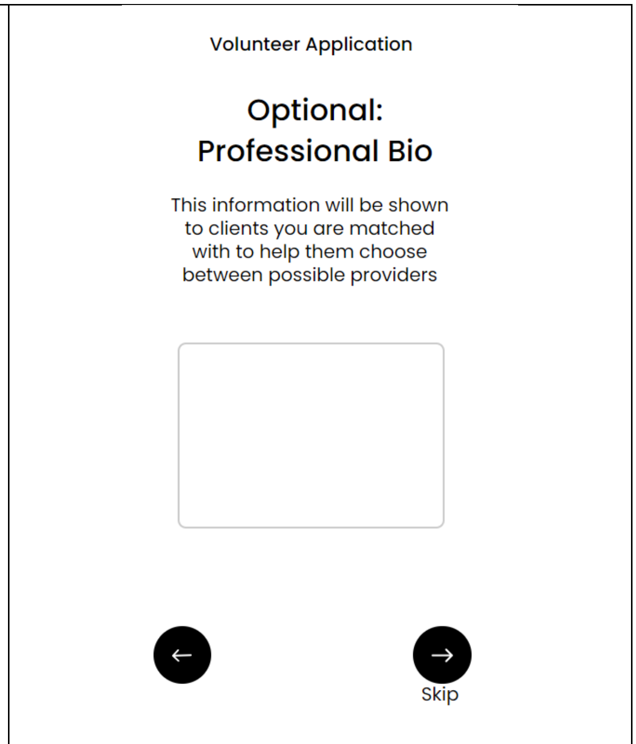


Page 71: Volunteer experience race

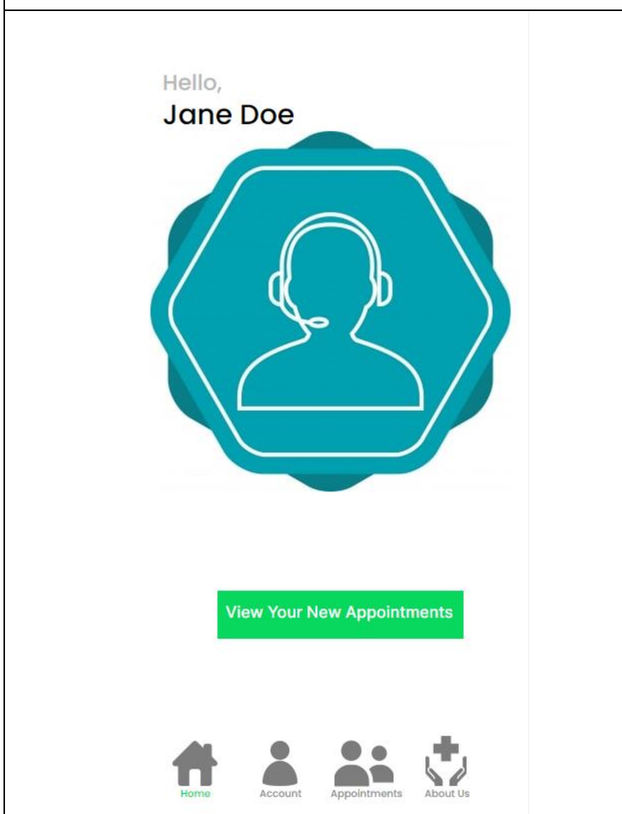
Page 72: Volunteer experience religion



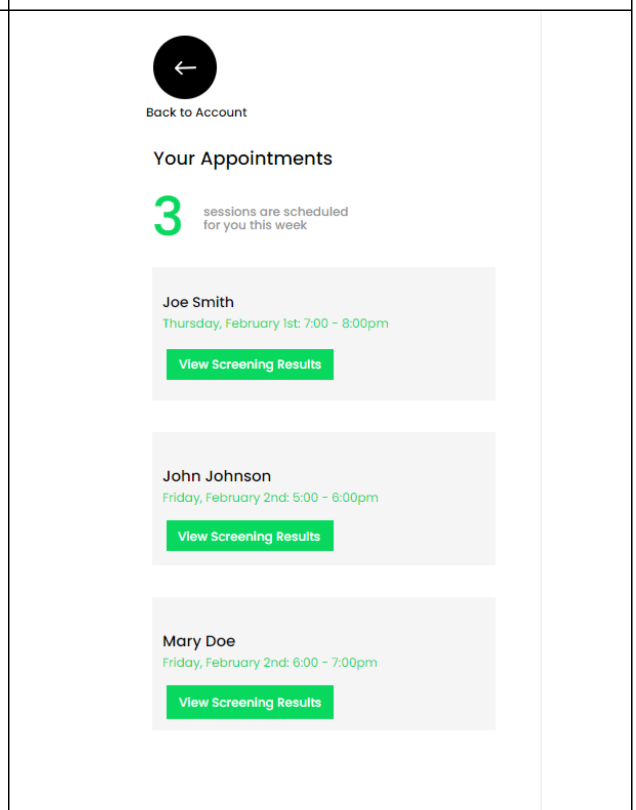
Page 73: Volunteer thank you page



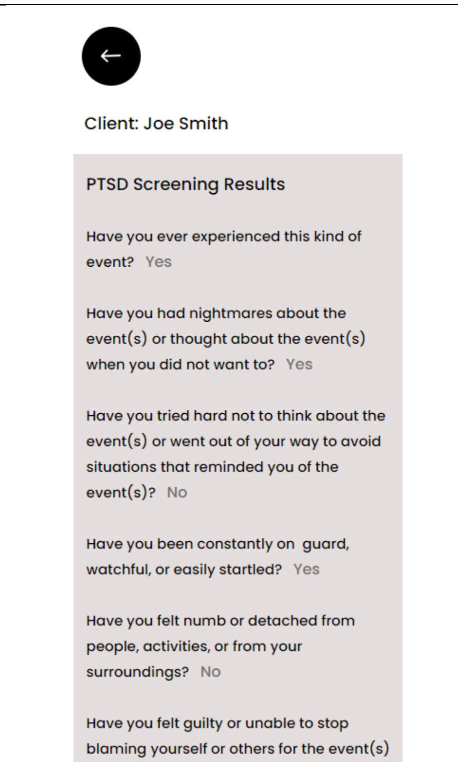
Page 74: Professional bio



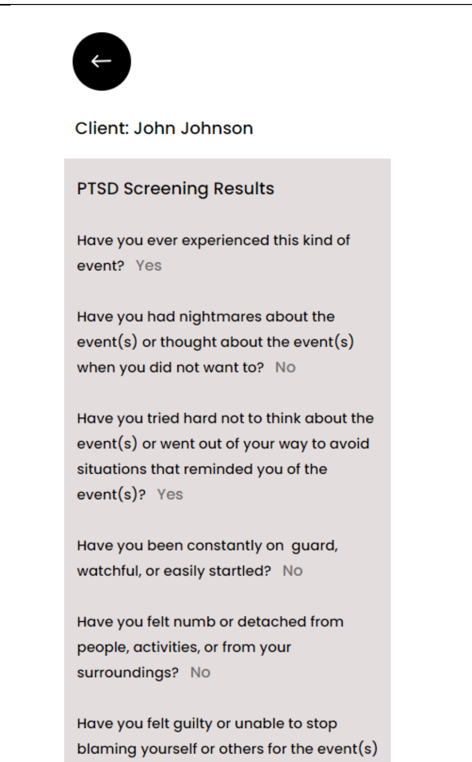
Page 75: Volunteer home page



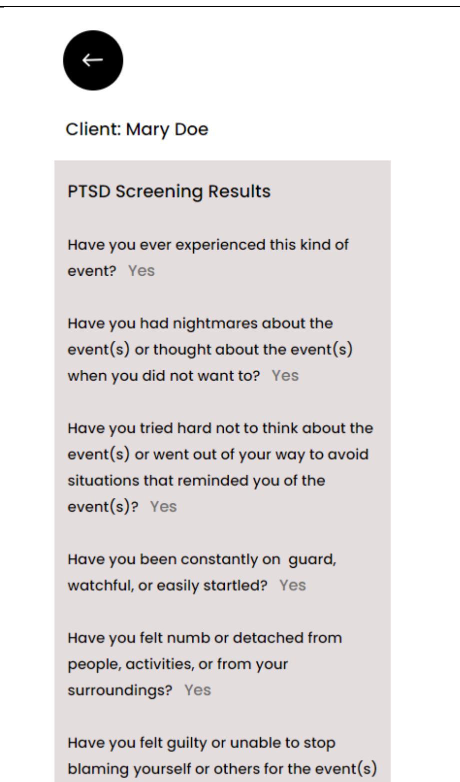
Page 76: Volunteer appointment view



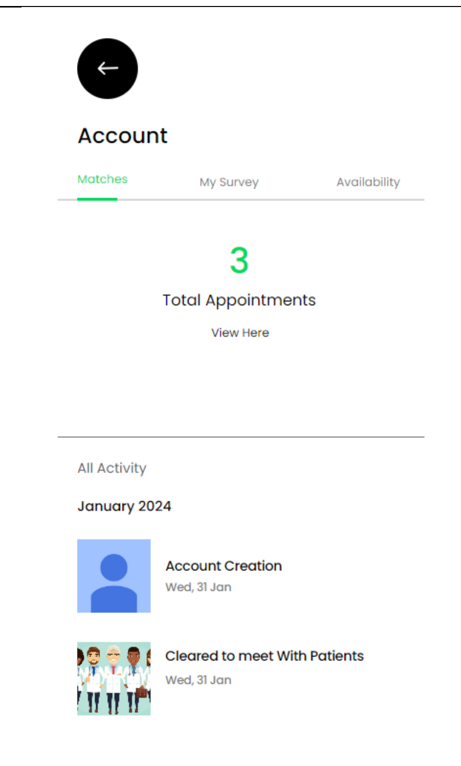
Page 77: Joe Smith screening



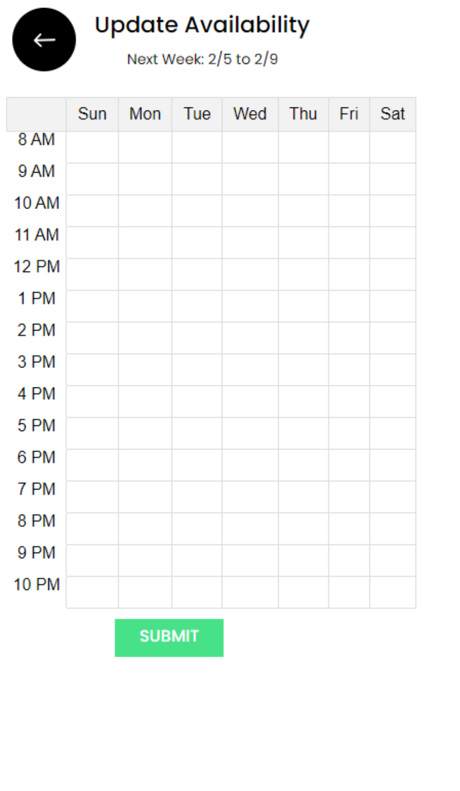
Page 78: John Johnson screening



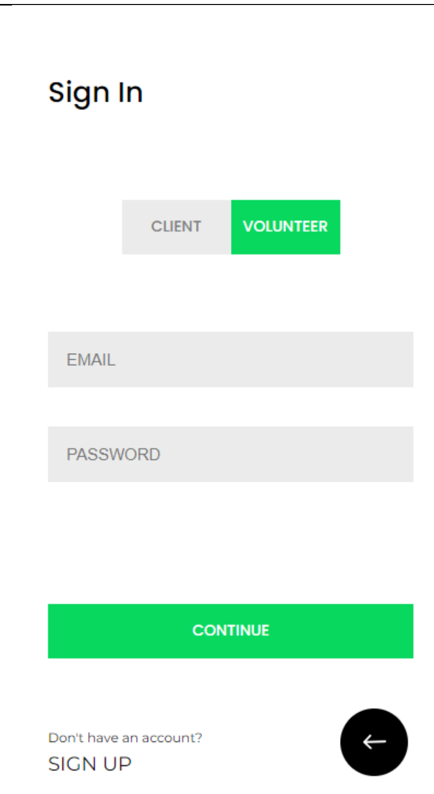
Page 79: Mary Doe screening



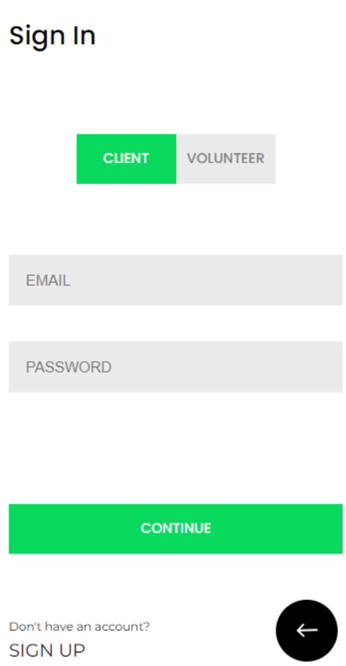
Page 80: Volunteer account view



Page 81: Volunteer update availability



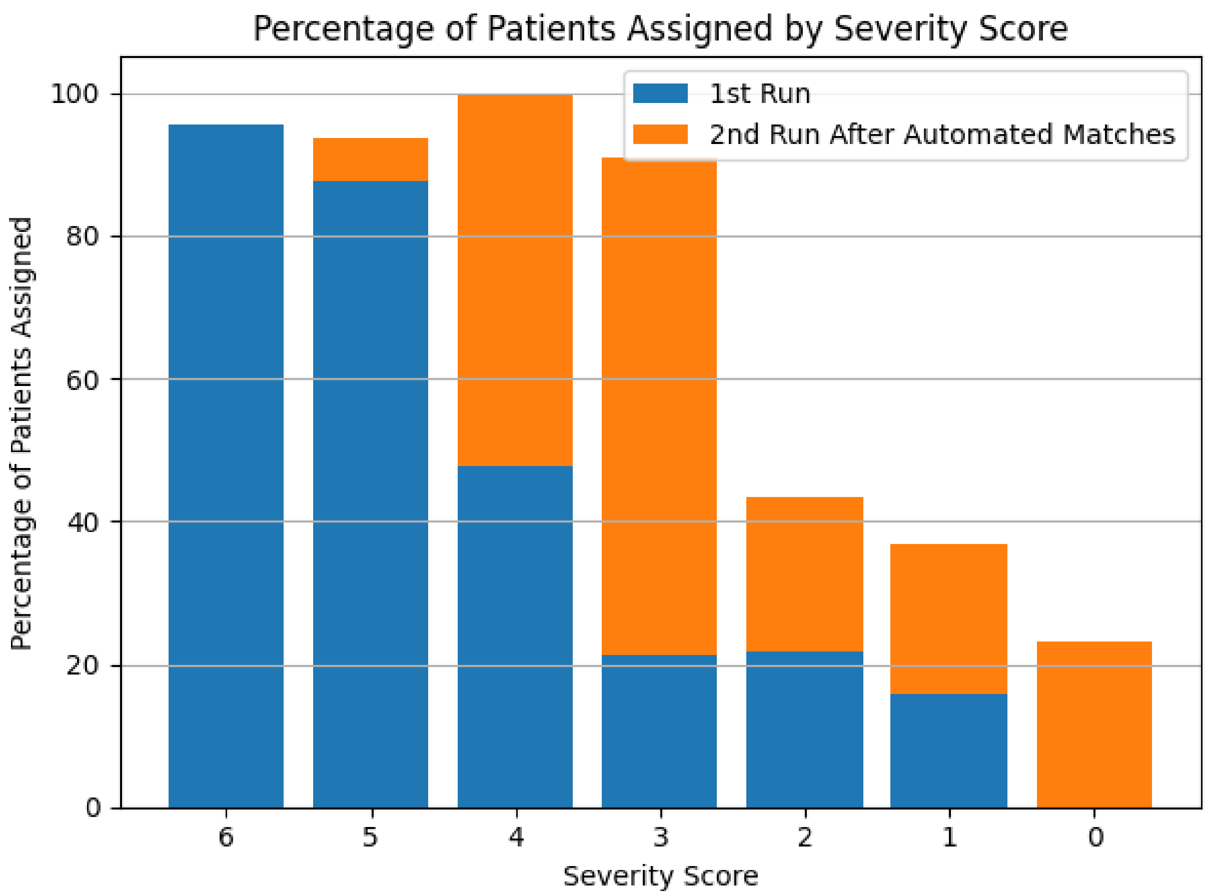
Page 82: Volunteer sign in



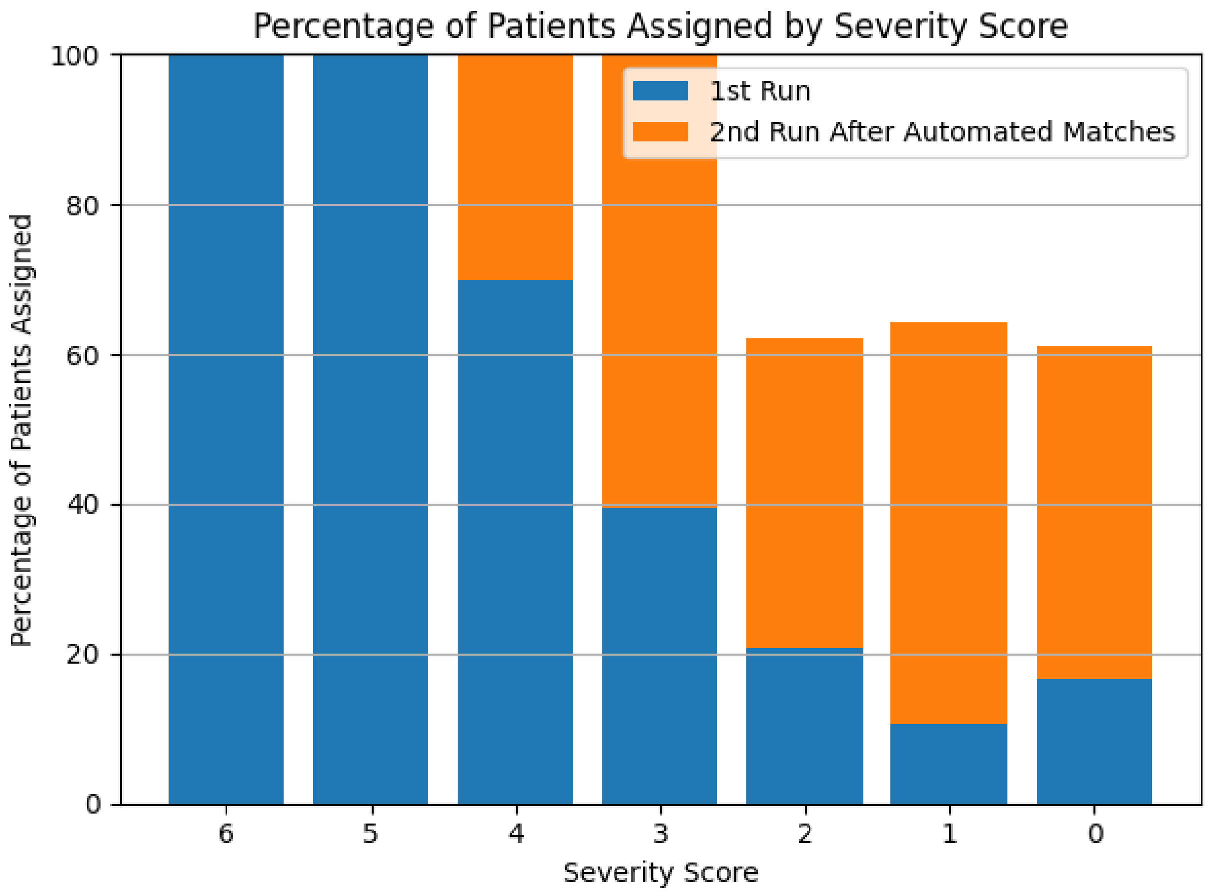
Page 83: Client sign in

Appendix 5

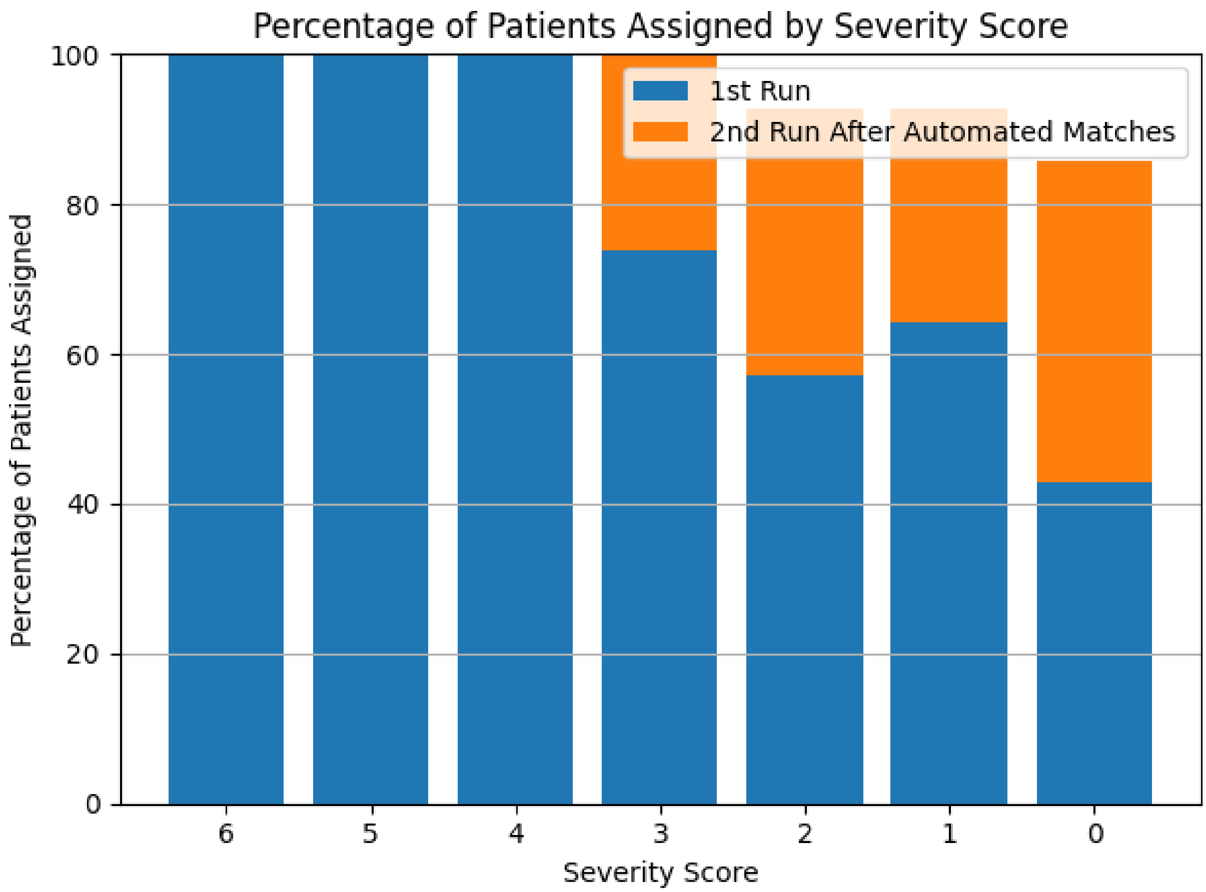
Mathematical Model Bar Charts



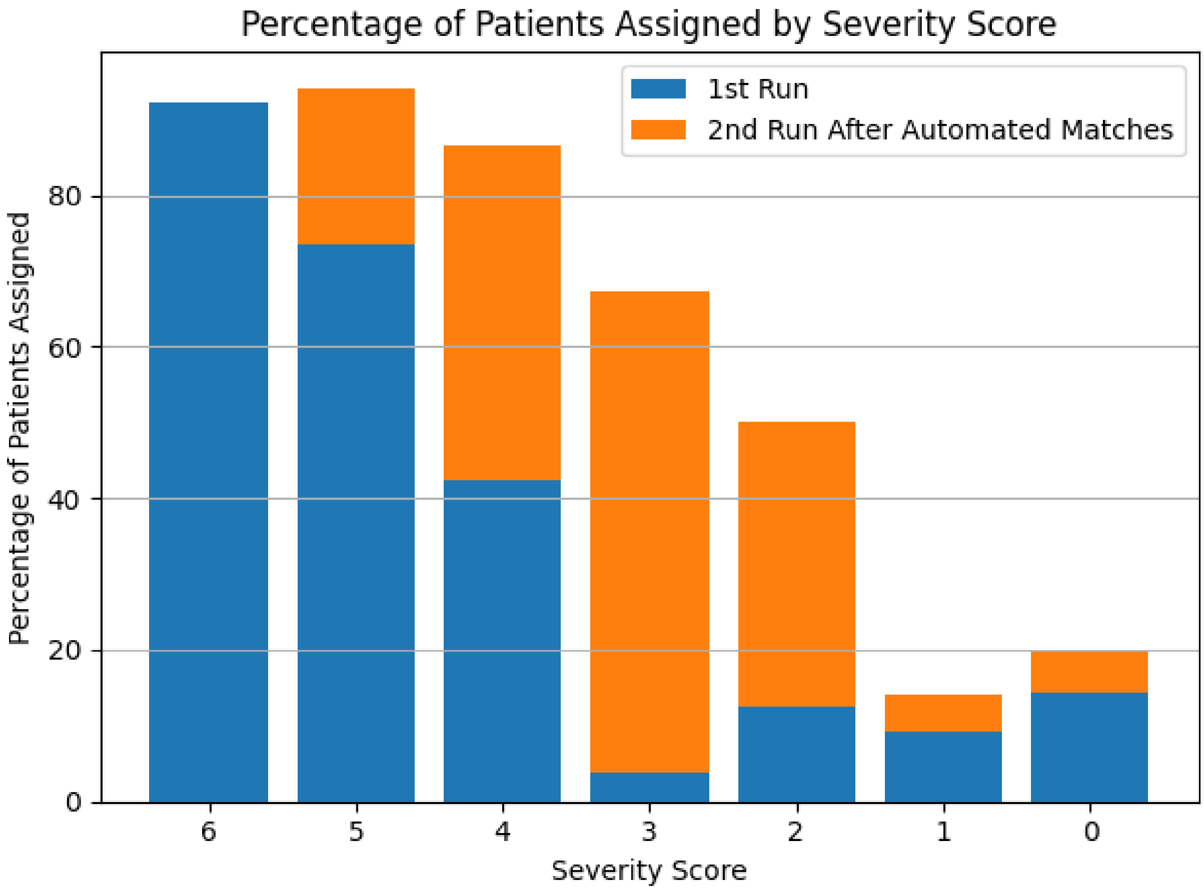
150 Patient: 15 Volunteer



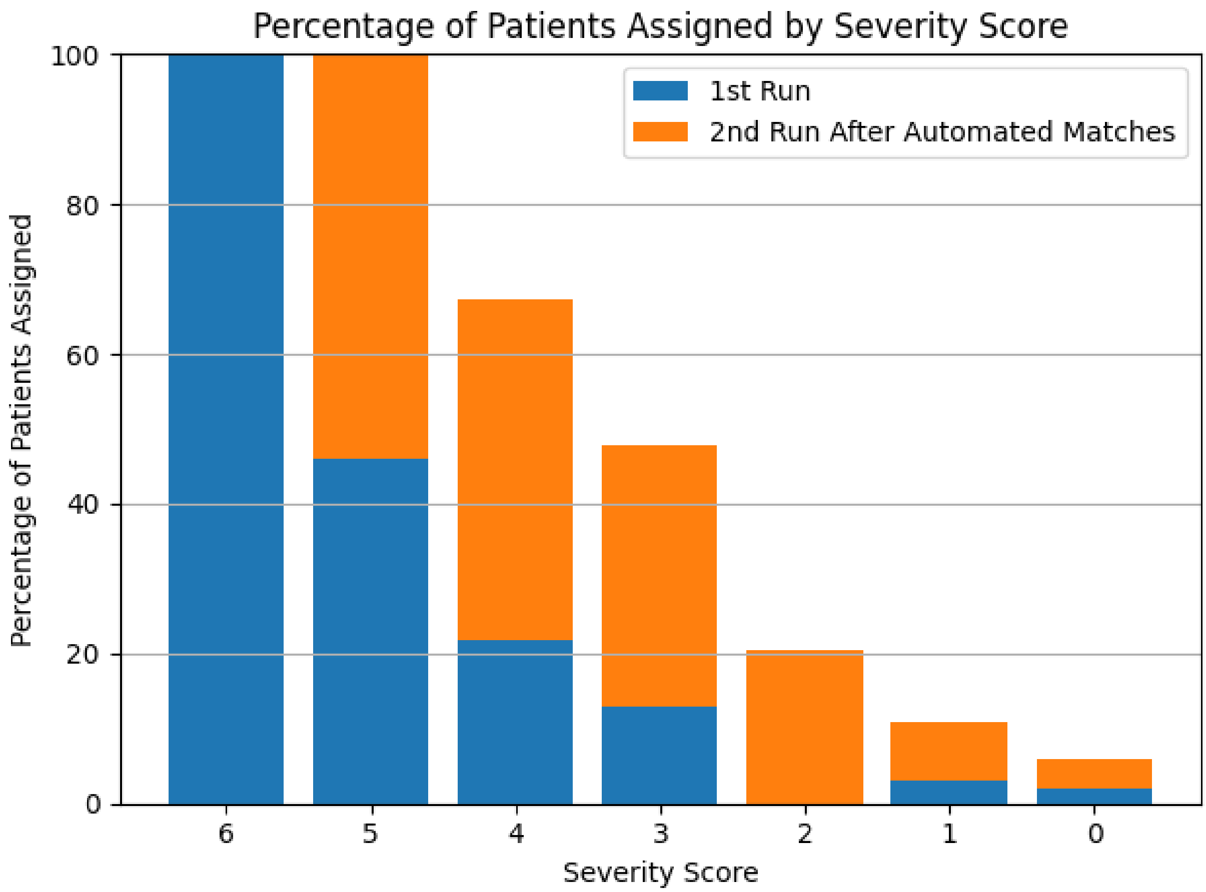
200 Patients : 25 Volunteers



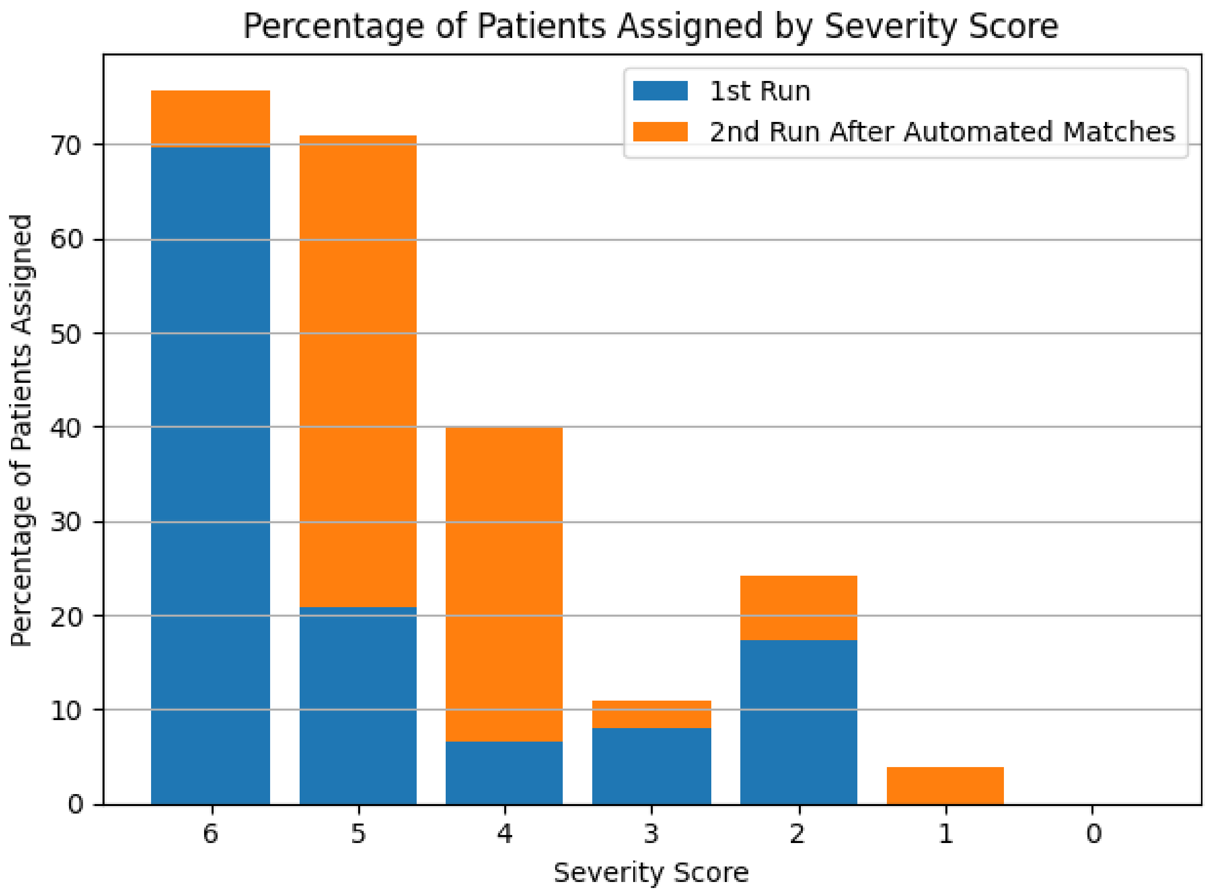
100 Patients: 25 Volunteers



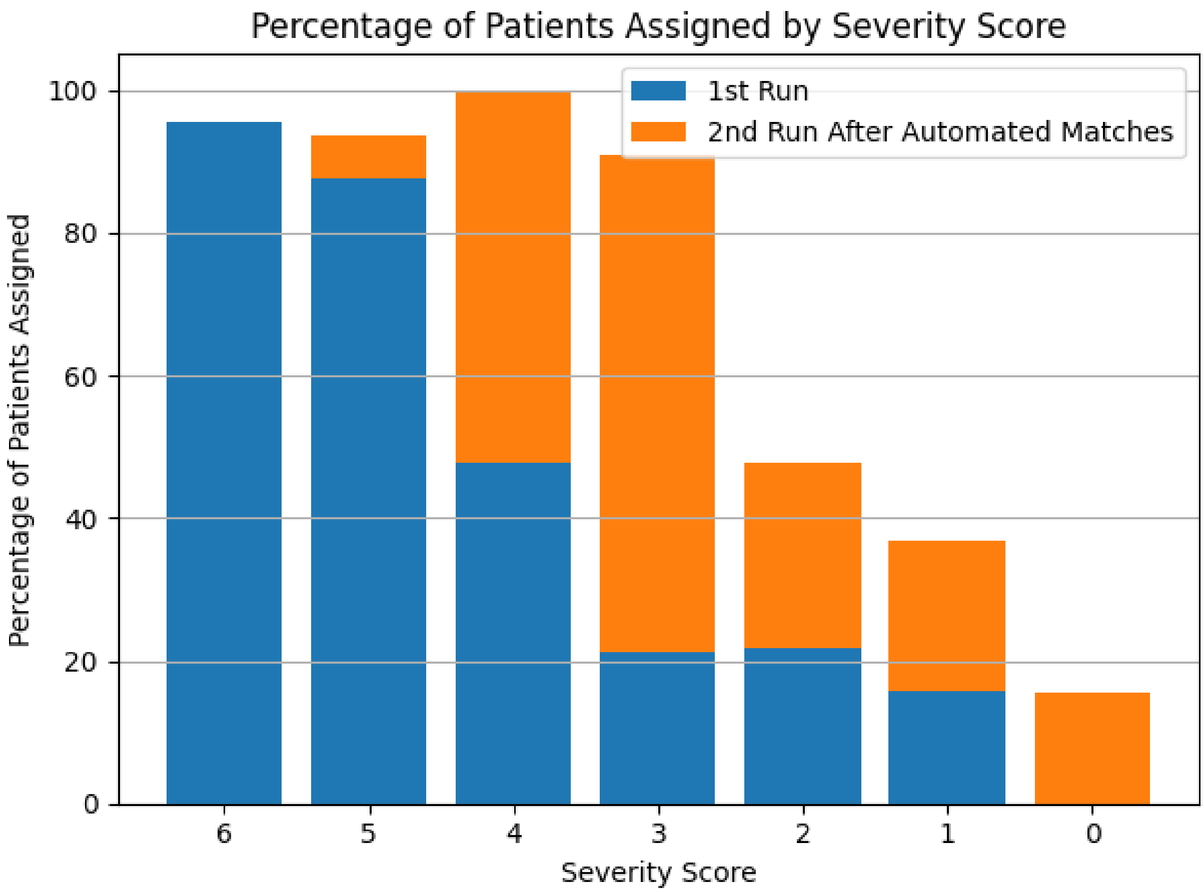
300 Patients:25 Volunteers



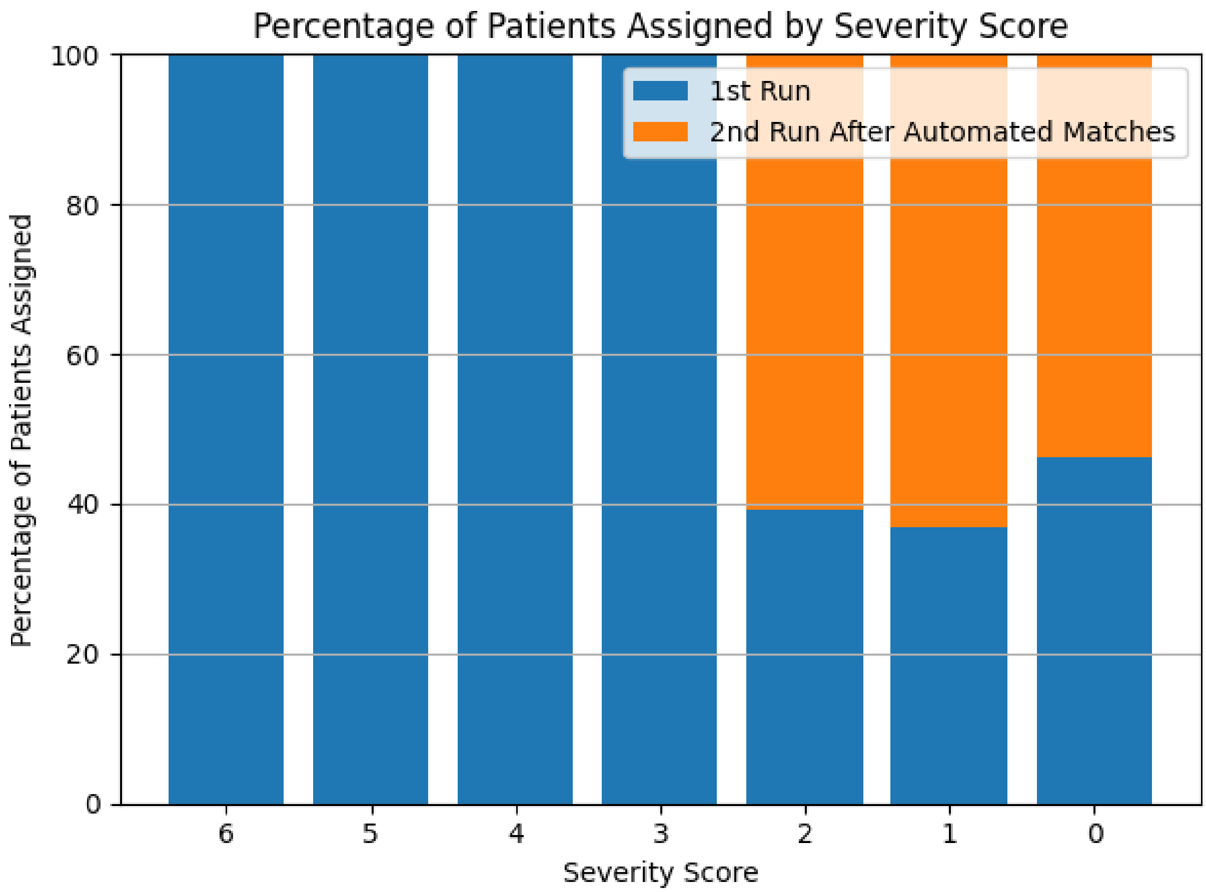
400 Patients :25 Volunteers



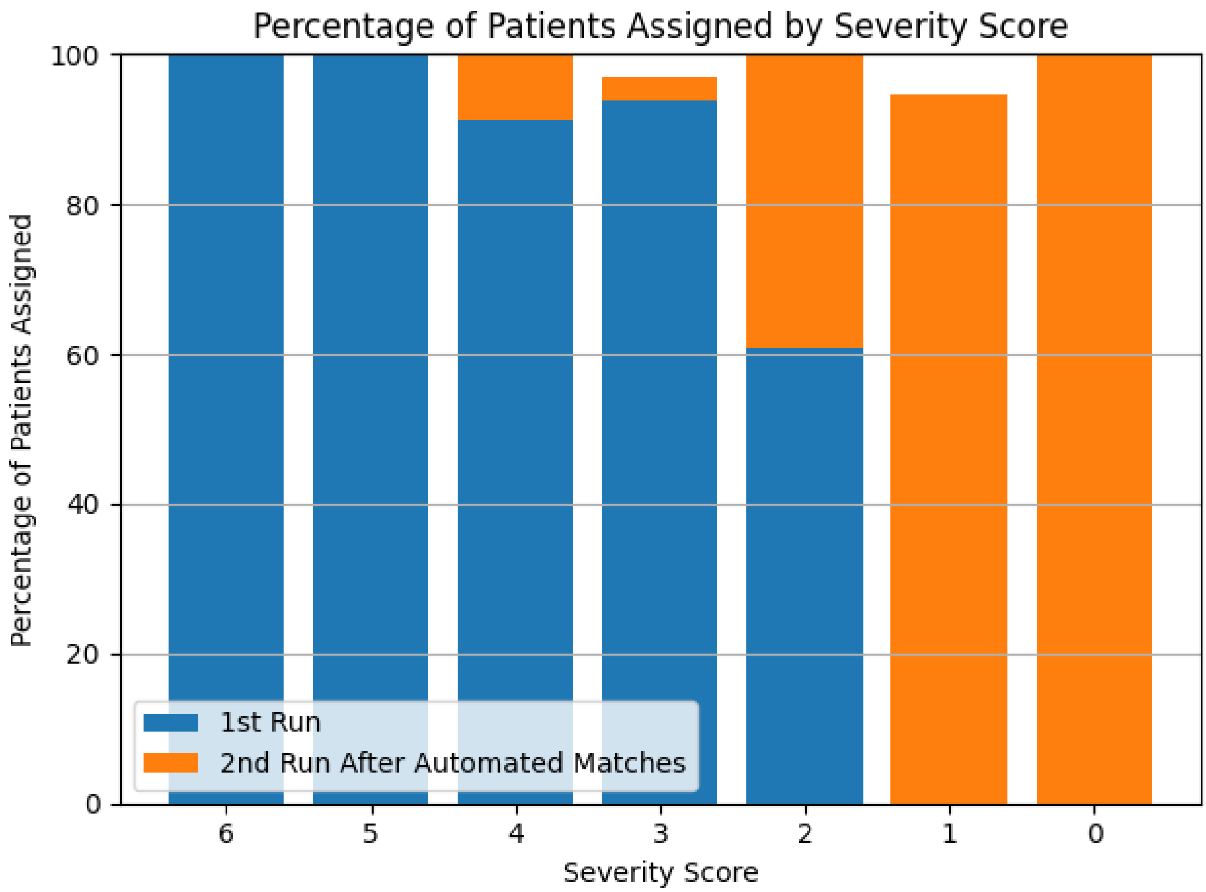
200 Patients :10 Volunteers



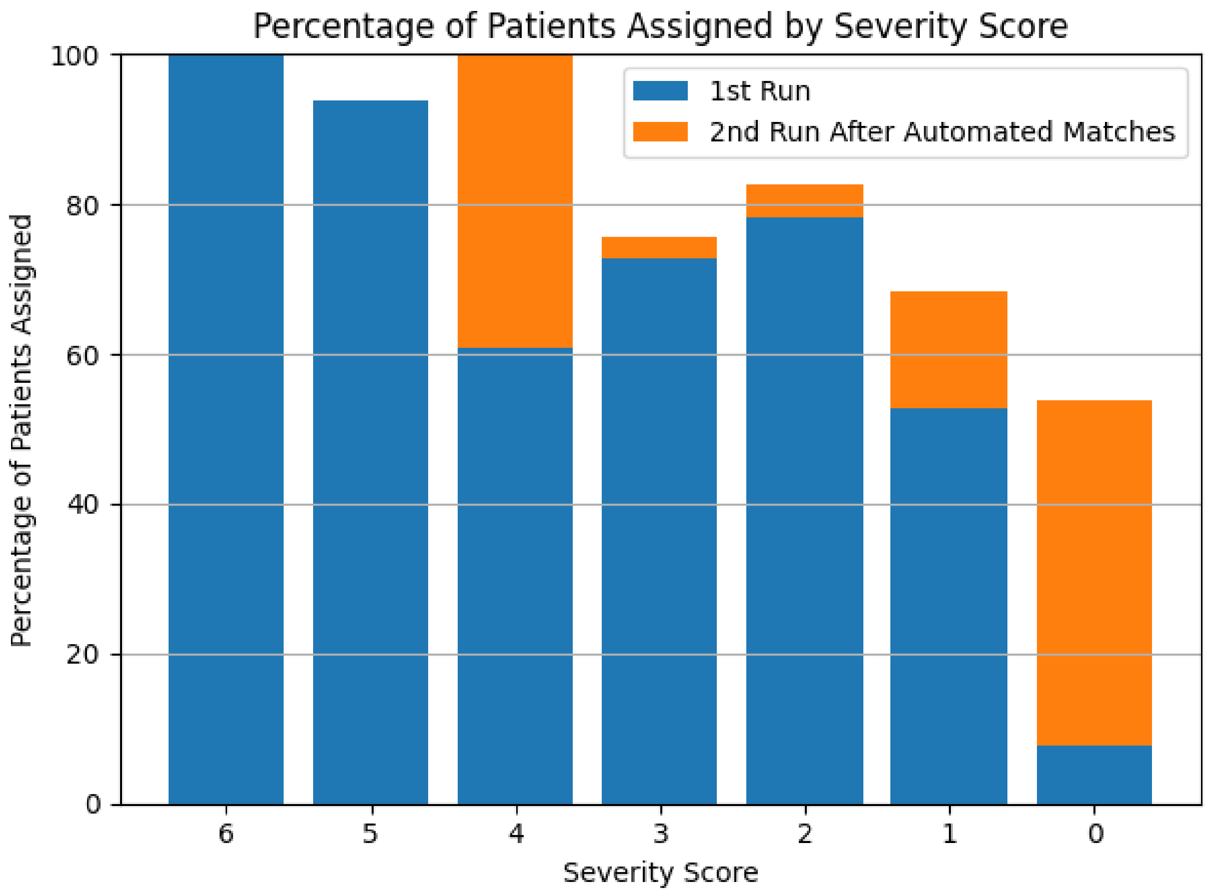
150 Patients with No Preferences :15 Volunteers



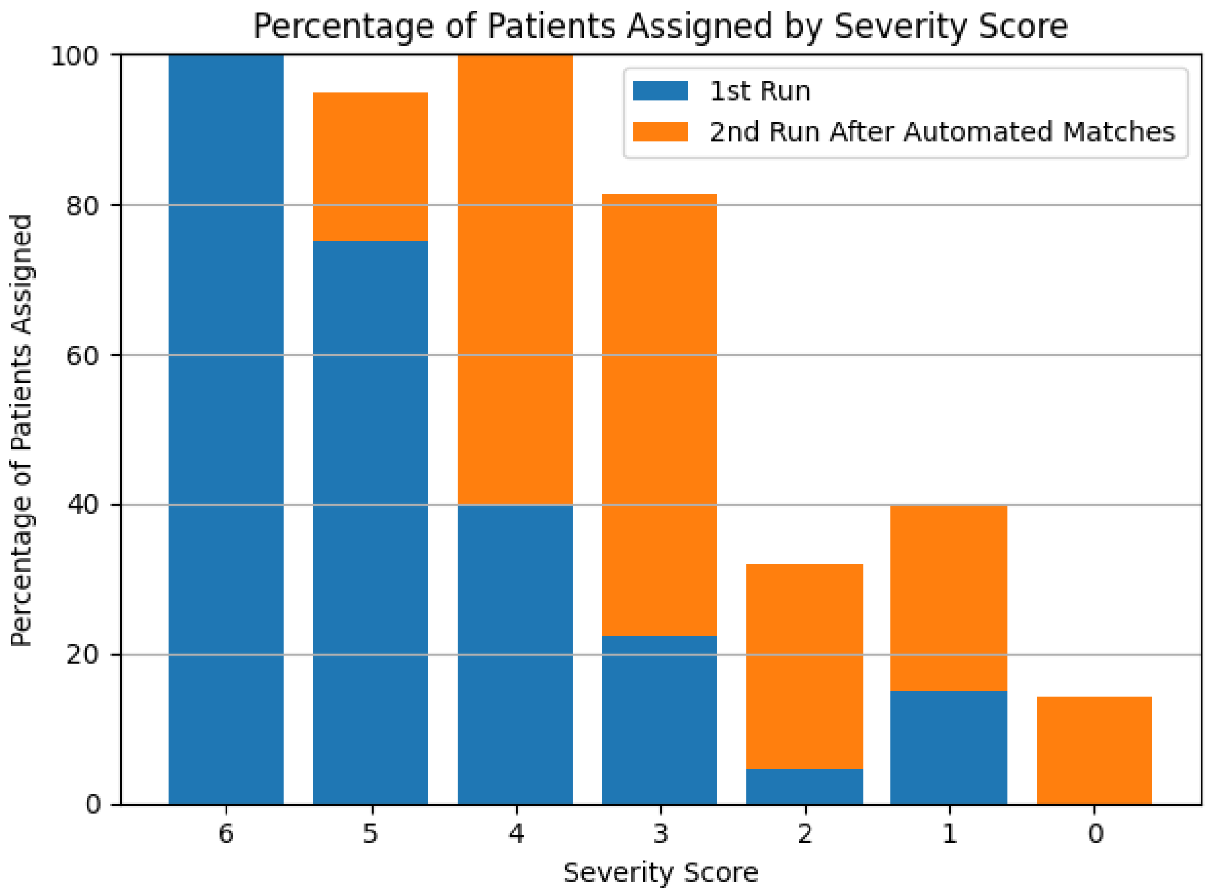
150 Patients: 15 Volunteers with the same Normally Distributed Availability



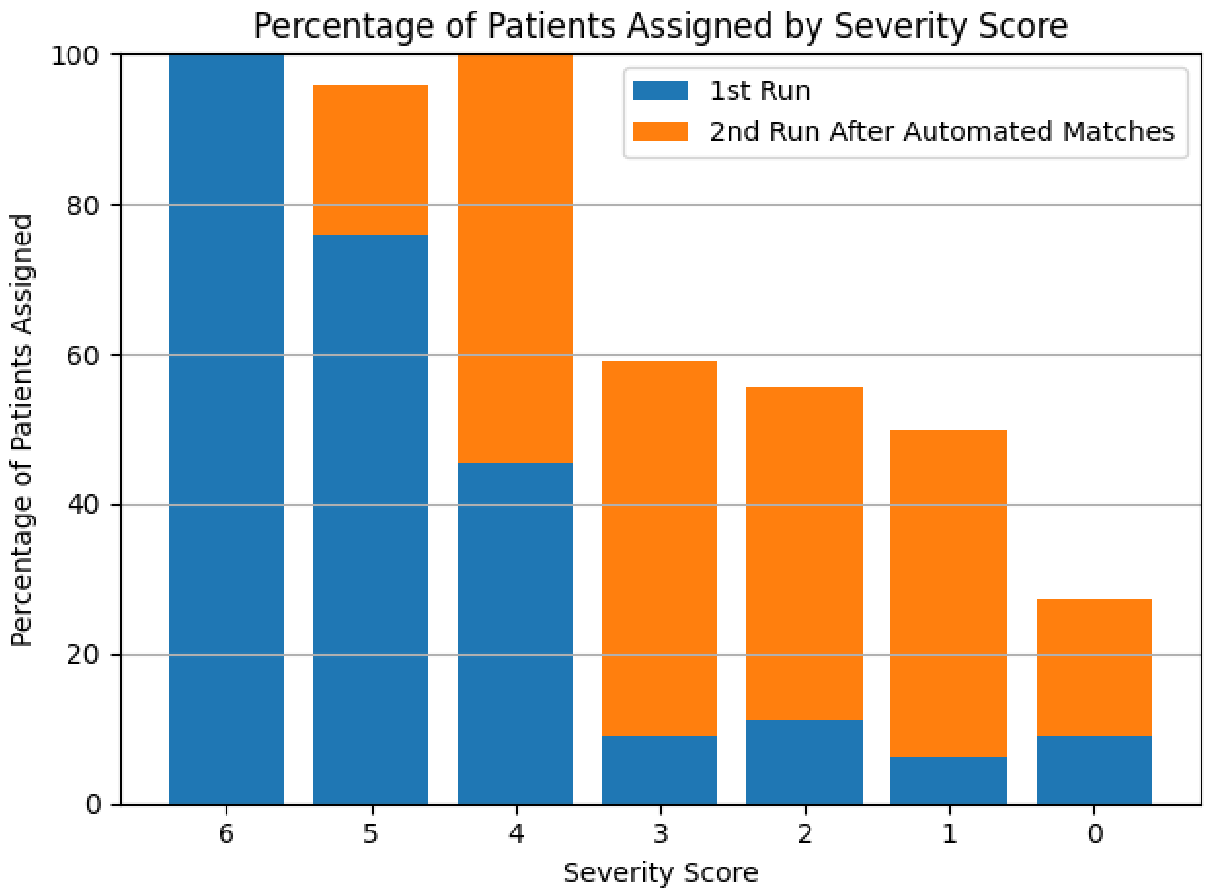
150 Patients with Uniformly Distributed Availability: 15 Volunteers with Poissant Distributed Availability



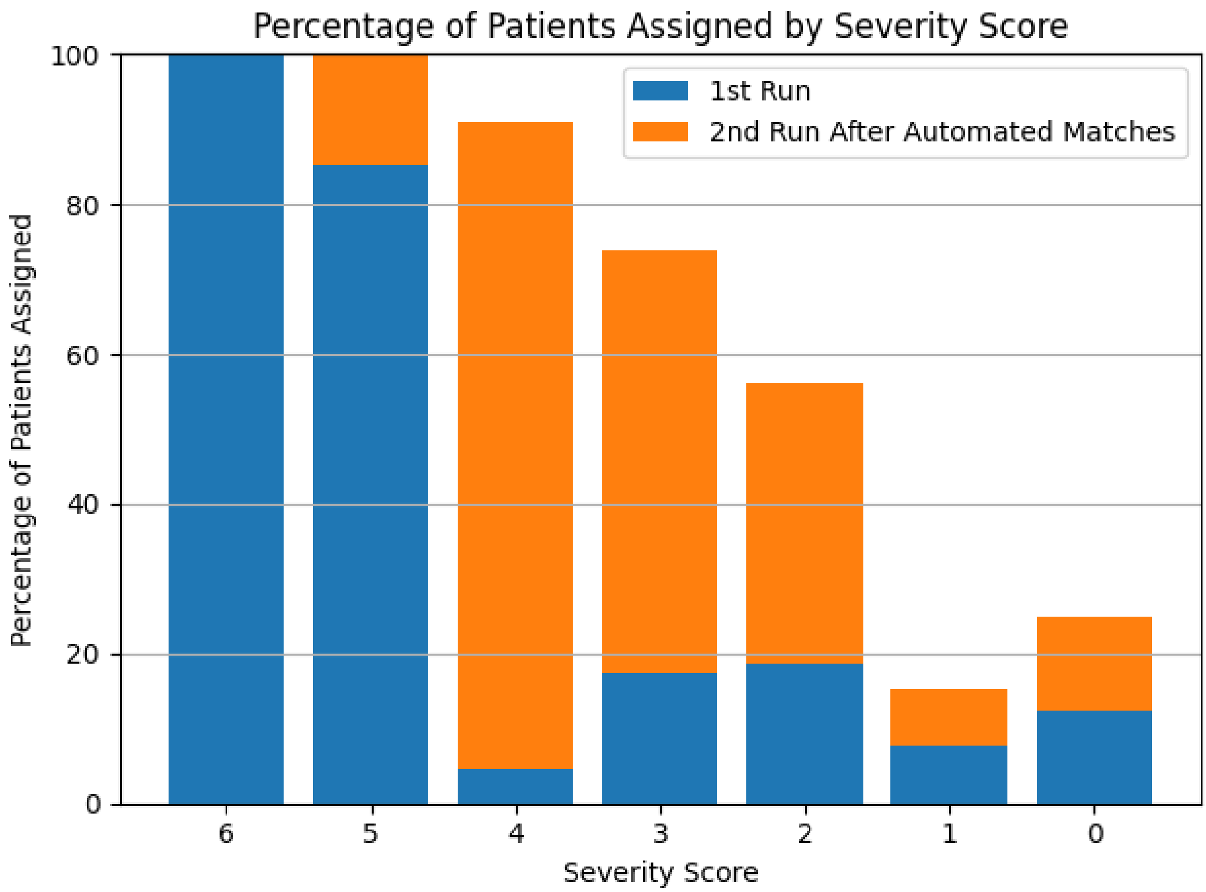
150 Patients with Normally Distributed Availability: 15 Volunteers Uniformly Distributed Availability



150 Patients with Texas Demographics :15 Volunteers with Random Demographics



150 Patients with Random Demographics: 15 Volunteers with Texas Demographics

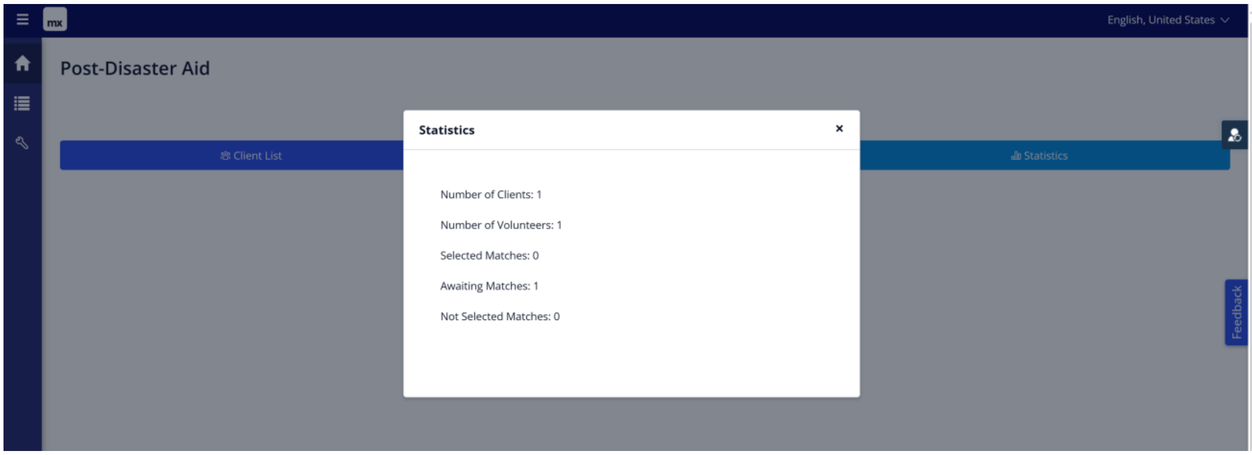


150 Patients with Random Demographics: 15 Volunteers with Random Demographics

Appendix 6

Mendix Screenshots

Administrative Homepage

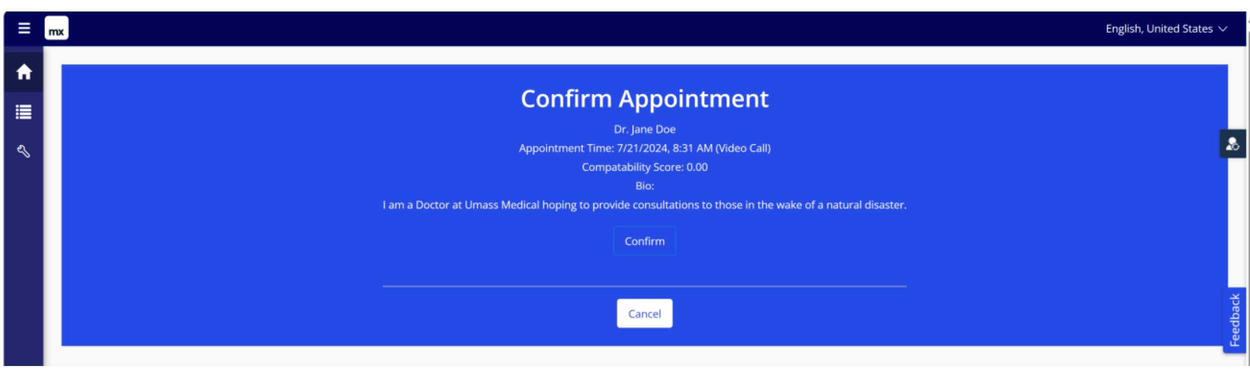


Statistics Page

Client Homepage/Overview

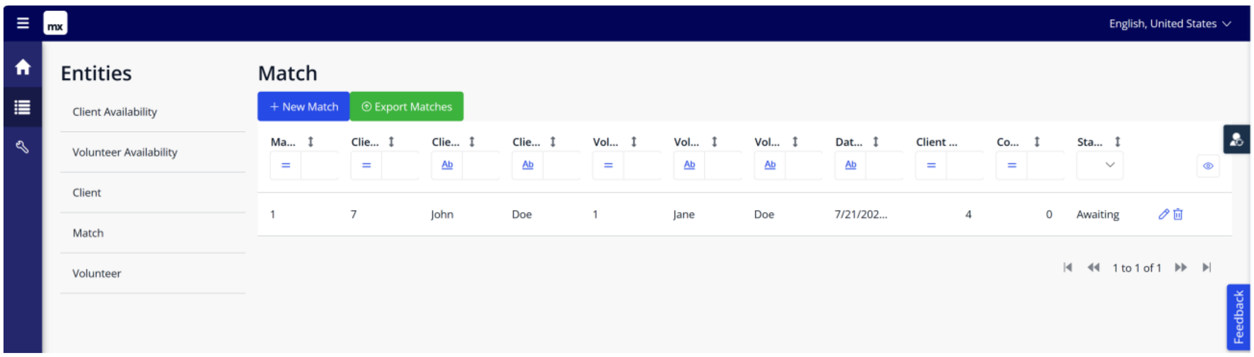
Volunteer Match Overview Page

Client Match Overview Page

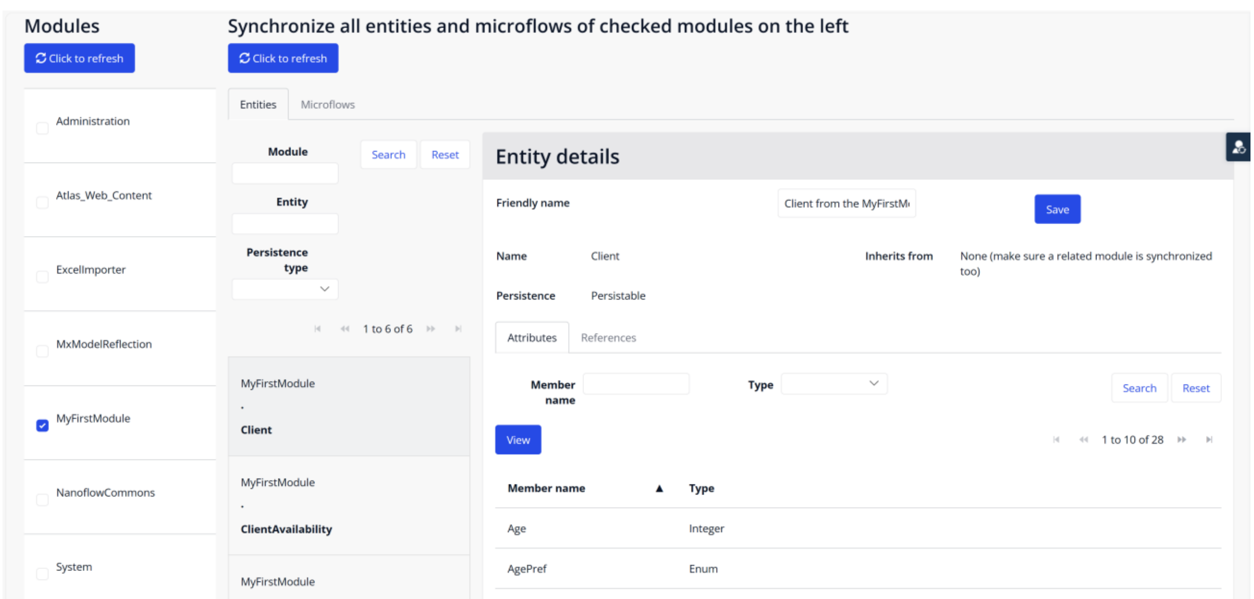


Match Confirmation Page

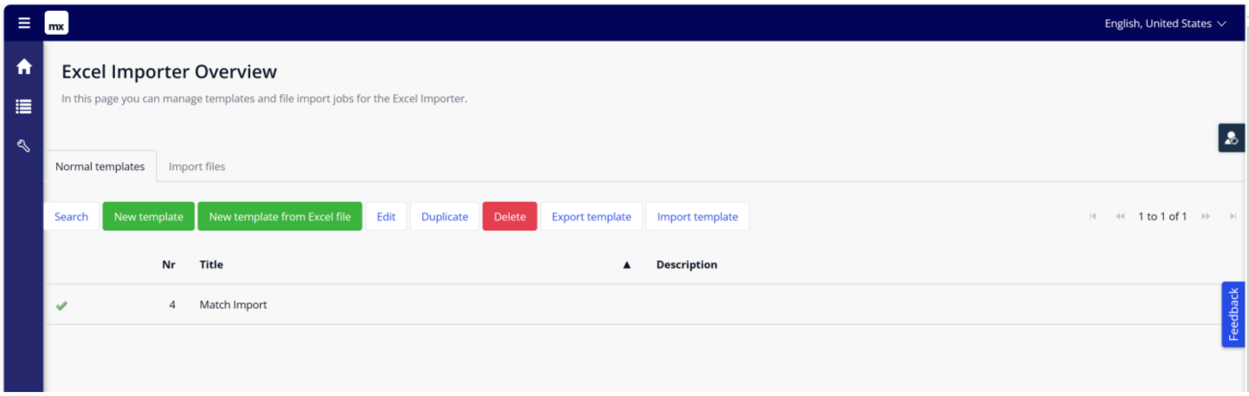
Client/Volunteer Availability Page



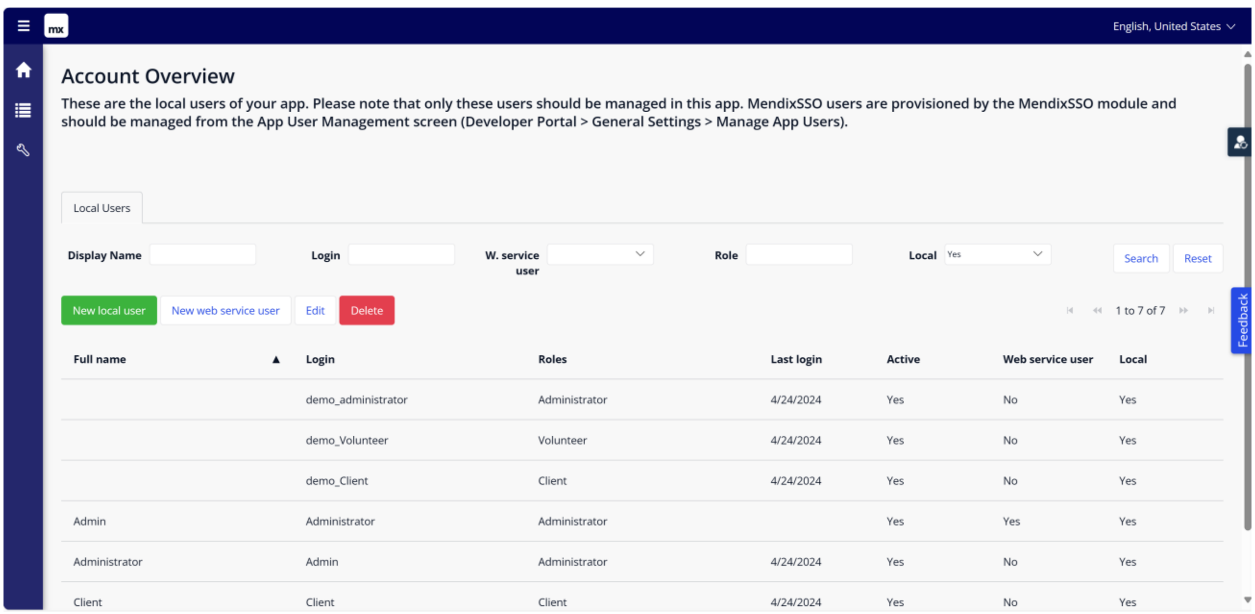
Administrative Data Grid Page



MxObjects Overview Page



Excel Importer Overview Page



Accounts Overview Page

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