Ambulatory Assessment of Mental Health and Well-being using an Experience Sampling Methodology: Pipeline

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Keywords: Mental Health and Well-being, Ambulatory Assessment, Experience Sampling Methodology, Software Development, Application Programming Interface.

Abstract: Mental health disorders are prevalent in our society today as they affect one in four people all over the world, according to the World Health Organization. This necessitates a proactive method of mental health assessment. Clinical assessments and paper-and-pen reporting are usually done through retrospective reports, which are subject to memory bias. With the advancement in technology and smartphones becoming an inherent and integral part of day-to-day life, ambulatory assessment of mental health and well-being would be greatly improved. In this study, we analyze different methods of mental health assessment, their respective benefits and drawbacks, and from which we propose a pipeline based on Experience Sampling Methodology (ESM). The pipeline is composed of a web application for therapists and a mobile application for patients. The therapist creates ESM-based assessments to their patients using the web application that communicates with the mobile application through an application programming interface. This pipeline aims to overcome retrospective biases in assessing the patient's mental health and well-being by using more reliable behavioural patterns from the data. Sophisticated data encryption may be utilized to ensure patient-therapist confidentiality. The same system is also designed to be used by psychologists to send ESM-based surveys to their intended participants and perform statistical analysis from the respondents' data, allowing improved data security for the respondents. With this capability, generation of data would be faster and safer, and more research can be done to improve and accelerate analysis and diagnosis of mental health and well-being.

1 INTRODUCTION

Mental health problems are a serious and growing issue among adolescents and adults worldwide. The World Health Organization (WHO) reports that 1 out of 4 people in the world, with 10-20% of children and adolescents, experience mental health problems. WHO adds that anxiety and depression are the most common causes of disability in adolescents and at worst can lead to self-harm and suicide. Severe mental health problems include depression, anxiety disorders, bipolar disorders, eating disorders, schizophrenia, dementia, developmental disorders, and substance use (Lake & Turner, 2017). Current medications and treatment models are insufficient to treat the complexities of mental health problems

mainly because it is underreported worldwide and lacks research. Other factors that stifle progress on mental health include lack of sufficient funds and existing societal prejudices.

The Philippines has recently passed its Mental Health Act in 2018 (Republic Act No. 11036) that aims to enhance mental health services and promote the safety of mental health patients. Universities and other institutions are taking the initiative to be more understanding of mental health problems and because of this, intervention and counselling is becoming commonplace. However, mental health remains underfunded, inaccessible, and oftentimes stigmatized in the country.

In adolescent population, depression is often prejudiced to be harmless and a normal part of their

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growth (Lee, et al. 2013). This is problematic as it ignores the dangers caused by not only depression but mental illnesses in general. Mental disorders are prevalent among adolescents, especially college students who spend most of their time in schools. College is a microcosm of society where it encompasses all activities, social relationships, and health conditions and is a challenging period in an adolescent's transition to adulthood. Hunt and Eisenberg (2010) reported that financial status, social support, trauma, and academic stressors are some of the factors that affect college students' mental health. Filipino students who frequently drink and smoke, lived away from parents, and are unsatisfied with their financial condition had higher depressive symptoms while students who have high levels of closeness with their peers and families tend to have lower levels of depressive symptoms (Lee, et al. 2013). A study by Cleofas (2020) shows that there is an increase in student suicide cases in recent years caused by social and academic factors to be addressed by social institutions (e.g., family, school, policy-making bodies). Universities have been taking steps to address mental health issues and protect students' well-being. The University of the Philippines Diliman has taken an initiative to address mental health problems within the university by establishing The UP Diliman Psychosocial Services (UPD PsycServ) to promote mental health and well-being among students, faculty, and staff (Santos 2020). Lake and Turner (2017) expressed that "mental illness is the pandemic of the 21st century and will be the next major global health challenge". Countermeasures are being demanded to prevent, avoid, and alleviate the consequences of these mental health problems.

2 MENTAL HEALTH ASSESSMENT

2.1 Traditional Methods

In assessing mental health, clinical experts often provide questionnaires to their patients in order to gather information about them. During therapy sessions, therapists also ask their clients about their experience over the past days or weeks. Normally, patients are given a diary form that contains their feelings, thoughts and experiences on each day so that they can monitor themselves and provide more accurate data for the therapists. These methods lack

process-mediating aspects and context sensitivity since they only focus on outcome measures.

2.1.1 Questionnaires

Questionnaires are the most common tool to collect self-report data from the study participants. They can contain close or open questions, or both. Close questions provide limited choices whereas open questions allow the participants to answer using their own words. Questions also involve response or rating scales where respondents usually express how strongly they agree or disagree with a particular statement.

Self-report questionnaires are frequently used in clinical assessments to identify signs and symptoms of psychological problems (Demetriou, et al. 2015). They serve as a screening tool that can help health care practitioners in their planning of treatment process for their patients. For instance, Beck Depression Inventory is a 21-item multiple choice self-report questionnaire widely used to measure the severity of depression. These questionnaires may be insufficient when diagnosing patients but are necessary for the assessment of their experiences (Demetriou, et al. 2015). Furthermore, retrospective questionnaires are used in feedback procedures of psychotherapy. Therapists often ask their clients to answer questionnaires in order to monitor the progress of the treatment. However, this method lacks information about the experiences in everyday life since the feedback forms are completed only before or after the therapy session (Schiepek, et al. 2016).

2.1.2 Diary

Self-report diary is a tool that contains intensive and repeated reports of person's thoughts, feelings, moods, pains or experiences near the time they occur. Diary methods increase the ecological validity of data as they capture the experiences of participants on a daily basis (Iida, et al. 2012). Unlike retrospective reports, diaries or frequent assessments are useful in examining psychological processes that are susceptible to rapid fluctuations (Schiepek, et al. 2016). This allows experts to observe how much the experiences of an individual vary over time and identify the events that might cause the changes (Iida, et al. 2012). Since a diary report is close to the time when the experience occurs, it reduces memory recall and retrospective biases, thus producing more reliable and accurate data (Stone, et al. 2003).

Traditional diary methods often involve pencil-and-paper system in which participants are provided with booklets of questionnaires, one for each diary

entry. The questionnaires in diaries are similar to typical survey questionnaires but they are shorter to reduce participant burden. Despite the advantages, diary methods also have drawbacks. Participants have to remember and complete diary entries in a timely manner. If participants fail to fill out a diary entry and complete it at a later date, the efficacy of diary methods will be undermined (Stone, et al. 2003). This makes the pencil-and-paper diary system more problematic as the examiners cannot track the compliance of the participants (Iida, et al. 2012). In this case, there is no guarantee that the participants are actually completing a diary entry each day. On the other hand, electronic diaries automatically record the date and time of each entry which allows researchers to determine if the entries were made on time or not. In addition, an electronic diary may have an alarm to remind the participants to respond to their diary entries. To record the compliance with pencil-and-paper diary methods, patients were given a diary embedded with sensors to keep track of date and time of the entries. The study by Stone, et al. (2003) found that most of the entries were fake or completed at later dates. The actual compliance rate in paper diaries was only 11% whereas electronic diaries produced a remarkably high compliance rate of 94%. According to the authors, the electronic diaries' features such as alarms may have an effect in the participants that urge them to comply with the daily protocol of self-report.

2.2 Ambulatory Assessment

Ambulatory assessment (AA) is a vital research tool used to investigate psychological, emotional, behavioral, and biological processes of individuals in their daily life. It encompasses various methods that aid in studying people in their natural environment, including momentary self-report, observational, and physiological (Trull & Ebner-Priemer 2014). Its goal is to minimize retrospective biases while gathering ecologically valid data from patients' everyday life in real time or near real time. The major characteristics of AA include investigation of mechanisms and dynamics of symptoms, prediction of future recurrence or onset of symptoms, monitoring of treatment effects and prediction of its success, and prevention of relapse (Trull & Ebner-Priemer 2013).

Through the advancement of technology, smartphone-based monitoring of objective and subjective data in mood disorders has become a rapidly growing approach and research field (Dogan, et al. 2017). This has paved the way for methods like ambulatory assessment and experience sampling method to collect real-time user data more efficiently

and accurately. This breakthrough has improved ecological validity of laboratory results through combined lab-field studies, and investigating gene-environment interactions (Trull & Ebner-Priemer 2013). Although promising, a much larger evidence-base study is necessary to fully assess the potential, as well as the risks, of such approaches. A discussion of acceptability, compliance, privacy, and ethical issues is yet to be concluded (Dogan, et al. 2017).

2.2.1 Experience Sampling Methodology

ESM is generally regarded as the "gold standard" for studies of emotions to acquire unambiguous information about participants' momentary feelings *in vivo et in situ*. One of the ways by which data collection is accomplished is through the use of smartphone applications or applications specifically designed to accommodate the experience sampling methodology.

As a research methodology, ESM has become widely recognized in a variety of fields in and out of psychology as an important tool in collecting data about different aspects of people's everyday experiences. Its potential has particularly been capitalized through the development of ESM applications that enable ease of data collection. For instance, research on the use of ESM apps in the field of mental health is proliferating (Verhagen, et al. 2016, Wichers, et al. 2011). ESM apps have been increasingly used for delivering psychological interventions, as well as monitoring symptoms of people with physical illnesses. ESM apps have also been used in investigating topics related to education (e.g., academic performance, student motivation), industrial/organizational psychology (e.g., employee performance, engagement, and well-being and workplace behavior), tourism (e.g., tourist experience), and communication studies (e.g., mass media and social media use) and many others.

As of late, available ESM apps for research are foreign-made and a one-year subscription costs an average of $1,500. While participants of ESM studies may download the apps for free, researchers must purchase a subscription package to avail the services of the app and web-based program. As such, the development of a locally designed ESM app may strongly encourage other Filipino researchers to pursue ESM-oriented studies and pave the way for new avenues to explore in research in the Philippines.

2.2.2 Mental Health Applications

Over the recent years, several mental health applications (mHealth apps) have been made

available to smartphone users. While definite evidence for successful outcomes cannot be assured, mHealth apps offer a big potential in the future of mental health care. The review and evidence-based recommendations for future developments made by Bakker et al. (2016) state the lacking features of these apps that would greatly improve their functionality or include features that are not optimized. Furthermore, mHealth apps developers rarely conduct or publish trial-based experimental validation of their apps. Indeed, a previous systematic review revealed a complete lack of trial-based evidence for many of the hundreds of mHealth apps available.

Another review concerning mHealth apps in psychotherapy context by Lui, et al. (2017) stated that mobile apps, especially in this generation, are of particular interest as they can be a platform for dissemination of interventions. These apps are also valuable when applied and used in a clinical context as they "can aid symptom assessment, provide psychoeducation, track treatment progress, provide real-time intervention and communication, and can take advantage of game technologies, global positioning system (GPS), and connectivity to external devices such as biofeedback sensors" (Lui, et al. 2017, Luxton, et al. 2015). Using these features may lead to better clinical outcomes as these promote user engagement, interaction, and motivation. Given that global mobile phone penetration reached 91% at the end of 2012 with 4.3 billion unique mobile subscribers identified, mobile health apps supported by mobile devices can thus be delivered to a large number of people worldwide. A study by Donker, et al. (2013) revealed that nearly 70% of patients expressed interest in using mobile health apps to self-monitor and self-manage their mental health. They claim that early evidence suggests that patients open up more while using an app compared to face-to-face therapy. Another study by Chandrashekar (2018) tried to investigate the effectiveness of these mHealth apps, which use cognitive behavioral therapy (CBT), mindfulness training, mood monitoring, and cognitive skills training to treat depressive symptoms. The author reported that using apps to alleviate symptoms and self-manage depression significantly reduced patients' depressive symptoms compared to control conditions ($p < 0.001$).

3 ESM-BASED PIPELINE

Self-report methods such as the use of retrospective questionnaires and daily diaries have limitations when assessing one's mental health. This study aims

to overcome these shortcomings of current assessment methods in clinical trials.

- **Manual Data Collection** - Paper-based surveys remain convenient for researchers as they are not required to be familiar with software programs to generate their questionnaires. However, data collection using paper forms can be time consuming and susceptible to data entry errors.

  Solution - Users can easily create surveys using the web app that allows easy access to data as soon as responses are submitted. monitor the results. They can view summary responses for each question as well as individual answers. The application also includes a dashboard that allows them to view trend in number of responses for each day.

- **Memory Biases** - In clinical trials, practitioners often ask their patients to report about their past experiences. However, retrospective recall is found to be unreliable as it introduces memory biases (Stone, et al., 2003). Interviews and retrospective questionnaires focus entirely on outcome measures that can be ineffective when monitoring psychological processes such as moods which are prone to sudden changes. Experts began to use diary methods such as ESM that involves repeated assessments over a period of time.

  Solution - Users can repeatedly prompt participants to complete self-report questionnaires in their smartphones. While this method may involve anonymous respondents, users can also create client accounts so they can view the names of the participants when monitoring the survey results. The web app is shall aid practitioners to conduct ESM and improve treatment processes where patients can learn to manage their mental states and behaviors.

- **Burden to Participants** - Despite the challenges, ESM has its drawbacks. The investment of time and effort required in repeated assessments can lower the participant compliance. In addition, implementing ESM where participants are frequently prompted to answer questions could interrupt their ongoing activities resulting in noncompliance with the assessment.

  Solution - Therapists can specify a time frame and the number of times in which a module is available to the participants' smartphone. This

allows control on the timing elements of their questionnaires.

The proposed ESM-based pipeline for ambulatory assessment is composed of a web application for therapists and a mobile application for patients. The therapist creates ESM-based assessments to their patients using the web application that communicates with the mobile application through an application programming interface (API). The same system is also designed to be used by psychologists to send ESM-based surveys to their intended participants and perform statistical analysis from the respondents' data.

3.1 Web Application

The ESM web application aims to support the needs of psychologists and psychiatrists as they build their own questionnaires. It allows creating, deleting, editing, and viewing of questionnaires and participants. It also interprets data collected into visual representations. Figure 1 shows the use cases of the web application for therapy use and psychological surveys for intended participants.

The user interface of the web app consists of the following:

- **Log-in Page** - where the user enters their credentials to gain access to the website. First-time users also have an option to sign-up.

- **Dashboard** - shows visual summaries of the user's surveys (Figure 2).

- **Surveys Module** - the main content of the application. It has two modes: view and create. View mode displays a survey's data while create mode allows the user to customize their own survey. The app allows several input response-types such as checkbox, date and time, number wheel, numerical, option, photo upload, rating, slider, text, and website link.

- **Clients Module** - allows the user to manage the list of clients. The user can add, delete, and view a client's data.

3.2 Mobile Application

According to a website called *statcounter*, a web analytics service tracking more than two million sites globally, 81.91% of the Mobile Operating System Market Share in the Philippines from May 2019 to May 2020 are Android. Since the majority of the targeted users are using Android-powered mobile devices, the initial application shall run with the said operating system. Moreover, the app requires

internet, camera, and external storage writing permissions. It has been heavily developed and tested on an Android version 10 smartphone with 6.26-inch touchscreen display, 1080x2340 pixels of resolution, pixel density of 412 pixels per inch (ppi) and an aspect ratio of 19.5:9. The mobile app also uses a local storage implementation to save user questionnaire progress, user preferences, app settings, and other necessary data that may be viewed offline.

Overall, pastel colors were chosen to display the whole UI as we wanted to achieve a calming and soothing effect for our app. According to an article which explains how to effectively use color in treatment facilities, pastel colors are optimal for treatment centers as they are soft and comforting (Hoisington 2017). Thus, we decided to incorporate these colors for our scheme.

Furthermore, the surveys were designed differently from the usual format of web surveys. A study done comparing data from web surveys and chatbots shows that chatbots encourage user engagement and produce higher quality data from the users (Kim, et al. 2019). Thus, we opted to have the surveys in chatbot form so that it will be more interactive for the users and encourage them to answer these surveys and still get quality data, even if it is required of them to answer these for a certain amount of time.

The user interface of the web app consists of the following:

Log-in Page – users are required to enter credentials given to them by the admin. Once successfully logged in, an authentic token shall be returned to the mobile app. This token shall serve as the "key" to access the user-assigned surveys, questionnaires, and account settings.
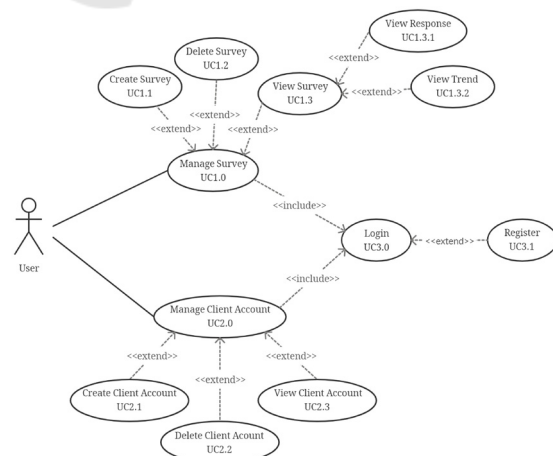

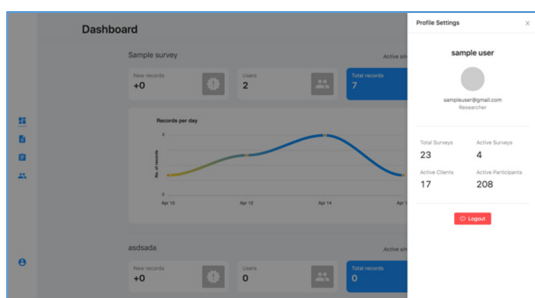Figure 1: Use cases for ESM web app.

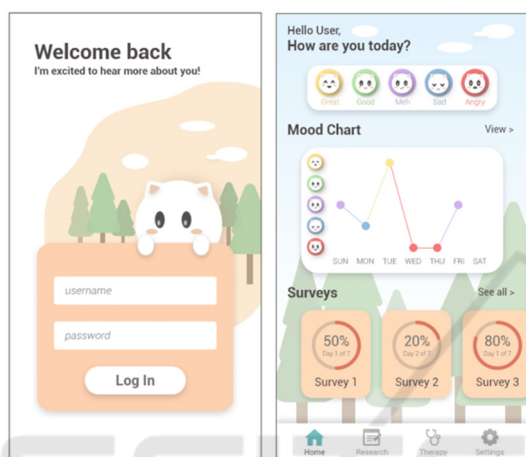Figure 2: User interface of the web app.

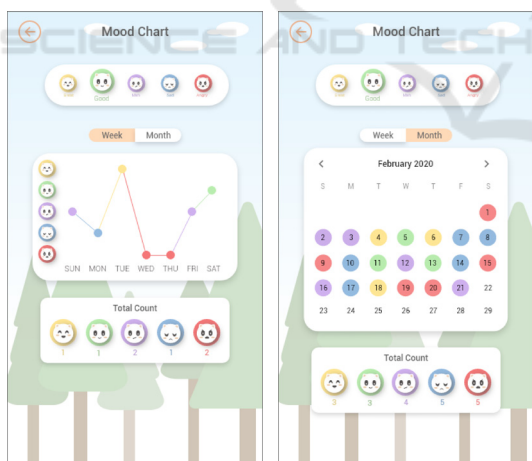Figure 3: Log-in and home screen of mobile app.

Figure 4: Weekly and monthly mood charts.

- **Home** - displayed after successful login. The topmost part of the screen features a daily mood selector which enables the users to input their current feeling for the day (Figure 3). The moods to be chosen from are "great", "good", "meh", "sad", "angry". The mood chart below the selector will automatically update upon selection and will

display the user's mood trend for the week. Users can also view a monthly tally of their mood as shown in Figure 4.

- **Therapy/Research Module** - the main content of the application. The research module contains all the queued surveys that are specific to the user for answering. Each survey has a progress bar showing the user's progress, visually and in percentage. The user will also be able to add surveys they wish to participate in by entering survey codes provided by the facilitators of the research. This is to ensure that the surveys are by invitation-only and that respondents can be easily monitored. The next button then leads to the survey form proper. The survey also has the same input response types from the used in the web app such as checkbox, date and time, number wheel, numerical, option, photo upload, rating, slider, text, and website link. The therapy module has the same features as the research module except that it is only available to users who are registered as presently undergoing treatment or counselling.

3.3 API and Databases

The web application is designed to exchange data with the mobile application through an application programming interface (API) that manages the database stored in the cloud (Figure 5). The database uses a relational structure using MySQL. The API implements token-based authentication with JSON Web Tokens (JWT) to ensure that every request is sent from a verified user. When users log in, the API checks if they are registered to the app. Once the user is authenticated, the API will generate a token and return it to the user. The token contains the user's information (e.g., username), the hashing algorithm used to sign the token, and the signature. Users should include this token in the HTTP authorization header for every request so that the API can verify them.

3.4 Pipeline Demonstration

To demonstrate that the system works, the Dialectical Behavior Therapy (DBT) Module is constructed in the web app. The module aims to help the patients to monitor their behaviors and eventually learn to manage them. The DBT Card from Valley Health shown in Figure 6 is commonly used by therapists for assessment of their patients in a weekly basis. An interactive ESM version of this was created as shown in Figure 7. This is then communicated to the patient's mobile app via an API and is displayed as a Therapy module (Figure 8). The patient's records are easily accessed and displayed in a table (Figure 9).
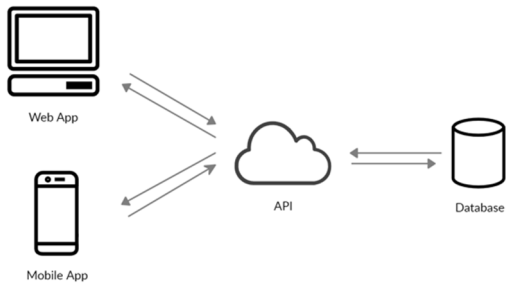
Figure 5: Structure of the ESM-based pipeline.

Figure 6: DBT Diary Card [valley-health.org].

Figure 7: DBT Module using the web app.

4 CONCLUSION

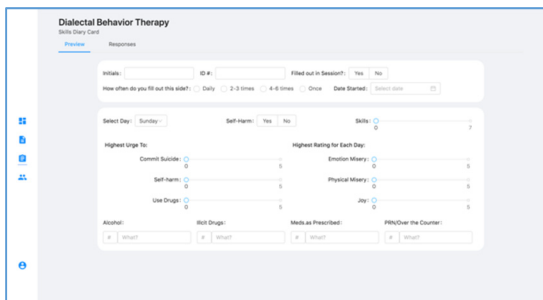Over time, the use of smartphones has been a constant and a necessity to most people especially to college

students. But with the rise of technology also came the escalation of mental health disorders. As such, therapeutic and research activities conducted online through mobile applications have also been an option to catch up with the increasing mental health demands. Such use of technology may prove to be beneficial to individuals who seek professional help, as well as to the researchers who aim to study these mental health concerns using more reliable data offered by ESM.

This paper aims to piece together an effective tool to bridge these concerns at least in a local context. An integrated web and mobile applications using an ESM pipeline is developed and is planned to be proposed to PsycServ to cater to increasing student demand at the University of the Philippines. The same system will be deployed to the university's Department of Psychology and is hoped to be used for ESM-based studies of mental health and well-being of students and other intended participants. This will pave wave to generation of data that will be used for researches and studies that could accelerate analysis and diagnosis of mental disorders. Moreover, the availability of user data, albeit anonymized, can be studied using machine-learning methods and from which artificial intelligence capabilities of the mobile app may be developed.
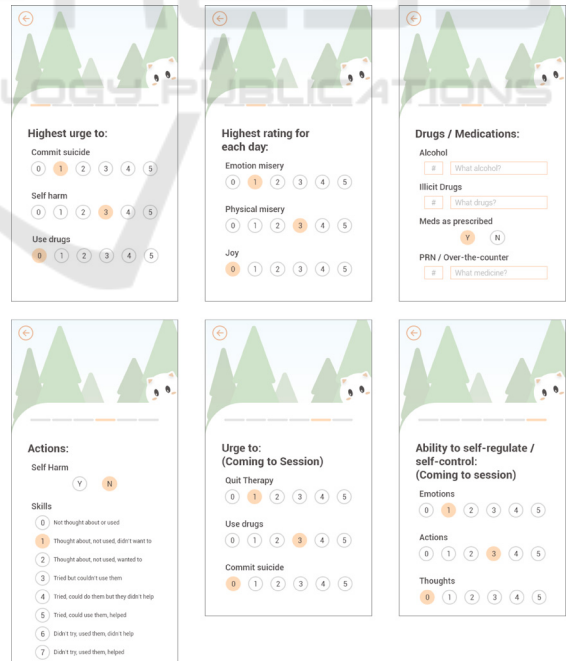

Figure 8: DBT Module screens using the mobile app.

Figure 9: DBT patient response page via the web app.

ACKNOWLEDGEMENTS

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