

Mobile Apps and Hardware Technology for Mental Health: A Product and Evaluation Analysis Research Paper

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ABSTRACT: The field of mHealth, or mobile health, has grown immensely due to advancements in technology and, with it, has brought several mobile applications to the market to address mental health needs. Individualized applications and technologies have revolutionized the health industry and have given users the capacity to monitor their mental well-being in many ways. Previously, we had only seen technological advances that cater to physical healthcare. However, as people have become aware of mental health, we have seen new mHealth apps to help individuals cope with stress, anxiety, and depression. These apps have gained immense popularity among users since they offer at-home in-terventions such as meditation, breathing exercises, and journaling. Some experts contend that such apps are unsuitable for clinical usage as they are rarely supported by robust scientific evidence.

Additionally, the comprehensive evaluation of the effectiveness of these applications has been over-looked. We explore the landscape of mHealth applications, consolidate the evaluation criteria for their assessment, and introduce a new wearable mental health technology: MentaId. In this review, we find that a distinct set of criteria has been used by existing literature. We consolidate these criteria into an encompassing mHealth assessment framework for developing technological advancements in Mental Health.

KEYWORDS: Systems Software; Mobile Apps; Mental Health; Mobile Health; Behavioral Technology.

■ Introduction

The increase in mHealth technology holds a promising future for accessible and engaging health care. The large-scale market for mHealth technology has been created due to the considerable rise in mobile phone use. mHealth, often known as mobile health, is a phrase that refers to the use of mobile devices to support the practice of medicine and public health. The recent increase in mHealth technology has specifically been geared toward mental health and wellness support. Most used are mobile apps for mental health aid and exercises.

Over 20,000 mental health applications exist, and this number continues to increase daily. While dis-tinct mental health apps recurrently gain popularity, this does not precisely indicate their utility regard-ing their clinical benefit. Recent literature has begun to emphasize the comprehensive evaluation of mental health applications to assess their impact on aiding mental health issues such as anxiety and depression. While there is no existing standard for evaluating mental health applications, we review the current literature on the topic and the proposed techniques for large-scale evaluation of mental health applications. We compare the criteria these research papers suggest for the clinical evaluation of mHealth apps. We consolidate these distinct criteria and unify them into one framework of the most critical aspects for mHealth app evaluation.

While the criteria proposed for mental health evaluation varies in the literature, some quantitative evaluation of an app's effectiveness is critical for large-scale mHealth application analyses. Further-more, this motivates the utility of an all-encompassing wearable health tracking device to provide concrete and quantitative evaluation of an individual's mental health and

provide a genuinely effective framework for effective mHealth clinical intervention. The literature review presented in this paper is crucial to further the field of mHealth app evaluation and work toward developing a clinical standard for these analyses. By exploring the similarities and differences in the literature, we can consolidate evaluation techniques to unify application review and assessment.

Hundreds of thousands of individuals have downloaded apps like Calm, Headspace, and Reflectly.³⁻⁵ Through these apps, users can engage in breathing exercises, meditation, and journal writing. Garnering high ratings and strong reviews, these apps have gained much popularity and have been recommended for teenagers who undergo stress from school.¹⁴ However, there have been remarks regarding these apps' credibility and effectiveness. Some audiences argue that while the apps are great for the average person, they are not practical for clinical use. Many apps fail to target a specific mental illness and provide broad and general intervention practices.

Apps like Fitbit, Apple Health, and Oura are used daily to help individuals measure their steps, calories, heart rate, and overall physical health. These apps have revolutionized the mHealth industry by allowing users to keep track of their health-related statistics from the comfort of their homes. As more individuals recognize the importance of mental health, we've witnessed an increase in apps catering to this field. mHealth technology has been proven to have many benefits. Especially in the mental health field, these apps allow individuals to seek care without the overwhelming stigma preventing them from doing so. Furthermore, many mental health apps are free or sometimes charge a very low cost. This is beneficial

as it ensures that regardless of one's economic status, one can seek some level of care for their mental health.

One critical barrier to the progress of the mHealth application field is the lack of a standardized evaluation system. By creating a standardized system for assessing the effectiveness of mental health-focused applications, they can more reliably integrate into the healthcare system and serve as a dependable and verifiable means of clinical aid to thousands of individuals.

■ Literature Review

Mental health apps are especially attractive to teenagers. Many adolescents have difficulty maintaining good mental health due to external stresses like school, family life, economic struggles, and, most relevant, COVID-19. Applications like Calm and Headspace advertise their capacity to grant teenagers a way to clear their minds by giving them a few minutes to recenter and engage in meditative exercises. Since teenagers tend to be on their phones more often than others, these apps are always within reach and helpful tools to use no matter where one is. While much of the new mHealth technology has been praised for its useful tools and accessibility, some experts argue that they are unsuitable for clinical use. Because these apps offer broad and generalized interventions, doctors rarely recommend them to patients with specific mental illnesses.

We will explore five main articles, each of which extensively explores the mHealth application domain for the creation of evaluation criteria. The first of these is the One Mind Psyberguide system. The second is the evaluation proposed by Olff in exploring the mobile mental health challenge.⁶ The third is the exploration of a rating and clinical recommendation system for mental health applications proposed by Torous *et al.*^{7,8} The fourth is the app evaluation framework of the American Psychiatric Association, reviewed by Lagan *et al.*⁹ The fifth is an exploration into the analysis of the integration of mHealth applications into clinical care, carried out by Price *et al.*¹⁰

Mobile Mental Health – Olff:

Tolff reviews several applications and tools for the field of trauma and PTSD to devise a standard set of criteria for evaluating their utility. She stresses the integration of evidence-based guidance in revising and recommending mental health interventions. Most notably among the interventions reviewed is Coach, a Cognitive Behavioral Therapy (CBT) based application that serves to walk PTSD-affected individuals through a system of recovery. Principles from the field of psychology and psychotherapy are adapted and integrated into a mobile application framework. Although there is no provable guarantee of the effectiveness of a CBT-based approach, research has shown its positive mental impact on the recovery process. Olff distinguishes four essential categories for the evaluation of mental health intervention tools:

- **Efficacy:** How effective is the application in improving an individual's mental health and well-being?
- **Cost-effectiveness:** Is the device or application reasonably priced for the average individual experiencing mental health troubles?
- **Safety:** Does the application ensure the confidentiality of the individual's information and provide a safe space for self-development?

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- **Post-marketing surveillance:** Is there some form of survey-based follow-up for individuals to indicate the utility and benefit of the app?

In combination with these evaluation criteria, Olff emphasizes the importance of adherence. In-person mental-health intervention includes some degree of therapist guidance.¹⁰ As such, ensuring compliance with a mental health application will best mimic in-person therapy and provide better clinical results. Beyond elaborating on the essential criteria that should be considered when devising or determining the significance and utility of an mHealth application, Olff additionally discusses the advantages of such applications when they meet the aforementioned criteria. Olff highlights the advantages of mHealth applications that satisfy the categories of efficacy, cost-effectiveness, safety, and post-marketing surveillance as achieving:

- **Capacity:** an astounding increase in capacity for everyday consumers and those in need of such help to be serviced in an efficiently scalable manner without needing access directly to a healthcare professional.
- **Availability:** the constant ability for consumers to access mental health help at any time due to its flexible application-based format.
- **Equity:** such mHealth applications capably and reliably provide a similar standard of care for all consumers despite any other factors, given that they have access to some smart device (e.g., smartphone, tablet, etc.).
- **Anonymity:** undeniably, applications that satisfy the criteria above provide the instrumental advantage of complete anonymity and provide a greater sense of security and relief for the consumers.

Furthermore, Olff highlights such advantages as the tailored approach mHealth applications have, their ability or potential to link into clinical healthcare systems, and more. As such, Olff emphasizes the benefits of mHealth applications that arise when they are constructed according to the defined criteria.

Rating and Clinical Recommendation – Torous *et al.*:

This article emphasizes building a consensus for the mental health app evaluation. Unlike the previous approaches, this additionally highlights the significance of data integration such that the progress of individuals can be recorded and easily transferable to existing medical record systems to clinically scale such applications.⁸ In all, Torous highlights the following criteria for evaluating mHealth applications.⁷

- **Data safety and privacy:** ensuring that health care standards for handling patient data are upheld in these applications.
- **App effectiveness:** incorporation of therapeutic principles must be well-defined for each application and undergo clinical trials. Existing therapeutic principles must match the outline of intervention in existing trials.
- **User experience/adherence:** UI and UX must be refined to be most inviting for individuals and improve compliance. Furthermore, the adaptability and flexibility of an app

must be defined and enhanced to best cater to a wide variety of individuals.

- **Data integration:** It must be easy to integrate to progress and outcomes of individuals into EHR systems with uniform data.

After highlighting these essential criteria, Torous *et al.* emphasize the central issue: the need for the creation of standardized criteria or framework for the evaluation of mental health applications as a whole. Even beyond this, he urges large-scale institutions to discuss the matter and unite on a single set of criteria for evaluating mHealth apps. He emphasizes that as time goes on, mHealth applications continue to gain traction and popularity. Additionally, the scale and quantity of mental health applications continuously gain magnitude. As such, performing an individual evaluation of mental health applications will not prove to be scalable in the years to come. Instead, institutions like the American Psychological Association and others should unite to devise a standard evaluation system for mHealth applications to make their analysis seamless, efficient, and more meaningful.

APA Evaluation – Lagan *et al.*:

Lagan thoroughly describes the criteria of the APA app evaluation framework. Like Torous *et al.*, this framework highlights the importance of interoperability (or data integration) to make it such that the progress and results of individuals can easily be communicated with clinical professionals. The evaluation framework described in the paper is created by consolidating over 900 questions from 45 different mental health apps with specific evaluation systems.⁹ Unlike the mentioned articles, this article additionally highlights the importance of verifiable evidence that an app is based on. Although similar to Torous *et al.*'s explanation of an app's effectiveness, Lagan *et al.* necessitate a thorough underpinning of an app's biological or therapeutic foundation for its proposed approach. The evaluation system consists of the following criteria:

- **Risk-privacy and Security:** individual medical information must be preserved at the clinical standard
- **Evidence:** Specific therapeutic underpinning of an application's approach must be sufficiently supplied.
- **Ease of Use:** how simple it is for individuals to utilize all aspects of an application or medical intervention technology.
- **Interoperability:** Exchange progress, data, and information from a mobile health application to medical record systems at large to allow for simple clinical integration.

In Lagan's review of the APA's app evaluation framework utilization and iteration, he noted several essential aspects of the mHealth app evaluation as a whole. Notably, he remarks that evaluation is typically carried out on a level-by-level, starting with assessing more fundamental levels essential to a successful mHealth application and moving onto more precise levels that present greater interoperability and interdisciplinary integration between the technological clinical and social spheres.

mHealth Integration – Price *et al.*:

Price highlights the importance of mHealth applications, their applicability, their benefits, and their manner of utilization.

He emphasizes the impact that mHealth applications can have in this day and age, echoing many of the ideas that other authors have mentioned. Notably, he says that mHealth applications can be utilized as a supplement and follow-up to in-person clinical care and can help provide simple, easy, and effective patient engagement.

Price then goes on to highlight optimal criteria that mHealth should aim to fulfill in its development, including:

- **Technical Knowledge:** developing an effective and encompassing app requires excellent technical knowledge. For this reason, Price emphasizes the significance of this specialized knowledge and the necessity to work collaboratively with a team of technically skilled individuals and those proficient in clinical subject matter knowledge to devise a meaningful and effective product.
- **Usability Testing:** a great application should be simple and easy to use.
- **App Maintenance:** beyond creating the application, it must be monitored and updated accordingly to suffice its members' needs and adapt to continue developing software and technologies.
- **Security Privacy:** ensuring that patient data is kept private and that all interaction with an mHealth application is kept to that individual patient and the healthcare practitioners they desire to share it with in accordance with HIPPA.

Overall, the mentioned evaluation frameworks all highlight the importance of data privacy, user experience, and some form of effectiveness. Some frameworks further highlight the importance of data interoperability to mHealth applications in clinical systems. This motivates the development of a standardized evaluation system that incorporates these three criteria. Additionally, including the criteria of application transparency and data interoperability would encompass all the points of the existing frameworks from the literature.

■ Discussion

One Mind Psyberguide:

The One Mind Psyberguide is an online app reviewing platform that evaluates mental health apps based on several criteria.¹¹ These criteria include credibility, user experience, and transparency, as depicted in Figure 1 below.¹² The One Mind Psyberguide is different from user reviews as it assesses apps based on their scientific foundation. When determining an app's credibility, Psyberguide examines whether the technology is supported by credible research and has been integrated throughout the development process. The user experience of the app is evaluated based on its ease of use and overall enjoyment. The Mobile App Rating Scale (MARS) is used to assess the quality of an app's UX. MARS was developed by a team of researchers at Queensland University of Technology (QUT), with expertise in developing digital health tools. Finally, the creators must be transparent about the data gathered and the research on developing the technology. These Psyberguide reviews help aspiring app developers better understand what makes a good mHealth app. It also allows individuals to browse through a catalog of apps and find one that suits their mental health needs.

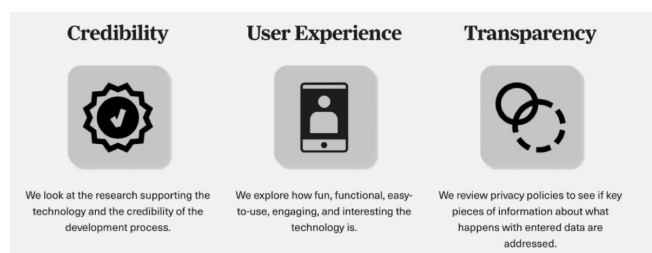


Figure 1: The criteria outlined by One Mind Psyberguide to evaluate the utility and effectiveness of mental health applications.

Alterations to mHealth App Criteria:

The distinct frameworks outlined previously highlight the importance of three overarching criteria: App Effectiveness, Ease of Use, and App Direction. Beyond the described definitions in the frameworks above, "Ease of Use" would also refer to how well the application integrates into a user's daily life. The authors above highlight that many applications are used once but never again. Therefore, an application that is used often by consumers ranks higher as an impactful mHealth application. Finally, the "App Direction" encompasses how the original intent of an application coincides with its actual benefit. If an application was intended to relieve anxiety but helps most with alleviating depression, it does not fulfill its original intent despite its effectiveness. Therefore, considering an application's original values and goal alongside obtaining user feedback on its utility would be conclusive in determining its overall benefit. Analyzing the app's fulfilled purpose, direction, and integratability in a user's life would provide a more accurate measurement of its efficacy. A proposed alteration to the previous frameworks is outlined as follows:

- **Technical Knowledge:** developing an effective and encompassing app requires excellent technical knowledge. For this reason, Price emphasizes the significance of this specialized knowledge and the necessity to work collaboratively with a team of technically skilled individuals and those proficient in clinical subject matter knowledge to devise a meaningful and effective product.

- **Ease of Use/Integratability into daily life** - something that flows well and is usable in an individual's life seamlessly. Measure through: higher frequency usage correlates to good integratability.

- **The focus of the application/marketing of an app:** alignment of an app's actual versus theoretical/marketed fulfillment of needs. User survey responses would be useful to address what it helped them with versus why they downloaded it. Target how/why people download the app, to begin with — selective link.

The Necessity of Wearable Technology:

mHealth is being revolutionized beyond mobile apps. Hardware technology, specifically wearable devices, has made at-home healthcare far more advanced. From heart rate monitoring to ECG maps, some of the most advanced medical technologies can be accessible all the time from the comfort of your home. In the mental health field, wearable technology holds much potential. By measuring biomarkers such as cortisol levels and heart rate variability, new technologies can

provide users with statistical evidence regarding an underlying mental health issue.

Acknowledgment of Limitations:

Technology's integration into mental health care will only be effective and beneficial if supported with the necessary scientific evidence and foundations. A prevalent issue with increased accessibility is that the range of perspectives in a space increases. Specifically, app programmers and designers can create apps for individuals to use without integrating the necessary scientific evidence and specialization for certain mental health conditions. Currently, the field of mHealth is tailored for the wellness space rather than the clinical mental health space. To make this shift, app developers and neuroscientists must collaborate closely to innovate new devices that bridge the gap between approachable, user-friendly interfaces and effective, scientifically-proven tools for individuals to use.

The Optimal mHealth Device:

Mentaid is a wearable device created in collaboration with the PanLab Center for Precision Mental Health and Wellness at Stanford University.¹³ The wearable device uses sensors to monitor physiological stress markers like cortisol, heart rate variability, and skin conductance. The device serves as an accessible monitoring system for individuals' mental health, much like how we have wellness apps to keep track of our sleep and steps, as depicted in Figure 2 below. Supplementing the hardware component is a mobile app for users to view their real-time data. The user will be notified via the mobile app if the sensor detects an abnormal measurement of one or more markers. Because the wearable alone cannot answer why a patient may be stressed or anxious, individuals will get a brain scan to determine their biotype and receive treatment if necessary, as depicted in Figure 3 below.

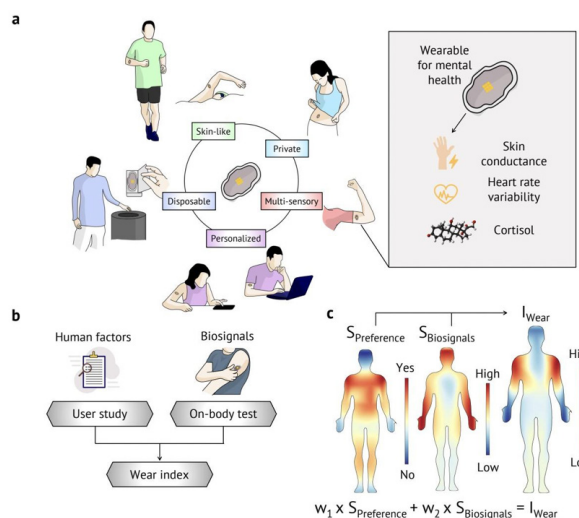


Figure 2: Depiction of the usage and applicability of wearable mental health technology. Sub-figure (a) highlights the simplicity and advantages of such a technology, signifying that it would work through monitoring sweat production and cortisol levels along with skin conductance and heart rate variability. Sub-figure (b) highlights the factors considered when determining the ease of wearability of such a device. Sub-figure (c) depicts the distribution of bio-signals on the body that the device would track and for what purposes to aid mental health advancement on an individual level.

The mobile app needed to serve as more than just a data collection tool. The Mentaïd app is unique as it offers questionnaires for users to engage in. From research about DSM-5 evaluations, various questionnaires were formulated to gauge a better understanding of a user on a psychological level. The app asks users questions about their feelings of stress, worry, and anxiety, as well as their ability to concentrate. Following a similar scoring function to the DSM-5 evaluations, the Mentaïd questionnaires prompt users to answer each question on a scale of 1-5 (1 = disagree, 5 = agree).

Furthermore, the app offers a journal reflection writing feature for users to free-write responses to questions about their mental state. Mentaïd provides a clear junction of hardware and software technologies in the field of mental health. Through its strong scientific foundation and friendly user experience, Mentaïd can be a vital tool for individuals and transform how we view mental health. The integration of hardware technology into the space of mHealth apps can transform the efficacy of such tools. Specifically, by utilizing measurement tools that quantify an individual's mental health, clinicians can compare qualitative and quantitative data points to understand mental health issues and use them to guide their diagnosis.

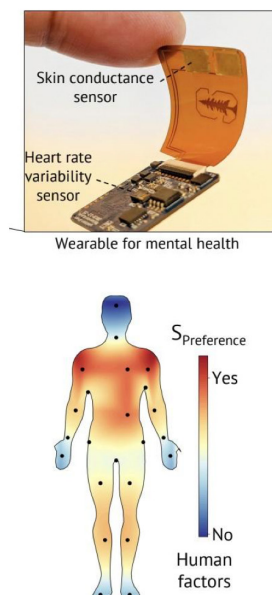


Figure 3: Shape, design, and usability of wearable technology. The sensor would be as small as one's finger-tip, would not be noticeable, and could be efficiently utilized to track various human factors to ascertain overall health. Such information can be directly applied to determine individuals' mental health and improvements.

■ Conclusion

Mental health care has been hindered due to its immense stigma and inaccessibility. Individuals often feel ashamed to receive the care they need, worsening their condition. Additionally, the already exist-ing support for mental health can be expensive and out of reach for many people. The cost of brain scans, psychiatric consultations, and therapy can be too high for many to afford. Technology holds much potential in the field of mental health. Mobile apps have allowed people to seek care and sup-port comfortably. However, to be eligible for clinical usage, many apps on the market need a sufficient

scientific foundation. We can move one step closer to a standardized evaluation framework for mHealth applications by assessing evaluation techniques across the literature. Thereby, mHealth ap-plications can more effectively make their way into the realm of reliable and supported clinical intervention. Hardware and software technology implementations and their proper evaluation are critical for their large-scale utilization. The proposed Mentaïd wearable and mobile app will transform how we take care of our mental health and serve to offer a mental health app evaluation standard through a more quantitative and systematic framework.

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■ References

1. Auxier, B.; Bucaille, A.; Westcott, K. Mental health goes mobile: The Mental Health App Mar-ket will keep on growing. <https://www2.deloitte.com/us/en/insights/industry/technology/technology-media-and-telecom-predictions/2022/mental-health-app-market.html> (accessed Jun 6, 2022).
2. Chandrashekar, P. Do Mental Health Mobile Apps Work: Evidence and Recommendations for Designing High-Efficacy Mental Health Mobile Apps. *mHealth* **2018**, 4, 6–6.
3. Calm – sleep, meditation and relaxation.
4. Headspace: Meditation and sleep made simple.
5. Reflectly – the world's first intelligent journal.
6. Olff, M. Mobile Mental Health: A Challenging Research Agenda. *European Journal of Psy-cho-traumatology* **2015**, 6 (1), 27882.
7. Torous, J.; Andersson, G.; Bertagnoli, A.; Christensen, H.; Cuijpers, P.; Firth, J.; Haim, A.; Hsin, H.; Hollis, C.; Lewis, S.; Mohr, D. C.; Pratap, A.; Roux, S.; Sherrill, J.; Areal, P. A. To-wards a Consensus around Standards for Smartphone Apps and Digital Mental Health. *World Psychiatry* **2019**, 18 (1), 97–98.
8. Torous, J.; Firth, J.; Huckvale, K.; Larsen, M. E.; Cosco, T. D.; Carney, R.; Chan, S.; Pratap, A.; Yellowlees, P.; Wykes, T.; Keshavan, M.; Christensen, H. The Emerging Imperative for a Consensus Approach toward the Rating and Clinical Recommendation of Mental Health Apps. *Journal of Nervous & Mental Disease* **2018**, 206 (8), 662–666.
9. Lagan, S.; Emerson, M. R.; King, D.; Matwin, S.; Chan, S. R.; Proctor, S.; Tartaglia, J.; Fortu-na, K. L.; Aquino, P.; Walker, R.; Dirst, M.; Benson, N.; Myrick, K. J.; Tatro, N.; Gratzner, D.; Torous, J. Mental Health App Evaluation: Updating the American Psychiatric Association's Framework through a Stakeholder-Engaged Workshop. *Psychiatric Services* **2021**, 72 (9), 1095–1098.
10. Price, M.; Yuen, E. K.; Goetter, E. M.; Herbert, J. D.; Forman, E. M.; Acierno, R.; Ruggiero, K. J. MHealth: A Mechanism to Deliver More Accessible, More Effective Mental Health Care. *Clinical Psychology & Psychotherapy* **2013**, 21 (5), 427–436.
11. The Mental Health App Guide designed with you in mind. <https://onemindpsyberguide.org/> (accessed Jun 6, 2022).
12. Neary, M.; Bunyi, J.; Palomares, K.; Mohr, D. C.; Powell, A.; Ru-zek, J.; Williams, L. M.; Wykes, T.; Schueller, S. M. A Process for Reviewing Mental Health Apps: Using the One Mind Psyberguide Credibility Rating System. *Digital Health* **2021**, 7, 205520762110536.
13. Williams, L. Precision Psychiatry and Translational Neuroscience Lab (PanLab). <http://williamspanlab.com/> (accessed Jun 6, 2022).
14. Borghouts J, Eikey E, Mark G, De Leon C, Schueller S, Schneider M, Stadnick N, Zheng K, Mukamel D, Sorkin D. Understanding

Mental Health App Use Among Community College Students:
Web-Based Survey Study. J Med Internet Res 2021.

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