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MoodMon – the first Polish application using AI in bipolar disorder and recurrent depressive disorders. Patients' preliminary assessment

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Summary

Aim. The analysis aims to present the subjective assessment of the MoodMon mobile application by users diagnosed with BD and MDD.

Material and methods. Data were obtained from 95 participants based on a 12-question survey. It was a part of a large clinical study of the MoodMon system.

Results. The reception of the MoodMon application was very similar regardless of the diagnosis. For most respondents, the application was a neutral tool (BD – 50.7%; MDD – 43.5%). Subjective satisfaction with using the application was reported by most users. The application was beneficial for 56.9% of respondents with BD and 78.3% with MDD disorders, primarily due to the ability to use modern technology to control symptoms. Most respondents did not see the need for changes to the application (BD – 70.8%; MDD – 60.9%). However, a small group suggested modifications to the form of voice sampling and the variety of questions. Nearly half of the patients with BD (48.6%) expressed a willingness to use the MoodMon application in the future, and a significantly higher percentage (73.9%) of those with MDD indicated the same.

Conclusions. In the subjective opinion of users, the MoodMon application is perceived as safe, useful and helpful in the treatment of affective disorders.

Key words: affective disorders, mobile application, user satisfaction

Introduction

The huge amounts of data generated by 80% of the general population during everyday use of mobile phones are, according to scientists, still underused for health assessment and scientific research [1-5]. Available data indicate that patients with mental disorders use mobile phones as often as the healthy population [6, 7]. In psychiatry, as in other fields of medicine, there is a race for new technologies (e-health),

and the research data seem encouraging [1-5]. In 2010, the era of research on the development of modern technological solutions in the field of affective disorders began. It is estimated that major depressive disorder (MDD) and bipolar disorder (BD) are disorders that occupy second and third place among mental disorders (after anxiety disorders). Globally, the prevalence of bipolar affective disorder is about 2-3%, and that of depression 6.3-10.3% [6, 8].

It has been proven that appropriate pharmacotherapy and increasing the patient's self-awareness about the disease (in-depth psychoeducation) prevent serious consequences of affective disorders [6, 9-11]. The same methods can simultaneously reduce the significant economic burden on health care systems [12]. It has been shown that in affective disorders, the most serious barriers to seeking help and adherence to treatment are stigma (including self-stigma), fear of being discriminated against, and unavailability of services [13-16]. It is postulated that access to and clinical analysis of large amounts of patient data from mobile devices can be a new opportunity by reducing the above-described individual and systemic problems that people suffering from affective disorders struggle with [5, 6].

The results of previous studies on monitoring the mental state using applications on patients' phones are so encouraging that conclusions have been drawn about the potential high usefulness of data transmitted to the doctor remotely. The psychiatrist will no longer be doomed to standard, infrequent clinical assessments (once every few weeks/months), but hypothetically may have insight into clinically important information from the periods between visits [5]. It is potentially possible to speed up diagnostics and interventions at earlier stages of affective episodes than is currently the case [5, 6, 17-21].

In the available, still sparse studies, data from applications from patients with affective disorders were divided into: (1) objective data transmitted automatically (without active patient participation), (2) subjective data – actively transmitted assessments of well-being, and (3) objective data transmitted actively by patients – the most important physical parameters of the voice, transmitted in the form of answers to questions or during conversations (there are restrictions regarding sensitive data and private content) [5, 17, 22]. The introduction of automatic data collection (background) seems to be beneficial for some patients who are reluctant to fill in electronic self-monitoring diaries and want to use monitoring applications. In addition, physicians would receive accurate and objective data in real time on patients' affective states based on collected voice characteristics. The ability to monitor symptoms in long-term outpatient settings may result in individual therapeutic interventions between outpatient visits [17, 22]. Literature reviews show that in this young field, different systems are being tested in terms of their feasibility and user compliance. At the same time, the relationship between the obtained monitored data and the mental state as well as the influence of information about the patient's condition collected via a smartphone on the clinical assessment made by a professional psychiatrist was analyzed [5].

The last few years have been a period of very intensive research on artificial intelligence (AI) worldwide. It can be used to analyze huge amounts of diverse data, which is why new practical applications are being sought. At the same time, multi-specialist teams around the world are creating a legal and ethical framework for AI [23].

In Europe, after a long stage of consultations and negotiations, an official final document was created with recommendations for the safe use of artificial intelligence. The European Commission believes that artificial intelligence is a very important element of the economy, because solutions based on AI enable better forecasting, optimization of operations and resource allocation, and personalization of services provided, which translates into results beneficial from the point of view of, among others, social security goals [24].

The use of artificial intelligence algorithms to predict changes in affective states (at the prodrome stage, currently elusive in a standard psychiatric examination or interview with a patient or relatives) is the main goal of the systems under testing. A very important supporting role is assigned to objective biomarkers, and among them the most promising are physical voice parameters [5, 6, 17, 22].

The Polish contribution to the development of modern technologies is the MoodMon system, created by a multi-specialist team of experts in artificial intelligence applications and experienced psychiatrists. The MoodMon system (consisting of a phone application of the same name, a wristband monitoring sleep and physical activity, and anonymized patient voice samples sent to servers) was tested, trained, and developed in the course of machine learning as part of a clinical trial (944 days in 2021-2023). Based on data from the application and clinical assessments by psychiatrists, artificial intelligence algorithms made decisions about sending an alarm in the event of a change in mental state. The system was continuously trained based on individual patient data and the entire study population. A detailed description of the methodology and course of the study goes beyond the scope of this publication and can be found in studies describing technical and clinical aspects [29, 30].

The study began with 100 patients: 75 with clinically confirmed bipolar disorder and 25 with diagnosed recurrent depressive disorder. During the two stages, a great deal of information was collected, and the results obtained thanks to the MoodMon system are very promising. The effectiveness of detecting changes in mental state and sending alerts to the psychiatrist by artificial intelligence algorithms turned out to be very high in the second phase of the study. This is evidenced by the results in the population of patients with bipolar disorder and recurrent depressive disorder. The effectiveness of the system (sensitivity – TPR, specificity – TNR) was high, the key to the assessment was the physical parameters of the voice (for both diagnosis together: TPR = 89.5%, TNR = 98.8%; for BD: TPR = 89.6%, TNR = 98.9%; for MDD: TPR = 89.1%, TNR = 98.5%). The artificial intelligence also trained an effective way of distinguishing disease phases in both disorders [3, 28]. To our knowledge, this is the first study in the world using artificial intelligence algorithms conducted over 12 months and simultaneously in two groups of patients with affective disorders (bipolar disorder, recurrent depressive disorder).

Aim

Most previous studies describing the technical aspects of applications for monitoring the mental state of patients with affective disorders emphasize the urgent need

to analyze the subjective assessments of patients as users [5, 22, 23]. The perspective of individuals with mental disorders who choose to use mobile applications as part of scientific research is crucial for the further development of these technologies.

The aim of the presented work, as part of an extensive clinical study of the MoodMon application, is to analyze the subjective reception of the application by a clinical population – patients with bipolar disorder and recurrent depressive disorder.

Materials

Data for the present analysis were provided by 95 patients of the multicenter clinical trial of the MoodMon system described above. The Bioethics Committee at the District Medical Chamber granted consent to conduct the study (consent KB 170/2021). The subjects were diagnosed and treated pharmacologically in accordance with Polish standards for recurrent depressive disorder and bipolar disorder.

After patients met the inclusion criteria for the study, psychiatrists assessed their current mental state to determine whether it allowed them to use the application. In-person psychiatric consultations, conducted according to the protocol, took place every 3 months. The monitoring of the mental state was supplemented by short telephone surveys conducted by a psychiatrist every 2 weeks. If the result of the survey indicated changes in the mental state, the clinician decided on the need for a full psychiatric examination, using additional diagnostic questionnaires assessing mental state. These included the 17-item versions of the HDRS (Hamilton Depression Rating Scale) and YMRS (Young Mania Rating Scale), as well as the CGI (Clinical Global Impression) scale.

Due to the naturalistic nature of the study, the mental state of individual patients varied at the beginning of the study. The diagnoses of the 100 patients who started the study (established after psychiatric assessment/confirmed by psychiatrists) were: depression (23), hypomania (11), euthymia (34), mixed state (5), and subdepression (27). On the day of completing the survey, psychiatrists diagnosed, among the 95 patients in the population, depression (11), hypomania (11), euthymia (50), and subdepression (23). During the study, the system detected 1,394 changes in patients' mental state based on various CGIs across two consecutive observations. Clinical assessments by psychiatrists were made for 1,344 of these changes.

Methods

At the end of using the MoodMon system, the study participants answered questions assessing their experience from a subjective point of view. The survey, consisting of 12 closed- and open-ended questions, was completed during the visit concluding the patient's individual participation in the study. The doctor read the questions aloud, and the patients provided their answers freely, with the option to decline to answer any question.

To analyze the data from the final survey, a correlation analysis was conducted, where the independent variable was the patient's diagnosed condition (bipolar disorder

or recurrent depressive disorder), and the dependent variables were the answers to individual questions on the questionnaire.

The frequency distributions of responses to each question were calculated based on the diagnosed condition (independent variable). The Pearson *r* correlation coefficient was calculated to test the statistical significance of these relationships. Additionally, the dependent variables, in the form of responses to questions expressed on a linear scale (from 1 to 5), were analyzed by comparing the arithmetic means between the two subgroups (patients with bipolar disorder and patients with recurrent depressive disorder). The calculations were performed using MS Excel software.

Results

Most of the open- and closed-ended questions were answered by 95 respondents, with some questions answered by a slightly smaller group. The analysis indicated that the differences in responses between patients diagnosed with bipolar disorder and those with recurrent depressive disorder were not statistically significant, as demonstrated by the graphical representations. The results obtained in the study are presented in the form of tables and graphs. Table 1 presents the demographic structure of the survey participants in the MoodMon study.

Table 1. **Participant demographics**

Category		Frequency (N = 95)	Percent
Gender	Female	57	60%
	Male	38	40%
Age	18 – 24	12	13%
	25 – 34	24	25%
	35 – 44	23	24%
	45 – 54	21	22%
	55 – 64	15	16%
Marital status	Single	46	48%
	Married	36	38%
	Divorced	11	12%
	Widowed	2	2%
Education	Elementary	0	0%
	Vocational	1	1%
	Secondary	28	29%

table continued on the next page

	Higher	66	69%
Professional activity	Student or pupil	11	12%
	Employed	65	68%
	Pensioner/Retired	10	11%
	Other	7	7%
	Unemployed	2	2%
Place of residence	Village	10	11%
	City (5k-200k inhabitants)	19	20%
	City (>200k inhabitants)	66	69%
Type of residence	Alone	23	24%
	With family	59	62%
	With partner	13	14%
Diagnosed disease	Bipolar affective disorder	72	76%
	Unipolar affective disorder	23	24%

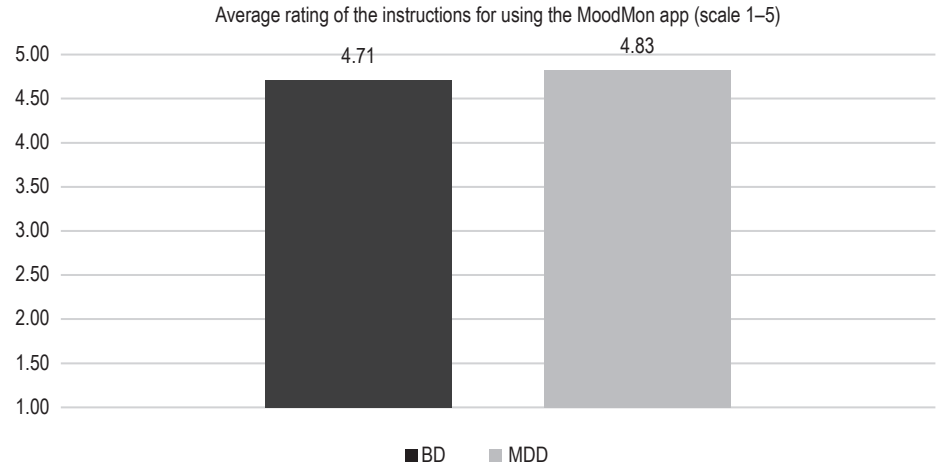

Figure 1. **Average rating by patients with affective disorders of the clarity of the MoodMon app usage instructions (r = 0.075, not significant)**

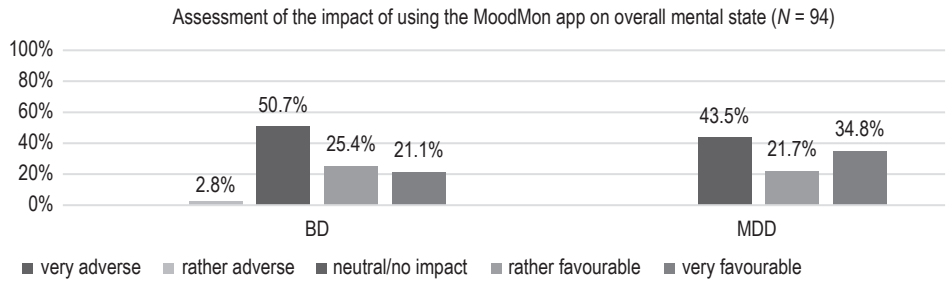

Figure 2. **MoodMon: no differences in the impact of using the application on the overall mental state of patients with BD vs. MDD (r = 0.133, not significant)**

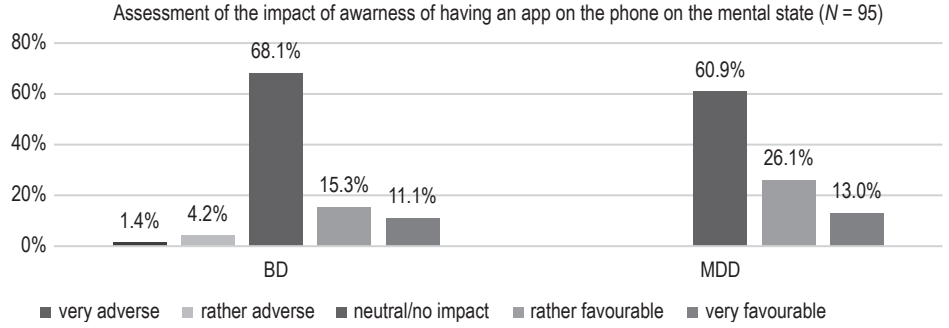

Figure 3. **MoodMon: no differences in the impact of awareness of having an application on the phone on the overall mental state of patients with BD vs. MDD (r = 0.121, not significant)**

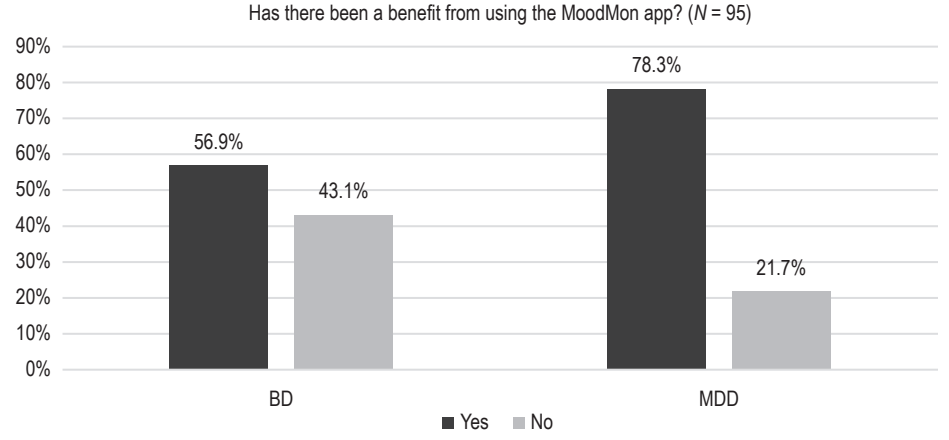

Figure 4. **MoodMon: no differences in the assessment of benefits from using the application between patients with BD and MDD (r = – 0.188, not significant)**

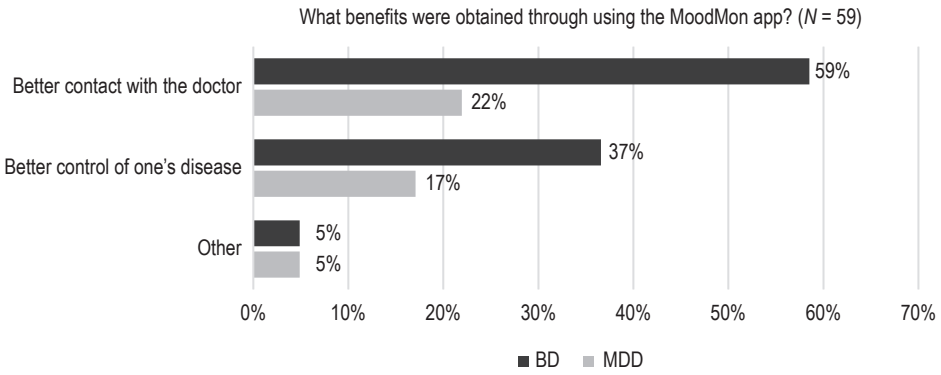

Figure 5. **Descriptive evaluation of the types of benefits from using the MoodMon app in patients with affective disorders**

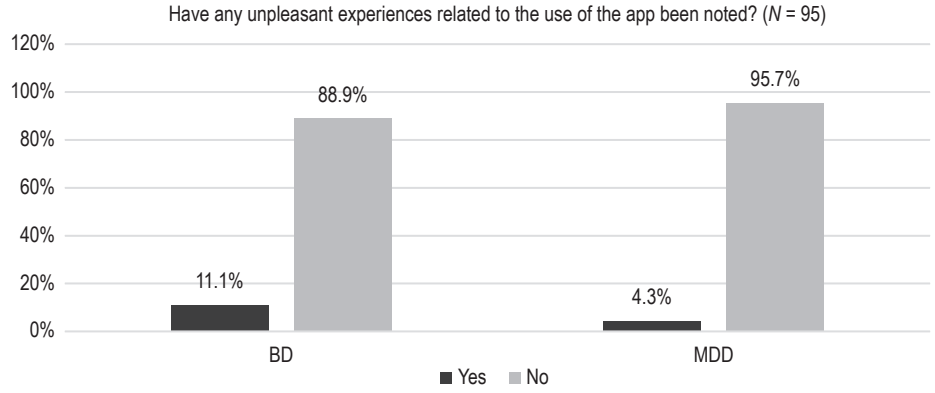

Figure 6. **MoodMon: no differences in the experience of unpleasantness related to using the application in patients with BD vs. MDD (r = – 0.188, not significant)**

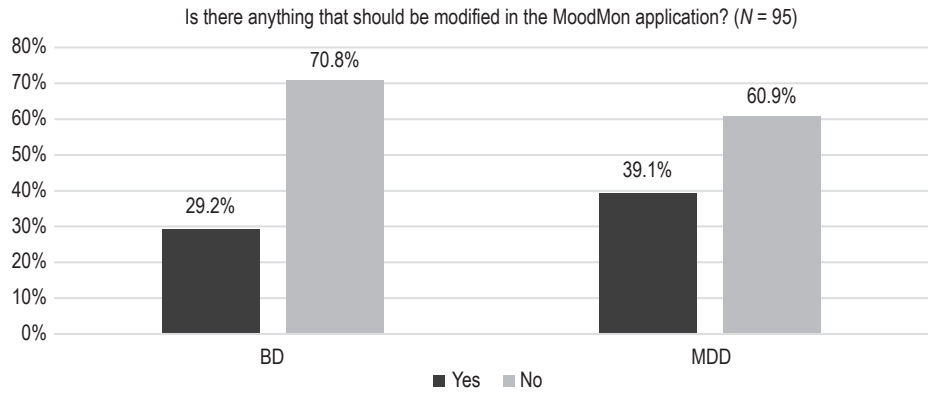

Figure 7. **MoodMon: no differences in the assessment of the need to introduce modifications to the application between patients with BD vs. MDD (r = 0.092, not significant)**

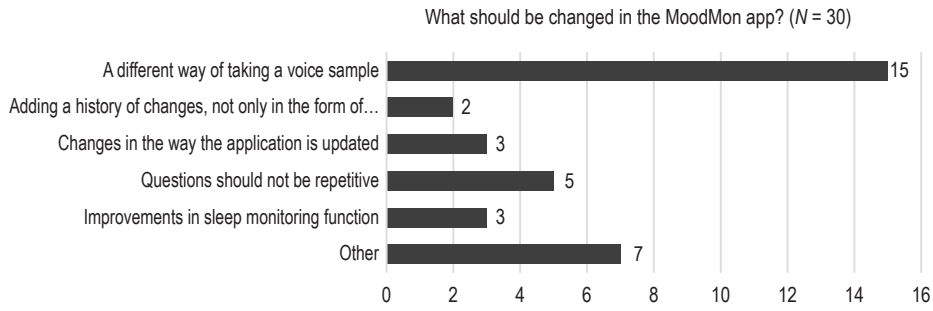

Figure 8. **Users' descriptive suggestions (*N* = 30, both diagnoses combined) for modifications to the MoodMon application (graph showing responses from both groups together – too few open-ended responses to separate into response categories)**

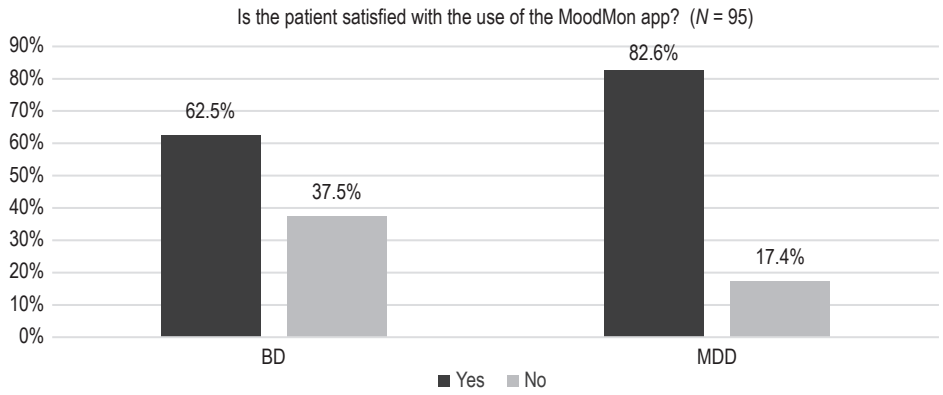

Figure 9. **MoodMon: no differences in patients' assessment of satisfaction with using the application (BD vs. MDD, r = – 0.184, not significant)**

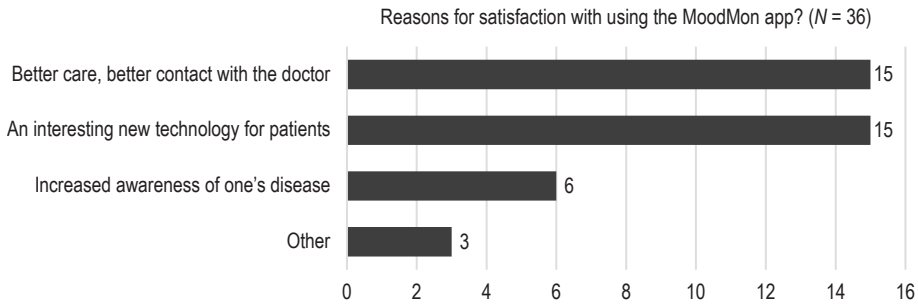

Figure 10. **Users' descriptive justifications (*N* = 36, both diagnoses combined) for satisfaction with using the MoodMon application (graph showing responses from both groups together – too few open-ended responses to separate into response categories)**

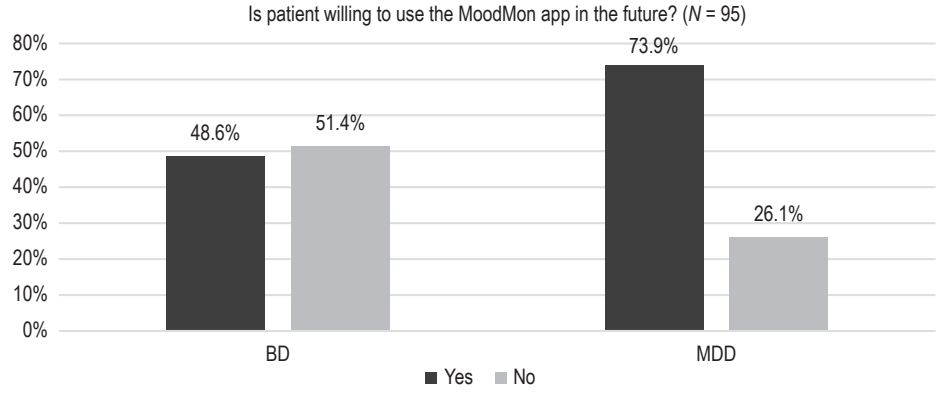

Figure 11. **MoodMon: no differences in patients' assessment of willingness to use the application in the future (BD vs. MDD, r = – 0.218, not significant)**

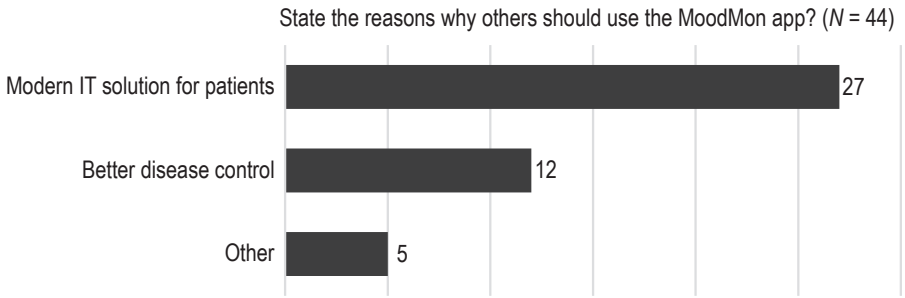

Figure 12. **Descriptive evaluation of the potential usefulness of the MoodMon app for new users with affective disorders**

Discussion

There are no data for direct comparison in the available articles [5, 17, 22, 25-28]. However, willingness to use affective disorder management apps and support systems has already been examined in one study. This was a two-stage survey in which patients were asked about their "theoretical/potential" willingness to use the application. It was shown that the respondents were interested in using such tools, including new and innovative functions, such as partner applications or analysis of facial expressions in video data with daily interaction. A limitation of the cited study is the uncertain diagnosis of 88 patients in the first stage and the small sample size ($N = 15$) in the second stage [29]. Nevertheless, the general attitude of patients with affective disorders towards the use of modern technological solutions for monitoring mental state has already been described quite extensively. During periods of remission, patients with bipolar affective disorder and recurrent depressive disorder usually respond positively to invitations and willingly agree to monitoring using smartphone applications [30-32].

In the MedLink pilot study, the apps were found to be easy to use and effective in improving treatment adherence among patients with depression [33]. Qualitative interviews with a subgroup ($N = 21$) of the AMoSS study (monitoring mood in patients with bipolar disorder using a smartphone connected to motion-sensing devices) showed a process of increasing satisfaction over the course of the study. Most patients ($N = 16$) reported that self-monitoring improved their insight into their illness, and half of the patients indicated that their mood improved because they were better able to identify their feelings [34].

Our study did not show any statistically significant differences between the responses of patients with bipolar disorder and those with recurrent depression. This allows us to draw the general conclusion that the MoodMon application was subjectively perceived similarly, regardless of the type of affective diagnosis. Participants were most often 25-54 years old at the time of the study, which indicates that even middle-aged individuals were willing to use the application. Patients rated the clarity of information provided before starting to use the MoodMon application highly (on a scale of 1-5: 4.71 for BD,

4.83 for MDD). This may have contributed to the small number of anonymized questions sent to the technical support team during the initial period of the study.

The principle of "do no harm" is paramount in medical practice and should equally apply to technological tools for monitoring mental state. Respondents were asked two slightly different questions in this context. Regarding the first question, on the overall impact of the application on their mental state, the largest percentage of respondents indicated a "neutral effect" (50.7% for BD; 43.5% for MDD). A "very beneficial" effect was reported by 34.8% of respondents with MDD and 21.1% of those with BD. The second subjective area of assessment was defined as "the impact of the awareness of having the MoodMon application on the phone on well-being". For patients with both diagnoses, this awareness most often had a "neutral effect" (68.1% for BD; 60.9% for MDD), with these percentages higher than those for the first question. These results suggest that awareness of an active monitoring application did not negatively affect the well-being of the vast majority of respondents.

Additionally, 56.9% of respondents with bipolar disorder reported benefiting from using the MoodMon application, compared to 78.3% of respondents with recurrent depressive disorder. When asked about the specific benefits experienced, patients most frequently mentioned "better contact with the doctor" (59% for BD; 22% for MDD) and "better disease control" (37% for BD; 17% for MDD), with a greater tendency among patients with bipolar disorder to describe these benefits.

Patients were asked whether they experienced any unpleasantness while using the MoodMon app. A small percentage of respondents with bipolar disorder (11.1%) and an even smaller percentage of those with depression (4.3%) responded affirmatively. It can therefore be assumed that the use of the app was not associated with any significant discomfort for either group of patients.

Respondents, as users, were asked to assess whether modifications to the MoodMon app were needed. Among the 95 respondents, the vast majority, regardless of diagnosis, did not perceive a need for changes (70.8% – BD; 60.9% – MDD). Those who provided practical suggestions ($N = 30$) primarily recommended modifying the voice sampling method ($N = 15$). This suggestion highlights a significant legislative issue related to data protection in smartphones, which the multidisciplinary team failed to solve during the development of the app. Formal data protection regulations for Android smartphones (statistically more common in Poland) did not permit voice sampling during naturalistic conversations. A possible future solution (already tested in studies on semantics and monitoring activity in patients with affective disorders) is the use of a voice bot to ask questions at a time selected by the patient [26-28, 35]. This approach could serve as an alternative to the current method, in which patients independently respond to three emotionally neutral questions at a chosen time of day.

Several respondents ($N = 5$) also reported the issue of repeated questions in the rotation, which were prepared in large numbers by psychiatric specialists. In the future, this problem could potentially be solved by creating an extensive pool of questions using artificial intelligence, ensuring no repetition over several months. However, a key challenge will be ensuring that the artificial intelligence does not solely determine which types of questions are most likely to be neutral for patients with affective

disorders. During the planning stage of our study, resolving this issue required many hours of discussion among practicing physicians to reach a final consensus. The validity of this consensus for patients is confirmed by the lack of comments regarding the content of the questions, with the only concern raised being their repetitiveness. Other suggestions focused on technical aspects of using the app, such as considering alternative methods for updating the application.

A significant proportion of respondents expressed satisfaction with the MoodMon app, with 62.5% of individuals with bipolar disorder and 83.6% of those with depression reporting positive experiences. These results confirm the previously discussed positive attitudes towards using smartphone apps among patients with affective disorders. The most frequently mentioned reasons for satisfaction, reported by 36 respondents, were "better care and better contact with the doctor" ($N = 15$) and "interest in new technology for patients" ($N = 15$).

A significant proportion of respondents expressed a desire to continue using the MoodMon application in the future. Specifically, 48.6% of patients with bipolar disorder and 73.9% of those with recurrent depressive disorder indicated this preference. This is a positive prognosis, especially since the data are derived from patients who had the application on their phones and were generally active users in their daily lives.

At the end of the survey, respondents were asked to shift from an individual perspective to that of the broader population of patients dealing with affective disorders. They were asked which arguments might be important for others to consider before deciding to use the MoonMon app. Forty-four participants responded. The most common descriptive argument was "the possibility of using a modern technological solution by patients" ($N = 27$), followed by "the possibility of achieving better disease control" ($N = 12$). These results suggest that the MoodMon app meets the expectations placed upon it and is viewed by users as a modern tool using artificial intelligence technology to improve disease control. And it is known, in affective disorders, allowing patients to monitor their own mental state can help prevent serious consequences [6, 9-11]. Modern psychiatry, therefore, has the opportunity to use digital devices based on artificial intelligence algorithms for this purpose. The latest guidelines take into account and clearly emphasize that the key condition for their safe and effective use in the future will remain the primary role of the physician [36, 37]. The impact of involving trained patients on the accuracy of the results obtained using the AI in the MoonMon app has been discussed in a separate article [38].

Conclusions

The study of patients with bipolar disorder and recurrent depressive disorder who used the MoodMon mobile app in their daily lives to monitor their mental state provided valuable insights for the emerging field of psychiatry that incorporates AI-based technological solutions.

Based on the analysis, it can be concluded that, in the subjective opinion of users, the MoodMon app proved to be both safe and useful for individuals with bipolar disorder and recurrent depressive disorder.

The conclusions from our study may serve as inspiration for other research teams, as they reflect the views of the users themselves, who in the world of technology often subjectively decide whether a given solution is beneficial and user-friendly in their everyday lives.

Limitations

The work represents a preliminary subjective assessment of the first users. Patients provided their answers at different time points, most often on the day of the planned end of the study according to the protocol. Some respondents answered the survey questions during a psychiatric visit on the day they withdrew from participation (shorter period of using the system). The number of questions asked was not large. Comparing the results was difficult because there are still few user assessments of other applications dedicated to patients with affective disorders and developed by multidisciplinary professional teams. This remains the case despite the observed rapid development of AI applications in psychiatry around the world.

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