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Conflict of interest

All the authors confirm they have no conflict of interest

Abstract

Background: Smartphone-based ecological momentary assessment (EMA) is a promising methodology for mental health research. The objective of this study is to determine the feasibility of smartphone-based active and passive EMA in psychiatric outpatients and student controls.

Methods: Two smartphone applications —MEmind and eB^2— were developed for behavioral active and passive monitoring. The applications were tested in psychiatric patients with a history of suicidal thoughts and/or behaviors (STB), psychiatric patients without a history of STB, and student controls. Main outcome was feasibility, measured as response to recruitment, retention, and EMA compliance. Secondary outcomes were patterns of smartphone usage.

Results: Response rate was 87.3% in patients with a history of STB, 85.1% in patients without a history of STB, and 75.0% in student controls. 457 participants installed the MEmind app (120 patients with a history of STB and 337 controls) and 1,708 installed the eB^2 app (139 patients with a history of STB, 1,224 patients with no history of STB and 346 controls). For the MEmind app, participants were followed-up for a median of 49.5, resulting in 22,622 person-days. For the eB^2 application, participants were followed-up for a median of 48.9 days, resulting in 83,521 person-days. EMA compliance rate was 65.00% in suicidal patients and 75.21% in student controls. At the end of the follow-up, over 60% of participants remained in the study.

Limitations: Cases and controls were not matched by age and sex. Cases were patients who were receiving adequate psychopharmacological treatment and attending their appointments, which may result in an overstatement of clinical compliance.

Conclusions: Smartphone-based active and passive monitoring are feasible methods in psychiatric patients in real-world settings. The development of applications with friendly interfaces and directly useful features can help increase engagement without using incentives. The MEmind and eB^2 applications are promising clinical tools that could contribute to the management of mental disorders. In the near future, these applications could serve as risk monitoring devices in the clinical practice.

Introduction

Mobile health (mHealth) is opening new prospects for the assessment and management of mental disorders (Marzano et al., 2015). The increasing use of mHealth has been boosted by the widespread ownership of smartphones, the enhanced precision of their sensors and the great diversity of applications they can host (Firth et al., 2015; GSMA, 2019). MHealth is well accepted among psychiatric patients (Hidalgo-Mazzei et al., 2018; Hendrikoff et al., 2019). Some examples of the potentials of mHealth to the field of mental health are monitoring early signs of psychotic relapse in people with schizophrenia (Eisner et al., 2019), providing computer-based cognitive behavioural therapy for depression (Huguet et al., 2016), or drawing a safety plan for people with a history of suicidal behaviour (Nuij et al., 2018).

Smartphones are very well-suited for behavioral monitoring, given the habit of carrying them with us at all times. One of the most common methods used in smartphone-based monitoring is Ecological Momentary Assessment (EMA), which consists of asking questions to the participants daily. This results in a continuous, real-time assessment that takes place in the users' environment with minimum interference (Shiffman, 2008). However, EMA requires active collaboration from the user, and there is a limited number of questions a person is willing to answer. Thus, compliance is likely to decrease over time due to the cumulative burden of response (Burke, Shiffman & Music, 2017). This is especially problematic for mental health research, given the high rates of non-adherence and lack of cooperation among the psychiatric population (Chakrabarti, 2014). A variant of this method is passive EMA, in which data is collected from the device's native sensors without the participation of the user. These data are later processed and used as proxies for clinical variables. The combination of both active and passive methods could further improve behavioral monitoring.

Continuous behavioral monitoring using active and passive EMA presents with several advantages over traditional assessment methods: it allows for nearly continuous collection of information, reduces recall bias, and provides a more valid ecological setting. It can also offer more nuanced information, such as fluctuation of variables over time (Silk et al., 2011). In addition to its advantages for research, patients can directly benefit from behavioral monitoring by increasing self-awareness of their mental state and tracking their progress (Gaggioli et al., 2012; Ortiz & Grof, 2016; Hartmann et al., 2019). An increasing number of studies are exploring the feasibility of smartphone-based continuous monitoring of mental health-related variables (Asselbergs et al., 2016; Hung et al., 2016; Schwartz et al., 2016; Babinski & Welkie, 2019; Faurholt-Jepsen et al., 2019). Some of them have explored this technology in suicide research (Kleiman et al., 2017; Czyz, King & Nahum-Shani, 2018; Forkmann et al., 2018; Littlewood et al., 2019; Hallensleben et al., 2019; Spangenberg et al., 2019). These studies usually have small sample sizes and short follow-up periods —often two weeks or less (Schwartz et al., 2016; Kleiman et al., 2017; Forkmann et al., 2018; Littlewood et al., 2019; Mackesy-Amiti & Boodram, 2018; Babinski & Welkie, 2019; Hallensleben et al., 2019; Spangenberg et al., 2019). In some of them, monetary incentives are used to increase engagement (Asselbergs et al., 2016; Kleiman et al., 2017; Czyz, King & Nahum-Shani, 2018; Mackesy-Amiti & Boodram, 2018). The use of incentives in biomedical research is controversial, for they limit the applicability of results and may be coercive for vulnerable populations (Singer & Couper, 2008; Groth, 2010; Ashcroft, 2011). Exploring feasibility in real-world settings is a necessary previous step to implementing mHealth tools in clinical practice.

We have developed two smartphone apps to monitor behavior. The MEmind app collects data through active EMA, while the eB^2 app employs a passive monitoring system using the smartphone's built-in sensors. The aim of this study is to evaluate the feasibility of the MEmind and eB^2 applications in non-incentivized psychiatric patients and student controls.

Materials and methods

Study context and design

This is a feasibility study framed in the cross-national multi-center project Smartcrisis. The protocol for the SmartCrisis study has been published elsewhere (Berrouiguet et al. 2019). This study was performed in agreement with the ethic requirements of the Declaration of Helsinki (JAVA, 2013) and approved by the Institutional Review Board of the University Hospital Fundación Jiménez Díaz (Madrid, Spain). All participants gave written informed consent to participate in the study.

Sample

The participants were placed in three groups: psychiatric patients with a history of suicidal behavior (STB) (group 1), psychiatric patients without a history of STB (group 2), and students of Psychology as controls (group 3).

Group 1. Patients with a history of STB were recruited at the Emergency Department and Outpatient Mental Health Clinic of the University Hospital Fundación Jiménez Díaz. Inclusion criteria for this group were: being 18 or older, having a history of suicide behaviour and/or suicidal ideation measured with the Spanish version of the Columbia Suicide Severity Rating Scale (CSSRS) (Posner et al., 2011; Al-Halabí et al., 2016), owning a smartphone with an Android or iOS operating system that was connected to a Wi-Fi network at least once a week, and being able to give written informed consent for the study. Participants were excluded if they were under the age of 18, illiterate, enrolled in other trials, or were in situations that did not allow obtaining written informed consent. No incentives of any kind were used in this group.

Group 2. Psychiatric outpatients with no history of STB were recruited at the Outpatient Mental Clinic of the University Hospital Fundación Jiménez Díaz. Inclusion criteria for this group were the same as in group 1, except for the absence of a history of STB, which was required for being assigned in this group. No incentives were used in this group either.

Group 3. Volunteers were recruited among students at a Spanish University. Inclusion criteria for this group were: being 18 or older, not having a history of STB or a diagnosed mental disorder, owning a smartphone with an Android or iOS operating system that was connected to a Wi-Fi network at least once a week, and being able to give written informed consent for the study. Participation was validated as an academic activity, as a form of non-monetary incentive.

Procedure

Recruitment took place between April 2018 and February 2019. After enrollment, participants underwent a baseline interview with a trained psychologist, who installed the applications and instructed the participants on how to use them. The MEmind app was installed for Group 1 and Group 3. The eB^2 was installed in all groups. Follow-up periods were calculated individually for each participant taking the date of the baseline interview as the starting point.

Smartphone-based monitoring

The SmartiCrisis platform consists of two smartphone applications for behavioral monitoring: MEmind and eB^2. The MEmind app collects data through conventional EMA, while the eB^2 app employs a passive monitoring system using the smartphone's built-in sensors. The platform also features a back-end server that stores and processes the collected data. Data were anonymized and translated to a unique data schema and finally transmitted via Wi-Fi to the back-end server where it was stored.

Both apps were developed by our translational psychiatry research team. A team of engineers from the Signal Theory department of University Carlos III of Madrid worked in the optimization of the eB2 app to make sure it was compatible with the built-in sensors of most smartphone models available in the market. Both apps are compatible with Android and IOs operative systems and are available via marketplaces such as Google Play or App Store. This allows us to continuously update and improve the app based on technology advancement and feedback from users. Snapshots of the applications are shown in figure 1.

The MEmind app. A detailed description of the MEmind app has been published elsewhere (Berrouiguet et al., 2019; Barrigón et al., 2017). The MEmind App was designed to monitor suicide risk, and employs EMA to assess suicidality, quality of sleep, negative feelings, and appetite. The EMA questionnaire is composed of 33 questions: 2 about death ideation ("Wish to die" and "Wish to live"), 13 about negative feelings, 11 about sleep quality and quantity, and 7 questions about appetite. Our questionnaire was based on the Salzburg Suicide Questionnaire (Fartacek et al., 2016), the Insomnia Severity Index (ISI) (Bastien, Vallieres & Morin, 2001; Fernández Mendoza et al., 2012), and the Council on Nutrition Appetite Questionnaire (CNAQ) (Wilson et al., 2005). The MEmind EMA questionnaire has showed good acceptability in a preliminary study (Lemey et al., 2019). In order to decrease the burden for the user, we have incorporated a turn-over system to avoid constant repetition of questions. Users had to answer 2-4 questions per day.

The eB^2 app. A detailed description of the eB^2 app has been published elsewhere (Berrouiguet et al., 2018; Berrouiguet et al., 2019). The eB^2 app continuously collects information using the smartphone native sensors while working in the background. This information is stored in the device and uploaded to the server once the user is connected to a Wi-Fi network. The app collects the following information:

- Smartphone usage patterns: time of use of the device, bluetooth and Wi-Fi connections, phone calls (time and duration, but not content), app usage (time and duration, but not content).
- Mobility: GPS location, distance travelled, and speed. Additionally, syncing with Google Play Services, we collected nearby location data.
- Physical activity: using the smartphone's inertial sensors.
- Sleep quantity: total sleep time, bedtime and wake up time.

In addition to the passive monitoring system, the application has an interactive interface that functions as a progress log. Users can track their physical activity and sleep duration, as measured by the smartphone's native sensors. They can also register the day-to-day fluctuations in their mood by choosing from five different emojis (angry, sad, indifferent, happy, and delighted) and/or introducing comments on a free-text space.

Smartphone usage

In participants using the Android operating system, we obtained information about daily use of the smartphone (access was denied with iOS).

Non-digital assessments

During the baseline interview, a trained psychologist assessed the participants using the Spanish versions of the following psychometric instruments: suicidality was assessed with the CSSRS (Posner et al., 2011; Al-Halabí et al., 2016), and the suicidality module of the Mini International Neuropsychiatric Interview 7.0.0 (Sheehan et al., 1998; García-Portilla et al., 2015); sleep quality was assessed with the Pittsburgh Sleep Quality Index

(ICSP) (Buysse et al., 1989; Hita-Contreras et al., 2014) and the ISI (Bastien, Vallieres & Morin, 2001; Fernández Mendoza et al., 2012), mood was assessed with the Inventory of Depressive Symptomatology (IDS) (Rush et al., 1996; Trujols et al., 2014), Young Mania Rating Scale (Young et al., 1978; Colom et al., 2002), and anxiety was assessed with the State-Trait Anxiety Inventory (STAI) (Spielberger, 2008; Buela-Casal & Guillén-Riquelme, 2017). Clinical diagnosis was collected from the electronic clinical records, which comply with ICD-10 criteria. Participants' demographic characteristics were also collected, including age, sex, marital status, employment status, country of birth, mother tongue, and level of education.

Outcomes

Our primary outcome was feasibility, measured as response to recruitment, retention rates at 2-month follow-up, and compliance with the EMA questionnaire. Additionally, we offer descriptive statistics of the sample, with a comparison of smartphone usage between the groups.

Data analysis

All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 24.0 software. We conducted a Kaplan-Meier survival analysis to estimate retention after two months of follow-up. We performed an ANOVA test to explore the differences in smartphone usage among the groups. Statistical significance was established at <0.05 P-values, using two sided tests and 95% confidence intervals.

Results

Results of the recruitment process

Group 1: 189 psychiatric patients with a history of STB were invited to participate in the study. 24 (12.7%) patients refused to participate and 165 (87.3%) accepted. 26 (13.8%)

could not participate in the study due to technical reasons (lack of smartphone, lack of storage space in the device, lack of internet access). 139 (73.5%) installed the eB^2 application, and 120 (63.5%) installed both the MEmind and eB^2 application.

Group 2: 1,706 patients with no history of STB were invited to participate in the study. 255 (14.9%) refused to participate and 1,451 (85.1%) accepted. Main reasons reported for refusal were lack of interest in the study (n=148; 8.7%), time constraints (n=40; 2.3%), and concerns with privacy (34; 1.9%). 227 (13.3%) patients could not participate in the study due to technical reasons: 110 (6.4%) had no smartphone that supported the applications, 69 (4.0%) could not have the applications installed due to lack of storage space, and 48 (2.8%) had no internet access. 1,224 (71.7%) installed the eB^2application (MEmind app was not installed in this group).

Group 3: 488 university students without a history of mental disorders were approached to participate in the study. 142 refused to participate. Most common reason for refusal was concern about privacy (n=58; 23.02%). 366 agreed to participate. 20 could not participate in the study due to technical reasons. 346 (70.9%) students signed the informed consent. All of them installed the eB^2 and 337 (69.1%) installed both apps.

Figure 2 shows the full results of the recruitment process.

Baseline characteristics of the sample

Table 1 shows the baseline characteristics of the three groups of participants. There was a majority of women in the three groups. Participants in group 1 and group 2 were of similar age, and significantly older than participants in group 3. Anxiety disorders were the most common psychiatric diagnosis in the two groups of patients (59.1% in Group 1 and 49.5% in Group 2), followed by personality disorders in Group 1 (46.0%) and mood disorders in Group 2 (29.0%).

Retention

Retention steadily decreased over two months. At the end of the follow-up, over 60% of all participants remained in the study, having at least one of the applications installed and working.

For the eB^2 application, retention rates were over 65% in all groups. Suicidal patients showed the highest retention rate, although the difference was not statistically significant. Participants with the eB^2 app were followed up for a mean of 48.9 days (53.2 days in Group 1, 48.6 days in Group 2, and 47.8 days in Group 3), resulting in 83,521 person-days. Mean days of follow-up were statistically significantly higher in suicidal patients compared to the total sample, as showed by the non-overlap in the confidence intervals obtained for these populations (see table 2).

For the MEmind application, retention rate was over 65% in all groups and statistically significantly higher in suicidal patients (over 80%) compared to the total sample, as showed by the non-overlap in the confidence intervals obtained for these populations (see table 2). Participants with MEmind app were followed up for a mean of 49.5 days (46.9 in Group 1, and 50.4 in Group 3), resulting in 22,622 person-days.

Table 2 shows the retention rates per group and application.

Figures 3 shows the survival curves for MEmind retention over the two months of follow-up for suicidal patients and student controls.

Figure 4 shows the survival curves for eB^2 retention over the two months of follow-up for suicidal patients, non-suicidal patients and student controls.

Compliance with active EMA

Over the two months of follow-up, participants answered a total of 45,267 questions out of the 66,540 that were asked, accounting for an overall compliance rate of 68.03% (95%

CI 67.67% – 68.38%). Compliance rate among suicidal patients was 65.00% (95% CI 64.36% – 65.63%), compared to 75.21% (95% CI 74.79 – 75.62) among student controls. These non-overlapping confidence intervals show that compliance rate was significantly higher in suicidal patients.

Smartphone usage

We could obtain information about daily use of the smartphone in 529 participants using the Android operating system. Mean time of use of the device was 3.6 hours per day in the entire sample. In group 1, time of use was 3.63 hours (95% CI 3.16 – 4.12); in group 2, it was 3.47 hours (95% CI 3.26 – 3.69), and in group 3, it was 4.53 hours (95% CI 4.09 – 4.97).

There were statistically significant differences in smartphone usage between the groups regarding total time of use, use of social applications, and communication, while there were no statistically significant differences regarding gaming and use of health applications (see table 3).

Discussion

In this study, we explored the feasibility of two smartphone applications for the active and passive monitoring of mental health-related variables. We obtained acceptable rates of recruitment response, study retention and EMA compliance. Our results suggest that passive and active EMA is feasible for the monitoring of mental health patients in a real-world setting.

Comparison to previous findings

Most previous EMA studies found similar rates of response, retention and compliance to our study. Kleiman et al. (2017) monitored 54 patients with a history of STB for 28 days using EMA. Response rate was 60% and compliance rate was of 63%. Czyz et al. (2018)

monitored 34 adolescents throughout four weeks and found that adherence was higher in those with a history of STB. Overall EMA compliance was 69%. Mackesy-Amitia & Boodram (2018) assessed mood and risk behaviour over 15 days in a sample of 185 drug users. 76% of participants completed the follow-up. Mean EMA compliance rate was 43%. However, participants in the above-mentioned studies received incentives, which —in addition to the shorter follow-up period— precludes a direct comparison of results *(*Kleiman et al. 2017*;* Czyz et al., 2018; Mackesy-Amitia & Boodram, 2018). Compared to other EMA studies with longer follow-ups, our retention rates were higher. For instance, Hung et al. (2016) explored smartphone-based EMA in 59 non-suicidal depressed patients over 8 weeks and measured days of active use. Over the follow-up period, participants used EMA for a mean of 11 days. At the end of the 8 weeks, application use had decreased almost ten times.

Regarding passive monitoring, Asselbergs et al. (2016) explored the feasibility of mood continuous assessment through unobtrusive EMA over 6 weeks in 27 healthy students, who were incentivized for participating. By day 42, 66% of the participants remained in the study, a very similar figure to the one we found in our student controls. Saeb et al. (2015) passively collected phone usage and GPS data to use as correlates of depressive symptoms in a sample of community-dwelling adults. At the end of the study, 28 out of 40 (70%) participants had sufficient data to carry out analyses.

Decreasing the EMA burden

Participants' fatigue is an important weakness of EMA methodology (Yang et al., 2019). Answering the same questions every day can be burdensome to participants and lead to their dropping out from the study. Regarding passive monitoring systems, participants could easily uninstall applications that offer no benefit for them. This probably contributes to the short follow-up periods found in most EMA studies, along with the common practice of using incentives. These incentives usually take the form of financial compensation, which sometimes is proportional to completion rates (Asselbergs et al., 2016; Kleiman et al., 2017; Czyz et al., 2018). The use of incentives limits conclusions on how these applications would work in real-world settings.

In our study, we compared non-incentivized patients with incentivized student controls (who could validate their participation in the study as an academic activity —no financial compensation was given). Response rate was higher in patients than in controls, and slightly higher in patients with a history of STB compared to those without such history. Although retention gradually decreased in the three groups, it was once again higher in patients than in controls, and also higher in suicidal patients. Reasons for study abandonment may include EMA fatigue, and loss of interest and/or motivation. Participants who remained until the end of study may represent those who found the application beneficial for their mental health. Regarding patients with a history of suicidal behavior, studies show that the risk of re-attempt is maximum in the first two months after an index attempt (Irigoyen et al., 2019). Thus, monitoring patients for this period of time could contribute to reducing risk.

In order to decrease EMA burden, we applied a turn-over system to the MEmind app questions, thereby reducing repetition. Additionally, we added functionalities in the eB^2 app so that, apart from serving as a passive monitoring system, the application could also be directly useful for the participants. The combination of active and passive monitoring did not decrease retention, since suicidal patients —who had both applications installed— exhibited higher retention rates than non-suicidal patients —who had only the passive monitoring system.

However, EMA compliance rate was higher in student controls than in suicidal patients. Participants in the control group were significantly younger than psychiatric patients, which may partially explain this higher rate, along with the differences found in mobile phone usage.

Privacy and safety concerns

One of the main reported barriers to the implementation of mHealth are users' concerns about safety and privacy (Stiles-Shields et al., 2017). Although privacy is highly appreciated by users, many health applications do not provide sufficient protection of personal information (Fernandez-Luque & Staccini, 2016). In our study, personal data were anonymized, and sensitive information, such as content of messages and calls, was not accessed.

Implications for clinical practice

The MEmind and eB^2 monitoring systems are still in the research stage, but the aim in the near future is that they can serve as risk monitoring devices that alerts us to an imminent psychiatric decompensation. Actively and passively collected data can serve as proxies of mental health-related variables. In addition, deviations from the usual patterns of activity, independently of the nature of such activity, may predict a change in the course of the disease, which could be harnessed for the prevention of relapses. In particular, passive monitoring has the advantage of not requiring the collaboration of the user. Lack of insight and inadequate compliance with follow-up appointments and treatment are common problems among the psychiatric population (Chakrabarti, 2014; Williams, Olfson & Galanter, 2015). This lack of compliance is more prominent in times of relapse and may in itself be a symptom of decompensation. When psychiatric patients are at their worst, they are less likely to ask for help. Passive monitoring could be established in a similar fashion to therapeutic contracts: a compromise made when the participants are stable to help decide what to do when they are not. In the same way, passive monitoring could be agreed upon in moments of stability and become a powerful tool to alert to relapse. Additionally, the applications can be directly beneficial for the patients. Strong evidence supports the motivational effects of behavior change techniques (BCTs), including self-monitoring (Webb et al., 2010; Hartmann, Sander & Lorenz, 2019). The eB^2 might be useful in this regard, since it allows users to track their physical mobility and sleep quality —passively-collected through the phone's native sensors—, and mood —actively-collected by selecting emojis.

Limitations

The MEmind and eB^2 applications are still in the research stage and have not been fully optimized for clinical practice yet. Cases and controls were not matched by age and sex, and controls are significantly younger than cases. Cases were patients who were receiving adequate psychopharmacological treatment and attending their appointments, which may result in an overstatement of clinical compliance.

Conclusion

Our study showed that active and passive smartphone-based behavioral monitoring is feasible in psychiatric patients without the use of incentives. Retention rates were higher in psychiatric patients compared to controls, and even higher in those patients with a history of STB. Smartphone-based systems for managing and monitoring behavior present a highly promising field of innovation in health care. Daily use of a smartphone could generate a greater amount of data than is normally collected in traditional studies. The MEmind and eB^2 applications are promising clinical tools that could contribute to the management of mental disorders. Particularly, these apps could be used for suicide risk monitoring in psychiatric patients. Digital phenotyping is emerging as a promising method in the assessment of patients with mental health conditions (Torous et al., 2017). Moreover, mHealth brings us closer to a participatory model in which patients are involved in the management of their mental disorders.

Contributors

Enrique Baca-García, Antonio Artés-Rodríguez, Sofian Berrouiguet, Jorge López-Castroman, Maria Luisa Barrigón, and Philippe Courtet conceived and designed the study. María Sandra Pérez-Rodríguez, Isaac Díaz-Oliván and José Heliodoro Marco were in charge of sample recruitment and data collection. María Luisa Barrigón and were in charge of data analysis. Alejandro Porras-Segovia and Rosa María Molina-Madueño wrote the manuscript.

All authors contributed substantially to the drafting and revisions of the manuscript.

All authors read and approved the final manuscript.

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Conflict of interest

All the authors confirm they have no conflict of interest

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Figure legends

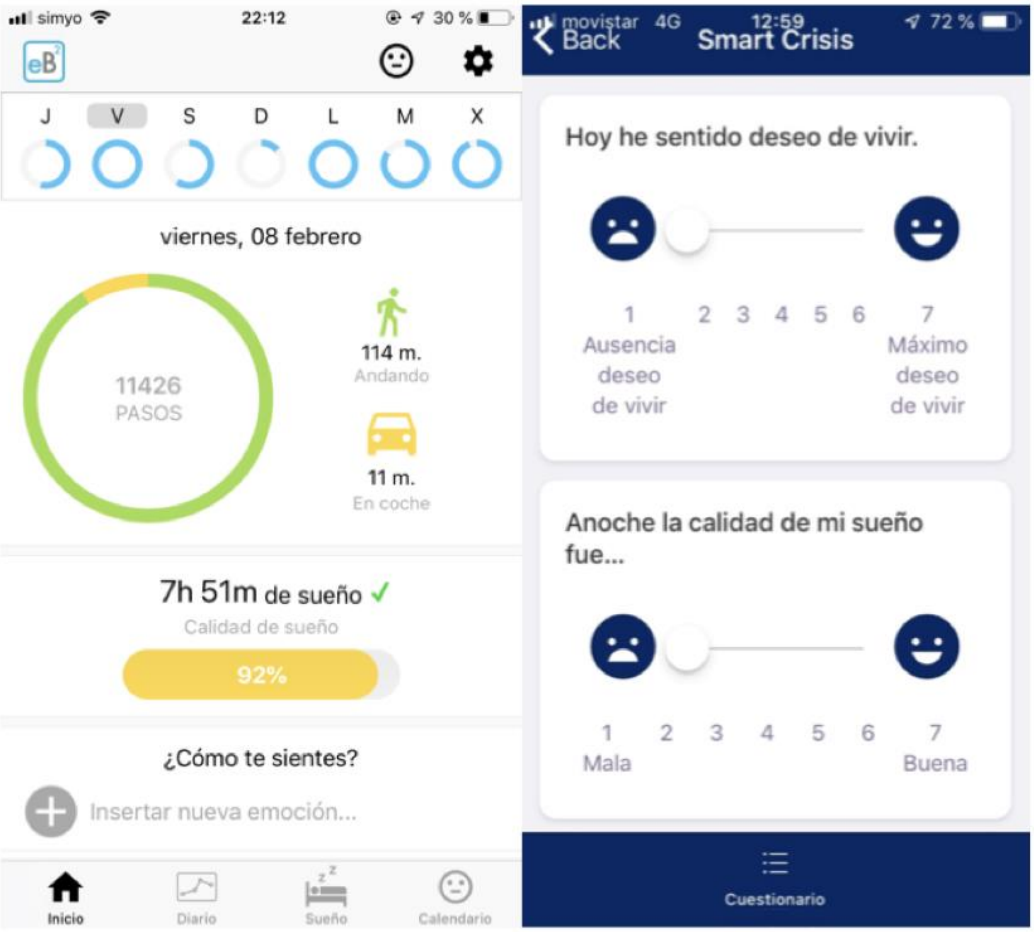

Figure 1. Left: snapshot of the eB² application [Text: Friday, 8th February, 11,426 steps, 114 minutes walking, 11 minutes. 7h 51minutes of sleep. Quality of sleep 92%. How are you feeling today? Insert new emotion. Home. Log. Sleep. Calendar]. Right: snapshot of the MEmind application [Text: Today I have a desire to be alive. 1: no desire to be alive. 7: Maximum desire to be alive. Last night the quality of my sleep was. 1 Bad. 7 Good. Questionnaire].

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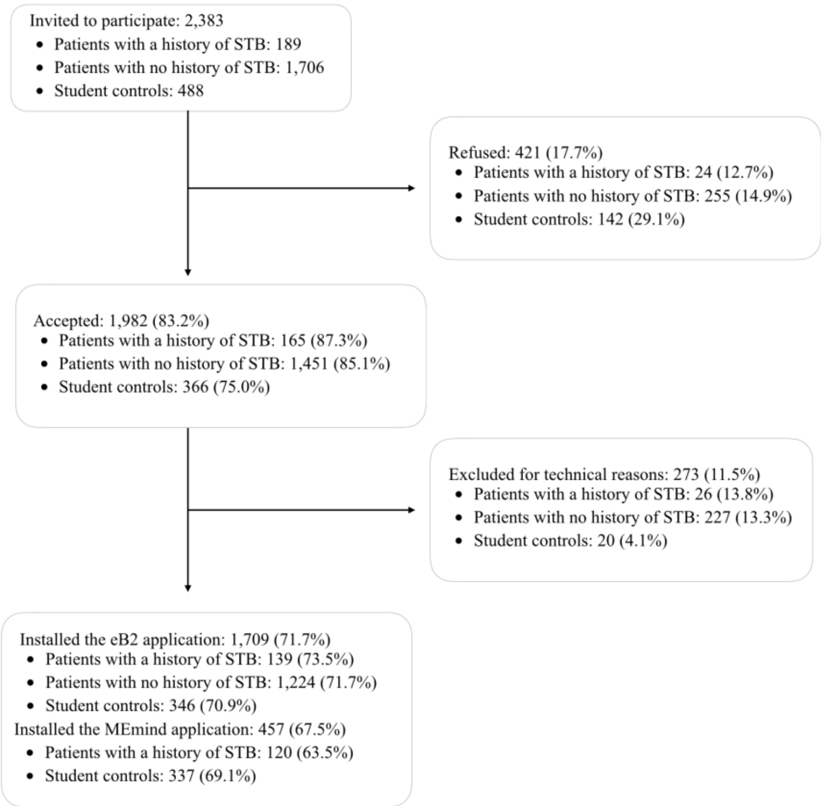

Figure 2. Flow chart of the recruitment process. STB=Suicidal Thoughts and/or Behaviours

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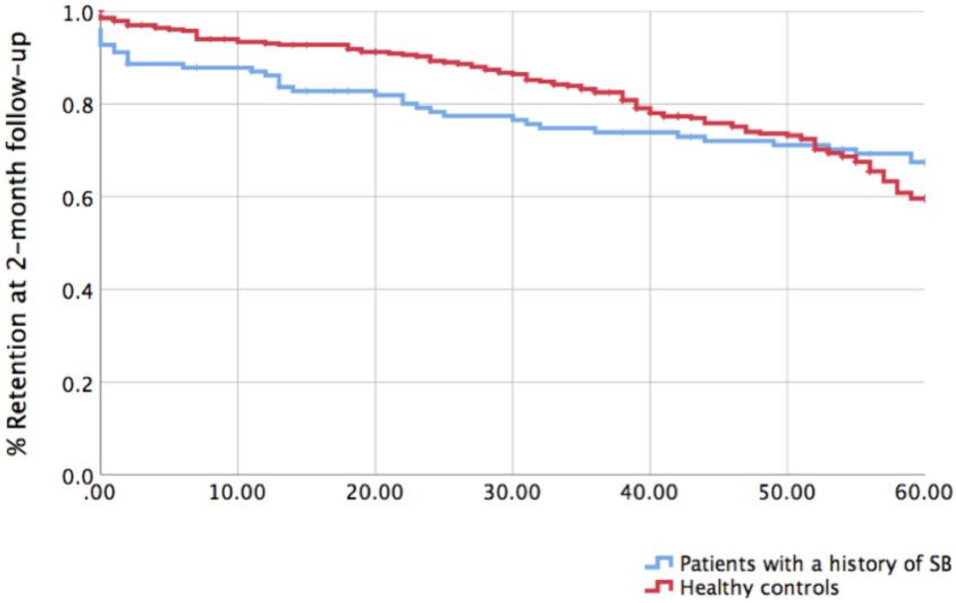

Figure 3. Survival curve of retention over the 2 months of follow-up (MEmind application)

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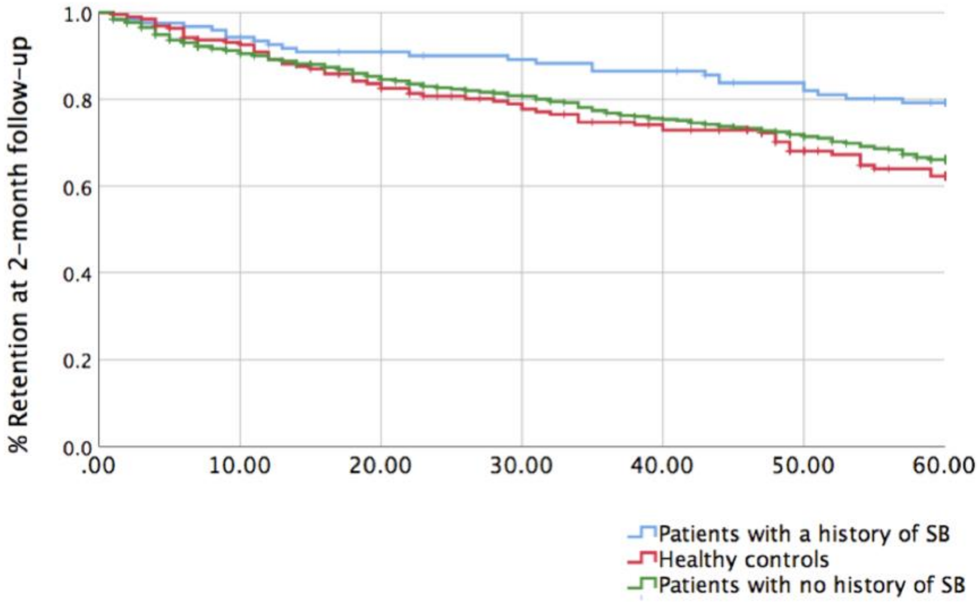

Figure 4. Survival curve of retention over the 2 months of follow-up (eB² application)

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Table 1. Baseline characteristics of the sample (total n=1,709)

	Group 1 (n=139)		Group 2 (n=1,224)		Group 3 (n=346)	
	n (%)	Mean (95% CI)	n (%)	Mean (95% CI)	n (%)	Mean (95% CI)
Age		44.2 (41.9 – 46.6)		45.4 (44.7 – 46.2)		22.9 (22.4 – 23.5)
Gender						
Male	50 (36.0%)		399 (32.6%)		60 (17.3%)	
Female	89 (64.0%)		825 (67.4%)		286 (82.7%)	
Psychiatric diagnosis						
F0: Organic, including symptomatic, mental disorders	1 (0.7%)		36 (2.9%)		-	
F1: Mental and behavioral disorders due to use of psychoactive substances.	19 (13.7%)		43 (3.5%)		-	
F2: Schizophrenia, schizotypal and delusional disorders	0 (0.0%)		44 (3.6%)		-	
F3: Mood disorders	61 (43.9%)		355 (29.0%)		-	

F4: Neurotic, stress-related and somatoform disorders	82 (59.1%)	606 (49.5%)	-
F5: Behavioral syndromes associated with physiological disturbances and physical factors	4 (2.9%)	100 (81.7%)	-
F6: Disorders of personality and behavior in adult persons	64 (46.0%)	128 (10.5%)	-
Any physical condition	14 (10.1%)	257 (21.0%)	-

Group 1: Patients with a history of Suicidal Thoughts and/or Behavior. Group 2: Patients with no history of Suicidal Thoughts and/or Behavior. Group 3: Healthy controls.

Table 2. Retention after two months, and mean days of follow-up

	MEmind app		eB^2 app	
	Mean days of follow-up (95% CI)	Retention after two months % (95% CI)	Mean days of follow-up (95% CI)	Retention after two months % (95% CI)
Group 1	46.9 (43.0 – 50.8)	80.3% (72.4% – 86.4%)*	53.2 (50.3 – 56.0)*	69.4% (60.8% – 76.8%)
Group 2	–	68.8% (65.8% – 71.6%)	48.6 (47.4 – 49.8)	–
Group 3	50.4 (48.6 – 52.2)	67.9% (61.0% – 74.1%)	47.8 (44.9 – 50.6)	65.6% (60.4% – 70.5%)
Total sample	49.5 (47.8 – 51.2)	69.8% (67.2% – 72.2%)	48.9 (47.9 – 50.0)	66.6% (62.2% – 70.8%)

* Statistically significant difference vs. total sample

Group 1: Patients with a history of Suicidal Thoughts and/or Behavior. Group 2: Patients with no history of Suicidal Thoughts and/or Behavior. Group 3: Healthy controls.

Table 3. Smartphone usage per group of participants

		N	Mean	95% Confidence Interval for Mean	
				Lower Bound	Upper Bound
Total time (hours) of use of the device (ANOVA test: F=8.159, df=2, p<0.001)	Group 1	59	3.63	3.16	4.12
	Group 2	389	3.47	3.26	3.69
	Group 3	76	4.53	4.09	4.97
	Total	524	3.65	3.46	3.83
Time (hours) using social applications (whatsapp, facebook and alike) (ANOVA test: F=17.255, df=2, p<0.001)	Group 1	59	0.64	0.46	0.81
	Group 2	389	0.56	0.49	0.63
	Group 3	76	1.10	0.91	1.30
	Total	524	0.65	0.58	0.71
Time (hours) using communication (calls & SMS) (ANOVA test: F=8.274, df=2, p<0.001)	Group 1	59	1.01	0.83	1.19
	Group 2	389	0.99	0.91	1.07

	Group 3	76	1.38	1.21	1.55
	Total	524	1.05	0.98	1.12
Time (hours) using games (ANOVA test: F=1.416, df=2, p<0.24)	Group 1	59	0.54	0.30	0.78
	Group 2	389	0.45	0.35	0.54
	Group 3	76	0.29	0.18	0.40
	Total	524	0.43	0.36	0.51
Time using health applications (including MEmind and eB[2]) (ANOVA test: F=2.135, df=2, p<0.12)	Group 1	56	0.10	0.05	0.14
	Group 2	76	0.07	0.05	0.09
	Group 3	267	0.06	0.05	0.08
	Total	399	0.07	0.06	0.08

Group 1: Patients with a history of Suicidal Thoughts and/or Behavior. Group 2: Patients with no history of Suicidal Thoughts and/or Behavior. Group 3: Healthy controls.

Highlights

- Ecological momentary assessment is a promising method for behavioral monitoring
- Smartphone applications can complement traditional therapeutic approaches
- Smartphone-based behavioral monitoring is feasible in mental healthcare
- Smartphones can serve for suicide risk monitoring, alerting of an imminent crisis
- Passive monitoring has the advantage of not requiring the collaboration of users