“Mind the Gap(s)“ in Mental Health Care. How mHealth applications are integrated in clinical practice for patients with schizophrenia spectrum disorders: A scoping review

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Abstract

People with schizophrenia spectrum disorders (SSD) have severe problems with participating in society, because of impairing symptoms like hallucinations and delusions. It is necessary and important, that they get a chance for improvement and recovery. Unfortunately, having these symptoms doesn't make it easy to seek help for therapy. Furthermore, dealing with stigmatization threats their quality of life, as well as treatment adherence. Nevertheless, there is a need for treatment during and after a psychosis. Integrating mHealth applications into clinical practice, as well in the daily lives of patients, could improve the whole therapy process. Regardless, many patients but also clinicians are still concerned about using technologies in clinical practice. There is a need to clarify the current options of mHealth applications, as well as how these applications can be implemented in mental health care, to further improve therapy outcomes for people who are suffering from SSD. To examine how mHealth applications for patients with SSD are implemented in clinical practice, a scoping review was conducted by exploring different databases. In total, 55 studies were included in this review. There were four different settings in which mHealth applications could be used. The applications could be used inpatient, outpatient, for data collection, and as an add-on treatment. Furthermore, the applications have different goals. This review could identify eight different targets of mHealth applications: medication and treatment adherence, relapse prediction and prevention, cognitive performance and skills, coping strategies, self-help strategies and illness-management, social goals, reducing symptoms, and diagnostics. The results of this review show that the concept of existing mHealth applications already targets important treatment gaps in people with SSD. Nevertheless, the implementation in clinical practice of these applications seems to be in its infancy. Further research and work should concentrate on examining the efficacy of these applications but also examine the clinician's acceptability of integrating mHealth applications in their daily work.

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[1] Note: This thesis is based on the guidelines of the Publication Manual of the American Psychological Association: 7th Edition (American Psychological Association, 2020).

List of abbreviations

CBT	Cognitive Behavioral Therapy (*CBT is based on the concept that our thoughts, feelings, physical sensations, and behaviors are interconnected*)
EMA	Ecological Momentary Assessment (*Investigative strategy to examine people's thoughts, feelings, and actions in real-time by filling out questionnaires on a smartphone or tablet on multiple occasions over time; EMA focuses on the dynamic unfolding of behaviors in natural environments*)
ESM	Experience Sampling Methodology (*See definition of EMA; ESM focuses on representativeness of the data*)
mHealth	Mobile Health (*Using mobile technology in mental health care*)
SCED	Single-Case Experimental Designs (*Intensive repeated observations of a particular subject in order to demonstrate precise control over targeted behavior*)
SMS	Short Messaging System (*Writing text messages via mobile phone*)
SSD	Schizophrenia Spectrum Disorders (*Group of a psychological disorder with symptoms of delusions, hallucinations, disorganized thinking, and negative symptoms like catatonia or social withdrawal*)
SST	Social Skills Training (*Type of behavioral therapy to improve social skills in people with mental disorders*)
TIPS	Telephone Intervention Problem Solving (*MHealth intervention for patients with SSD*)
VR	Virtual Reality (*computer-generated simulation of a three-dimensional image or environment*)

Introduction

Based on personal experiences with someone very near to me, I have witnessed how experiencing psychosis can have a huge negative impact on someone's life in different areas. First, being delusional can impede someone from getting help as there is less illness insight during a psychosis. Especially, in episodes where the person experiences positive symptoms, there is no thinking about possible consequences of one's often erratic behavior. For people surrounding the person who suffers from psychosis, the behavior of this person appears very incomprehensible and somehow insane. For example, it seems they are talking without any context, but for the person itself, it seems, that he or she is enlightened about all the connections in our world. When psychotic, one may be unaware of the possible damage being caused, afterwards, one is confronted with the consequences of their actions, leaving them with burgeoning feelings of shame or embarrassment.

A psychosis can appear in different kinds of disorders, e.g., in Schizophrenia spectrum disorders (SSD). Some of the defining symptoms of SSD are delusions, hallucinations, disorganized thinking (speech), grossly disorganized or abnormal motor behavior (including catatonia), and negative symptoms according to the Diagnostic and Statistical Manual 5th edition (American Psychiatric Association, 2013). Negative symptoms can include social withdrawal, the inability to feel or express pleasure, a lack of motivation, or a seeming lack of interest in the world. The DSM-5 specifies several disorders within the schizophrenia spectrum, such as, e.g., schizoaffective disorder, psychotic disorder, or schizophrenia. All have in common, that patients experience a psychosis, which means experiencing one or more of the abovementioned symptoms.

In their daily life, people with schizophrenia have to deal with heavy issues of stigmatization (Nasrallah, 2021) and therefore are less prone to seek help (Clement et al., 2015). A study showed that once the people with SSD concurred with public stigma and internalized it, they were likely to show poorer adherence to psychosocial treatment (Fung et al., 2008). Offering mHealth – short for *mobile health* – solutions could help these people to receive treatment at home and therefore improve treatment adherence. Adibi (2015) defines mHealth as the practice of eHealth (the use of information and communication technologies for health) assisted by mobile technologies, like smartphones, tablets, or wearables, which are used to capture, analyze, process, and transmit health-based information from sensors and other biomedical systems.

People who are suffering from SSD might feel less stigmatized receiving treatment at home, as they get less confronted with other people. Being in a safe place, e.g., at home, might lead to a feeling of comfort, which could be an important fact for people who are suffering from delusions or hallucinations (Tomar et al., 2003; Baumgardt et al., 2021). In addition, mHealth applications could be practically used, e.g., helping to remind them to take their medication in time. Also, mHealth could serve as an aftercare service after termination of treatment. Another option would be using mHealth, if there is no ambulatory treatment available after discharge from hospital admission. So, offering mHealth applications could be a possibility to fill in gaps in treatments for schizophrenia.

MHealth Applications in Mental Health Care

MHealth interventions in mental health care, specifically for mental health-related issues, aim to improve the therapy process by increasing treatment adherence, changing behavior, and targeting the right treatment options for patients (Grossman et al., 2020). One example of an implementation of mHealth in mental health care is provided by Cruz et al. (2015). They developed a wearable and mobile intervention for individuals with a panic disorder. The wearable device is worn on a patient's chest and monitors several physical parameters, like monitors the heart rate. Regarding the physiological data of the patient, the app provides breathing exercises when it is deemed necessary or provides other health-related information. So, mHealth applications can be used for patients by reducing their symptoms and living with the remaining symptoms in their daily lives. Furthermore, mHealth applications can provide patients with educational information about the treatment process. For example, patients with a panic disorder can be informed about their symptoms (Price et al., 2014). Therefore, mHealth applications have the potential to improve the therapy process in mental health care by giving psychoeducation and delivering health care information but also by promoting the therapy in general. Several mHealth interventions are already available for treating SSD. They are increasingly suggested to ensure the continuity of care, relapse prevention, and long-term disease management (Gallinat et al., 2021). Recent technologies like virtual reality (VR) applications have shown promising when trying to improve communication and cognition and in increasing treatment adherence (Geraets et al., 2018).

Not only the therapy itself can be enriched by using mHealth applications, but also, clinical-relevant health data can be collected by using mHealth applications. Ecological momentary assessment (EMA) is one specific strategy for it. It involves the repeated sampling of subjects' current behaviors and experiences in real-time, in subjects' natural environment. The data is examined by technological devices, like biosensors or smartphones (Shiffman et al., 2008). Patients answer different questions on a smartphone about current pain, feelings, or other symptoms. Besides the information about the current status of the patient, the time and duration of the input are saved. Collected data is evaluated by clinicians. Using EMA can be a good way of improving the therapy process. As patients provide real-time experiences, the treatment can be tailored to every patient individually (Shiffman et al., 2008).

Barriers of mHealth in Clinical Practice

Integration of generated data into clinical workflow and user and clinician concerns about technology in general are some of the barriers that need to be overcome to integrate mHealth into clinical practice. Mostly personal generated health data is generated from a wide variety of devices that have no standard method of summarizing, displaying, and sharing information (Burgermaster et al., 2020), which makes it hard to transform them into actionable insight for patients and clinicians. Often the complexity of the data makes it difficult to identify relevant trends and develop clinically relevant goals. Furthermore, there are often no guidelines or validated processes that can transform the patient's data into personalized recommendations, which makes it hard for using in clinical practice (Burgermaster et al., 2020).

Another barrier of implementing mHealth into clinical practice is that a subset of patients and clinicians, for example, due to a lack of experience in using mHealth, are unconvinced of the possible benefits of mHealth applications and aren't willing to integrate them into clinical practice (Feijt et al., 2018). This is in some way also the case for clinicians that are working with patients with SSD. Academic research results often highlight the potential negative effects of using computers and the internet among people with SSD, like getting susceptible to addiction and emotional dysregulation (Sharma et al., 2017). These potential negative effects and barriers could get clinicians and patients skeptical about using mHealth in clinical practice. Therefore, it is necessary to enlighten patients and clinicians about the possible benefits of integrating mHealth into clinical practice to improve their acceptability.

Treatment of Schizophrenia Spectrum Disorders

The treatment approach of SSD can be pharmacological intervention, i.e., prescribing antipsychotic drugs or psychological, e.g., offering treatment based on cognitive-behavioral, client-centered, or other techniques and interventions. A mixed approach is also possible and usually the choice of preference. Several findings suggest that antipsychotics are effective in reducing psychotic symptoms like delusion, hallucinations, and excitability (Leucht et al., 2009). Antipsychotics may only have a small effect on negative symptoms though (Engh et al., 2015). However, negative symptoms, like social withdrawal, can be improved by using psychological interventions, like social skills training (SST) (Elis et al., 2013). Also, mHealth applications could address negative symptoms in SSD. In the last few decades, various models of psychological interventions have been developed and implemented as an adjunct to medical treatments. Current treatment options are CBT, psychoeducation, family therapy, SST, and cognitive remediation therapy (Chien & Yip, 2013).

Both types of interventions, medical and psychological interventions, have in common that there is less treatment adherence for patients with SSD than for patients who are suffering from other mental health problems. Adherence can be defined as the “active, voluntary, and collaborative involvement of the patient in a mutually acceptable course of behavior to produce a therapeutic result” (Ho et al., 2009). There are several aspects that make treatment adherence in general especially challenging in SSD. These include limited illness awareness, social isolation, comorbid substance abuse, and stigmatization (Haddad et al., 2014). A systematic review of 39 studies reported a mean rate of medication nonadherence in schizophrenia of 41% (Lacro et al., 2002). This is problematic because, for an optimal effect of antipsychotic medication, they must be used uninterrupted for longer periods of time, otherwise the occurrence of psychotic symptoms gets more likely. Furthermore, nonadherence to psychological treatment can also lead to a lack of quality of life, e.g., when social withdrawal and lack of motivation remain symptoms in their daily life. A way of increasing treatment adherence, in general, could be integrating mHealth applications into clinical practice.

Objective of this Review

As was discussed above, people with SSD have severe problems with participating in society, because of impairing symptoms like hallucinations and delusions. It is necessary and important, that they get a chance for improvement and recovery. Furthermore, dealing with stigmatization threats their quality of life, as well as treatment adherence. On top of this, many patients but also clinicians are still skeptical about using technologies in clinical practice and do not consider it a viable option. All these barriers stand in the way of treatment in a group that actually needs treatment in any case. Integrating mHealth applications into clinical practice, as well in the daily lives of patients, could improve the whole therapy process. Due to treatment gaps like social isolation that leads to treatment adherence, and concerns about technology, there is a need to clarify the current options of mHealth applications, as well as how these applications can be implemented in mental health care, to further improve therapy outcomes for people who are suffering from SSD.

The current research paper aims to provide an overview of the state of art on how mHealth applications for people with SSD are integrated into clinical practice. Therefore, the following research questions arise:

How is mHealth integrated into clinical practice for patients with SSD?

The research question is divided into the following two sub-questions:

(1) What types of mHealth applications exist for people with SSD?

(2) What are the goals of the existing types of mHealth applications for people with SSD?

Methods

The present literature review can be classified as a scoping review. A scoping review is a way of mapping the key concepts that underpin a research area (Peters et al., 2015). More specifically, this process enables identifying types of available evidence in a given field, clarifying key concepts in literature, identifying key characteristics or factors related to a concept, and identifying and analyzing knowledge gaps (Munn et al., 2018). The conduction of the current scoping review is based on the preferred reporting items for systematic and scoping reviews (Tricco et al., 2018).

Search Strategy

Relevant databases for the current literature review are *Web of Science*, *EBSCO*, and *Scopus*. In *EBSCO* the following databases were used: *APA PsychInfo*, *Psychology and Behavioral Science Collection*, *Library, Information Science & Technology Abstracts* and *APA PsychArticles*. The topic of the present review integrates psychological, and technological aspects, whereas the databases combine the different domains, so focusing on more than one domain was estimated as representative. The search was performed on the 20th of March 2022. The concepts “schizophrenia” and “mHealth applications” served as the basis for the constructed search string. Based on the two concepts, related search terms emerged as follows: (schizophrenia OR psychosis OR psychoses OR psychotic disorder OR schizophrenic disorder or delusional disorder) AND (mhealth OR mobile health OR m-health OR mobile app OR mobile application OR smartphone application OR app OR apps). The search revealed overall 799 articles. After removing duplicates, an overall of 643 articles remained.

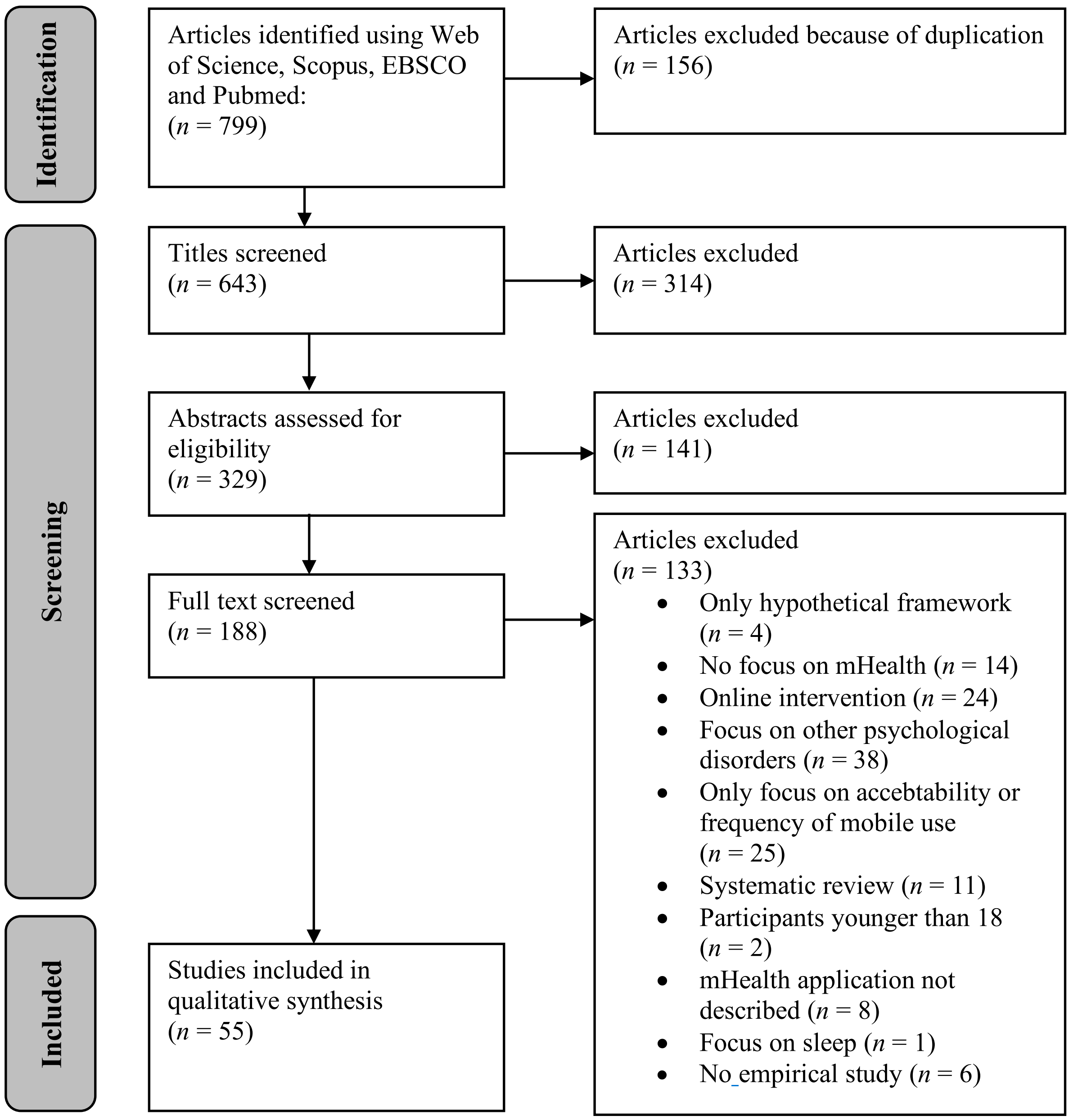
Selection and Exclusion Criteria

The extraction of data was based on the PRISMA Checklist (Tricco et al., 2018). In the first step general information of each article such as author, year of publication, and abstracts were recorded in *EndNote 20* (The EndNote Team, 2013). The search only included papers in English or German. Secondly, only peer-reviewed Academic Journals were accessed. Furthermore, only studies with adult patients, aged 18 or older, were included. Only original publications of empirical studies, pilot studies, and design projects were included. Systematic or scoping reviews, as well as interviews and focus groups, were excluded. Additionally, only publications from the last five years were included. This time frame was chosen to ensure the inclusion of novel and up-to-date methods and modern mHealth applications.

643 titles were screened and checked for eligibility. 314 articles were excluded after their titles were screened. Excluded were titles that dealt with the consequences of Covid-19, other psychological disorders, antipsychotic polypharmacy, genetics, and articles that present mHealth applications in general. After that, all abstracts were screened for eligibility. Studies were excluded when SSD was part of a study that focused on severe mental illness because this review focuses explicitly on SSD and not on severe mental illness in general, where also severe, major depression is included. Furthermore, papers were excluded, when their focus was on other topics, like smoking cessation, ethnic identity, and veterans. Subsequently, 188 full texts were screened. Reasons for excluding articles are shown in Figure 1. After the inclusion of eligible studies, relevant data were extracted, which will be presented in the result section.

Figure 1

PRISMA flow diagram for article selection on the topic mHealth applications and schizophrenia spectrum disorder



Results

The studies were published between 2017 and 2022. The sample sizes in the included studies ranged from 5 to 1139 patients (*M* = 96). All studies have in common that the patients experienced a form of psychosis, whose symptoms can thus be classified as part of the SSD.

The duration of the interventions ranged from 3 hours to 19 months (*M* = 18 weeks). All in all, there were 25 experimental studies, 13 randomized controlled trials, 9 pilot studies, 5 design projects, 1 mixed-method design, 1 experience sampling study, 1 observational study, and 1 qualitative study. In total, 31 different mHealth applications were used in the studies. A further classification of the study designs is presented in Table 1. It should be mentioned that not every study mentioned their used study design.

It should be also noted here that there was no information in the integrated studies if the presented mHealth application is already integrated into the mental health care system. Furthermore, there was no information given on how one can download and access the several mHealth applications, neither for working clinicians nor for patients. In the following, the results regarding the two sub-research questions will be presented. For reasons of space and for legible reasons, only some of the studies will be presented in detail. Table 1 shows an overview of all studies that were included in this thesis.

Types of mHealth Applications

The studies used different types of mHealth applications for people with SSD. Locally, types of mHealth applications can be defined as use case scenarios in clinical practice. Table 1 shows 4 different types of mHealth: Data collection, Add-on Treatment, Outpatient, and Inpatient. Data collection does mean, that the authors used the data for their academic research purposes to answer research questions. Add-on treatment means that the mHealth application can be used as an additive intervention that is integrated into a face-to-face psychological treatment, whereas the other mHealth types can be seen as independent interventions, that can be used as a distinctive adjunct to other treatments. Some of the mHealth applications can be used for outpatients, who are receiving an ambulatory treatment or when they are living at home and discharged from the hospital. MHealth applications for inpatients mean, that these applications can be used in a clinical setting as a distinctive adjunct to their treatment possibilities. It cannot be ruled out that some of the applications could be used in more than one setting. The information regarding their type of use is referring to the information given in the studies based on their study sample.

Most of the mHealth interventions were used for outpatients, in total 41 of the applications. In 20 studies the mHealth applications were used for data collection for research purposes. 13 mHealth applications were used inpatient. The mHealth application functioned as an add-on treatment 5 times. In the following, the goals of the mHealth applications are described.

Goals of mHealth Applications

The different mHealth applications are organized into categories by focusing on the goals. Categorizing the applications, it became clear that some of the applications have more than one goal. The presentation of the applications was based on their main goal, although all goals will be mentioned. 'Symptom and health monitoring' isn't presented as a goal, as it was more seen as a feature that helps to reach the main goals. The number of applications that targeted the specific goal is mentioned in brackets after the heading. There is also the number of applications that were presented in the result section.

Relapse Prediction and Prevention (17 applications; 3 presented)

The smartphone app *CrossCheck* was used in the studies of Ben-Zeev et al. (2017), Buck et al. (2021), Buck, Hallgren et al. (2019), and Buck, Scherer et al. (2019). The app can be used inpatient and outpatient. Its aim is to predict the relapse of patients with SSD by using Ecological Momentary Assessment (EMA) digital self-report questionnaires. The questionnaires are about symptoms of psychosis (e.g., hallucinations, persecutory ideation), general mental health (e.g., stress, depression, hopefulness, clarity of thought), and functioning (e.g., socialization, sleep). Furthermore, the system of the app uses behavioral sensing. Behavioral sensing data consists of data from measurements of the physical activity of the user, geospatial activity, speech frequency and duration, telecommunication, duration of app use, and phone unlock. The collected data is sent to the clinicians of the patient to evaluate the data. If a patient gives answers that lead to worrying over several reports, they are placed on a watching list and are closely monitored by clinicians. In weekly clinical meetings, the data is discussed, after which clinicians or therapists decide if it is necessary to reach out to the patient. The clinical meetings are organized by the clinician who is responsible for the patient. The results of the study by Buck, Hallgren et al. (2019) claim that persecutory ideation can be detected by the behavioral sensing data that is collected by the *CrossCheck* app, including reductions in moving or traveling, and time spent around others or on phone conversations. Buck, Scherer, et al. (2019) found that reductions in the number and duration of outgoing calls, as well as the number of text messages, were associated with relapses in SSD. Buck et al. (2021) found that brief symptom surveys of psychotic symptoms detect meaningful signals that precede psychiatric relapses.

RedCap is a smartphone app that was used in the study by Lahti et al. (2021). In their study, they also used a wearable device, the *Garmin Vivofit,* and the *Philipps Actiwatch*. The smartphone app was not connected to the wearables, however. The smartphone application can be used for outpatients. The goal is to predict relapses for patients with SSD by using symptom surveys and measuring the physical activity of the patient. On the *REDCap* app patients are asked to fill out self-assessments and symptom-tracking questionnaires. The results of the study by Lahti et al. (2021) indicate that the wearables and an app for symptom surveys could be effectively deployed and potentially used to monitor patients with SSD. The results also showed that metrics-based prediction models can assist in detecting earlier signs of symptom changes (Lahti et al., 2021).

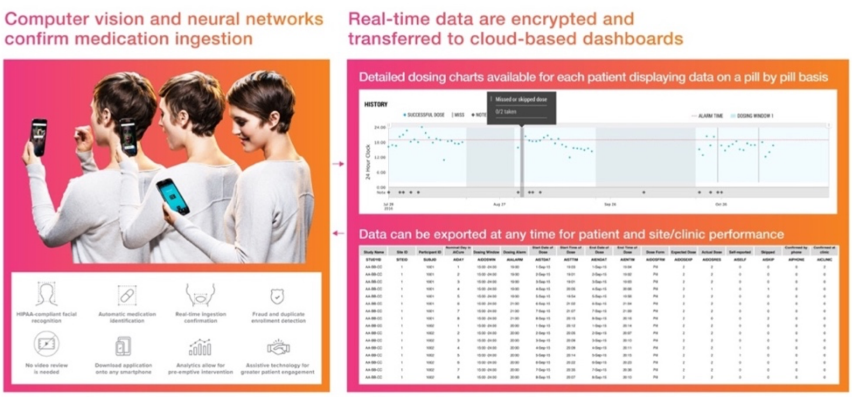
LEAN is a smartphone app that was used in the study by Xu et al. (2019). The app can be used for outpatients. Its goal is to increase medication adherence, but also to prevent patients with SSD from relapsing. The name of the app *LEAN* stands for the four program components: Lay health supporters, E-platform, Award, and iNtegration (Xu et al., 2019). The app offers medication reminders to the patient, provides health education, and symptom monitoring. The results of the study by Xu et al. (2019) have shown a 27% improvement in medication adherence.

Medication and Treatment Adherence (14 applications; 3 presented)

The smartphone and tablet app *AiCure* was used in the study of Bain et al. (2017). *AiCure* can be used inpatient and outpatient. *AiCure* is an artificial intelligence platform that visually confirms medication ingestion (Bain et al., 2017). The goal of the app is to increase the medication adherence of patients with SSD. The app uses facial recognition. Software algorithms can identify the patient, and the drug and confirm ingestion, more about it is shown in Figure 2. Date and time are saved after the patient has taken the pill. The app collects different categories of adherence (visual confirmation; self-reported dose; missed dose; dose taken in clinic) (Bain et al., 2017). After each dosing, encrypted data is sent to a cloud-based dashboard for real-time monitoring that can be viewed by clinicians. The results of the study by Bain et al. (2017) indicate the potential of *AiCure* to increase adherence, detect nonadherence and predict future nonadherence. Patients who participated in the study and used *AiCure* demonstrated a percentage change in adherence of 25%.

Figure 2

Presentation of the visual medication ingestion (Bain et al., 2017)



ReMindCare is another smartphone app that was used in the study of Bonet et al. (2020). The app can be used for outpatients. Its goal is to monitor the patients' health, as well as to increase medication adherence. To do so, the app contains different questionnaires. There are three daily questions assessing levels of anxiety, sadness, and irritability. The weekly questionnaires aimed at assessing adherence to medication, the presence of side effects from antipsychotic medication intake, the attitude toward medication intake, and the presence of early psychosis symptoms (Bonet et al., 2020). For clinicians, it is possible to receive an alert by email in case of low engagement (not responded to for seven days) or abrupt changes in survey responses from the patients. The results of the study by Bonet et al. (2020) highlight the potential benefits of this mHealth intervention. Patients who used the app had significantly fewer relapses and fewer hospitalizations (Bonet et al., 2020).

Beebe et al. (2017) and Uslu & Buldukoglu (2020) presented the *Telephone Intervention Problem Solving* (TIPS), a telenursing application. Telenursing refers to the use of technology in the provision of nursing services when there is a physical distance between the patient and nurses. For this intervention, smartphones were used. This mHealth application can be used for outpatients. Its aim is to increase medication adherence. TIPS is conducted with weekly telephone interviews that contain several topics: (1) medication intake, (2) next appointments, (3) symptoms, (4) alcohol or drugs, (5) social life, (6) questions about anything this week, (7) other topics the patient wants to talk about. Furthermore, nurses provide information, e.g., about the benefits and values of medication adherence (Uslu & Buldukoglu, 2020). The results of the study by Beebe et al. (2017) showed higher medication adherence for patients compared to a control group. Uslu & Buldukoglu (2020) also found in their study that medication adherence scores were higher in the intervention group.

Self-Help Strategies and Illness-Management (10 applications; 2 presented)

The smartphone app *TechCare* was used in the study by Gire et al. (2021). The app can be used for outpatients but was also used for data collection. Its aim is to provide self-help strategies to patients with psychosis and to increase medication adherence. The app alerts patients via notifications to answer a series of questions. Based on their answers, the app provides a tailored CBT-based intervention, which could include patients' preferred multimedia such as music, images, or videos. The app uses Experiential Sampling Methodology (ESM) as a research methodology, which allows patients to record, subjective experiences in real-time about different kinds of topics (Gire et al., 2021). The results of the study by Gire et al. (2021) have shown that *TechCare* is an acceptable and feasible mHealth intervention for patients with psychosis.

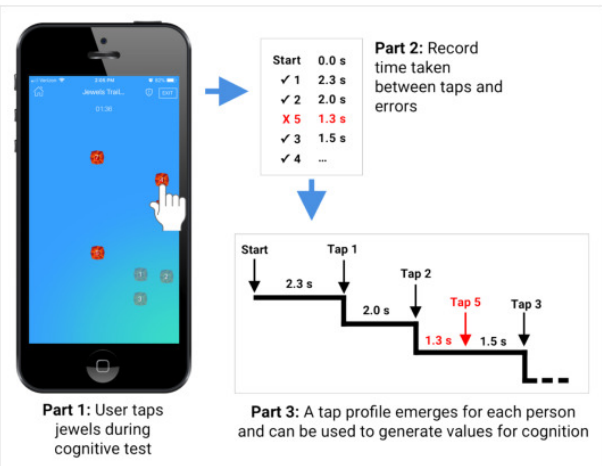
The smartphone app *MindFrame* was used in the study by Terp et al. (2018). The app can be used for outpatients. Its aim is to provide illness self-management and psychoeducation. The app is affiliated with a website to support collaboration with health care providers of the patient. Patients are required to fill out a self-assessment on the app. With the data of these assessments, the system can identify triggers and early warning signs. If this is the case, the patient and the clinician will be notified. The results of the study by Terp et al. (2018) indicated that young adults with SSD are amenable to using a smartphone app to monitor their health, manage their medication, and stay alert to the early signs of illness exacerbation.

Cognitive Performance and Skills (9 applications; 2 presented)

The smartphone app *mindLAMP* or also called *LAMP* was used in the studies by Kalinich et al. (2022), Liu et al. (2019), and Shvetz et al. (2021). The app can be used for outpatients. The goal is to improve cognitive functioning for patients with SSD. The app combines cognitive tests, symptom surveys, and environment tagging, which are also called actively collected data. Passive data like GPS, calls and text logs are also collected. The app offers to journal, a medication tracker, a safety plan, guided meditation, and a goal setter. In their studies on the *mindLAMP* app, Kalinich et al. (2022), Liu et al. (2019) and Shvetz et al. (2021) concentrated on the cognitive test – *The Jewel Pro Game* or also called *Jewels Trail Test*, which is integrated with the app. It is a game that trains executive functioning. Through machine learning, it is also possible for clinicians to assess executive functioning in people with SSD. While playing the game, the screen shows numbered jewels in random order. The patient should tap on them as quickly and accurately as possible, more about it is shown in Figure 3. Kalinich et al. (2022) tested whether the data that is collected by the *mindLAMP* app can also be used to categorize users and identify those with SSD. For this purpose, they employed machine learning. The results of the study by Kalinich et al. (2022) indicate that machine learning can accurately identify patients with schizophrenia versus healthy controls. The results of the study by Liu et al. (2019) showed it is feasible for patients with SSD to use their smartphones to complete cognitive assessments. Furthermore, patients with SSD achieved lower scores in more complex assessments than the control group. The results of the study by Shvetz et al. (2021) support the initial accessibility, validity, and reliability of using the *Jewels Trail Test* to measure cognition in SSD.

Figure 3

Jewels Trail Test (Liu et al., 2019)



The smartphone and tablet app *SlowMo* was used in the study by Hardy et al. (2018). The app can be used as an add-on treatment. The *SlowMo* app aims to help the patient to build metacognitive skills of noticing thoughts and thinking habits, but also adherence. The treatment program of the app contains eight individual, face-to-face sessions between the therapist and the patient that are supported by a tablet or a laptop. These sessions are assisted by a website with interactive stories and games, to help people find out how fast thinking habits can contribute to upsetting thoughts. The mobile app supports the use of different strategies in daily life. People can try out tips to learn what helps them slow down their thinking and cope with worries. There are modules about psychoeducation and normalizing stories of others, that may help to contribute to a feeling of coherence with others. There is also the possibility to skip content to allow tailoring to the patients' needs. The results of the study by Hardy et al. (2019) have shown that the *SlowMo* app is feasible, the efficacy was tested in a different study.

Social Goals (8 applications; 2 presented)

App4indipendence is a smartphone-based app that was used in the study by Kidd et al. (2019). It can be used inpatient and outpatient treatment. Its goal is to target social isolation for patients with SSD and can be used for symptom monitoring. Furthermore, the app uses sound detection for hallucination coaching (self-help strategies) and gives the user reminders on when to take their medication, in order to increase medication adherence. The patient can use the sound detector when he or she hears voices. So, the patient can check if these voices are also recognizable to others or not. The CBT-based content addresses four main topics: (1) living with schizophrenia, (2) social activation, (3) stress and anxiety, and (4) motivation and cognition. Social isolation is addressed through personalizing prompts, scheduling of activities, and connections through a range of resources relevant to social engagement. The app also includes a peer-peer engagement platform, where patients can connect with each other. The results of the study by Kidd et al. (2019) indicated significant improvement in some psychiatric symptoms of people with SSD. There was no significant change in recovery engagement and medication adherence. Patients' satisfaction with the app was high.

+Connect is a smartphone app that was used in the study by Lim et al. (2020). The app can be used for outpatients. Its main goal is to target social isolation for patients with SSD. The content of the app is based on positive psychology interventions. First, when patients open the app, they are asked to log their moods via a mood evaluation tracker. They are proceeded to the tasks which are delivered in four ways: (1) via text and images; (2) through shared experience videos, (3) through expert videos featuring academics introducing core concepts, and (4) actor videos who model a range of social behaviors. After patients accessed daily videos, they were given a task to answer questions in relation to the material, taking under a minute to complete. This gamification feature aims to encourage engagement. The content differs every day and depends on the day the patient used the app and, on their level, e.g., Level 5, Day 10-12 is a Gratitude module. The results of the study by Lim et al. (2020) indicated that *+Connect* yielded high levels of acceptability and feasibility.

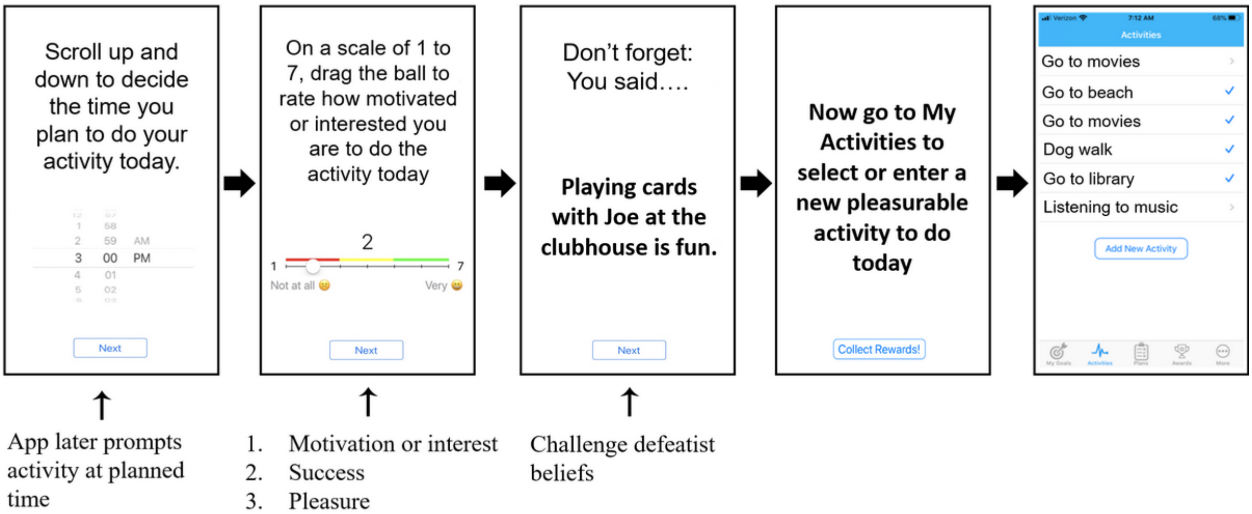
Reducing Symptoms (5 applications; 2 presented)

FOCUS-AV is a smartphone app that was used in the study by Ben-Zeev et al. (2018). The app can be used for outpatients. One of the goals is to reduce psychotic and depressive symptom severity in patients with schizophrenia by offering illness management interventions. These interventions target auditory hallucinations, social functioning, medication use, mood problems, and sleep disturbances. The interventions are structured in different modules in which patients are asked to rate their clinical status daily using multiple-choice options. Illness management suggestions are delivered in written text and images. Next to *FOCUS-AV,* there is also the app *FOCUS*, which also includes all features of the *FOCUS-AV* app. The *FOCUS-AV* app contains on-top video adaptations for all the *FOCUS* content (Ben-Zeev et al., 2018). The videos show a trained clinician who offers shortened versions of illness management strategies that would typically be administered in the context of live therapy (e.g., relaxation). The results of the study by Ben-Zeev et al. (2018) have shown that *FOCUS-AV* is a feasible, usable, and acceptable video-based mHealth application for people living with schizophrenia (Ben-Zeev et al., 2018).

CBT2go is a smartphone app that was used in the study by Granholm, Holden, Dwyer, et al. (2020. The app can be used as an add-on treatment for face-2-face therapy. Its goal is to decrease negative symptoms in patients with SSD by using several CBT-based exercises. Therefore, the app integrates skill-based interventions including recovery goal setting, thought challenging, scheduling of pleasurable activities and social interactions, and pleasure-savoring interventions. Furthermore, the app uses personalized statements developed in groups to challenge social disinterest and defeatist attituded in real-time. These statements are entered by the therapist of the patient. Figure 4 shows how these personalized statements are used to challenge low expectation ratings of motivation. Besides this, the patient also can create an action plan, of which behavioral experiments are part of it. The results of these experiments can be discussed in the actual therapy session. The results of the study by Granholm, Holden, Dwyer, et al. (2020) have shown a high frequency of use. Furthermore, the severity of defeatist attitudes and experiential negative symptoms declined significantly in the experimental group with large effect sizes.

Figure 4

Screenshots of the CBT2go app (Granholm, Holden, Dwyer et al., 2020)



Note. Low motivation, high defeatist attitudes, or low anticipatory pleasure ratings triggered personalized reappraisal evidence. A separate My Activities tool was used to plan and savor activities (see Granholm, Holden, Dwyer, et al., 2020).

Coping Strategies (3 applications; 1 presented)

Actissist is a smartphone-based app that was used in the studies by Berry et al. (2020) and Bucci et al. (2018). The app targets patients who have experienced the first episode of psychosis. The app can be used inpatient. The content of the app suggests ways of coping with difficult experiences in the patients' life. The contents of the app are CBT-based. The app is divided into two parts. Firstly, patients are invited to complete a series of self-assessment questions about cognitive appraisals, belief conviction emotions, and associated behaviors. Depending on the selected appraisal, the app offers cognitive or behavioral strategies aimed at suggesting ways of coping. This functions as the CBT-informed content. The second part of the app is a menu with different multi-media options, e.g., relaxation and mindfulness exercises, recovery stories, a range of fact sheets, links to web-related content, daily diaries, and emergency contacts. Furthermore, the app provides a graphical summary of data points entered over the previous seven days. There is also the possibility for patients to personalize the app, e.g., with meaningful personal images that can be set as wallpaper (Bucci et al., 2018). The results of the study by Bucci et al. (2018) have shown that *Actissist* is a feasible and acceptable app for early psychosis patients. Berry et al. (2020) only reported their results of multidisciplinary work on the development of *Actissist*, which led to several changes and features that were added to the platform.

Diagnostics (3 applications; 1 presented)

Ilumivu is a program for EMA surveys that was used in the study by Raugh et al. (2020). The study sample were outpatients and the platform *Ilumivu* was used for data collection. Their goal was to examine if geolocation can be used as a digital phenotyping measure of negative symptoms. The smartphones are used to collect the geolocation of the patient every ten minutes. Furthermore, the patients use their smartphones to fill out EMA surveys. The EMA surveys examine information about current location, activity, and social interaction. The items are designed to measure avolition, asociality, and anhedonia, common negative symptoms in SSD. The results of the study by Raugh et al. (2020) indicate that geolocation is a reliable and valid objective measure of negative symptoms and functional outcomes. Patients with SSD have shown less activity than the control groups.

Table 1

Study characteristics

	Authors	Disorder	Sample Size	Study Design	Duration	Modality	Case scenario	Goal	Characteristics
1	Achtyes et al. (2019) (USA)	Chronic SSD	*N* = 368	ES (Prospective, multicenter longitudinal study)	6 months	Smartphone (Android) (*FOCUS*)	Outpatient	Relapse prevention SM	Guidance for Medication, Mood, Social, Sleep, Voices
2	Atkins et al. (2017) (USA)	Schizophrenia	*N* = 48	ES (Single study visit)	3 hours	Tablet (iOS) (*BAC*)	Inpatient Data collection	Diagnostics (Cognitive impairment)	Audio recording feature + tests about verbal memory, working memory, motor function, verbal fluency, speed of processing, executive functions
3	Bain et al. (2017) (USA)	Schizophrenia	*N* = 431	PS (Multicenter, randomized, double-blind, placebo-controlled, parallel-group study)	6 months	Smartphone (iOS & Android) (*AiCure*)	Inpatient Outpatient	MA	Visual confirmation of medication ingestion + Self-reported medication dose (Missed dose, skipped dose, Dose taken in clinic)
4	Barnett et al. (2018) (USA)	Schizophrenia	*N* = 17	PS	3 months	Smartphone (iOS & Android) (*Beiwe*)	Inpatient Outpatient	Relapse prediction SM	In-app symptom surveys + Collects data from GPS, accelerometer, anonymized calls, screen on/off time, phone charging status

5	Beebe et al. (2017) (USA)	SSD	*N* = 105	RCT	6 months	Smartphone (*TIPS*)	Outpatient	MA	Manualized telephone nursing intervention addresses: knowledge of medication, attending appointments, coping with symptoms, abstaining from substances, social support
6	Ben-Zeev et al. (2017) (USA)	Schizophrenia schizoaffective disorder psychosis	*N* = 5	RCT	12 months	Smartphone (Android) (*CrossCheck*)	Inpatient Outpatient	Relapse prediction	EMA Self-report questionnaires + collects multimodal behavioral sensing and device use data (physical activity, geospatial activity, speech frequency, telecommunication, App use, phone unlock)
7	Ben-Zeev et al. (2018) (USA)	Schizophrenia schizoaffective disorder	*N* = 10	MMD	1 month	Smartphone (Android) (*FOCUS-AV*)	Outpatient	Reducing psychotic and depressive symptoms Illness-management	Written interventions or video versions
8	Berrouiguet et al. (2017) (Spain)	SSD	*N* = 353	PS (Multicenter, nonrandomized, observational feasibility study)	4 months	Smartphone (–) (*MEmind*)	Inpatient	SM Relapse prediction	EMA + monitoring and analyzing practitioners' antipsychotic prescription habits and linking these data to inpatients' symptom changes
9	Berry et al. (2021) (UK)	Schizophrenia	*N* = 30	ES (Cross-sectional study)	1 week	Wearable + Smartphone (Android)	Inpatient Data collection	Illness management	Examines physical activity and sleep time +

						(*SleepBot* App)			record movements and sounds during sleep
10	Berry et al. (2020) (UK)	Early psychosis	*N* = 13	DP (Qualitative focus groups and interviews; qualitative interviews; Expert reference group)		Smartphone (Android) (*Actissist* App)	Inpatient	Coping strategies	Questionnaires about cognitive appraisals, belief conviction, emotions, associated behaviors + menu of multimedia options (relaxation, mindfulness, recovery stories, fact sheets, TEDTalks, daily diary, emergency contact resources)
11	Bonet et al. (2020) (USA)	Early psychosis	*N* = 90	ES (Usability study)	19 months	Smartphone (Android) (*ReMindCare*)	Outpatient	MA Health monitoring	Daily questionnaires about anxiety, sadness, irritability + weekly questionnaires about MA, side effects from antipsychotic medication, attitude toward medication intake, presence of prodromal psychosis symptoms
12	Bucci et al. (2018) (UK)	Early psychosis	*N* = 36	RCT	12 weeks	Smartphone (Android) (*Actissist* App)	Inpatient	Coping strategies	Questionnaires about cognitive appraisals, belief conviction, emotions, associated behaviors + menu of multimedia options (relaxation, mindfulness, recovery stories, fact sheets, TEDTalks, daily

									diary, emergency contact resources)
13	Buck et al. (2021) (USA)	Schizophrenia, schizoaffective disorder, psychosis	*N* = 61	RCT	12 months	Smartphone (Android) (*CrossCheck*)	Inpatient Outpatient Data collection	Relapse prediction SM	EMA questionnaires + collects multimodal behavioral sensing and device use data (physical activity, geospatial activity, speech freqeuency, telecommunication, App use, phone unlock)
14	Buck, Hallgren, et al. (2019) (USA)	SSD	*N* = 62	ES	12 months	Smartphone (Android) (*CrossCheck*)	Inpatient Outpatient Data collection	Relapse prediction SM	EMA about mental health and functioning + collects multimodal behavioral sensing measures (physical activity, geospatial activity, speech frequency and duration, device use measures)
15	Buck, Scherer, et al. (2019) (USA)	SSD	*N* = 61	RCT	12 months	Smartphone Android) (*CrossCheck*)	Inpatient Outpatient Data collection	Relapse prediction SM	EMA about mental health and functioning + collects multimodal behavioral sensing measures (physical activity, geospatial activity, speech frequency and duration, device use measures)
16	Cella et al. (2019) (UK)	Schizophrenia	*N* = 14	ES	10 days	Wearable + Smartphone (iOS + Android) (*ClinTouch*)	Inpatient Outpatient Data collection	Relapse prediction SM	Collects physiological and behavioral measures including heart rate, motion, EDA and skin temperature + Symptom self-assessment

17	Cella et al. (2018) (UK)	Schizophrenia	*N* = 30	ES (Cross-sectional study)	6 days	Wearable	Data collection	Relapse Prediction SM	EDA + Blood volume pulse + Acceleration
18	Dabit et al. (2021) (USA)	Schizophrenia schizoaffective disorder	*N* = 24	RCT	9 weeks	Smartphone (iOS) (*CLIMB*)	Outpatient	Social goals	Integrates neuroplasticity based SCT with an experimental intervention that pairs EMA of emotional and cognitive status with group therapy video sessions and IM
19	De Almeida et al. (2018) (Portugal)	Schizophrenia	*N* = 9	PS (Quantitative pre-experimental research emplying pretest and posttest design)	8 weeks	Smartphone (–) (*weCope* App)	Outpatient	Illness self-management	4 Modules: Symptom monitoring module (CBT), Problem solving module, Anxiety management module, Goal setting module
20	Dupuy et al. (2022) (France)	Schizophrenia	*N* = 33	PS (Controlled investigation)	1 week	Smartphone (Android)	Outpatient Data collection	Cognitive performance Relapse prediction	EMA about Physical location, Activity, Mood states, Experience of positive psychosis symptoms + Stroop test
21	Eisner et al. (2019) (UK)	SSD	*N* = 18	ES (Cross-sectional phase; prospective, longitudinal phase; qualitative interviews)	6 months	Smartphone (Android) (*ExPRESS*)	Data collection Outpatient	Relapse prediction SM	Questionnaires about psychotic symptoms + mood symptoms + basic symptoms + early signs of relapse
22	Fichtenbauer et al. (2019) (Austria)	Schizophrenia schizoaffective disorder	*N* = 10	PS	8 weeks	Tablet + Smartphone (iOS + Android) (*DIALOG*+)	Add-on treatment	Reducing symptoms	Evaluation of satisfaction in 8 areas of life and 3 treatment aspects

23	Fulford et al. (2020) (USA)	Schizophrenia schizoaffective disorder	*N* = 8	DP (Interviews; usability testing; pilot testing)	2 weeks	Smartphone (Android) (*MASS*)	Outpatient Data collection	Social goals	Targets 11 different social goals based on SST + EMA about affect and motivation
24	Fulford et al. (2022) (USA)	Schizophrenia schizoaffective disorder	*N* = 31	PS (Open pilot intervention study)	8 weeks	Smartphone (Android) (*MASS*)	Outpatient Data collection	Cognitive Performance Adherence	Questions on social behavior, social goals + SST videos
25	Gire et al. (2021) (UK)	Psychosis	*N* = 28	MMD	10 months	Smartphone (–) (*TechCare*)	Outpatient Data collection	MA Self-help strategies	ESM + intelligent Real-Time therapy + CBT tailored interventions
26	Granholm, Holden, Dwyer, et al. (2020) (USA)	Schizophrenia schizoaffective disorder	*N* = 31	ES (Single-arm, open-trial, pre-post evaluation)	24 weeks	Smartphone (iOS) (*CBT2go* App)	Add-on treatment	Reducing negative symptoms	Skill-based interventions including recovery goal setting, thought challenging, scheduling of pleasurable activities and social interactions and pleasure-savoring interventions
27	Granholm, Holden, Mikhael, et al. (2020) (USA)	Schizophrenia schizoaffective disorder	*N* = 82	ES (ESM)	7 days	Smartphone (Android) (*Samplex*)	Data collection Outpatient	Social goals	EMA about functioning behaviors
28	Hanssen et al. (2020) (Netherlands)	SSD	*N* = 64	ES (ESM)	3 weeks	Smartphone (Android) (*SMARTapp*)	Outpatient	Health monitoring Social goals	ESM about symptoms, social activities and mood + general questions about the day
29	Hardy et al. (2018) (UK)	Nonaffective psychosis	*N* = 14	DP (Inclusive, user-centered design research)	12 weeks	Smartphone + Tablet (Android) (*SlowMo* / *Native*)	Add-on treatment	Metacognitive skills Adherence	Thought record (CBT) 8 f2f-sessions supported by a tablet Native app: providing a bridge between therapy

									meetings and everyday life Unlocking new content based on learning topic in webapp
30	Kalinich et al. (2022) (USA)	Schizophrenia	*N* = 25	ES	90 days	Smartphone (iOS + Android) (*mindLAMP* App)	Outpatient	Cognitive skills Diagnostic	Jewels Pro game, an instrument for assessing executive functioning
31	Kidd et al. (2019) (Canada)	Psychosis	*N* = 211	ES (Pre-post design, examining implementation, clinical outcomes, satisfaction outcomes)	1 month	Smartphone (iOS + Android) (*App4indipendence*)	Inpatient Outpatient	Social goals SM Self-help strategies MA	Addresses four main topics: (1) living with schizophrenia, (2) social activation, (3) stress and anxiety, and (4) motivation and cognition + Daily wellness and goal attainment check-ins + Passively collected data on phone use as a proxy for sleep and activity levels
32	Kim et al. (2018) (Korea)	Early psychosis	*N* = 24	DP	1 day	Smartphone (iOS + Android) (*HYM*)	Add-on treatment	Illness management SM	3 theoretical models: CBT, vulnerability model, early intervention model 6 main modules: Thought record, symptom record, daily life records, official notices, communication and scales
33	Kimhy et al. (2020) (USA)	SSD	*N* = 54	ES	36 hours	Mobile Device (–)	Data collection	Reducing symptoms	ESM about suspiciousness, thought insertion, mind reading, auditory and visual hallucinations

34	Kimhy et al. (2017) (USA)	Schizophrenia or related disorders	*N* = 40	ESM		Mobile Device + Wearable (–)	Data collection	Reducing symptoms	ESM about severity of momentary auditory hallucinations + recording of cardiac autonomic regulation
35	Krzystanek et al. (2019) (Poland)	Paranoid schizophrenia	*N* = 290	ES (Multicenter, open-label randomized trial)	12 months	Smartphone (Android) (*MONEO*)	Outpatient	Cognitive functioning MA	Cognitive training (Cognitive remediation therapy) + medication reminder
36	Krzystanek et al. (2020) (Poland)	Paranoid schizophrenia	*N* = 290	ES (Multicenter, open-label randomized trial)	12 months	Smartphone (Android) (*MONEO*)	Outpatient	Cognitive functioning MA	Cognitive training (Cognitive remediation therapy) + medication reminder
37	Lahti et al. (2021) (USA)	Schizophrenia schizoaffective disorder	*N* = 40	OS	4 months	Wearable + Smartphone (–) (*Ginger* / *REDCap*)	Outpatient	Relapse prediction	Tracking of ambulatory activity, tracking sleep, apps for self-assessment & symptom tracking
38	Lewis et al. (2020) (UK)	Schizophrenia	*N* = 181	RCT	12 weeks	Smartphone (Android) (*ClinTouch*)	Outpatient	Relapse prediction Relapse prevention	Rate symptoms several times a day + uploads these in real time to a secure central server
39	Lim et al. (2020) (Australia)	Psychotic disorder	*N* = 12	PS	6 weeks	Smartphone (–) (+*Connect*)	Outpatient	Social goals	Mood evaluation + tasks delivered in 4 ways (text/images, SEVs, EVs, AVs) + PPI exercises
40	Liu et al. (2019) (USA)	Schizophrenia	*N* = 18	PS	12 weeks	Smartphone (iOS + Android) (*LAMP*)	Outpatient	Cognitive functioning	Jewels Pro Game + Survey assessment about clinical symptoms
41	Luther et al. (2020) (USA)	SSD	*N* = 56	RCT	8 weeks	Smartphone (–) (*MEMS*)	Outpatient	Self-help strategies	Reminder of smaller subgoals + encouragement that goal is worth the effort +

									assessment of subgoal completion
42	Meyer et al. (2018) (UK)	Schizophrenia	*N* = 15	ES	8 weeks	Smartphone + wearable (Android) (*SleepSight*)	Outpatient	SM Relapse prediction	Sleep diary + symptom diary
43	Minor et al. (2022) (USA)	SSD	*N* = 64	RCT	24 therapy sessions	EAR	Add-on treatment	Social goals	Collects behavioral samples at pre-programmed intervals using audio recordings
44	Moitra, Park, Ben-Zeev, et al. (2021) (USA)	SSD	*N* = 24	ES (EMA)	1 month	Smartphone (Windows) (*MyExperience*)	Outpatient Data collection	Relapse prediction SM	Surveys about Positive symptoms of paranoia, Positive and negative affect, Perceived social support, Functional impairment & quality of life, Alcohol, drugs, MA
45	Moitra, Park, & Gaudiano (2021) (USA)	SSD	*N* = 10	DP	1 month	Smartphone (iOS + Android) (*MACS*)	Inpatient	Adherence Coping	3 prompts + MACS session (5-10 min) about coping, substance use, symptoms, treatment adherence, behavioral activation, quality of life
46	Moran et al. (2018) (USA)	Schizophrenia	*N* = 30	ES (EMA)	1 week	Smartphone (Android)	Data collection Outpatient	Social goals	Emotional experience, daily social interaction, social interest
47	Niendam et al. (2018) (USA)	Psychosis	*N* = 76	ES	14 months	Smartphone (Android) (*Ginger.io*)	Outpatient	Illness Self-management SM	Collects active (self-report surveys) + passive data (steps etc.)
48	Raugh et al. (2020) (USA)	Schizophrenia schizoaffective disorder	*N* = 51	ES (Initial laboratory visit, digital	1 week	Smartphone (–) (*Ilumivu*)	Outpatient Data collection	Diagnostic	EMA + phone sensors to collect geolocation every 10 minutes

				phenotyping, final laboratory visit)					
49	Reinertsen et al. (2017) (UK)	Schizophrenia	*N* = 12	ES	4 weeks	Wearable + Smartphone (–)	Outpatient Data collection	Illness Self-Management	HR data, ECG-derived Accelerometry-derived locomotor activity data
50	Shvetz et al. (2021) (Canada)	Schizophrenia	*N* = 29	ES	3 months	Smartphone (iOS + Android) (*mindLAMPapp*)	Outpatient Data collection	Cognitive function	Jewels Trail Test + self-report mood and sleep quality surveys
51	Terp et al. (2018) (Denmark)	Schizophrenia	*N* = 98	QS (Third phase of a participatory design process)	12 months	Smartphone (iOS + Android) (*MindFrame*)	Outpatient	Illness Self-management SM	Self-assessment + Visualization / Psychoeducation + Early warning signs + Triggers and alerts + Action plan+ Medication overview+ Settings / customization of resources
52	Uslu & Buldukoglu (2020) (Turkey)	Schizophrenia	*N* = 45	RCT	2 months	Smartphone (*TIPS*)	Outpatient	MA	Medication + Next appointments + symptoms + alcohol/drugs + social + questions about the week
53	Valimaki et al. (2017) (Finland)	Psychosis	*N* = 1139	RCT	12 months	Smartphone (SMS)	Outpatient	MA Relapse prevention	Text messages regarding medication and treatment appointments
54	Xu et al. (2019) (China)	Schizophrenia	*N* = 271	RCT	6 months	Smartphone (–) (*LEAN*)	Outpatient	MA Relapse prevention	Medication reminders, health education, monitoring, awarding of token gifts for positive behavioral improvement
55	Zhu et al. (2020) (China)	Schizophrenia	*N* = 84	RCT	6 months	Smartphone (iOS + Android) (*WeChat*)	Outpatient	MA Relapse prevention	Reminders for taking medication + educational messages

Note. SSD = schizophrenia spectrum disorders; ES = experimental study; PS = pilot study; RCT = randomized controlled trial; MMD = mixed-methods design; DP = design project; ESM = experience sampling method; OS = observational study; QS = qualitative study; App = application;

MA = medication adherence; GPS = global positioning system; SMS = short messaging system; FOCUS-AV = FOCUS audio/video; BAC = brief assessment of cognition; AI = artificial intelligence; TIPS = telephone intervention problem solving; iOS = iPhone operating system; MASS = motivation and skills support; CBT = cognitive behavioral therapy; HYM = Heal your Mind; LAMP = Learn, Assess, Manage, Prevent; MEMS = Mobile Enhancement of Motivation in Schizophrenia; EAR = Electronically Activated Recorder; MACS = Mobile After-Care Support; LEAN = Lay health supporters, E-platform, Award and Integration; EMA = ecological momentary assessment; EDA = electrodermal activity; SCT = social competence training; IM = Instant Messaging; SST = Social Skills Training; f2f = face-to-face; SEV = shared experience videos; EV = expert videos; AV = actor videos; PPI = Positive Psychology Interventions; ECG = Electrocardiogram; CDSSs = clinical decision support systems; mHealth = mobile health; MERIT = Metacognitive Reflection and Insight Therapy; HR = Heart rate; SM = Symptom monitoring; (–) = no information about the operating system.

Discussion

The present scoping review aimed to explore existing treatment gaps in clinical practice for patients diagnosed with SSD and how mHealth applications could therefore be integrated into clinical practice. A current treatment gap for people with SSD is adherence to pharmacological and psychological treatment, e.g., because of the perception of stigmatization and as a result social isolation. Furthermore, people with SSD suffer from impairing symptoms that contribute to a lack of quality of life. Especially after crisis situations and discharge from the hospital, there is a need for the aftercare of the patients. To gather information necessary to gauge the sorts and extent of current gaps in treatments for patients with SSD, I searched for different use case scenarios of mHealth applications and their main treatment goals. Therefore, a scoping review that included 55 studies was performed.

Main Findings and Directions for Future Research

The first research question aimed at exploring types of mHealth applications, that further can be operationalized as *use case scenarios* of mHealth applications for people diagnosed with SSD. The results indicate that there are four different use case scenarios of mHealth applications. The mHealth applications could be used stand-alone in inpatient, outpatient settings, for data collection, or as a dedicated add-on to an existing treatment. The category of outpatient use also encompasses those patients who were discharged from the hospital, living at home, and/or don't receive any additional ambulatory treatment. Unfortunately, no further categorization was possible, as there was less information about the patients' current ambulatory treatment status or living situation. The results showed that mHealth applications can be used in several areas of clinical practice. Integrating mHealth applications, especially for outpatients could be important, as research has shown that people diagnosed with SSD are disadvantaged regarding ambulatory treatment. Data on outpatient treatment indicates an underrepresentation of patients with schizophrenia, at least in Germany (Schlier & Lincoln, 2016). Inadequate outpatient and semi-inpatient structures may favor hospital readmissions, hence mHealth applications could support these structures (Weinmann et al., 2009). In conclusion, mHealth applications for patients with SSD can be used in different areas of clinical practice.

The second research question aimed at exploring the goals of mHealth applications for patients with SSD. The review of the studies in this scoping review yielded eight types of goals the app could have: (1) Relapse prevention and prediction, (2) Medication adherence and treatment adherence, (3) Self-help strategies and illness-management, (4) Cognitive performance and skills, (5) Social goals, (6) Reducing symptoms, (7) Coping strategies, (8) Diagnostics.

In total, 14 mHealth applications aimed to improve medication or treatment adherence for people with SSD. As was discussed earlier, medication and treatment adherence seems to be a big problem for people with SSD (Fung et al., 2008), but there are already some applications that aim to fill in this treatment gap. Also, social isolation is one aspect that seems to influence treatment adherence in people with SSD (Haddad et al., 2014). Some of the existing mHealth applications targeted social isolation (Dabit et al., 2021; Fulford et al., 2020; Granholm, Holden, Mikhael, et al., 2020; Hanssen et al., 2020; Kidd et al., 2019; Lim et al., 2020; Minor et al., 2020; Moran et al., 2018), which could indirectly influence adherence, but is also relevant for increasing the quality of life of the patients. What also influences the quality of life of the patients are the symptoms that are accompanied by SSD. Negative symptoms could be reduced with the help of mHealth applications (Granholm, Holden, Dwyer, et al., 2020). Also, positive symptoms like auditory hallucinations were addressed by mHealth applications (Kimhy et al., 2020; Kimhy et al., 2017). Symptom monitoring seemed to be a goal that many of the mHealth applications included, but it was always combined with other goals, so it wasn’t considered as a stand-alone goal, but more as a feature that helps to reach the main goals. Nevertheless, this shows that symptom monitoring with EMA seems to be an important feature for mHealth applications for people with SSD, as so many applications included it.

As discussed earlier, many clinicians are still concerned about using technology in clinical practice (Feijt et al., 2008; Sharma et al., 2017). None of the studies that were integrated into the current scoping review, assessed the acceptability of the mHealth technology by clinicians. Indeed, some studies have shown promising results regarding schizophrenia patients’ acceptability of mHealth applications (see Lim et al., 2020). In further research, it could be useful to examine the clinician’s acceptance of mHealth applications to integrate into clinical practice. In their literature review, Rus-Calafell & Schneider (2020), pointed out that the view of clinicians should be taken into account when designing these tools. All the design projects, that were integrated into the current scoping review, involved clinicians that were involved in the process of designing an application. So, it is much more necessary to also include the clinicians' view in the next steps of implementing these applications into clinical practice. Therefore, more studies should be done considering the acceptability of clinicians about mHealth applications in general. Another next step would be offering more training about mHealth applications in psychiatric hospitals.

In none of the studies, there was information about which applications are already implemented in mental health care, which makes it difficult to answer the main research question, how mHealth applications are implemented in clinical practice. A few applications seem to be ready to be tested in clinical trials (see Kidd et al., 2019), but for most of them, only the feasibility and acceptability of the applications were examined. Integrating mHealth applications into clinical practice seems to need to overcome a lot of barriers to making these applications publicly. MHealth applications without evidence of their effectiveness won’t reach any attention of mental health services. Without attention, there won't be any change of laws regarding the use of mHealth in clinical practice. Integrating these applications isn't only a decision of practitioners in clinical care, also politicians and health insurances need to be integrated into the process of integrating mHealth into clinical practice. This process involves a lot of costs, here it may be unclear how these costs can be covered. Politicians and health insurance may also see a lot of risks by using mHealth applications. Apps are collecting bundled information, which can also include misinformation. This misinformation could lead to several sources of danger, e.g., if the information is used as a decision basis for diagnoses, which can lead to a wrong type of treatment. Also, ethical considerations are a big topic that needs to be covered during the process of integrating mHealth into clinical practice. To mention some, Data safety, and data privacy issues are very important areas that need to be considered in the process of using technology-based features in mental health care. These are areas that could be enlightened in a different kind of work. Not only clinicians themselves may be skeptical about using mHealth in practice, but also the attitude of the patients should be considered. It seems questionable if a patient who suffers from delusions, like several electronic devices are "reading his mind", is convinced that mHealth applications could help them. Therefore, it seems important to choose individually which patients with SSD would benefit from mHealth applications.

Referring to the main research question, it may be noted that a lot of mHealth applications were already designed for using them in clinical practice for patients with SSD, at least they are targeting important features that are necessary for patients with SSD. The applications target different goals and can be used in several areas of the mental health service system. Nevertheless, it seems that there are a lot of next steps necessary until mHealth applications for people with SSD can be used, inpatient and outpatient. For clinical practice, more randomized controlled trials should be done in examining the effects of mHealth applications. Also, single-case experimental designs (SCED) seem to be an important way of examining the effects of mHealth applications for mental health care. SCEDs seem to be a good way to examine treatment effectiveness, especially when the symptoms of a specific disorder are highly idiosyncratic in nature (Tanious & Onghena, 2019), which is indeed the case for patients diagnosed with SSD. None of the studies used a SCED as a study design. In general, it is hard to compare the results of the studies, as all studies used a lot of different study designs, which makes it hard to say something about the quality of the different apps. Not only the study designs were different, but also the apps themselves use different approaches for targeting SSD. It remains unclear, which of the chosen way of therapies, e.g., CBT, metacognitive therapy, and psychoeducation, are really helpful for the patients when mobile technologies are the choice of mediation. Regarding the big amount of several mHealth therapy options, patients, but also clinicians could get overwhelmed by this. This leads to the question, what way is the best to offer mHealth applications and how to find the right idiosyncratic mHealth intervention for a patient with SSD.

Another important point would be the enlightenment about the advantages of mHealth applications in psychiatric hospitals for clinicians, but also for patients. Another topic of concern is the availability of these mHealth applications for the target group: how can people with SSD download or access mHealth applications if no ambulatory treatment or other connections to the mental health system is there? The integrated studies in the current scoping review included no information about where, and how several apps can be downloaded and accessible. For further steps, there is a need to clarify if mHealth apps are available for everyone on an app store or if patients need to have a certificate from their responsible clinician or from the responsible mental health insurance.

Strengths and Limitations

The current scoping review displays strengths and limitations that need to be considered. The primary strength of this review is the copious and practical overview of different mHealth applications for people with SSD. This overview could be used for working clinicians to search for an existing application for their patients with specific needs, as the applications are sorted by their main goals and types.

A limitation of the current review is that not every study which was presented in Table 1 is described in the result section. The result section should only give some more detailed information about some applications ordered by their main goal. Furthermore, none of the included studies stated if the mHealth application is already used in clinical practice. So, the main research question, how mHealth applications are implemented in clinical practice, couldn't be answered. It could only be found that the applications already target important goals that are necessary for the treatment of patients with SSD.

Conclusion

The current scoping review has provided information on mHealth applications for patients diagnosed with SSD. All in all, it seems that the design of mHealth applications is already right in place and already fills in treatment gaps for patients with SSD. The applications target several important goals that are necessary for the right treatment for this population. On the other hand, it seems that these applications aren't ready yet to be implemented in clinical practice, as there is a lot of research on their effectiveness to do. Furthermore, the question remains open, if clinicians and therapists accept this kind of intervention and applications to implement in their daily work. Future work should concentrate on training for therapists and clinicians, and how mHealth applications can be used and integrated. Therapists and clinicians need to be enlightened about the opportunities and benefits of mHealth applications for patients with SSD. Although it couldn't be found out how mHealth applications are already implemented in clinical practice, this work provides a current overview of existing applications for patients with SSD.

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