A Scoping Review of the Application of Interactive Technology for Treating Hallucinations In Schizophrenia

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Abstract

Introduction: Schizophrenia is a severe and chronic brain condition that affects people's actions, thoughts, and perceptions of the world. This disorder has a serious impact on the well-being of the patients by, for example, leading to high treatment costs for the patient and often leading them to complete social isolation. They commonly experience hallucinations, which are percepts without corresponding external stimuli and cause severe distress. Current treatment methods have gradually shifted away from relying solely on drugs with limited efficacy and toward a greater role for technology. One popular approach is using smartphone apps to collect data regarding such hallucinations and the patients' well-being. This scoping review, which examined several databases on the topic, offers an overview of the interactive technology interventions now being used to monitor and treat hallucinations in schizophrenia, as well as information on their feasibility, acceptability, and effectiveness.

Methods: The studies were collected through three databases: Google Scholar, PubMed, and APA PsycNet. 11 studies were selected after establishing the exclusion and inclusion criteria and conducting a thorough search. Data was then extracted about the participant characteristics, the study characteristics in the form of the study designs and different types of interactive technological interventions, the effectiveness of those interventions and their relevant measurement instruments, and finally, the feasibility and acceptability of those interventions. The data were grouped and displayed in tables to better visualise the findings.

Results: The studies used a wide range of sample sizes. However, all studies included patients with schizophrenia who also experienced auditory hallucinations. The most popular technological intervention was AVATAR therapy, followed by smartphone apps. The pilot trial was also the most common study design. All technologies were feasible, and despite patients' concerns about their privacy, they also had a high rate of acceptability. Additionally, most interventions effectively reduced the symptoms associated with those hallucinations and

frequently improved the patients' quality of life. The studies also used a variety of measurement tools to report their findings.

Discussion: Hallucinations in schizophrenia are tracked and treated using a variety of interactive technological interventions. The review also revealed a shift away from putting patients in a passive role and towards a more active role through the use of interactive technologies. These technologies provide new treatment options a for a long-standing and persistent problem that medications frequently fail to address. Therefore, interactive technologies should be considered for broader implementation in treating hallucinations in schizophrenia. Given that auditory hallucinations are not limited to schizophrenia, these interactive technologies could also be used to treat other disorders, but this needs to be researched first. Nonetheless, some technological interventions require extensive software knowledge and training and therefore need further studies to study the cost-effectiveness of providing therapists with adequate training. Future scoping reviews should scope more databases and take steps to minimize biases.

Keywords: Schizophrenia, Auditory hallucinations, Interactive technology, Treatment, Tracking

A scoping review of the application of interactive technology for treating hallucinations in schizophrenia

Schizophrenia is a severe and chronic mental health condition that affects around 20 million people globally (World Health Organization, 2019). It is a mental illness that affects a person's behavior, cognition, and perception of the world (Ganguly et al., 2018). Symptoms of this medical condition include delusions, hallucinations, disorganized speech, and diminished emotional expression. Research depicts the mental disorder as a severe illness with serious economic and social consequences (Stepnicki et al., 2018; Buck et al., 2021). Patients tend to suffer from social disability and disconnectedness, making it difficult to establish and maintain social relationships. Typically, people with schizophrenia are more likely to socially isolate themselves, which can be devastating as social relationships are critical to people's psychological well-being and mental health (Wang et al., 2017). Regarding economic implications, annual treatment costs for schizophrenia are estimated to be twice that of major depression and four times that of anxiety disorders (Zhu et al., 2008).

One of the most common symptoms of schizophrenia is hallucinations, which are percepts without corresponding external stimuli (Corlett et al., 2019). Patients with schizophrenia often experience auditory hallucinations (Pienkos et al., 2019), commonly in the form of harassing voices commenting on their actions, conversing with them or talking about them (Picchioni & Murray, 2007). Hearing such voices is upsetting for the patients because negative voices, which are the focus of this scoping review, are more frequently reported than positive ones. Hor and Taylor (2010) demonstrated that hallucinations strongly correlate with high suicidal rates among schizophrenic patients. Thus, hallucinations put people suffering from the disorder at a higher risk of suicide. Typically, patients only have these auditory hallucinations. Therefore, it is nearly impossible for healthcare practitioners to

recognize and fully comprehend those auditory hallucinations when they occur without a patient's input. Both physicians and patients must work together to track these hallucinations. Approaches requiring in-person interactions have been used for years, but due to the difficulties associated with such strategies, such as memory bias, they are deemed impractical (Buck et al., 2021).

As a result, alternative tracking options, such as interactive technology, must be considered. eMentalHealth, which uses digital technology to deliver mental health care, is one option. Another option is to use mMentalHealth, which is a sub-set of eMentalHealth. mMentalHealth typically refers to the delivery of medical care via a mobile device. According to Hilty et al. (2017), key features of mMentalHealth include voice and video calls, Short Message Service (SMS), Multimedia Messaging Service (MMS), device connectivity, and GPS sensors. mMentalHealth can range from being treated and assessed via an app to virtually communicating with clinicians, online learning, storing electronic copies of a patient's records, and sending medication reminder notifications (Istepanian et al., 2004). It is thereby apparent that the use of technology can help track the mental health of a patient. Nonetheless, studying their usability and effectiveness is essential. Effectiveness is the extent to which set goals are achieved due to an activity or intervention designed to achieve the desired effects (Enrique & Marta, 2020).

In terms of medications, Clozapine is the most effective drug for treating schizophrenia (Nathou et al., 2019) despite its mixed acceptability. Acceptability is defined as determining how well the target audience will receive an intervention and how well it will meet the needs of that population (Ayala & Elder, 2011). Despite Clozapine being the most effective drug for resistant cases of schizophrenia, Clozapine has a relatively low effectiveness rate of 30 % (Nathou et al., 2019). Furthermore, it frequently causes metabolic

side effects such as weight gain, increasing the risk of death from cardiovascular disease in people with schizophrenia (Patel et al., 2014). In instances where there is no significant improvement for the patients after a year, medicine alone is no longer considered a viable option. Thus, attempts to help the patient through CBT are integrated. However, this technique is poorly implemented in patients with psychotic disorders (Jongeneel et al., 2018). As a result, brain stimulations, such as magnetic therapies, are being considered (Nathou et al., 2019; Sommer et al., 2012). Brain stimulation treatments have become more common in recent years (Horacek et al., 2006). However, a meta-analysis concluded that while the results of repetitive transcranial magnetic stimulation were promising, they were not stable. Therefore, no concrete conclusion could be made about its effectiveness in treating auditory hallucinations in Schizophrenia (Li et al., 2020). According to Dougall et al. (2015), people who receive this treatment rarely report side effects such as headaches or tightening of the jaw and face. Given the previous information, it is also clear that treatment frequently places patients in a passive role, even when technology is used.

Furthermore, treatments, especially medications, frequently have side effects and risks. In contrast, interactive technological interventions that allow people to interact with one another or allow practitioners to create or manipulate content give patients a more active role (Khosrow-Pour, 2017). Given their growing popularity, gaining an understanding of their effectiveness is critical.

Background of eMentalHealth technologies in healthcare

As previously stated, schizophrenia causes extra healthcare costs, and one of the significant contributors to the high costs is psychiatric relapses (Buck et al., 2021). Relapses are quite common and can be highly damaging to patients. With each relapse, the likelihood of suicide, poor treatment response, and subsequent relapses increases (Buck et al., 2021).

Relapses are "potentially detectable before full-blown relapse" since they are usually "preceded by smaller elevations in symptoms (e.g., delusions, hallucinations, suspiciousness, anxiety) (Buck et al., 2021)." As a result, addressing these symptoms as soon as they appear is critical to reducing the likelihood of relapse.

One of the interventions that can be leveraged is tracking a patient's progress. Existing approaches have been used for years, though their feasibility is questionable due to several challenges. These traditional methods include evaluating clinical impressions via "in-person interviews or clinician-administered rating scales, which require direct contact with a trained provider" (Buck et al., 2021). In-person interactions are typically challenging to scale and cannot reach a large number of people at once because they take a lot of time and resources. Furthermore, mentally ill people who are not receiving regular care are frequently at risk of missing out on the tracking process. Traditional approaches require summarizing a patient's experiences over long periods of time. As a result, the strategies become significantly less accurate because they are more susceptible to memory and interpretive errors. To promote effective patient care, technologies that enable patient-physician interaction with minimal errors can be incorporated into the mental healthcare system.

An interactive technology that can be used is eMentalHealth. The innovation includes, though is not limited to, social media sites, websites, video conferencing, video conferencing remedies, portals, chatbots, and smartphone software applications. It also includes "wearable devices with sensors" (devices that measure physiological and behavioural data, such as heart rate and sleep patterns) (Lal, 2019). Scholars believe that mHealth is a component of eMentalHealth services; however, the former is typically limited to portable intelligent devices, such as smartphones (Chivilgina et al., 2021; Hilty et al., 2017).

Regarding the feasibility of mobile technologies, they allow the use of an ecological momentary assessment (EMA) tool, which facilitates the measurement of hallucination frequency, intensity, and intrusiveness. Integrating this measuring instrument makes this innovation practical because it significantly reduces recall bias when used in a clinical setting to detect a symptom increase (Buck et al., 2021). Through mobile devices, concise, self-report measures can be administered daily to constantly assess a patient's mental state. The technological strategy thereby allows for detecting a patient's risk of relapsing and their mental state after relapsing. Moreover, unlike traditional approaches that lack scalability, intelligent devices can quickly gather an enormous amount of data from a large number of people (Enock & McNally, 2013). Thus, these digital techniques save essential resources, such as time and labour. Integrating eMentalHealth, including mMentalHealth, seems logical because they play an essential role in fostering efficiency, the accuracy of data, and scalability.

Some innovations, such as virtual realities (VR), create simulation spaces for patients essential for teaching clients coping skills transferrable to their daily lives (Chivilgina et al., 2021). Another popular intervention that frequently uses virtual reality is Avatar therapy, which uses technology to construct an avatar with a human face or, if wanted, an environment (Du Sert et al., 2018). It allows the therapist to communicate with the patient via the avatar using voice modulation and lip synchronization software (Leff et al., 2013). The avatar construction and voice modulation are done directly with the patient to create a more animated avatar. The patient instructs the therapist about the sound of the voice they hear and what their aggressor looks like in their imagination. Afterwards, the healthcare practitioner assumes the avatar's role with the assistance of these software, allowing the patient to confront the avatar directly. Avatar therapy aims to provide patients with a safe space in which they can confront the voice that haunts them and validate their experiences. Moreover,

it also allows them to take control of the interactions and relationships they have with this voice and later on even engage in a supportive relationship with them (Leff et al., 2013). This therapy gives patients more control over the voices against which they frequently feel helpless. Like the other interactive technological interventions, its usability needs to be assessed. Usability is defined as the extent to which the users can use a product to achieve specified goals with effectiveness, efficiency, and satisfaction in a specific context of use (Mosqueira-Rey & Moret-Bonillo, 2010

eMentalHealth services may substantially benefit patients by requesting assistance and receiving help. Nonetheless, technologies often present several challenges, such as the constant need to access a stable internet connection, which places individuals without it at a disadvantage (Enock & McNally, 2013). Moreover, technology is ever-evolving, meaning patients and clinicians will be constantly subjected to unfamiliar technological changes, necessitating training, which can be costly and time-consuming (Versluis et al., 2020).

Another major issue confronting eHealth is user usage among the elderly population. Younger people are the most technologically savvy. eMental Health entails digitalizing the existing psychometric tools in order to improve patient engagement while also decreasing the time required to diagnose patients (Demeulemeester et al., 2015). As a result, it is highly likely that fewer older people will seek and participate in managing and treating their mental health. Young people decline to seek mental health services, despite the potential long-term benefits, in fear of the stigma associated with mental disorders. Nonetheless, it provides opportunities for younger patients.

Given the information presented above, it is clear that schizophrenia is a devastating public health issue that needs to be addressed. Suicidal thoughts and hallucinations accompany the disorder, which is costly to treat and manage. Thus, the disorder is a public

health issue as it significantly contributes to undesirable economic and social consequences, such as premature deaths among youths (Stepnicki et al., 2018; Buck et al., 2021). Interactive technologies might provide help in tackling it. Given that no reviews on the tracking and treatment of hallucinations with interactive technologies were found, this study addresses this knowledge gap by listing the current technologies used to track and treat hallucinations in order to reduce their symptoms and improve their quality of life. The focus is on hallucinations because they are well-reported symptoms that cause patients much distress. The review will also assess the feasibility, acceptability, and effectiveness of those interactive technologies used to treat hallucinations.

Current study

The following research questions guided this scoping review:

1) Which interactive technologies are used to treat and monitor hallucinations?

2) What is the interactive technology's feasibility and acceptability for treating and monitoring hallucinations?

3) How effective are interactive technological interventions for tracking and treating hallucinations?

Methods

Search strategy

The electronic databases PubMed and Google Scholar were used to search for relevant papers between 2000 and 2022. This range was chosen because the treatment of hallucinations with the help of technology is an understudied topic. Those databases were chosen as they were most likely to yield relevant results. PubMed focuses on relevant medical topics, and because schizophrenia is a severe mental illness, it was likely to aid in discovering a sufficient number of papers. Google Scholar is another massive database with a

wide range of topics that may help find relevant papers. Given that Pubmed's primary focus is medical, Google Scholar supplements it by providing more papers focusing on technology.

Furthermore, the ability to check which papers cited the ones in the database can lead to the discovery of additional papers that may be relevant to the review. Another advantage was that it could provide access to previously unknown open-access journals. The database APA PsycNet was also used to find relevant peer-reviewed papers due to its focus on psychology and mental illnesses. However, only six papers were discovered. Of those six papers, only two dealt with hallucinations and schizophrenia. However, those were duplicates previously found elsewhere, so they were excluded.

Searches were conducted on each database to find relevant articles for this scoping review. The following combination of search terms was used to find relevant articles: (eHealth OR mHealth OR phone OR technolog* OR app OR web OR PC OR software) AND (Schizophrenia OR Hallucinations) as well as (eHealth OR mHealth OR phone OR technolog* OR app OR web OR pc OR software) AND (Schizophrenia OR Hallucinations) AND (Feasibility OR usability OR acceptability OR effectiveness) to find further information about their feasibility, acceptability and effectiveness. However, the simple search strings of (Technology AND hallucinations) and (Technolog* AND hallucinations) also yielded promising results in finding relevant papers for this review. With the help of the search terms above, the databases' titles, abstracts, and keywords were scanned. The chosen timeline was from the 1st of January 2000 to the 1st of January 2022. Given how the treatment of hallucinations with the help of technology is an understudied topic, finding a decent number of papers could otherwise be difficult. As a result, this timescale would allow for the discovery of further articles. This procedure began in late September 2021.

Eligibility criteria

The following inclusion and exclusion criteria were established:

Inclusion criteria.

1. The articles were written in English, German, or French.
2. The articles were published in peer-reviewed journals.
3. The year of publication had to be from 2000 onwards. The broad year range was chosen due to the understudied nature of this topic.
4. The studies needed to use interactive technological interventions where participants actively used technology.
5. The study participants had to be diagnosed with schizophrenia and experience hallucinations.

Exclusion criteria.

1. Essays, student theses, and short responses to other authors were excluded.
2. Articles that used passive technological interventions, so technology in which the participants did not actively use technology but were rather exposed to it, were excluded.

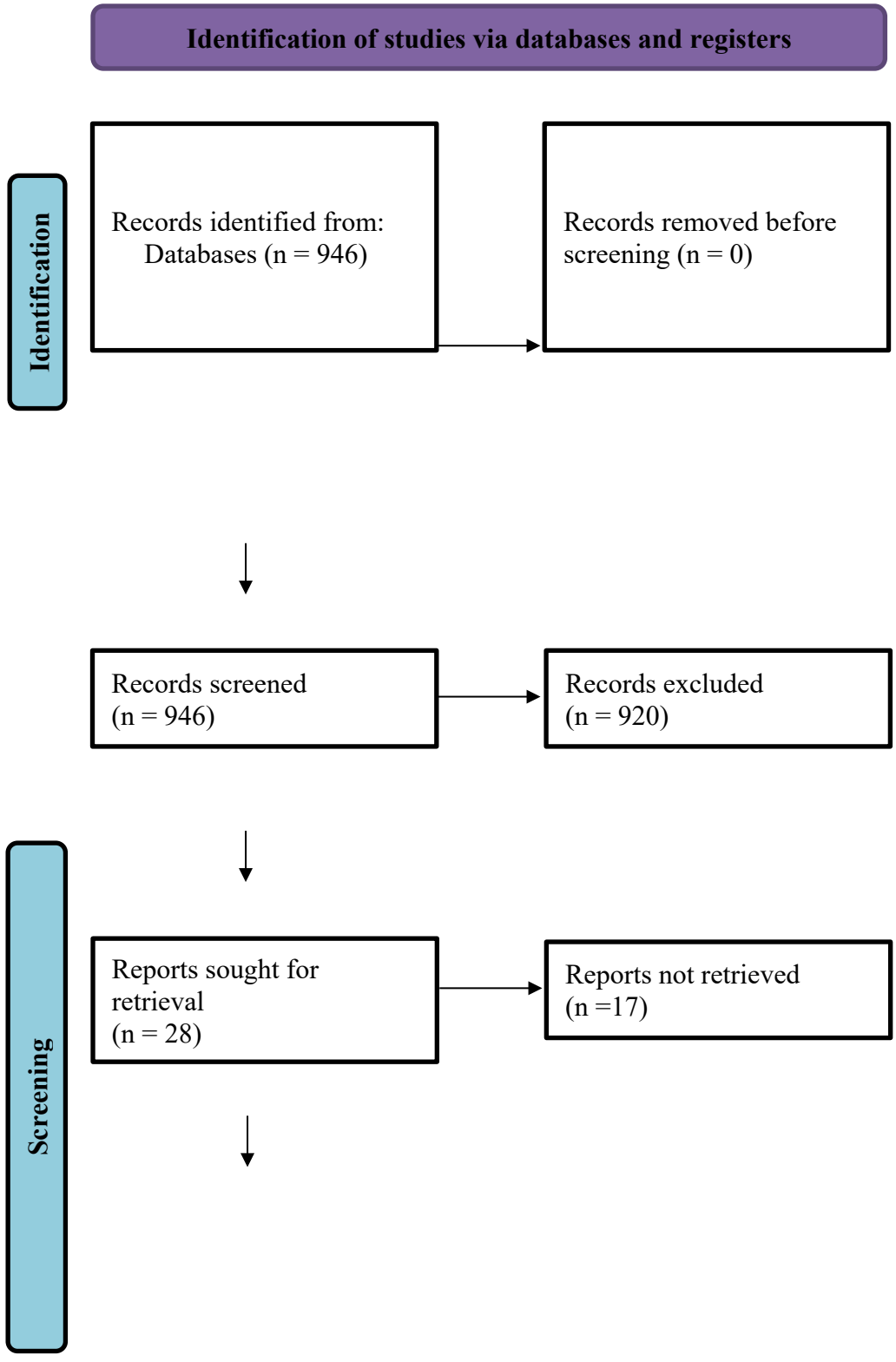
Study selection

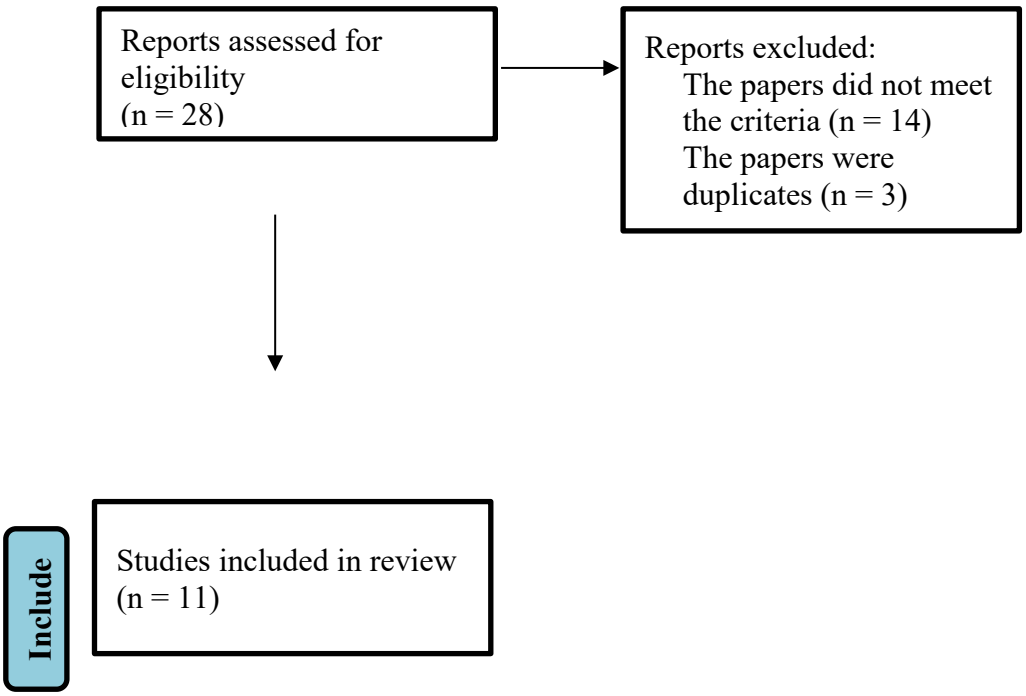
The titles of the 946 papers were initially evaluated by the master student who served as the sole researcher. Afterwards, the abstracts were to determine whether or not they were appropriate. Following up on the initial interest, the entire papers were evaluated to decide whether or not they fulfilled this review's exclusion and inclusion criteria. Afterwards, the

reference lists of the included studies were examined to find additional papers. It was also determined whether there were any duplicates among the papers. A flowchart illustrating this scoping review's study selection process is depicted in Figure 1 below.

Figure 1

Study selection process





Data extraction

The articles were carefully read and analyzed in accordance with the goal of the scoping review. The researcher extracted all the data from the selected articles. Data items that were extracted included participants' characteristics, study design, and technological intervention. The study's effectiveness, its measurement instrument used, and information about the feasibility and acceptability of the study were also extracted.

Participant's characteristics

First, data about the study participants was extracted. The extracted information here consisted of three items in each study. The first item extracted from each paper was the study's sample size. Secondly, information on the male-to-female gender ratio was also extracted from the studies. Finally, the mean age of the participants was extracted in order to compare the different studies and obtain information about the average age as well as the minimum and maximum age ranges.

Study and intervention characteristics

The study design was the study characteristic that was extracted from the articles. It was vital to extract information about the study design to estimate the strengths of the studies' obtained results according to the scientific hierarchy of evidence (Evans, 2003). However, the technological interventions extracted were the interactive technologies the studies used during the interventions. Again, this was relevant information to understand what technology researchers use to track and treat hallucinations. It also revealed whether a particular technological intervention is more commonly employed than others.

Effectiveness and measurements

Information about the measures used in the studies was collected to get an overview of the different measurement instruments that were used when dealing with patients suffering from hallucinations. However, directly related measurement instruments were also extracted, given how hallucinations affect quality-of-life satisfaction. Finally, information about the effectiveness of the technological interventions was gathered from the studies by evaluating if they reduced the symptoms related to hallucinations or improved quality of life. The various measurement instruments provide information about their effectiveness with their data.

Feasibility and acceptability

Information on the interventions' feasibility was also gathered to determine how feasible such technological interventions are in practice. The researchers' comments on feasibility were extracted, as barely any instruments to measure it were used in all but one case. Furthermore, information about acceptability was obtained by skimming the papers and noting what the patients had to say about the technological interventions. Gathering information about the patients' perceived acceptability of those interventions was done almost

exclusively by asking them for their opinions and listening to what they had to say about them.

Results

A total of 11 studies were reviewed for this scoping review. While there were differences between the studies using the same technologies, six different technological interventions were used throughout the studies.

Participant characteristics

Table one below shows the participant characteristics. All the patients were diagnosed with schizophrenia. Two papers did not provide information about the participants' genders. Additionally, three papers provided no information on the mean age of their participants, with one of them also not giving information about the participants' genders. The sample size ranged from one to 109 participants. The studies had a mix of majority female and majority male samples. Finally, the participants' mean ages ranged from 17.7 in the lowest range to 48.7 in the highest range.

Table 1

Participant characteristics

	Authors	Sample size	Gender	Mean age
1	Granholm et al. (2011)	42	69% male	48.7
2	Leff et al. (2013)	26	61. 54% male	-
3	Gottlieb et al. (2013)	21	62% male	40.10
4	Gottlieb et al. (2017)	37	-	-
5	Torous & Roux (2017)	1	Male	28
6	Du Sert et al. (2018)	15	66.7% male	42.9
7	Bell et al. (2018)	1	Male	38
8	Stefaniak et al. (2019)	23	57% female	33.2
9	Smelror et al. (2019)	3	-	17.7
10	Moore et al. (2020)	12	75% female	-
11	Brander et al. (2021)	109	65. 14% female	32.30

Study characteristics

Table 2 summarizes the study characteristics that were used in this review. The majority of the studies (N = 5) were pilot studies. One of those pilot trials (N = 1) was also a clinical trial. There were two randomized controlled trials and one pilot study (N = 2). Two of those studies (N = 2) were case reports. One study (N = 1) was a randomized, single-blind, partial crossover trial. Finally, one exploratory study (N = 1) and one development and usability study (N = 1) were conducted.

Study interventions

The selected papers also used various technological interventions. However, AVATAR therapy (N = 4) is the most commonly used technological intervention for treating hallucinations. There are, however, slight differences in the studies using AVATAR therapy. The most prevalent strategy (N = 3) was for the therapist to be in the same room as the

patient while supporting the AVATAR therapy with virtual reality. However, there were also AVATAR interventions without virtual reality (N = 2). In one study, the therapist was in a different room than the patient. Another common technological intervention used to treat and track hallucinations is smartphone apps (N = 3). In one study, old Motorola phones were used for an interactive text-messaging intervention. CBT techniques were used to challenge the patients' thoughts after gathering information about their thoughts regarding medications, socialization, and the voices they heard. They then also received a behavioural experiment assignment (N = 1). Then, some studies used web-based cognitive behavioural therapy (CBT) programs to educate the patients about the hallucinations, teach them how to cope with those hallucinations, and work on changing their thoughts (N = 2). Finally, a case report described a patient using a smart tally counter. With this device, the patient could press a button to send information about the time and frequency of the hallucinations. This data was sent to a website, which he could later access to view the collected information (N = 1).

Table 2

Study characteristics

	Authors	Study design	Technological intervention
1	Granholm et al. (2011)	Pilot trial	Mobile assessment and treatment for schizophrenia interactive text-messaging intervention (MATS)
2	Leff et al. (2013)	A randomized, single-blind, partial crossover trial	AVATAR therapy with the therapist in a different room
3	Gottlieb et al. (2013)	Pilot study	Web-based cognitive behavioural therapy
4	Gottlieb et al. (2017)	Randomized controlled trial	Internet cognitive behavioural skills-based program
5	Torous & Roux (2017)	Case report	Smart tally counter
6	Du Sert et al. (2018)	Pilot clinical trial	AVATAR therapy supported by virtual reality
7	Bell et al. (2018)	Intervention development and case report illustration	Smartphone-based ecological assessment and intervention in a blended-coping therapy
8	Stefaniak et al. (2019)	Pilot study	AVATAR therapy with the therapist in the same room
9	Smelror et al. (2019)	Exploratory study	Smartphone app
10	Moore et al. (2020)	A pilot, randomized, controlled trial	Smartphone-supported coping-focused therapy
11	Brander et al. (2021)	Development and usability study	AVATAR therapy supported by virtual reality

The effectiveness of the studies

Most studies employed the Psychotic Symptom Rating Scale hallucinations subscale (N = 6). It was, however, frequently used in conjunction with other assessment instruments. In one study, the average PSYRATS score was reduced by 8.75 points (P = 0.003). (Leff et al., 2013). For example, the Revised Beliefs About Voices Questionnaire was also well-liked (N = 4). Several studies also used the Psychotic Symptom Rating Scale as a measurement tool

(N = 3). In more than one study (N = 2), semi-structured interviews and the Brief Psychiatric Rating Scale were used. In one study, a visual analogue scale was also used.

The most commonly reported improvement was decreased distress due to auditory hallucinations, which became less severe when the technological treatments were used (N = 6). Several studies (N = 5) also reported changes in patients' beliefs about their hallucinations. Those were most frequently associated with beliefs about the hallucinations' malevolence (N = 3) and omnipotence (N = 3). A decrease in the frequency of hallucinations was also observed in several studies (N = 3). In one study, a patient stated that the intervention had helped him cope with the voices. In another study, after the intervention, the patient's confidence in dealing with the voices increased from 5/10 to 8/10. (Bell et al., 2018).

Interestingly, some studies reported increased auditory hallucinations among patients using smartphone apps (N = 2). Nonetheless, there were also improvements in related areas, such as a reduction of depressive symptoms (N = 2), improved medication adherence (N = 1), and improved social functioning and interpersonal relationships of the patients (N = 1). Additionally, one patient reported improved quality of life (N = 1).

Table 3

Effectiveness measures

	Authors	Measurement instruments	Effectiveness
1	Granholm et al. (2011)	The self-reported medication adherence and severity of hallucinations. The secondary outcome measures used the Positive and Negative Syndrome Scale (PANSS).	There were significant improvements in medication adherence and reduced severity of auditory hallucinations. No significant differences in the secondary outcomes.
2	Leff et al. (2013)	The hallucinations section of the Psychotic Symptom Rating Scale (PSYRATS) and the Omnipotence and Malevolence subscales of the Revised Beliefs About Voices Questionnaire (BAVQ-R).	A frequency and intensity reduction of the auditory hallucinations and the disruptions they cause. There was also a change in beliefs about the hallucinations.
3	Gottlieb et al. (2013)	The PSYRATS auditory hallucinations subscale was used for the primary outcomes. Secondary outcomes were measured using the BAVQ-R, the delusions subscale of the PSYRATS and the Brief Psychiatric Rating Scale (BPRS)	Improvements in the frequency, duration and severity of the hallucinations, reduction in the perception of the voices as an outside entity and negative commentary from the voices. Also, improved perceived control over the voices. Moreover, there were reductions in psychopathology, psychosis, depression, and activation on the BPRS scale.

4	Gottlieb et al. (2017)	The BPRS and PSYRATS auditory hallucinations scales. The Specific Level of Functioning Scale (SLOF) and the BAVQ were used for the secondary outcomes.	A significant reduction in the severity of hallucinations over time. Also, significant improvement in social functioning and interpersonal relationships.
5	Torous & Roux (2017)	-	-
6	Du Sert et al. (2018)	The PSYRATS scale and BAQV-R measured auditory hallucinations and beliefs about their malevolence and omnipotence. The PANSS measured psychiatric symptoms. The Quality of Life Enjoyment and Satisfaction Questionnaire-Short Form measured life satisfaction.	A reduction of distress due to auditory hallucinations and reductions in the beliefs about voices as malevolent and omnipotent. Finally, there was also a reduction in depressive symptoms and an improvement in the quality of life.
7	Bell et al. (2018)	A 10 points visual analogue scale about the confidence in one's ability to deal with the voices in daily life, the negative impact scale of the Subjective Experiences of Psychosis Scale (SEPS), a measure of the negative emotional and functional impact of psychotic experiences and the auditory hallucinations subscale of the PSYRATS.	After the intervention, the patient's confidence in coping with the voices increased from 5/10 to 8/10. The patient also experienced a reduction in the SEPS negative impact of the voices. However, the PSYRATS score slightly increased as he experienced more hallucinations attributed to external stress.

8	Stefaniak et al. (2019)	PSYRATS scale and the Voice Power Differential Scale (VPDS).	Long-term improvements in the perceived control over the auditory hallucinations and their frequency on the PSYRATS scale. Also, significant improvements in the power and superiority they believed to have over them on the VPDS.
9	Smelror et al. (2019)	The Schedule for Affective Disorders for School-Age Children-Present and Lifetime version, Children Global Assessment Scale (CGAS), PANSS, BAVQ-R and semi-structured user-experience interviews to collect subjective experiences.	General improvements in the BAVQ-R scale scores, especially regarding the belief about the malevolence and omnipotence of the auditory hallucinations. One participant, however, reported hearing more voices due to the increased awareness.
10	Moore et al. (2020)	A semi-structured interview to gather in-depth data.	The patients noted that technology improves and supports therapy but does not replace face-to-face therapy. There was a reduction of distress related to hearing voices.
11	Brander et al. (2021)	-	-

The feasibility and acceptability of the technologies

Table 4 below lists the feasibility and acceptability of the technologies. All the studies (N = 11) were feasible and frequently based their research on methods and interventions previously supported by research. One study also used the System Usability Scale to measure the usability of virtual reality human-human interface to deliver psychotherapy to people who experienced auditory hallucinations and had a mean SUS global score of 81,49 (SD 11.1). This information, in turn, again supports the potential of at least the AVATAR therapy. The acceptability of these interventions yields similar results. Most reported that the patients found the interventions acceptable (N = 9). Information about the acceptability was gathered through interviews with the patients.

Nonetheless, some study participants (N = 2) found the technological interventions to be unacceptable. One study omitted data on its acceptability and feasibility. Instead, it asked participants how useful they thought the intervention was. The various populations surveyed all rated the intervention's usefulness as excellent, which may lead one to believe that it is also feasible. Finally, another study found that patients had mixed feelings about the smartphone app because they were concerned about their privacy.

Table 4

The feasibility and acceptability of the studies

	Authors	Feasibility	Acceptability
1	Granholm et al. (2011)	Feasible. Between 83 – and 86% of patients responded to the text messages. 86% also returned the phone without any damage.	Accepted, but some participants found handling the old phones too complicated.
2	Leff et al. (2013)	AVATAR therapy sessions are short, which the patients and professionals often prefer.	A high dropout rate of 34.6 %.
3	Gottlieb et al. (2013)	A high level of program completion. 81% completed more than 50% of the program.	High levels of satisfaction with the program and high levels of perceived helpfulness.
4	Gottlieb et al. (2017)	A high rate of participation. 79% completed all ten sessions.	A high rate of satisfaction with the program.
5	Torous & Roux (2017)	Feasible. The patient could track his data by pushing a button and accessing it with an internet connection.	The patient found it acceptable as it was easy to use and practical in social situations.
6	Du Sert et al. (2018)	Feasible. Good outcome compared to previous treatment methods and short therapy sessions.	Acceptable as the therapy slowly promotes acceptance and empowers the patients.

7	Bell et al. (2018)	Feasible. The reminders and new coping strategies were reported to be helpful. The individualization of the app was also praised as the most valuable part of the intervention.	Acceptable as the consistency of reminders helped break his circuits and apply the new knowledge. The timing and number of EMA/I items were acceptable. However, fewer surveys per day would be better.
8	Stefaniak et al. (2019)	Feasible like the other AVATAR therapies.	Acceptable. The patients valued their safety by constantly having the therapist in the same room.
9	Smelror et al. (2019)	Feasible. There was high compliance with the sampling procedure (74% response rate), and participants could use the phone app without special training. It was reported as easy to understand, requiring little time, and the possibility of adding notes was also good.	Mixed acceptability. Participants became more aware of their auditory hallucinations, which was negative for one of the three participants instead of positive. There were also concerns about personal privacy during phone and app usage.
10	Moore et al. (2020)	Feasible. The Ecological Momentary Assessments are generally considered feasible, and the patients also noted that they positively supported the therapy.	EMA is generally highly accepted. Patients in this study reported the same. The ability to collaboratively develop personalized coping strategies and receive reminders about those was especially positive.
11	Brander et al. (2021)	Likely feasible. It achieved an excellent benchmark in the System Usability Scale.	Likely acceptable as various populations rated it to be excellent.

Discussion

This scoping review explored the scientific literature on how interactive technology could be used to treat hallucinations in patients with schizophrenia. The first research question of this review was to investigate what kinds of technologies are used to track hallucinations and treat those hallucinations in schizophrenia. This review paper found that AVATAR therapy is popular for treating schizophrenia. Avatar therapy strives to provide patients with a safe space to confront the voice that haunts them and validate their experiences. Moreover, it also allows them to take control of the interactions and relationships they have with this voice and later on even engage in a supportive relationship with them (Leff et al., 2013). This therapy gives patients more control over the voices against which they frequently feel helpless against.

Furthermore, virtual reality is frequently used to support AVATAR therapy to create a more realistic intervention (Du Sert et al., 2018). However, various other technological interventions are also used in this study besides the AVATAR therapy. Some interventions are also relatively simple. In one case report, a patient used a smart tally counter to track his hallucinations, then viewed the data online and showed it to his therapist so that he could adjust his medicine accordingly and track the treatment's effectiveness. In addition to a variety of possible treatment methods, these findings that interactive technologies are not only effective at tracking hallucinations but also treating them are somewhat surprising, as the treatment of hallucinations in schizophrenia and psychosis is often limited to medication (Ruiz et al., 2016) and CBT (Jongeneel et al., 2018) as was previously mentioned and even those treatments often fail. Given the variety of interventions, these review findings, moreover, imply that the therapist's creativity is partly a limitation and that numerous technologies can be used instead of only the old favorites, such as medications or

technologies in which patients play a passive role, such as transcranial magnetic stimulation (Dougall et al., 2015). Sometimes it is simply a matter of considering different technologies, such as the tally tracker, which was suggested by the patient rather than a therapist. The goal of researching what other interactive technologies can be applied in the mental healthcare context has the potential to open many doors to previously unconsidered treatment options. According to one study, healthcare practitioners are not always the only ones who understand which technologies can be used to track and treat hallucinations (Torous & Roux., 2017).

Therefore, greater communication with patients should be considered to determine what else they could imagine being used for this purpose. After all, the practitioners' knowledge and perspectives are often limited by their studies and experiences. Gathering new ‘’outside’’ ideas might be beneficial. Most patients agree to participate in a small amount of healthcare-related trials, so interviewing them or sending surveys to collect ideas might be viable (Moorcraft et al., 2016). Finally, the conclusion of this scoping review for the first research question is that various interactive technological interventions can be used to treat hallucinations in schizophrenia. These technological interventions do not have to be complicated. Many people use smartphone apps, and since smartphones have become an essential part of life, many people are already familiar with their use. A straightforward intervention proposed by a patient is to use the button of a smart tally tracker to record real-time data concerning hallucinations later and share it with the healthcare practitioner (Torous & Roux, 2017). Nonetheless, AVATAR therapy is the most commonly used technological intervention to treat hallucinations in schizophrenia, closely followed by smartphone apps that also allow tracking hallucinations.

This scoping review's second research question focused on determining how feasible and acceptable certain technologies are for monitoring and treating hallucinations. All the listed studies were shown to be feasible. One reason might be that these studies were often

built upon methods and interventions previously scientifically supported as being largely feasible. The patients also had a high acceptance rate of the technological interventions. Most gave those interventions positive reviews when information about their subjective experiences was collected through interviews. While the beforementioned gathered data is subjective data and objective data about its acceptability is often favoured in science due to the belief that there is less bias in them, it is also sometimes the case that subjective data is more valuable than objective and especially online collected data (Tempelaar et al., 2020). One significant advantage is that in-person interviews with patients allow researchers to delve into the participants' thoughts, feelings, and opinions about a specific topic and gain a more in-depth insight into the patients' experiences (DeJonckHeere & Vaughn., 2019). As a result, the interviews assisted in gathering detailed information about the acceptability of the interventions, what the patients valued specifically, and how they experienced those interventions. These findings imply that those studies should not be overlooked because they may be useful and should be tested outside of the research setting. After all, given their feasibility and acceptability, both of which are important factors in determining the effectiveness of research interventions in the healthcare field, they could work very well (Bowen et al., 2009).

Interestingly, a previous review that examined the use of mobile digital technologies for treating schizophrenia instead noted that there was a mistrust of these digital technologies among the patients and healthcare practitioners (Chivilgina et al., 2021), which is the opposite of what this review found given the high acceptability of the current review. The mistrust in the previous review was often due to ethical concerns such as privacy concerns. Nonetheless, this review also found that one study reported one out of three patients having the same concerns when using a smartphone and app provided by the researchers. The patient was concerned about their privacy, a valid concern that has to be considered when opting to

use smartphone apps as an intervention method (Smleror et al., 2019). After all, medical research often stores sensitive data about the patient, yet this data is often shared with the scientific community to maximize scientific benefits (Jacobs & Popma., 2019). While this concern is frequently addressed in the scientific setting because patients are frequently identified only by codenames rather than their actual identities, this is not the case in natural healthcare settings, where the patient must be identifiable. However, it might be beneficial to inform the patients that there already is a shift in big data in health care, making the patients' data less identifiable. The generalization technique, for example, makes data more anonymous by substituting specific values with broader categories (Abouelmehdi et al., 2018). When using this method, the patient's actual date of birth, for example, is replaced by only listing the birth year. This review concludes that those technologies have high feasibility and acceptability and are worth trying in healthcare settings. Concerns about privacy invasions can be addressed by making people aware of a new trend in healthcare: better patient data privacy.

This paper's third and last question was how effective those technologies are in tracking and treating hallucinations. According to this review's data, technological interventions effectively track and treat hallucinations in patients with schizophrenia. This effectiveness is further supported by various measurement instruments, ranging from objective to subjective, with the vast majority reporting significant improvements. These findings suggest that healthcare practitioners and patients believe these interactive technological interventions effectively track and treat hallucinations in patients with schizophrenia. However, the hierarchy of evidence for ranking research evidence evaluating health care interventions should also be considered to further analyze the effectiveness and possible implementation outside the research setting, as multiple factors can impact the interventions' success. As a result, using the hierarchy of evidence to evaluate health care

interventions adds another layer of investigation because it recognizes that, when evaluating an intervention, a variety of research methods can contribute valid evidence rather than only seeing randomized controlled trials as valuable, which is also important for this review (Evans, 2003). After all, the majority of the studies included in this review were pilot trials, and several were randomized control trials. According to the above-mentioned evidence hierarchy, the majority of the study findings in this scoping review are considered fair to good evidence, which is encouraging. (Evans, 2003).

This review concludes that those technologies are adequate for tracking and treating hallucinations. They create a difference for patients by reducing their symptoms related to hallucinations and sometimes help improve their quality of life. Compared to standard medications (Patel et al., 2014), those therapies appear to perform quite well due to their higher effectiveness. Moreover, the studies rank reasonably well in the hierarchy of evidence for the effectiveness of interventions, and this scoping review might provide promising results. Technological interventions are particularly effective in reducing the severity and frequency with which patients experience auditory hallucinations. The interactive technological interventions with the AVATAR therapy and, in one case, even a smartphone app were also effective at changing the patients' beliefs about those auditory hallucinations that they experienced (Du Sert et al., 2018; Gottlieb et al., 2013; Leff et al.,2013; Stefaniak et al., 2019; Smelror et al., 2019). After the interventions, the patients perceived the auditory hallucinations as less evil and less omnipotent. Nonetheless, it is essential to highlight that two patients in two studies experienced the side-effect of experiencing auditory hallucinations more frequently than before, rather than having them less frequently after becoming more aware of them. Both studies used smartphone apps to send reminders to patients and have them fill out brief questionnaires.

Strengths and limitations

The review's strength is that it provides a concise overview of the technologies used to track and treat auditory hallucinations in schizophrenia and their effectiveness, feasibility, and acceptability. It also only used peer-reviewed papers. This use of only peer-reviewed papers is, in particular, a considerable strength, as peer-reviewed articles are trusted in the scientific community (Kelly et al., 2014) and are therefore considered the gold standard. Additionally, it used, albeit in a limited scope, papers with a mix of qualitative and quantitative measurement methods that rely on numbers and data in the form of subjective patient experiences. However, there are also limitations to this paper. First, only three databases were used to find relevant papers. If more databases were scoped for articles, the number of included studies could have been substantially more extensive, resulting in even more relevant information to answer the questions.

Additionally, only one researcher conducted this research. While the papers were chosen carefully, a discussion and exchange of ideas with at least one other researcher could have led to better inclusion and exclusion criteria for this review and the consideration of more databases.

Another limitation of this study was that the scoping review did not account for potential biases and did not take any steps to minimize those biases, such as adhering to the PRISMA statement (Drucker et al., 2016).

Directions for future research

his review bolsters the notion that technological interventions are acceptable, feasible, and capable of tracking and treating hallucinations. This understanding is critical because treating hallucinations in schizophrenia is extremely difficult, and even medical drugs

frequently fail (Patel et al., 2014). However, this review also listed various study designs. That also included two case studies, which ranked poorly in the hierarchy of evidence for the effectiveness of interventions (Evans, 2003). Nonetheless, it was essential to include the case study to illustrate a unique type of technology that was completely different from the rest. As a result, future scoping reviews should scan more case studies to determine whether other technologies that were not previously considered could be employed for patient care.

Technological interventions can sometimes potentially have unintended side effects as well. In one study using a smartphone app, one patient reported experiencing an increase in the frequency of auditory hallucinations since he became more aware of them because of the app. The participant attributed it to the intervention rather than external factors, such as experiencing more stress than usual (Smelror et al., 2019), as was the case in another study where a patient reported increased stress and hallucinations due to outside factors at the end of the study (Bell et al., 2018). Experiencing more hallucinations due to the increased awareness was damaging enough for one patient to drop out of the study. Future studies should consider this possibility and account for the possible increase in hallucinations when using phone apps. They should also provide additional interventions to help the patient cope with the increased auditory hallucinations as they undergo this treatment. This further assistance could, for example, include thinking about unique coping strategies with the therapist and having additional in-person sessions with the therapist to discuss their experiences with the intervention, as well as giving them reminders of their coping strategies. The patient in one study valued this additional personal communication and stated that receiving these reminders helped him break his usual coping strategies (Bell et al., 2018). Therefore, it might be worth offering it as a solution that patients could use if they wish.

Consistently with another review, there were also privacy concerns when using phone apps which future studies should address by, for example, providing alternatives such

as offline versions of the apps that do not save data online (Smelror et al., 2019) if the patients wish so. Another solution could be to store the data as usual but give the patients power over their data. Giving patients power might be as simple as telling them that they can ask for their data to be deleted at any time or allowing them to delete their data with the click of a button. It is also possible to address such concerns during the participant recruitment phase or at the start of the study. Addressing those concerns could include informing the patients that the data is stored in an untraceable manner and informing the patients about the slow transition in how private data is handled in health care. It might also be appropriate to give them examples of methods such as the data generalisation (Abouelmehdi et al., 2018) previously mentioned. Such examples could give the patients a higher sense of security during the study and greater trust in how healthcare institutions handle their data.

Another concern that future studies should consider is that the dropout rate, particularly for AVATAR therapy, can be relatively high, as the patients are often too scared to confront their voices or those voices tell them to drop out (Leff et al., 2013). This distress could be alleviated by providing more counselling sessions to patients. While having the patient be in the same room as the therapist already provides them with a greater sense of safety compared to the usual AVATAR therapy treatment of being in separate rooms (Stefaniak et al., 2019), patients often still only see technology as a support to the additional therapy rather than completely replacing face-to-face therapy and communication with the psychologists (Moore et al., 2020). Therefore, providing additional brief counselling sessions to further validate the patients' concerns and provide them with some support outside of the AVATAR therapy might be an option.

Additionally, future studies should investigate if it would be feasible to implement the technological interventions from a more technical and practical perspective. After all, some of them require extensive knowledge and training in specific software, which serves as the

therapy's foundation. For example, AVATAR therapy requires professionals to have trained with the Unity software to create environments and learn how to work with voice modulation software to make the avatar seem more real and use the voice that the patient reported (Leff et al., 2013). Both of those necessities require extensive training to learn how to use them. As a result, it would be interesting to conduct a study to determine if this training could be provided to present therapists cost-effectively and if it is even possible.

Finally, future studies should investigate if these interactive technological interventions could be applied to other disorders where patients experience hallucinations. After all, hallucinations are not only experienced by individuals with schizophrenia but are also prevalent in severe depression, postpartum psychosis, borderline personality disorder, and post-traumatic stress disorder (Chaudhury, 2010). Therefore, these interactive technological treatment methods could be effectively used for various disorders.

Conclusion

In conclusion, this scoping review identified the different technological interventions currently used to track and treat auditory hallucinations in schizophrenia. There is also high feasibility of the technological interventions and a generally high approval rate. Given this information, the use of technology should at least be considered for broader implementation for treating hallucinations in schizophrenia, especially given how most of those interventions were also effective compared to usual treatment methods. Of course, there are challenges, such as providing the therapists with the necessary training to use these interactive technological interventions. Nonetheless, interactive technologies open possible treatment solutions to a long-standing problem and give the patient a more active role than previous treatment methods.

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