Schizophrenia Research: Cognition 28 (2022) 100247

Contents lists available at ScienceDirect

Schizophrenia Research: Cognition

journal homepage: www.elsevier.com/locate/scog

Digital technology for addressing cognitive impairment in recent-onset psychosis: A perspective☆

Imogen Bell[a,b], Roos M.C.A. Pot-Kolder[a,b,*], Stephen J. Wood[a,b,d], Barnaby Nelson[a,b], Nicola Acevedo[a,b,c], Alexandra Stainton[a,b], Katie Nicol[a,b], James Kean[a,b], Shayden Bryce[a,b], Cali F. Bartholomeusz[a,b], Amity Watson[a,b], Orli Schwartz[a,b,e], Rothanthi Daglas-Georgiou[a,b], Courtney C. Walton[a,b], Donel Martin[f], Magenta Simmons[a,b], Isabel Zbukvic[a,b], Andrew Thompson[a,b], Jennifer Nicholas[a,b], Mario Alvarez-Jimenez[a,b], Kelly Allott[a,b]

[a] *Orygen, 35 Poplar Rd, Parkville 3052, Melbourne, VIC, Australia*
[b] *Centre for Youth Mental Health, University of Melbourne, Parkville, VIC, Australia*
[c] *Centre for Mental Health, Swinburne University of Technology, Melbourne, VIC, Australia*
[d] *School of Psychology, University of Birmingham, UK*
[e] *Department of Psychiatry, University of Melbourne, Melbourne, VIC, Australia*
[f] *School of Psychiatry, University of New South Wales and Black Dog Institute, NSW, Australia*

A R T I C L E I N F O

Keywords:
Cognition
Psychosis
Treatment
Digital therapy
Functional recovery

A B S T R A C T

Cognitive impairments in psychosis negatively impact functional recovery and quality of life. Existing interventions for improving cognitive impairment in recent-onset psychosis show inconsistent treatment efficacy, small effects, suboptimal engagement and limited generalizability to daily life functioning. In this perspective we explore how digital technology has the potential to address these limitations in order to improve cognitive and functional outcomes in recent-onset psychosis. Computer programs can be used for standardized, automated delivery of cognitive remediation training. Virtual reality provides the opportunity for learning and practicing cognitive skills in real-world scenarios within a virtual environment. Smartphone apps could be used for notification reminders for everyday tasks to compensate for cognitive difficulties. Internet-based technologies can offer psychoeducation and training materials for enhancing cognitive skills. Early findings indicate some forms of digital interventions for cognitive enhancement can be effective, with well-established evidence for human-supported computer-based cognitive remediation in recent-onset psychosis. Emerging evidence regarding virtual reality is favorable for improving social cognition. Overall, blending digital interventions with human support improves engagement and effectiveness. Despite the potential of digital interventions for enhancing cognition in recent-onset psychosis, few studies have been conducted to date. Implementation challenges affecting application of digital technologies for cognitive impairment in recent-onset psychosis are sustained engagement, clinical integration, and lack of quality in the commercial marketplace. Future opportunities lie in including motivational frameworks and behavioral change interventions, increasing service engagement in young people and lived experience involvement in digital intervention development.

1. Background

Cognitive impairment is a common symptom in psychotic disorders (Keefe and Fenton, 2007), seen across most domains including attention, processing speed, working memory, verbal learning and memory, executive functioning, and social cognition (Bowie and Harvey, 2006). Most people with schizophrenia demonstrate lower cognitive functioning than their expected level if they had not developed the illness (Keefe and Fenton, 2007). These cognitive deficits are already established in recent-onset psychosis (ROP) (Uren et al., 2017; Mesholam-

☆ This was funded by the Wellcome Mental Health team through a 2021 "Cognitive impairment in psychosis" commission awarded to Associate Professor Kelly Allott at Orygen. It is available under a CC BY-NC licence from Wellcome (https://wellcome.org/).

* Corresponding author at: Orygen, 35 Poplar Rd, Parkville 3052, Melbourne, VIC, Australia.
E-mail address: Roos.pot-kolder@orygen.org.au (R.M.C.A. Pot-Kolder).

https://doi.org/10.1016/j.scog.2022.100247
Received 21 December 2021; Received in revised form 25 February 2022; Accepted 25 February 2022

Gately et al., 2009; Reichenberg et al., 2010; Mollon et al., 2018). Cognitive impairments interfere with functional recovery (Allott et al., 2013; Cowman et al., 2021). Individuals with psychosis report cognitive impairments are distressing and negatively impact self-confidence, vocational functioning and daily life activities (Wright et al., 2019).

Early interventions for psychosis are both clinically-effective (Correll et al., 2018) and cost-effective (Aceituno et al., 2019) in reducing the burden associated with psychosis. However, current treatment options have limitations in terms of cognitive outcomes. First, on average, antipsychotics are associated with negligible benefits for cognition (Karson et al., 2016), and may in fact adversely affect cognitive function (MacKenzie et al., 2018). Second, low engagement levels and non-adherence are a long-standing challenge in ROP treatment (Casey et al., 2016). Technological advancement brings new possibilities for research and treatment (Rus-Calafell and Schneider, 2020) that can address these challenges. The current perspective examines how digital technology could be used to address cognitive impairment and functional recovery in ROP.

2. Digital interventions in mental health treatment

Digital interventions involve the use of technologies such as stand-alone computer programs, internet delivered programs, smartphone apps or virtual reality (VR) to deliver mental health treatment (Torous et al., 2021). The increasingly wide-spread availability of digital technologies and unique capabilities for providing accessible support in daily life make them well suited to support existing treatment models to address cognitive impairment (Table 1). Providing continuous access to treatment in daily life ensures support is available on demand within the everyday contexts where it is needed. Delivering interventions such as cognitive remediation via technology can address limitations in the availability of evidence-based treatment for ROP (Wykes, 2018). Real-world learning can occur through delivering interventions in daily life using smartphone apps, or within simulated virtual environments in the case of VR (Bell et al., 2020a). Further, the use of technologies to support treatment may hold greater appeal for young people (Hollis et al., 2017; Valentine et al., 2020), for whom traditional treatments tend to lack engagement (Harpaz-Rotem et al., 2004). The generation born after 1990 can be seen as digital natives who consume digital information and stimuli quickly and comfortably through digital devices and platforms (Prensky, 2001).

3. Digital interventions for cognitive impairment in recent-onset psychosis

Despite the potential of digital interventions for enhancing cognition in ROP, few studies have been conducted. To our knowledge, there are no systematic reviews or meta-analyses that specifically examine cognitive enhancement with digital interventions in ROP or persisting psychosis populations. However, broader reviews of treatments targeting cognitive impairment in these populations have included various interventions delivered via technology (Glenthoj et al., 2017; Revell et al., 2015), and some individual trials have been conducted that provide early insights.

Table 1
The potential of digital technologies for treatment of cognitive impairment in recent-onset psychosis.

Digital technology	Potential use for treatment of cognitive impairment in recent-onset psychosis
Computer programs	Standardized, automated delivery of cognitive remediation training via a laptop or tablet using a software program.
Virtual and augmented reality	Learning and practice of cognitive skills in real-world scenarios within a virtual environment.
Smartphone apps	Notification reminders for everyday tasks to compensate for memory, planning and organisation difficulties.
Online and internet-based technologies	Online-software, self-guided programs providing psychoeducation and training materials on enhancing cognitive skills. For example, guided virtual therapeutic environments and real-time interactive worlds.

3.1. Computer-assisted cognitive remediation

Cognitive remediation (CR) refers to nonpharmacological training-based methods of improving cognitive function, with the goal of improving independent and vocational functioning in people with severe mental disorders (Wykes et al., 2011; Bowie et al., 2020). CR is one of the most widely investigated treatments for cognitive impairment in psychosis, and is typically delivered via a computer, sometimes with assistance of a therapist (Kambeitz-Ilankovic et al., 2019; Vita et al., 2021). CR traditionally involves automated 'drill-and-practice' type exercises targeting training of specific cognitive domains with increasing levels of difficulty, such as the speed and accuracy of recognition and recall. Some versions involve applying these cognitive skills to everyday scenarios through simulated real-world environments (Reeder et al., 2017). A meta-analysis of CR in ROP identified 11 randomized controlled trials (RCTs), of which six involved computerized delivery (Revell et al., 2015). Four used computerized CR 'drill and practice', two combined computerized practice with the training of everyday tasks. For global cognition outcomes, moderator analysis revealed a smaller effect size for computerized ($d = 0.09$) compared to paper-and-pencil ($d = 0.16$) techniques; however, both effects were small and non-significant. Effect sizes for functional outcomes were also small and did not differ significantly between intervention types (computer $d = 0.15$, paper-and-pencil $d = 0.20$). Looking at the studies that used computerized CR tasks specifically, two studies found above average effect sizes on the outcome of functioning. One study found a large effect ($d = 0.68$) on psychosocial functioning, mediated by immediate learning and memory (Lee et al., 2013). The second study found a large effect ($d = 0.73$) on functioning compared with a control group, with group differences maintained at 10-year follow-up (Wojtalik et al., 2017). Both studies had adjunctive psychiatric rehabilitation to CR. This is consistent with the overall finding of the meta-analysis that CR combined with psychiatric rehabilitation has a significantly more positive effect on functioning than those which were not. Similar overall small effects have been reported in populations with persistent psychotic symptoms, although these tended to be larger for some outcomes (global cognition and working memory, but not for functioning) and when human support is provided (Kambeitz-Ilankovic et al., 2019). A meta-analysis on computer-assisted CR in schizophrenia reported improvements in general cognition, with the largest effect sizes found for improved social cognition (Grynszpan et al., 2011). Findings consistently indicate that CR can be delivered effectively via a digital platform, and the involvement of human support improves outcomes.

3.2. Virtual reality

Very few studies have explored the use of technologies beyond computer-based CR. Some recent work has been conducted using VR. Two systematic reviews have together identified six RCTs and five non-randomized trials of VR interventions for social cognition or cognitive rehabilitation in psychosis (Riches et al., 2021; Schroeder et al., 2021), of which only one was in a ROP population (Thompson et al., 2020). These interventions involved real-world virtual environments to facilitate training in social skills (e.g., virtual conversations with avatars) (Park et al., 2011; Rus-Calafell et al., 2014; Thompson et al., 2020), cognitive training (e.g., decision-making; Chan et al., 2010), functional rehabilitation (e.g., performing everyday tasks) (Amado et al., 2016), and vocational recovery (e.g., job interview training) (Smith et al., 2015). All of these studies reported some evidence of improvements in cognitive functioning, particularly memory, attention, planning, social cognition (e.g., emotion recognition and cognitive biases) and vocational outcomes (e.g., job offers). VR appears suitable for delivering treatment that improves social cognition and functional outcomes in psychosis (Rus-Calafell and Schneider, 2020) and is cost-effective (Pot-Kolder et al., 2020).

Looking trans diagnostically, a recent review of immersive VR cognitive training identified nine RCTs across neurological and psychiatric disorders, including three with persisting psychosis samples (Jahn et al., 2021). The interventions involved performing tasks in real-world environments, such as making judgements about emotions and meaning when conversing with others. Whilst, most of the included studies were pilot studies, the strongest effects were observed for attention and executive functioning across a range of psychological conditions, suggesting immersive VR could offer some transdiagnostic potential for cognitive impairment. However, additional scientific research is warranted for specific populations, including ROP.

3.3. Smartphone apps

To date, smartphone apps to aid cognitive functioning have received minimal empirical investigation in the field of psychosis. One that has been tested in an RCT is the Personalised Real-time Intervention for Motivational Enhancement (PRIME) app, which was developed for young people with ROP to improve motivation and other cognitive-related outcomes (Schlosser et al., 2018). The app helps participants work towards self-identified goals with support of a virtual community of peers and clinicians. Participants were randomized to either the Prime app or waiting list. Participants were recruited in different sites throughout the USA, therefore adjunct care was not consistent. However, 86% reported taking anti-psychotic medication and 70% reported seeing a psychologist. App interventions consisted of both automated reminders on their goals and challenges, and real time messaging with a clinician. Significant improvements were found for anticipated pleasure and effort expenditure in favour of the intervention group. A small (n = 80) RCT found that a memory and attention training smartphone app called 'SMART', was effective in improving attention, but not memory, in a sample people at clinical high risk of psychosis (Li et al., 2021). This effect was related to greater time spent using the app. In this Chinese study the intervention group performed attention and memory training via a Specific Memory Attention Resource and Training (SMART) application in their smart phones for 10 min per day, five days per week for three months. There were nine memory games and five attention games. The control group received treatment as usual. However, no clarification was given as to what treatment as usual entailed or if it was withheld from the intervention group.

While these early studies show some promise, there exists a well-recognized gap between industry and research in the field of digital mental health (Torous et al., 2021). Research conducted in 2019 found that only 3% of commercially available mental health apps had any evidence base (Marshall et al., 2019), and that many apps used pseudoscience and scientific jargon to make unsubstantiated claims of effectiveness (Larsen et al., 2019). This issue extends to digital interventions for cognition, with numerous commercially available programs claiming to support cognitive enhancement. In the absence of many investigator-initiated evidence-based interventions in this space, unfortunately, it is often commercial interventions of unknown quality, that are available to clinicians and consumers. All of the afore mentioned 3% industry studies (10 apps) are targeting mood (i.e. anxiety and depression) using techniques from mindfulness or cognitive behavioral therapy. None are targeting cognitive functioning as defined in this paper.

4. Online and internet-based technologies

The authors believe the unique characteristics of the technology should be considered when developing interventions for current treatment challenges to ensure added value over digitalization only. While the first three modalities described in Table 1 are mostly hardware related, the forth is software related. With continuous access to online services becoming more stable and readily available, like the internet and GPS tracking, so do new software possibilities. Online-software provides additional opportunities above offline-software. For example, an app sending supportive texts or helpful reminders based on GPS location, or a remote therapist guided VR exposure at home for people too afraid to leave their house or living in remote areas. There is also the possibility for real-time therapy in a completely virtual environment. This area is under-explored for treating cognitive impairments in ROP.

5. Challenges to progress or implementation of digital interventions

Several acknowledged challenges in the digital mental health field generally also affect the application of digital technologies in ROP. These include problems with sustained engagement, clinical integration, and lack of regulation and variable quality in the commercial marketplace. These issues must be addressed to advance the evidence base and to support implementation.

Poor long-term engagement with digital interventions is a well-recognized barrier to effectiveness and successful implementation (Torous et al., 2018). Underlying themes suggest these barriers apply when digital interventions are not designed with service users in mind, do not solve problems users care most about, and when are user concerns about privacy and trustworthiness. Digital interventions will need to match user expectations and standards for implementation to happen.

Motivation difficulties, as well as over-exposure to digital products in youth populations, may make this issue particularly challenging for young people with ROP (Bell and Alvarez-Jimenez, 2019). Research suggests that the best solutions for overcoming these issues include: 1) involving human support, such as peer support or coaching to enhance engagement (Biagianti et al., 2018), or 'blending' digital interventions with standard care (Bell et al., 2020b); and 2) working more closely with end users, using participatory design methods, and industry partners, to design more engaging, compelling and purpose-built digital interventions (Liverpool et al., 2020). Recent evidence indicates that by combining human and peer support it is feasible to engage young people with psychosis for sustained periods of time. For example, the Horyzons study, an RCT evaluating a moderated online social therapy platform integrating peer support and moderation, expert clinician and vocational support demonstrated that almost 50% of young people actively engaged with the platform for ≥9 months (Alvarez-Jimenez et al., 2021). The use of elements of video game design in non-game contexts like digital health interventions also seeks to prolong engagement. While this area is still developing, emerging studies are applying elements of gamification to improve cognitive function in psychosis (Amado et al., 2016; Fox and Barnes, 2016).

Another barrier to the wide-spread use of digital interventions for cognitive recovery concerns the complexity of integrating digital interventions within healthcare service contexts. Staff and service user attitudes, organizational readiness, and technology 'fit' within existing service systems, are all factors known to influence the success of implementation within routine care (Aref-Adib et al., 2019; Camacho and Torous, 2021). While young service users are digital natives, many current mental healthcare staff may be less digitally 'savvy' and accept and navigate technology with more difficulties (Prensky, 2001). Proposed solutions include: 1) designing digital interventions for the implementation context and developing the service model and implementation plan alongside the technology (Mohr et al., 2017); 2) developing digital interventions in conjunction with end-users harnessing user-centered design approaches, to ensure the product matches user expectations and standards; 3) conducting trials within the implementation context to ensure findings are readily transferable and generalizable; 4) drawing on knowledge from the field of implementation science to guide an understanding of the unique barriers and enablers of implementation in a specific context (Damschroder et al., 2009); 5) ensuring technologies are flexible and adaptable to the changing implementation context over time; and 6) staff training and support to shift attitudes and build knowledge on the use of technology to support service delivery.

Costs of technology can be considered another barrier. A Cost Utility evaluation of cognition-enhancing interventions for individuals with ROP showed computerized cognitive remediation did not appear to be a cost-effective addition to coordinated specialty care services (Breitborde et al., 2021). Overall, costs are coming down, however. From our personal experience, while in 2010 a VR headset was around 20.000 USD, this dropped to 5.000 USD in 2013, and at time of writing to 500 USD. A similar trend can be seen in VR software development. Where every detail had to be manually programmed, currently many virtual items and basic VR environments can be bought in store. However, professional programmers are still essential for translating that into a stable and interactive VR environment. The development of Apps by comparison is cheaper. In general there is a need for cost-effectiveness to be added to trials to estimate if implementation of digital solutions is economically viable for treating cognitive impairment (Bryce et al., 2021).

6. Opportunities and recommendations

The authors believe further developments should include smartphone and VR-based interventions, particularly supporting human-supported CR and functional recovery in real-world environments. So far, research on digitalized cognitive remediation does not show generalization to everyday life. We believe this to be the case because of the technology used. Active ingredients are likely to differ per technology. If we want to encourage generalization of skills, we could either bring everyday life into the treatment room with VR/AR, or bring treatment into everyday-life by using smartphone apps. These two technologies both have a potential for bridging the gap and could potentially improve current small effect sizes. Studies indicate feasibility, acceptability, and effectiveness of VR for measuring and improving social cognition in ROP (Riches et al., 2021). An RCT on VR therapy for improving social functioning in psychosis found improvement in social cognition to be an important mediator of treatment effect (Pot-Kolder et al., 2018). There are recent examples of successful digital interventions targeting functional deficits in ROP (Alvarez-Jimenez et al., 2021). These interventions have employed motivational frameworks such as self-determination theory coupled with social cognition and strengths-based interventions embedded into a social network environment to foster functional recovery (Alvarez-Jimenez et al., 2018). Factors such as motivation and self-efficacy mediate the relationship between cognitive performance and functional outcome (Allott et al., 2020). This indicates that the next generation of digital interventions targeting cognition and functioning in ROP could widen the focus to include motivational frameworks and behavioral change interventions designed to foster engagement, behavioral change and ultimately functioning (Teixeira et al., 2020).

Commercially developed cognitive training technologies should be approached with caution, due to concern regarding the validity of their scientific claims (Max-Planck-Institute, 2014). Nonetheless, many of these applications are commercially popular. We would suggest partnerships between industry and research to develop digital interventions to improve cognition and establish the evidence base while learning from commercial parties on reward and -engagement. Importantly, we believe funders should be aware that the development pipelines of digital interventions require funding models supporting significant upfront development costs and evaluation frameworks that enable flexibility in adapting the technology over time. Both hardware and software become rapidly obsolete and continued upgrading and adapting is needed for an intervention to stay available. One example is the Accelerated Creation-to-Sustainment model (ACTS; (Mohr et al., 2017)), which is a three-phase evaluation framework covering technology development, trialing and sustainment. This research model is well suited to digital intervention development because it allows for the establishing of evidence within the implementation context, ultimately maximizing sustainability in a real-world setting.

An important opportunity afforded by digital technology is enhancing engagement with cognition treatments, particularly for young people. As dropout rates are high and engagement often poor (Harpaz-Rotem et al., 2004), designing digital interventions that make use of evidence-based techniques for reinforcing motivation and engagement, such as gamification, challenges, tracking and feedback, reward and competition (Cugelman, 2013), may overcome these barriers and improve the experience of treatment (Liverpool et al., 2020). For example, adapting 'drill-and-practice' CR techniques into gamified digital formats, such as a smartphone app, that offer rewards and challenges for activity completion. We speculate that while engagement is a challenge for both clinical and digital therapies, engagement for young people in particular can be increased with the addition of technology. For them as digital natives digital technologies and cyberspace are already an integral and central part of their everyday lives (Prensky, 2001). However, both the hardware and software design used should align with the young person's needs and expectations for this potential to be met.

No direct comparison has been done between digital treatment for cognitive impairments in ROP versus more chronic stages of psychosis. Reviews of research on cognitive remediation for schizophrenia have included mixed samples (Kambeitz-Ilankovic et al., 2019). We suggest that future studies investigate whether there are differences in response to digital interventions between ROP and samples with persistent psychosis. While outside of the scope of this paper, many cognitive challenges present in ROP are not unique for this group of people and there is an opportunity to learn from other fields, such as cognitive neurology. Another potential opportunity is delivering digital cognitive interventions alongside other treatments. There is evidence that receiving computer-delivered CR alongside standard therapist-delivered cognitive behavioral therapy can result in more rapid symptomatic improvement for ROP (Drake et al., 2014). As people with cognitive impairment tend to be more reliant on services, resulting in greater costs (Patel et al., 2006), offering access to digital forms of CR alongside other treatments may provide opportunities to enhance the efficiency and efficacy of care (Wykes, 2018). For example, a novel online social therapy for ROP showed improvements in vocational recovery, and reduced visits to emergency departments over 18-months compared to usual treatment (Alvarez-Jimenez et al., 2021). Platforms such as this could also integrate digital interventions for those with cognitive deficits, potentially creating synergistic effects through increasing engagement, treatment personalization and concurrently addressing comorbid symptomatology. Another opportunity is to adopt technologies as vehicles through which interventions can be delivered remotely, reducing demand on services and improving accessibility. This is well supported by experiences of clinicians and young people within clinical services during COVID-19 (Davenport et al., 2020; Nicholas et al., 2021). We believe purposely-built platforms are needed that build in functionality to support different types of interventions.(Thompson et al., 2020).

It will be interesting to see the extent of integration of these different technologies into blended care, both with each other and with face to face care to combine strengths. Blended care can be defined as the integration of talking therapies (e.g., CBT, social skills training) with digital content and technologies. Overall access to technology and internet for people with ROP is strong in high income countries. A study on technology access in people with ROP reports PCs/laptops were used by all participants; cellphones/smartphones by 92%, and consoles by 83% (Abdel-Baki et al., 2017). For those individuals with no access to a certain technology, mental health institutions might consider loaners to mitigate this barrier. However, both access to technology and access to reliable and affordable internet connections are likely to form a barrier for many middle- and low-income countries. This is also known as the global digital divide, and refers to the gap between those who benefit from the Digital Age and those who do not (Akhter, 2003).

We believe that to ensure digital technologies match needs and expectations of end-users they need to be included in the design process. Including end-users in the co-design of technological mental health interventions is essential for user uptake (Bevan Jones et al., 2020), and if done appropriately, shows promise for engaging traditionally hard to reach service user groups (Realpe et al., 2020). A significant emphasis on participatory methods has emerged from the broader digital mental health literature over the past decade. Several articles have been written on the importance of lived experience involvement in digital intervention development, including in ROP (Nakarada-Kordic et al., 2017). Most trials of digital interventions include descriptions of lived experience involvement detailing how the intervention was developed (Realpe et al., 2020). What is less clear is the best approach to user involvement. This depends on the aim and purpose of the intervention. However, there has been a recent shift away from pure 'co-design' approaches, which weigh the power differential between researcher and end-user equally in making decisions about design, towards 'user-centered' design or participatory approaches. The latter draws more heavily on methods to 'understand' the lived experience of the end-user as it relates to the intervention, typically through focus groups and usability sessions (Scholten and Granic, 2019) in order to make informed decisions about the design. As such, the researchers and developers retain decision-making control throughout the process. These methods have not been compared empirically, however the latter is more commonly adopted in neighboring academic fields such as computer-human interaction, as well as in industry settings. Regardless of the approach, lived experience involvement is now a standard expectation within the field of digital mental health.

In summary, cognitive impairments are a core symptom of ROP and current treatment options fall short. Using digital technologies to address current limitations is promising. There is evidence showing that integrated use of computerized CR combined with human support to be beneficial, especially for improving functional outcomes. There is early evidence that VR therapy can be used to improve specific cognitive domains like social cognition. However, many opportunities in using digital technology like smartphone apps and online therapeutic learning environments for improving cognitive impairment in ROP are under-explored, and implementation barriers need to be addressed. Additional research in this space is warranted and should involve user-centered, participatory and implementation science methodologies to maximize the chances of developing acceptable, effective, and sustainable supports.

CRediT authorship contribution statement

IB performed the main literary review. IB and RP-K drafted the first version of the manuscript. KA supervised the manuscript. All *authors* provided critical feedback and helped shape research and the final manuscript.

Declaration of competing interest

The authors have declared that there are no conflicts of interest in relation to the subject of this study.

References

Abdel-Baki, A., Lal, S., O, D.C., Stip, E., Kara, N., 2017. Understanding access and use of technology among youth with first-episode psychosis to inform the development of technology-enabled therapeutic interventions. Early Interv. Psychiatry 11, 72–76.
Aceituno, D., Vera, N., Prina, A.M., McCrone, P., 2019. Cost-effectiveness of early intervention in psychosis: systematic review. Br. J. Psychiatry 215, 388–394.
Akhter, S.H., 2003. Digital divide and purchase intention: why demographic psychology matters. J. Econ. Psychol. 24, 321–327.
Allott, K.A., Cotton, S.M., Chinnery, G.L., Baksheev, G.N., Massey, J., Sun, P., Collins, Z., Barlow, E., Broussard, C., Wahid, T., Proffitt, T.M., Jackson, H.J., Killackey, E., 2013. The relative contribution of neurocognition and social cognition to 6-month vocational outcomes following individual placement and support in first-episode psychosis. Schizophr. Res. 150, 136–143.
Allott, K., Steele, P., Boyer, F., de Winter, A., Bryce, S., Alvarez-Jimenez, M., Phillips, L., 2020. Cognitive strengths-based assessment and intervention in first-episode psychosis: a complementary approach to addressing functional recovery? Clin. Psychol. Rev. 79, 101871.
Alvarez-Jimenez, M., Gleeson, J.F., Bendall, S., Penn, D.L., Yung, A., Ryan, R., Eleftheriadis, D., D'Alfonso, S., Rice, S., Miles, C., Russon, P., Lederman, R., Chambers, R., González-Blanch, C., Lim, M.H., Killackey, E., McGorry, P., Nelson, B., 2018. Enhancing social functioning in young people at Ultra High Risk (UHR) for psychosis: a pilot study of a novel strengths and mindfulness-based online social therapy. Schizophr. Res. 202.
Alvarez-Jimenez, M., Koval, P., Schmaal, L., Bendall, S., O'Sullivan, S., Cagliarini, D., D'Alfonso, S., Rice, S., Valentine, L., Penn, D.L., Miles, C., Russon, P., Phillips, J., McEnery, C., Lederman, R., Killackey, E., Mihalopoulos, C., Gonzalez-Blanch, C., Gilbertson, T., Lal, S., Cotton, S.M., Herrman, H., McGorry, P.D., Gleeson, J.F.M., 2021. The Horyzons project: a randomized controlled trial of a novel online social therapy to maintain treatment effects from specialist first-episode psychosis services. World Psychiatry 20, 233–243.
Amado, I., Brenugat-Herne, L., Orriols, E., Desombre, C., dos Santos, M., Prost, Z., Krebs, M.O., Piolino, P., 2016. A serious game to improve cognitive functions in schizophrenia: a pilot study. Front. Psychiatry 7, 64.
Aref-Adib, G., McCloud, T., Ross, J., O'Hanlon, P., Appleton, V., Rowe, S., Murray, E., Johnson, S., Lobban, F., 2019. Factors affecting implementation of digital health interventions for people with psychosis or bipolar disorder, and their family and friends: a systematic review. Lancet Psychiatry 6, 257–266.
Bell, I.H., Alvarez-Jimenez, M., 2019. Digital technology to enhance clinical care of early psychosis. Curr.Treat.OptionsPsychiatry 6, 256–270.
Bell, I.H., Nicholas, J., Alvarez-Jimenez, M., Thompson, A., Valmaggia, L., 2020a. Virtual reality as a clinical tool in mental health research and practice. Dialogues Clin. Neurosci. 22, 169–177.
Bell, I.H., Rossell, S.L., Farhall, J., Hayward, M., Lim, M.H., Fielding-Smith, S.F., Thomas, N., 2020b. Pilot randomised controlled trial of a brief coping-focused intervention for hearing voices blended with smartphone-based ecological momentary assessment and intervention (SAVVy): feasibility, acceptability and preliminary clinical outcomes. Schizophr. Res. 216, 479–487.
Bevan Jones, R., Stallard, P., Agha, S.S., Rice, S., Werner-Seidler, A., Stasiak, K., Kahn, J., Simpson, S.A., Alvarez-Jimenez, M., Rice, F., Evans, R., Merry, S., 2020. Practitioner review: co-design of digital mental health technologies with children and young people. J. Child Psychol. Psychiatry 61, 928–940.
Biagianti, B., Quraishi, S.H., Schlosser, D.A., 2018. Potential benefits of incorporating peer-to-peer interactions into digital interventions for psychotic disorders: a systematic review. Psychiatr. Serv. 69, 377–388.
Bowie, C.R., Harvey, P.D., 2006. Cognitive deficits and functional outcome in schizophrenia. Neuropsychiatr. Dis. Treat. 2, 531–536.
Bowie, C.R., Bell, M.D., Fiszdon, J.M., Johannesen, J.K., Lindenmayer, J.P., McGurk, S. R., Medalia, A.A., Penades, R., Saperstein, A.M., Twamley, E.W., Ueland, T., Wykes, T., 2020. Cognitive remediation for schizophrenia: an expert working group white paper on core techniques. Schizophr. Res. 215, 49–53.
Breitborde, N.J.K., Bell, E.K., Woolverton, C., Pine, J.G., Waslter, H., Moe, A.M., 2021. Cost utility of cognition-enhancing interventions for individuals with first-episode psychosis: a naturalistic evaluation. Cost Eff. Resour. Alloc. 19, 36.
Bryce, S., Zbukvic, I., Wood, S.J., Allott, K., 2021. Cognitive remediation to address impairment in schizophrenia: moving beyond effectiveness and toward implementation. Psychiatry Res. 305, 114232.
Camacho, E., Torous, J., 2021. Interest and readiness for digital mental health in coordinate specialty care for early course psychosis: a survey study of 42 programs in 30 states. Early Interv. Psychiatry 15, 1243–1255.
Casey, D., Brown, L., Gajwani, R., Islam, Z., Jasani, R., Parsons, H., Tah, P., Birchwood, M., Singh, S.P., 2016. Predictors of engagement in first-episode psychosis. Schizophr. Res. 175, 204–208.
Chan, C.L., Ngai, E.K., Leung, P.K., Wong, S., 2010. Effect of the adapted virtual reality cognitive training program among Chinese older adults with chronic schizophrenia: a pilot study. Int. J. Geriatr. Psychiatry 25, 643–649.
Correll, C.U., Galling, B., Pawar, A., Krivko, A., Bonetto, C., Ruggeri, M., Craig, T.J., Nordentoft, M., Srihari, V.H., Guloksuz, S., Hui, C.L.M., Chen, E.Y.H., Valencia, M., Juarez, F., Robinson, D.G., Schooler, N.R., Brunette, M.F., Mueser, K.T., Rosenheck, R.A., Marcy, P., Addington, J., Estroff, S.E., Robinson, J., Penn, D., Severe, J.B., Kane, J.M., 2018. Comparison of early intervention services vs treatment as usual for early-phase psychosis: a systematic review, meta-analysis, and meta-regression. JAMA Psychiatry 75, 555–565.
Cowman, M., Holleran, L., Lonergan, E., O'Connor, K., Birchwood, M., Donohoe, G., 2021. Cognitive predictors of social and occupational functioning in early psychosis: a systematic review and meta-analysis of cross-sectional and longitudinal data. Schizophr. Bull. 47, 1243–1253.
Cugelman, B., 2013. Gamification: what it is and why it matters to digital health behavior change developers. JMIR Serious Games 1, e3.
Damschroder, L.J., Aron, D.C., Keith, R.E., Kirsh, S.R., Alexander, J.A., Lowery, J.C., 2009. Fostering implementation of health services research findings into practice: a consolidated framework for advancing implementation science. Implement. Sci. 4, 50.

Davenport, T.A., Cheng, V.W.S., Iorfino, F., Hamilton, B., Castaldi, E., Burton, A., Scott, E.M., Hickie, I.B., 2020. Flip the clinic: a digital health approach to youth mental health service delivery during the COVID-19 pandemic and beyond. JMIR Ment. Health 7, e24578.
Drake, R.J., Day, C.J., Picucci, R., Warburton, J., Larkin, W., Husain, N., Reeder, C., Wykes, T., Marshall, M., 2014. A naturalistic, randomized, controlled trial combining cognitive remediation with cognitive-behavioural therapy after first-episode non-affective psychosis. Psychol. Med. 44, 1889–1899.
Fox, L.G., Barnes, D., 2016. BoosterBuddy: using gamification as a compensatory strategy for motivational deficits. Psychiatr. Serv. 67, 141–142.
Glenthoj, L.B., Hjorthoj, C., Kristensen, T.D., Davidson, C.A., Nordentoft, M., 2017. The effect of cognitive remediation in individuals at ultra-high risk for psychosis: a systematic review. NPJ Schizophr. 3, 20.
Grynszpan, O., Perbal, S., Pelissolo, A., Fossati, P., Jouvent, R., Dubal, S., Perez-Diaz, F., 2011. Efficacy and specificity of computer-assisted cognitive remediation in schizophrenia: a meta-analytical study. Psychol. Med. 41, 163–173.
Harpaz-Rotem, I., Leslie, D., Rosenheck, R.A., 2004. Treatment retention among children entering a new episode of mental health care. Psychiatr. Serv. 55, 1022–1028.
Hollis, C., Falconer, C.J., Martin, J.L., Whittington, C., Stockton, S., Glazebrook, C., Davies, E.B., 2017. Annual research review: digital health interventions for children and young people with mental health problems - a systematic and meta-review. J. Child Psychol. Psychiatry 58, 474–503.
Jahn, F.S., Skovbye, M., Obenhausen, K., Jespersen, A.E., Miskowiak, K.W., 2021. Cognitive training with fully immersive virtual reality in patients with neurological and psychiatric disorders: a systematic review of randomized controlled trials. Psychiatry Res. 300, 113928.
Kambeitz-Ilankovic, L., Betz, L.T., Dominke, C., Haas, S.S., Subramaniam, K., Fisher, M., Vinogradov, S., Koutsouleris, N., Kambeitz, J., 2019. Multi-outcome meta-analysis (MOMA) of cognitive remediation in schizophrenia: revisiting the relevance of human coaching and elucidating interplay between multiple outcomes. Neurosci. Biobehav. Rev. 107, 828–845.
Karson, C., Duffy, R.A., Eramo, A., Nylander, A.G., Offord, S.J., 2016. Long-term outcomes of antipsychotic treatment in patients with first-episode schizophrenia: a systematic review. Neuropsychiatr. Dis. Treat. 12, 57–67.
Keefe, R.S., Fenton, W.S., 2007. How should DSM-V criteria for schizophrenia include cognitive impairment? Schizophr. Bull. 33, 912–920.
Larsen, M.E., Huckvale, K., Nicholas, J., Torous, J., Birrell, L., Li, E., Reda, B., 2019. Using science to sell apps: evaluation of mental health app store quality claims. NPJ Digit Med. 2, 18.
Lee, R.S., Redoblado-Hodge, M.A., Naismith, S.L., Hermens, D.F., Porter, M.A., Hickie, I. B., 2013. Cognitive remediation improves memory and psychosocial functioning in first-episode psychiatric out-patients. Psychol. Med. 43, 1161–1173.
Li, H., Yang, S., Chi, H., Xu, L., Zhang, T., Singleton, G., Tang, Y., Stone, W.S., Wang, J., 2021. Enhancing attention and memory of individuals at clinical high risk for psychosis with mHealth technology. Asian J. Psychiatr. 58, 102587.
Liverpool, S., Mota, C.P., Sales, C.M.D., Cus, A., Carletto, S., Hancheva, C., Sousa, S., Ceron, S.C., Moreno-Peral, P., Pietrabissa, G., Moltrecht, B., Ulberg, R., Ferreira, N., Edbrooke-Childs, J., 2020. Engaging children and young people in digital mental health interventions: systematic review of modes of delivery, facilitators, and barriers. J. Med. Internet Res. 22, e16317.
Mackenzie, N.E., Kowalchuk, C., Agarwal, S.M., Costa-Dookhan, K.A., Caravaggio, F., Gerretsen, P., Chintoh, A., Remington, G.J., Taylor, V.H., Mueller, D.J., Graff-Guerrero, A., Hahn, M.K., 2018. Antipsychotics, metabolic adverse effects, and cognitive function in schizophrenia. Front. Psychiatry 9, 622.
Marshall, J.M., Dunstan, D.A., Bartik, W., 2019. The digital psychiatrist. In search of evidence-based apps for anxiety and depression. Front.Psychiatry 10, 831.
Max-Planck-Institute, 2014. A consensus on the brain training industry from the scientific community. Available. Max Planck Institute for Human Development and Stanford Center on Longevity. https://longevity.stanford.edu/a-consensus-on-the-brain-training-industry-from-the-scientific-community-2/. (Accessed 26 November 2021).
Mesholam-Gately, R.I., Giuliano, A.J., Goff, K.P., Faraone, S.V., Seidman, L.J., 2009. Neurocognition in first-episode schizophrenia: a meta-analytic review. Neuropsychology 23, 315–336.
Mohr, D., Lyon, A., Lattie, E., Reddy, M., Schueller, S., 2017. Accelerating digital mental Health Research from early design and creation to successful implementation and sustainment. J. Med. Internet Res. 19, e153.
Mollon, J., David, A.S., Zammit, S., Lewis, G., Reichenberg, A., 2018. Course of cognitive development from infancy to early adulthood in the psychosis spectrum. JAMA Psychiatry 75, 270–279.
Nakarada-Kordic, I., Hayes, N., Reay, S.D., Corbet, C., Chan, A., 2017. Co-designing for mental health: creative methods to engage young people experiencing psychosis. In: Design for Health, 1, pp. 229–244.
Nicholas, J., Bell, I.H., Thompson, A., Valentine, L., Simsir, P., Sheppard, H., Adams, S., 2021. Implementation lessons from the transition to telehealth during COVID-19: a survey of clinicians and young people from youth mental health services. Psychiatry Res. 299, 113848.
Park, K.M., Ku, J., Choi, S.H., Jang, H.J., Park, J.Y., Kim, S.I., Kim, J.J., 2011. A virtual reality application in role-plays of social skills training for schizophrenia: a randomized, controlled trial. Psychiatry Res. 189, 166–172.
Patel, A., Everitt, B., Knapp, M., Reeder, C., Grant, D., Ecker, C., Wykes, T., 2006. Schizophrenia patients with cognitive deficits: factors associated with costs. Schizophr. Bull. 32, 776–785.
Pot-Kolder, R., Geraets, C.N.W., Veling, W., van Beilen, M., Staring, A.B.P., Gijsman, H.J., Delespaul, P., van der Gaag, M., 2018. Virtual-reality-based cognitive behavioural therapy versus waiting list control for paranoid ideation and social avoidance in patients with psychotic disorders: a single-blind randomised controlled trial. Lancet Psychiatry 5, 217–226.
Pot-Kolder, R., Veling, W., Geraets, C., Lokkerbol, J., Smit, F., Jongeneel, A., Ising, H., van der Gaag, M., 2020. Cost-effectiveness of virtual reality cognitive behavioral therapy for psychosis: health-economic evaluation within a randomized controlled trial. J. Med. Internet Res. 22, e17098.
Prensky, M., 2001. Digital natives, digital immigrants part 1. In: On the Horizon, 9, pp. 1–6.
Realpe, A., Elahi, F., Bucci, S., Birchwood, M., Vlaev, I., Taylor, D., Thompson, A., 2020. Co-designing a virtual world with young people to deliver social cognition therapy in early psychosis. Early Interv. Psychiatry 14, 37–43.
Reeder, C., Huddy, V., Cella, M., Taylor, R., Greenwood, K., Landau, S., Wykes, T., 2017. A new generation computerised metacognitive cognitive remediation programme for schizophrenia (CIRCuiTS): a randomised controlled trial. Psychol. Med. 47, 1–11.
Reichenberg, A., Caspi, A., Harrington, H., Houts, R., Keefe, R.S., Murray, R.M., Poulton, R., Moffitt, T.E., 2010. Static and dynamic cognitive deficits in childhood preceding adult schizophrenia: a 30-year study. Am. J. Psychiatry 167, 160–169.
Revell, E.R., Neill, J.C., Harte, M., Khan, Z., Drake, R.J., 2015. A systematic review and meta-analysis of cognitive remediation in early schizophrenia. Schizophr. Res. 168, 213–222.
Riches, S., Pisani, S., Bird, L., Rus-Calafell, M., Garety, P., Valmaggia, L., 2021. Virtual reality-based assessment and treatment of social functioning impairments in psychosis: a systematic review. Int.Rev.Psychiatry 1–26.
Rus-Calafell, M., Schneider, S., 2020. Are we there yet?!-a literature review of recent digital technology advances for the treatment of early psychosis. Mhealth 6, 3.
Rus-Calafell, M., Gutierrez-Maldonado, J., Ribas-Sabate, J., 2014. A virtual reality-integrated program for improving social skills in patients with schizophrenia: a pilot study. J. Behav. Ther. Exp. Psychiatry 45, 81–89.
Schlosser, D.A., Campellone, T.R., Truong, B., Etter, K., Vergani, S., Komaiko, K., Vinogradov, S., 2018. Efficacy of PRIME, a mobile app intervention designed to improve motivation in young people with schizophrenia. Schizophr. Bull. 44, 1010–1020.
Scholten, H., Granic, I., 2019. Use of the principles of design thinking to address limitations of digital mental health interventions for youth: viewpoint. J. Med. Internet Res. 21, e11528.
Schroeder, A., Rahman, T., Thérond, A., Bogie, B., Matheson, H., Guimond, S., 2021. Virtual reality for rehabilitation interventions in individuals with psychosis: systematicreview.
Smith, M.J., Fleming, M.F., Wright, M.A., Roberts, A.G., Humm, L.B., Olsen, D., Bell, M. D., 2015. Virtual reality job interview training and 6-month employment outcomes for individuals with schizophrenia seeking employment. Schizophr. Res. 166, 86–91.
Teixeira, P.J., Marques, M.M., Silva, M.N., Brunet, J., Duda, J.L., Haerens, L., la Guardia, J., Lindwall, M., Lonsdale, C., Markland, D., Michie, S., Moller, A.C., Ntoumanis, N., Patrick, H., Reeve, J., Ryan, R.M., Sebire, S.J., Standage, M., Vansteenkiste, M., Weinstein, N., Weman-Josefsson, K., Williams, G.C., Hagger, M.S., 2020. A classification of motivation and behavior change techniques used in self-determination theory-based interventions in health contexts. Motiv.Sci. 6, 438–455.
Thompson, A., Elahi, F., Realpe, A., Birchwood, M., Taylor, D., Vlaev, I., Leahy, F., Bucci, S., 2020. A feasibility and acceptability trial of social cognitive therapy in early psychosis delivered through a virtual world: the VEEP study. Front. Psychiatry 11, 219.
Torous, J., Nicholas, J., Larsen, M.E., Firth, J., Christensen, H., 2018. Clinical review of user engagement with mental health smartphone apps: evidence, theory and improvements. Evid. Based Ment. Health 21, 116–119.
Torous, J., Bucci, S., Bell, I.H., Kessing, L.V., Faurholt-Jepsen, M., Whelan, P., Carvalho, A.F., Keshavan, M., Linardon, J., Firth, J., 2021. The growing field of digital psychiatry: current evidence and the future of apps, social media, chatbots, and virtual reality. World Psychiatry 20, 318–335.
Uren, J., Cotton, S., Killackey, E., Saling, M., Allott, K., 2017. Cognitive clusters in first-episode psychosis: overlap with healthy controls and relationship to concurrent and prospective symptoms and functioning. Neuropsychology 31.
Valentine, L., McEnery, C., Bell, I., O'Sullivan, S., Pryor, I., Gleeson, J., Bendall, S., Alvarez-Jimenez, M., 2020. Blended digital and face-to-face care for first-episode psychosis treatment in young people: qualitative study. JMIR Ment. Health 7, e18990.
Vita, A., Barlati, S., Ceraso, A., Nibbio, G., Ariu, C., Deste, G., Wykes, T., 2021. Effectiveness, core elements, and moderators of response of cognitive remediation for schizophrenia: a systematic review and meta-analysis of randomized clinical trials. JAMA Psychiatry 78, 848–858.
Wojtalik, J., Keshavan, M., Eack, S., 2017. 107. Ten-year durability effects of cognitive enhancement therapy in early course schizophrenia. Schizophr. Bull. 43, S56.
Wright, A.L., Phillips, L.J., Bryce, S., Morey-Nase, C., Allott, K., 2019. Subjective experiences of cognitive functioning in early psychosis: a qualitative study. Psychosis 11, 63–74.
Wykes, T., 2018. Cognitive remediation - where are we now and what should we do next? J. Psychopathol. 24, 57–61.
Wykes, T., Huddy, V., Cellard, C., McGurk, S.R., Czobor, P., 2011. A meta-analysis of cognitive remediation for schizophrenia: methodology and effect sizes. Am. J. Psychiatry 168, 472–485.