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Digital Technologies in the Treatment of Anxiety: Recent Innovations and Future Directions

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Abstract

Purpose of Review—This review aims to provide a comprehensive overview of the efficacy, limitations, and future of e-health treatments for anxiety. Within this, we provide detail on "first-generation" e-health approaches, such as computerized therapies. Additionally, we assess the emergence and early efficacy of newer methods of treatment delivery, including smartphone apps and virtual reality interventions, discussing the potential and pitfalls for each.

Recent Findings—There is now substantial clinical research demonstrating the efficacy of internet-delivered cognitive behavioral therapy in the treatment of anxiety. However, the ability of

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these interventions for engaging patients in “real-world” settings is unclear. Recently, smartphone apps for anxiety have presented a more popular and ubiquitous method of intervention delivery, although the evidence base supporting these newer approaches drastically falls behind the extensive marketing and commercialization efforts currently driving their development. Meanwhile, the increasing availability of novel technologies, such as “virtual reality” (VR), introduces further potential of e-health treatments for generalized anxiety and anxiety-related disorders such as phobias and obsessive compulsive disorder, while also creating additional challenges for research.

Summary—Although still in its infancy, e-health research is already presenting several promising avenues for delivering effective and scalable treatments for anxiety. Nonetheless, several important steps must be taken in order for academic research to keep pace with continued technological advances.

Keywords

e-Health; VR; m-Health; Technological; Affective disorders; Internet

Introduction

Recent advances in the capabilities of digital technologies, along with the much-improved affordability and usability of personalized computerized devices, have presented new opportunities for the assessment and treatment of psychiatric disorders [1]. These developments have also been reflected in rapidly growing academic interest in the utility of “e-health” interventions for enhancing mental healthcare [2]. Across all mental health conditions, anxiety disorders may present one of the clearest and promising interventional targets for technological therapies, for multiple reasons. For instance, the epidemiological prevalence of anxiety-related disorders across the population vastly exceeds the capacities of mental health services to provide face-to-face therapy for all those affected [3], thus demanding novel approaches for delivering therapy. Additionally, a large proportion of the population also experiences subclinical symptoms of anxiety which impedes daily functioning and wellbeing, but is associated with low levels of help seeking or falls below the radar of psychiatric services [4]. Thus, creating accessible and effective digital technologies that help individuals to manage and reduce their own anxiety, independently of accessibility or engagement with clinical services, could potentially reduce the growing personal, social, and economic burden of this increasingly widespread mental health condition.

The aim of this review is to summarize the current “state of affairs” regarding e-health approaches towards anxiety disorders and outline key opportunities for future research. Specifically, we (i) provide a comprehensive overview of recent developments in e-health approaches for anxiety disorders, (ii) critically evaluate the current evidence base for existing e-health interventions for anxiety, and (iii) discuss the emerging issues in the continued development and future implementation of digital technologies within mental health services and population-scale interventions for anxiety.

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“First-generation” e-Health Treatments for Anxiety: Established Efficacy and Ongoing Limitations

The potential of digital technologies in the treatment of anxiety was first realized by large-scale randomized controlled trials (RCTs) indicating that computerized versions of cognitive behavioral therapy (CBT) delivered via the internet (termed “iCBT,” and not to be confused with insomnia CBT) could reduce symptoms of anxiety with similar efficacy to face-to-face treatments [5, 6, 7•]. iCBT courses typically consist of a series of standardized modules or lessons, delivered over a fixed time frame that mimics face-to-face CBT interventions (e.g., 8–12 weeks). Online modules provide psychoeducation about the targeted anxiety disorder and teach the user how to implement key CBT skills to change the key maladaptive thoughts, emotions, behaviors, and physical sensations that maintain anxiety [8••]. Like face-to-face CBT, practical “homework” or between session tasks are recommended to help the person learn to self-manage symptoms. Although programs differ in their format and style of delivery, most include thought monitoring, thought challenging, and behavioral experiments to modify unhelpful thinking patterns and reduce distressing emotions, graded exposure to reduce maladaptive avoidance patterns, and relapse prevention. While some iCBT programs can be done completely alone as “self-help,” most involve some form guidance from a clinician, as this approach has been shown to help patients stay engaged in the program [9]. Clinician support is remote, via phone, email, text messages, or messages delivered via a secure platform. Along with these treatment programs, various automated prevention-focused initiatives, delivered through community- and school-based programs, have also demonstrated efficacy for reducing anxiety [10, 11].

Since the earliest computerized CBT programs were developed in the early 2000s to treat panic disorder and specific phobias [12], the field has rapidly evolved, and a large body of evidence has grown supporting the use of iCBT in the treatment of a range of anxiety disorders [13•]. Conditions that can benefit from using iCBT include specific phobias [14], panic disorder [15], generalized anxiety disorder [16], social anxiety disorder [17], health anxiety [18, 19], obsessive compulsive disorder (OCD) [20], and posttraumatic stress disorder [21]. More recently, transdiagnostic programs for mixed anxiety disorders [22] and anxiety comorbid with depression [23] have also been shown to be effective and achieve similar outcomes with disorder-specific approach to treatment [24], but are able to treat multiple and complex comorbidities within the one program. The latest evidence indicates that iCBT achieves similar results to face-to-face CBT [7•], although direct head-to-head comparisons are limited. Importantly, iCBT has demonstrated long-lasting improvements in symptoms, observed up to 5 years posttreatment [25].

Despite the growing evidence of efficacy in clinical trial settings, motivating patients to stay engaged in iCBT remains an ongoing challenge for researchers and clinicians. Effectiveness trials show that iCBT remains effective when delivered in routine care [26•, 27•, 28, 29]. However, in contrast to the completion rates observed in clinical trials (up to 80–90%), only 50–60% of patients complete iCBT in primary care settings [29], and less than 15% complete unguided programs [30].

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While several studies have shown that tailored treatment via the internet is feasible and effective [27•], the majority of existing iCBT programs are delivered in a relatively fixed and standardized format, with little ability to tailor treatment to a patient's presenting problems, maintaining factors, or skills deficits. In addition, similar to face-to-face CBT, approximately one quarter of patients who complete a course of treatment do not respond [31]. More research is needed to determine the moderators and predictors of treatment response and to develop new internet treatment options for individuals who do not currently respond to iCBT. One alternative option for treating anxiety is "attention bias modification training" (ABMT), which can be delivered via computerized format with moderate efficacy[32].However, more recent internet-delivered versions of ABMT have produced null results [33]. Furthermore, the first trial of a smartphone-based version found that although the active ABMT did significantly reduced anxiety over the 4 weeks, similar improvements were also observed in participants receiving the "inactive" version of the smartphone app [34]; indicating that ABMT efficacy may be no greater than placebo when delivered in internet/smartphone-based format.

Other technological approaches towards managing anxiety include internet-delivered mindfulness and acceptance-based behavior (ACT) therapy, both of which may also be as effective as online anxiety disorder treatment [35, 36•], but these studies await replication, and effective programs need to be disseminated.

Contraindications to iCBT and other treatments such as internet-delivered mindfulness are not known. While evidence indicates that iCBT is effective for severe and complex anxiety disorders, it is not known whether iCBT is effective for comorbid symptoms of anxiety in suicidal individuals or people with bipolar disorder, or psychotic disorders, because these diagnoses and presenting issues are often excluded from clinical trials of iCBT for anxiety.

Smartphones as "Next-Generation" e-Health Treatments: Early Evidence and Potential Pitfalls

Most recently, the dawn of smartphone technologies has presented a new, portable, and ubiquitously accessible platform for delivering psychological therapies [37]. The rapid uptake and widespread engagement with smartphone technologies, even among psychiatric populations, adds further promise to the potential utility of these approaches [38]. Evidence for the efficacy of smartphone-based interventions is also growing, as multiple RCTs have already demonstrated that "mental health apps" can significantly reduce symptoms of common mental disorders [39, 40]. For instance, a 2017 meta-analysis of smartphone interventions for anxiety identified nine RCTs, with 1837 participants [39]. Results showed that smartphone versions of psychological treatments, such as CBT and ACT, significantly reduced anxiety, with moderate effect sizes.

Of note, the effects of smartphone interventions for anxiety are significantly smaller when compared to active (rather than waitlist) control conditions [39]. Furthermore, numerous individual studies have demonstrated that although mental health apps appear to significantly reduce anxiety, psychologically "inactive" versions of the same apps may produce equal improvements [34, 41], whereas bolstering an app with additional therapeutic

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components and psychological techniques does not increase effects [42]. Collectively, this could indicate that the observed psychological effects of apps may be partly attributable to a "digital" placebo effect, whereby an individual's sense of personal connection/reliance on their device, along with their frequent engagement with apps while pursuing expected benefits, may result in perceived psychological improvements following app-based interventions, regardless of actual efficacy [43].

Along with RCTs adequately controlling for any "digital" placebo effects, future research should also attempt to actually distil what aspects of smartphone engagement could produce symptomatic benefits, independent of traditional/established psychological therapies. The readily available and personalized nature of smartphone interventions may provide an empowering form of therapy for people with anxiety; who may find the concept of evidence-based anxiety treatment only ever being a few swipes away a constant reassurance. Thus, the unique aspects of smartphone interventions, and how this interacts with psychological status, require further investigation in order to both understand and optimize future interventions [44].

Despite their clear potential, there remains a surprisingly small evidence base for the efficacy of anxiety smartphone apps. For instance, in the aforementioned meta-analysis [39], only nine studies were identified, with pooled effect sizes varying between $g = 0.45$ for studies with a waitlist control group (i.e., small to moderate effects) compared to a mean of 0.19 for studies with an active control group (small effects). Furthermore, the impact of individual study biases [45] in digital health research remains largely unexplored. Thus, the likelihood of smartphone app effectiveness in RCTs translating into real-world benefits for clinical settings and everyday use is unknown. Many apps that are developed and studied in academic environments may not be easily available for consumer use or placed on app stores. The limited research base for these anxiety apps stands in stark contrast to the hundreds of anxiety-related apps available for immediate download on the Apple iTunes and Google Android Play marketplaces. A review of select anxiety-related apps from these marketplaces noted that only 3.8% have ever been rigorously evaluated that 67.3% lacked involvement of any health professional in their development [46]. Another review focusing on social anxiety apps available for download today reported that none had any published evidence to support their efficacy [47].

While evidence for efficacy remains nascent, evaluation of mental health smartphone apps also necessitates new considerations. While an app may not have traditional side effects like a drug, these digital tools do present potential novel risks. Considering the American Psychiatric Association app evaluation framework [48], it is important to also consider the safety/privacy, evidence, engagement, and interoperability of these apps. Many anxiety apps available to consumers note in their terms and conditions that they are not medical devices and thus not subject to medical privacy regulations. This means that many apps may be capturing a plethora of personal information such as geolocation, internet browsing history, anxiety symptoms, and medication logs that the app company now owns, markets, and even sells [49]. Currently, there have been no studies examining privacy protections for anxiety apps. Another important consideration of anxiety apps is that currently there are little data regarding engagement. Evidence from conditions such as PTSD and schizophrenia suggests

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that app users rarely adhere to apps in the long term, and few use them more than two or three times before abandoning them [50, 51]. There are also currently little data on which patients are best suited to use an anxiety app, what is the ideal duration and dose of anxiety app use, and what drives high levels of utilization for anxiety apps. Finally, even an anxiety app that is safe, effective, and engaging is of less value if it silos patient information and impedes data sharing. Many apps today are not able to send data directly to the electronic medical record and instead force both patients and clinicians to log onto proprietary portals to access patient-generated data or progress reports. Ensuring that anxiety apps do not fragment care and clinical data is thus another further important consideration. Finding an anxiety app that protects patient privacy, possesses clinical evidence, engages users, and shares data remains a challenge even today and underscores numerous opportunities for the field.

Given the realities of the few anxiety apps with evidence and many that potentially may impede on patient privacy, a conservative approach is warranted when approaching these apps. Realizing that apps are themselves dynamic, often updating and changing on a weekly or monthly basis [52], static recommendations, scores, and lists of “top anxiety apps” are actually of little value. Instead, a useful approach may be to have an informed conversation with a patient about the security of the app based on the privacy policy, level of evidence based on research claims, checking how the patient feels the app will be engaging and fit into their lifestyle, and formulating a plan to access and review data in line with treatment goals. Just as careful and personalized consideration is used for each patient when selecting a mediation or therapy, it is no different for apps.

Emerging Opportunities in e-Health for Anxiety

Along with using smartphone apps to deliver therapeutic interventions specifically targeting symptoms of anxiety, studies can also consider the potential role of using smartphones for more generalized wellbeing management, and thus reducing anxiety as a peripheral benefit. The strength of this approach is noted in a recent systematic review [39], which found that smartphone interventions which targeted overall psychological wellbeing had consistent anxiolytic effects. Specific examples include a recent study which explored the effects of the “SuperBetter” app [42] on overall mental health and wellbeing. Two versions of the app were compared: one which focused on promoting self-esteem and personal acceptance and an enhanced version which facilitated the use of CBT techniques and positive psychology. The app was used for 10 min per day for 1 month and aimed to reduce symptoms of depression and improve overall wellbeing. Additionally, Proudfoot et al. [53] used an app in conjunction with a computer interface to deliver the “mycompass” intervention: a self-guided psychological treatment with the aim to reduce mild/moderate depression, anxiety, and stress. Participants were encouraged to self-monitor their mental health and complete CBT modules such as problem solving and engage with principles of positive psychology over a period of 7 weeks. Results revealed that both approaches in SuperBetter and the mycompass program conferred significant benefits, producing significant reductions in anxiety over a short period of time.

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Smartphone apps also have the potential to expand their capacities for direct interaction with the user through the use of “biofeedback”: smartphone-to-user feedback loops which create a new sensation-based interface for interaction between the user and the device. This capability presents further potential for anxiety self-management. For instance, Dillion et al. [54] developed a smartphone app which measures galvanic skin response (through the fingertips) alongside heart rate (through wearable pulse oximetry) to measure signals of stress while users engaged in smartphone games. One game (“relax and race”) was developed to provide user feedback in such a way that self-relaxation was rewarded with greater performance in the game, whereas the other control game (“free flow”) did not. The study showed that after just 30 min, participants in the relaxation biofeedback condition had significantly greater reductions in stress/anxiety from both self-reported and objectively measured (heart rate) signals of stress/anxiety than the control condition. This novel study highlights how, in future, smartphone apps may capitalize on biofeedback systems, in order to support self-management of anxiety through down-regulation of acute affective states.

Additionally, the potential of using smartphone apps to reduce anxiety by facilitating healthy lifestyle behaviors should not be neglected, as recent studies have demonstrated that increasing physical activity [55•, 56] and improving diet [57] confer beneficial effects for anxiety. An increasing amount of studies show that smartphones (along with associated wearable technologies) can be effective tools for fostering healthy lifestyle behaviors [58], even in psychiatric populations [59]. However, the potential anxiolytic effects of digitally delivered healthy lifestyle interventions have yet to be explored.

Whereas smartphone apps seem to have the greatest current research attention among next-generation e-health interventions for anxiety, the continued rapid advancements in both the capabilities and availability of digital technologies mean that the entire landscape of e-health continues to shift as new innovations arise. For instance, virtual reality (VR) technology is now becoming increasingly accessible, affordable, and engaging. As advancements in VR evolve, this may present a novel and effective method for providing efficacious interventions for certain anxiety disorders. Until recently, expensive hardware and software have limited the use of VR in the mainstream treatment of anxiety disorders. To date, the majority of research on VR has focused on “VR exposure therapy” (termed “VRET”). Using VRET, a patient can be taken through a series of controlled, safe, and planned exposures to feared situations in virtual worlds, either as preparation for in vivo (real life) exposure, or enabling the person to overcome fears of situations that would be impossible or unsafe to re-create in real life. Several RCTs show that VRET is an effective and useful treatment for specific phobias such as heights (acrophobia) and flying phobia (aviophobia), agoraphobia, PTSD, and social anxiety disorder [see 60, 61–63]. Head-to-head comparisons with in vivo or face-to-face exposure therapy have found that VRET delivers similar outcomes, especially for specific phobias [64]. However, direct comparisons have not been conducted for most anxiety disorders, and there has been some criticism of the quality of the studies evaluating VRET, especially the use of small sample size and the lack of control groups.

Most research has focused on the efficacy of VRET, and less is known about its mechanism of action or which patients will respond best to it. In addition, despite new affordable and low-cost headsets and freely available software, most research has been done in specialized

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VR clinics in the USA and Europe, leaving it unclear whether their effects generalize to the community. There is little research on whether low-cost VR options are feasible or effective to deliver at scale via smartphone apps or online [65]. A less positive consequence of the low-cost VR options is that there is now a range of free and readily available VR programs which claim to "cure" anxiety (e.g., spider fears) that have not been evaluated. While most of the research into VR has focused on delivering exposure therapy, there remains an untapped opportunity to use VR as an assessment tool intervention beyond exposure and as an preventative tool to target processes that render an individual vulnerable to developing anxiety (e.g., threat hypervigilance, hyper arousal) or skills deficits (e.g., social skills training).

Conclusions

Overall, the digital health movement is one of the fastest moving and rapidly evolving sectors in health research. Whereas this presents great potential for producing innovative and scalable interventions for anxiety disorders, capitalizing upon this opportunity requires continued rigorous research. This is clearly a challenge for academic sectors, as it is becoming increasing apparent that existing research paradigms are insufficient for capturing clinically applicable data in a timely fashion, and translating this into efficacious real-world interventions, congruent with the pace of technological breakthroughs. Our broad review across all e-health interventions for anxiety shows that only recently have researchers managed to quantify and establish the efficacy for even the "first-generation" computerized therapies. The subsequent explosion of smartphone technologies, along with the potential for commercialization of mental health apps, has widened the gap between the availability and marketing of such interventions compared to their scientific support. Additionally, the recent dawn of even newer technologies (such as virtual reality interventions) further highlights the need to re-consider how both research and healthcare can stay "up to date" with recent advances, and provides the best possible advice for applying e-health within the treatment of anxiety disorders.

Initiatives which may bolster current efforts to assess and moderate novel e-health interventions for anxiety as they arise include:

- **i.** Developing novel and standardized research paradigms for pragmatic evaluation of e-health interventions in "real-world settings," in order to quickly benchmark the effectiveness of new interventions (or software updates for existing interventions) against set criterion, without the need for constantly conducting additional RCTs.
- **ii.** Incentivizing commercial technology companies to embed independent scientific research as a core aspect of their development process; perhaps by public and private healthcare providers producing consensus statements on the levels of evidence required for e-health interventions to be integrated within their healthcare systems.
- **iii.** Working with government bodies to implement clear regulatory standards; ensuring that all e-health interventions which are marketed/advertised to

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individuals with anxiety disorders are evidence based and meet established criteria for safety and data privacy. This process would be catalyzed by developing business and regulatory models which incentivize industry partnerships.

iv. Despite these challenges for e-health research, the underlying reason behind the imperative for keeping pace with technological advances is a positive one; as detailed throughout this review, there is already emerging efficacy for various digital interventions in the treatment of anxiety. Given that the entire field of e-health research is currently within its infancy, these early findings hold great promise for the future. As conventional health services are increasingly over-stretched and under-resourced, the potential for scalable, effective, and ubiquitously accessible digital interventions presents a clear possibility for addressing the growing societal burden associated with anxiety disorders. Nonetheless, translating technological advances "from code into care" will rely upon the formation of creative alliances between healthcare, research, and commercial sectors.

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