Viewpoint

Using Principles of Design Thinking to Address Limitations of Digital Mental Health Interventions for Youth

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Abstract

Numerous reviews and meta-analyses have pointed to technology’s enormous potential to improve the appeal, effectiveness, cost, and reach of mental health interventions. Yet the promise of digital mental health interventions for youth has not been realized. Significant challenges have been repeatedly identified including engagement, fidelity, and the lack of personalization. We introduce the main tenets of design thinking and explain how they can specifically address these challenges, with an entirely new toolbox of mindsets and practices. We also provide examples of a new wave of digital interventions to demonstrate the applicability of design thinking to a wide range of intervention goals. Moving forward, it will be critical for scientists and clinicians to implement their scientific standards, methods and review outlets to evaluate the contribution of design thinking on the next iteration of digital mental health interventions for youth.

Key words: e-mental health, anxiety, depression, youth, design thinking
Mental health problems for children and adolescents have significantly increased, with the current prevalence rate of mental disorders estimated to be 13.4% [1-4]. According to the latest update from the World Health Organization [5], half of all mental health disorders in adulthood start by age 14 and three-quarters by the mid-20s. As a result of rising overall prevalence rates and increases in rates of mental health concerns for young people specifically [1], along with little change in the availability of mental health interventions, 64-87% of mental health issues in young people are undetected and untreated [5, 6-8].

The rapid growth of technological innovations has been welcomed by many in the mental health research and practice communities as an unprecedented opportunity to address the increasing gap between demand and supply of mental health services [9,10]. Review after review have pointed to the enormous potential to improve effectiveness, efficiency, cost, reach, personalization, and appeal of mental health interventions with the use of technology [e.g., 11-15]. Under the rubric of "e-mental health," such advantages are proposed to rely on the ubiquitous role of interactive media in the daily lives of young people [16]. Yet the effectiveness of digital technology to reduce the burden of mental health at a population level is progressing slowly at best [17-20]. It remains uncertain whether the hype and promise of e-mental health solutions will actually be realized [14,21].

In the current viewpoint, we examine the evidence for the efficacy of digital interventions for young people, with a focus on those targeting anxiety and depression. There are already many excellent reviews and meta-analyses summarizing the efficacy of digital interventions; this viewpoint does not attempt the same. Instead, we briefly summarize the evidence pointing to disappointing outcomes, especially for youth. We have only included effects based on post-intervention measurements because most meta-analyses did not have power to make reliable conclusions about the effects on follow-up measurements. We then go on to outline an altogether new approach, using principles from the discipline of design.
Design thinking is usually considered outside the purview of scientific research; however, we argue that this cross-disciplinary approach may be key to galvanizing progress. Three tenets of design thinking are introduced and preliminary empirical evidence from our own lab demonstrate both the opportunities and challenges inherent in this new approach. Finally, as this design framework is new in the mental health arena, we end with recommendations for systematic programs of research that directly test its impact on effectiveness and its implications for implementation.

Outcome Research on Digital Mental Health Interventions

The widespread availability of digital technology has led to a proliferation of digital mental health interventions (DMH). The vast majority of DMH approaches target depression and anxiety and are based on cognitive behavioral therapy (CBT), originally developed several decades ago for face-to-face treatment and adjusted for self-help books and manuals [11]; we focus our review and recommendations on this class of DMH interventions. There is also a growing body of promising research on virtual reality interventions, especially in the clinical context, but it is not directly relevant to our current purposes [see 22, for review].

Overall, the efficacy of DMH programs for depressed and anxious adults has been established by over 100 studies [11]. Based on the latest meta-analysis for anxiety disorders among adults [15], guided DMH interventions are more effective than a waiting list, attention, information, or online discussion group (disorder specific symptoms: Hedges’ $g = 1.06$; general anxiety symptoms: Hedges’ $g = 0.75$; low to moderate quality of evidence). For depression [23], DMH interventions were favored over waiting list only (Hedges’ $g = 0.90$). There was less data available comparing DMH interventions to an active treatment control group (one study: hedges’ $g = 0.45$) or placebo control groups (three studies, no aggregation of effect sizes), however the available data suggests that DMH interventions are more effective (yet smaller effect sizes than when compared to a waiting list). Other studies also
suggest that guided DMH interventions do as well as active treatment control groups (i.e., face-to-face CBT) for anxiety [15] and for depression [12].

There is still considerable variability in outcomes and the inclusion (or exclusion) of human guidance could be one of the key factors that explain this variance. The influence of human guidance on DMH interventions for adult anxiety and depression is still being debated [24,25]. Some meta-analyses report equal effects for guided and unguided DMH interventions for anxiety [15; note however that the evidence was very low in quality] and depression [23], whereas other studies have shown that guided DMH interventions outperform unguided ones [e.g., 26-28]. Based on a recent meta-analysis on depression symptoms [29], unguided DMH interventions are more effective than waiting list, attention placebo, no treatment, or treatment as usual (Hedges’ $g = 0.27$), however the effect is much smaller than for guided DMH interventions ($g_{\text{unguided}} = 0.27$ vs. $g_{\text{guided}} = 0.90$). Importantly, Ebert and Baumeister [24] argue that these meta-analyses are solely based on randomized clinical trials which require a high level of commitment and adherence from patients, unlike the conditions in routine clinical care. It is likely that the reported effect sizes of unguided DMH interventions under laboratory settings are overestimated for their potential in routine clinical care. Thus, despite optimism as to the potential of DMH tools as standalone interventions for adults, human involvement in its delivery and monitoring seems an important mediator of success for routine clinical care outside the laboratory.

When moving to the comparably smaller body of evidence available for children and adolescents, the results are less optimistic. Based on the most recent meta-review by Hollis and colleagues [14], overall effect sizes for youth are moderate to large (hedges’ $g$: 0.53-1.41) for anxiety disorders, and small to moderate for depression disorders (hedges’ $g$: 0.16-0.62) when DMH approaches are compared to a waitlist or an attention control group. Analyses comparing DMH interventions for both anxiety and depression with active controls (e.g.,
face-to-face CBT, usual care or active controls), however, have generally failed to show superiority of DMH interventions [30-33]. For example, Pennant and colleagues [34] showed that face-to-face CBT was more effective than DMH interventions. Thus, although the available evidence is not conclusive yet for youth-focused studies, some sort of human guidance seems to be important for the effects on anxiety and depression.

The role of human guidance in youth-focused studies is even harder to disentangle, as the level of human support is poorly specified across trials [14]. However, one of the most recent studies [35] reported that the interventions in their meta-analysis that favored the DMH intervention group included face-to-face guidance, monitoring of engagement, or follow-up telephone calls by teachers and health professionals. Importantly, the quality of the youth-focused studies for DMH programs is generally low to moderate, most often caused by methodological flaws such as intervention heterogeneity in terms of content, dose, settings, or quality [14,36]. Furthermore, problems such as insufficient search processes of the literature, small sample sizes, differences at baseline in study samples and publication bias play important roles in the quality of these studies as well [34,37]. In sum, there is some support for the role of DMH tools in improving anxiety and depression problems in adults, but there are less promising results for children and adolescents. For the youth-focused research, poorer overall outcomes, the heterogeneity of results, and the poor quality of many studies prevent definitive conclusions.

Limitations of DMH Interventions for Youth

Despite some promise, there is growing consensus around the limitations of DMH approaches, with almost every meta-analysis and systematic review (both with adult- and youth samples) highlighting the same problems. First, high attrition rates and low adherence to protocols are consistently problematic, although more so in unguided [29,35,37,40] compared to guided DMH interventions [35,38]. Considering only unguided digital
interventions, Karyotaki and colleagues’ [39] meta-analytic study showed that almost 70% of participants dropped out before completing 75% of the intervention. Attrition and low adherence are even bigger challenges among children and adolescents; the younger the participant sample, the greater the dropout [35,39]. Välimäki and colleagues [35] showed that young people (between the ages of 10 and 24 years) in the digital intervention groups (most often guided DMH interventions) left the study earlier than the control groups participants. Thus, the use of guided digital interventions seems to be the best solution; yet the need for therapists compromises the most oft-espoused advantage to DMH interventions, their scalability (i.e., easily deployed across the globe to populations with different economic and ethnic backgrounds; [14]).

In addition, and most importantly, DMH tools do not remotely approximate the level of attractiveness and interactivity to which young “digital natives” have grown accustomed [16,34,41]. In this first generation of DMH tools, most researchers and intervention scientists seem to have assumed that putting content online, and providing youth the agency to navigate this content at their own pace and in their own context, makes this content more engaging in comparison to conventional treatment approaches. However, in the vast majority of cases, the content of DMH interventions is not significantly changed from the manuals from which they were derived. In the understandable and commendable effort to remain “evidence-based”, most DMH interventions for youth are little more than modified and uploaded CBT treatment manuals and workbooks (e.g., MoodGym, Cool Kids, Camp Cope-a-lot, BRAVE; for review, [34,42]). It is likely that the digital incarnations of these CBT interventions are rendered even less engaging than in their original format because they are less flexible and personalized. The therapist is not available to maintain motivation for change, build trust and hope, and to sensitively tailor the treatment to personal idiosyncrasies.
Furthermore, many DMH interventions are based on a one-size-fits-all approach (e.g., a linear progression with content released to all participants using time-based rules; [42]), which has its advantages because it is systematic, but remains problematic because of its perceived inflexibility [43]. Young people in particular value self-reliance and control when accessing digital products [44] or mental health services [45], and current DMH interventions are often perceived as impersonal and unresponsive to their individual needs [14,41]. In addition, DMH interventions are content-focused (i.e., CBT techniques) and not user-focused (i.e., they are not designed with how and when young people prefer to engage with digital experiences; [46]), resulting in a large disconnect between the world in which youth live and the content and style of DMH interventions. For the current and upcoming generation of youth who play video games and socialize online daily, the norm is digital experiences that are exquisitely designed to adjust to the pace, content preferences, and skill levels of their users [47]. Personalization is consistently mentioned as one of the biggest advantages of digital solutions, but at this point, personalization, dynamic adjustment, and tailoring has not been realized with DMH tools [14,41,48].

The cognitive load of DMH programs seems to be an additional limitation for young people especially. Many e-mental health programs are overly pedantic, didactic and cognitively focused [42], thereby potentially overloading children and youth who find this approach too difficult and inaccessible [49]. Homework assignments pose an additional problem, relying on the abilities of the child or adolescent to practice the CBT-based exercises and learn accordingly. More often than not, however, youth fail to adequately follow through on these offline homework assignments, either because they simply do not understand them well enough to practice or because they are not motivated to do so [32,37]. The same practice and homework problems can arise in conventional CBT, of course, but in face-to-face
treatments, therapists are there to motivate, encourage, answer questions, and keep clients accountable [11].

At this point, an important caveat is in order: We are by no means advocating getting rid of therapists, coaches and teachers altogether, especially in serious, chronic mental health cases with youth. Our best outcomes for serious clinical youth cases may come from combining face-to-face interactions with digital intervention “homework” in which young people practice the lessons they have learned in the comfort of their own home or on mobile devices embedded in their everyday lives (e.g., “blended” approaches; [50]). However, this digital homework still requires attention to the factors that motivate and engage users.

In sum, a convincing set of reviews and meta-analyses suggest that the promises of digital solutions, especially those targeted at youth, have not yet been realized [10,11,35]. Specifically, the benefits of DMH interventions, including increased engagement and motivation, fidelity to intervention protocols, and the opportunities for personalization [11,46,48,51] remain largely unrealized. Perhaps unsurprisingly, all the reviews we have summarized end with general recommendations for reflection and reform, urging future efforts to take engagement, retention and fidelity more seriously. But these critical reflections consistently stop there, providing very few concrete, actionable solutions to address the limitations they revealed [52-55]. In the rest of this viewpoint, we elaborate on a set of guiding principles and concrete strategies for potentially addressing this impasse.

Design Thinking: Novel Recommendations and Proposed Solutions

In the following section, we outline a design framework that has helped us reimagine the development of DMH solutions for children and adolescents. Our approach grew directly from identifying the limitations of past DMH interventions for youth and attempting to address each head on. A major step toward such solutions derives from our work with applied
video games for mental health. Elsewhere [47], we provided a detailed empirical review that supports the rationale for using digital games as intervention tools for young people. In short, well-designed applied games are intrinsically motivating, they offer a strong sense of agency, and are simply fun. They also provide a compelling virtual playground to not only gain knowledge, but to practice skills. Finally, applied games can overcome the stigma associated with visiting a “mental health” website or downloading a DMH tool.

We are not the first to suggest that applied games are useful intervention approaches. A zeitgeist has emerged in the medical and educational fields for applied or “serious” games as tools for enhancing medical care [56-59]. Although much less work has been done with serious games for mental health, several game-based interventions have been developed [60-63]. A big part of our message is that not all digital interventions -- including games -- are designed equally, and most serious games suffer from the same limitations that we have outlined for DMH interventions more generally. Our solution has been to adopt a design thinking (DT) framework which provides a cohesive set of principles and recommendations for DMH delivery more generally.

Defining Design Thinking

Before proceeding to define DT, it is important to say that this approach is not simply about making products or services more attractive, pretty or graphically sophisticated. It often does involve some degree of aesthetic improvement, but fundamentally, DT is both a mindset and a set of practices that are solution-based. The business community, as well as healthcare, transportation and creative industries, have benefited enormously from the adoption of DT [54, 64-68]. Compared with scientific practices in which data are “objective,” observable facts that are tested against a priori hypotheses, DT is a fundamentally subjective practice which concerns itself with discovering the emotional needs of users, their idiosyncratic contexts,
their motivational concerns, and so on. DT approaches aim to build a practical product or service that serves a very particular need.

As a stand-alone practice, we are not suggesting DT is enough to address the concerns we have listed about DMH interventions for youth. But combined with rigorous scientific standards and methodologies, this cross-disciplinary approach holds a great deal of promise. There are three core tenets of DT: (1) Empathy: A human-centred approach that keeps the emotional, motivational and functional needs of users at the centre of the development process; (2) Multidisciplinary Ideation: Solutions generated by cross-disciplinary teamwork and collaboration; and (3) Experimentation: The practice of rapid prototyping and iteratively testing products or services with target users, during rather than after, the development phase. These terms have varied meanings in psychology, psychiatry and clinical practice, but they have very specific meanings in the discipline of design, as elaborated next.

**Empathy**

At its core, empathy-based design is a human-centred approach that answers, “who is it for?” rather than “what does the product look like and contain?” Empathy seems a fuzzy, unscientific lens through which to consider evidence-based practice, but it is the most crucial and perhaps least understood or integrated practice in the development of digital interventions. Empathy-driven design seeks to optimize user engagement, immersion, and motivation and, in so doing, it has the potential to address key limitations of conventional DMH approaches (i.e., high attrition, low adherence, cognitive load). Instead of starting with the common premise, “we’re going to design an app that does X,” empathic design begins with, “we’re going to solve X for a specific population” and, thus, helps developers expand beyond the exclusive content focus of DMH programs (e.g., CBT techniques) towards user concerns (e.g., the young person’s preferences, digital habits, and so on).
Beyond understanding the demographics, personalities, and preferences of individual users, empathic design necessitates keeping the whole end-to-end user experience in mind. Applied to youth mental health, user experience can be conceptualized according to these questions: (a) How are young people going to find an intervention/game/service? (b) When they find it, does that digital ecosystem motivate them to keep discovering more, or does it shut them down? (c) Are there positive expectations for change embedded in a growth mindset [69,70]? (d) How long after they purchase or freely download the product, service, or game will it provide feedback about progress and how will that make users feel? (e) Can they share it with like-minded peers and concerned adults? (f) Will it be updated with new content to keep them interested over longer periods? (g) When the experience ends, is there a feeling of mastery?

An empathy-driven approach also includes participatory design; that is, we not only design for young people but with them as well, and do so from the start of the design process. As digital natives [71], young people are using interactive media and technology almost from birth[16] and on a daily basis. By the time they come to engage with any particular DMH product, they have grown accustomed to interacting with highly engaging, sophisticated, and immersive contexts. If digital interventions are going to stand a chance of improving the mental health of youth in the coming decades, they will need to be designed to stimulate and retain users’ attention. The first step towards ensuring that this will happen is to invite these users to co-develop products aimed at their cohort. Several other researchers have suggested the importance of recruiting young people in the development process. This practice has been referred to as participatory design, participatory research, co-design, and user-centered design [41,60,61,72,73]. But in the mental health context, this process often amounts to professionals asking youth about the products they have already designed, with little time or money allocated for the suggested changes that emerge through the process [72,74,75].
We argue that, in the mental health fields, the greatest barrier to adopting a participatory approach is the implicit paternalistic mindset that may have become ingrained in many academics and practitioners. Mental health researchers and clinicians often assume that young people, especially those who are emotionally vulnerable, do not know when they are suffering and are incapable of asking for the kind of help they need [6,76,77]. However, most youth with anxious and depressive symptoms are well aware of their vulnerabilities and struggles [78]. The key barrier to better outcomes for these youth is not their own ignorance of whether they need help, or even the kind of help they need, but their ability to find the resources and services that will support and train them in a way that speaks to their preferences and modes of learning [76,78,79]. By recruiting youth with mental health challenges from the outset of the design process, to teach us how they interact and seek information online, we have a better chance of designing something they will find initially engaging, that will retain their attention, and that will ultimately be viewed as relevant to their needs [44].

In our own work, we have taken on this empathy-driven, participatory approach to fundamentally change our starting point in applied game design. Participatory design starts very early, even before any programming of intervention games has begun (e.g., using paper prototyping methods, interviews, focus groups). Traditionally, this user-research phase is rushed through to get to the “real science.” However, we argue that the scientific outcomes we seek to enhance will not be realized unless empathic, participatory methods are placed at the forefront of our process.

*Example 1: Smoking cessation game for adolescents.* A specific example from our lab may be useful to clarify the strengths of using an empathy-driven approach to digital intervention design. In this project, we aimed to design and test a game to help young people quit smoking. Although it did not directly target mental health, the example is illustrative of
principles and practices that are entirely relevant to mental health applications and useful for making explicit the practices we previously described. Before designing this applied game, we invited young people who smoke to talk specifically about their smoking experiences, and how they feel about quitting. Past research on smoking cessation claim that, because young people have only just started smoking, they are not motivated to quit [80]. Thus, psychoeducational programs that outline the negative consequences of smoking are the most common intervention approach, skill-training based on CBT techniques and motivational interviewing are traditionally employed as well [81-83]. None of these interventions has been successful [81,83].

We started with a different approach, using structured tools from DT with young people who smoke (e.g., card sort tasks, screen-shot photos of youths’ own phones, interview protocols; d-school resources, [84]). The insights we review were all gained from qualitative interviews with young smokers that were part of unpublished user research with early versions of the game. Our aim was to discover previously misunderstood or overlooked factors that could contribute to designing an end-to-end intervention experience that would effectively help youth quit smoking. We learned, contrary to common assumptions, that they are well aware of the negative consequences of smoking and are often motivated to quit (for corroborating empirical evidence, see [85-87]). Despite their motivation to quit, they did not know where to look for help; indeed there are currently no evidence-based interventions available for young people attempting to quit [81,83]. They explained their feelings of inferiority and anxiety that accompany failed attempts to quit. Given the stigma associated with smoking, they resist asking for help with their addictive vulnerabilities, at least from adults. They are aware they are struggling and some seek help online, anonymously. But the advice they get online is perceived as didactic, outdated, and boring.
Instead of focusing on the unhealthy and harmful outcomes of smoking, an empathy-driven lens led us to dig deeper into the emotional and social contexts in which smoking behaviors emerge. We sought to understand what smoking meant to these young people, how it served important needs and where they felt smoking blocked their goals. We discovered that there was a great deal of variability in terms of where and when young people chose to smoke, suggesting the importance of tailoring a DMH intervention to these individual preferences. We also learned that smoking served several functions: to cope with stress, to overcome boredom during the day (e.g., waiting for the bus) and, crucially, to socialize with friends during breaks. These functional and motivational accounts of young smokers served as the essential scaffold on which we hung other evidence-based practices, such as inhibition training [e.g., 88].

From these empathy-focused conversations, we designed the intervention to serve as a functional replacement for the smoking habit. We made the game into a “casual runner”, a genre that lends itself to short bursts of intensely engaging gameplay (i.e., 3-5 minutes per session, the approximate time it takes to overcome a craving moment, or to smoke a cigarette). To address the problems with the “one size fits all” approach, we made sure that the game could be played during individualized moments of high craving or boredom. We designed tailored prompts that reminded users to play when they previously indicated suffering from high levels of craving. To enhance relevance in youths’ everyday lives, the game is played on mobile devices so that young people had access to it whenever they might want to smoke. See Figure 1 for screenshots and leaderboard example.
In addition, we learned how important it was to bring their peer network into the intervention context. We tried to increase motivation, commitment and engagement through game-based experiences that were fundamentally interactive and brought them together with like-minded smoking peers who were motivated to quit. We also strove to decrease stigma through cooperative (as well as competitive) team-based gameplay that mimicked other online social games with which they were already familiar. Through the cooperative team-based design, youth could learn that there were many like-minded peers that suffer from the same problems they do and they could playfully apply “friendly” peer pressure to encourage each other to play the game (which implicitly sent the message that they were all quitting together). The competitive elements helped them stay motivated and focused on quitting without resorting to didactic or stigmatizing scare tactics.

RCTs are currently underway to test the efficacy of this new approach and whether the specific design elements mediate efficacy. We do not have these data yet. But our main aim in elaborating this example was to provide concrete instantiations of design decisions that would not have otherwise emerged without an empathy-based DT approach.
**Multidisciplinary Ideation**

DT places a great deal of value on cross- and inter-disciplinary collaborations with the conviction that only through a multiplicity of perspectives can true innovation arise. A crucial part of DT practices is the generation of a large set of ideas, at first without an eye towards evaluating the veracity of those ideas, but simply towards collecting the broadest range possible. This approach is in stark contrast to the way most scientists work, starting from a place of established principles and evidence-based techniques. Although we strongly believe that scientific principles and practices should form the basis from which DMH interventions grow, the potential for new opportunities to engage and retain young people’s attention and time may come from allowing teams to creatively explore options outside of these empirically-established methods. That exploration is much more likely to yield genuinely novel design possibilities when diverse perspectives are encouraged and then culled via scientific constraints.

We suggest that a wide multidisciplinary net needs to be cast in order to bring DT practices to bear on the development of immersive digital products for young people’s mental health. For example, in our own work, we cultivate collaborations among developmental psychologists, neuroscientists, veteran game developers that have extensive experience in the commercial game industry, programmers, and artists, all of whom need to learn each other’s domain-specific language and co-develop a set of shared terms and goals. For DT methods to work, it is also important to invite stakeholders, who may include teachers, clinicians, physicians, parents and children themselves, to be part of the co-design process. In doing so, we can integrate empirically validated principles of clinical change with evocative art and design to render user experiences that are enriching, engaging and “sticky” enough to bring young people back for more.
The DT framework as it applies to DMH interventions requires ideation from more than designers, artists, and mental health professionals. Programmers and formally-trained engineers are also crucial partners. Most often, technology and technical requirements are ignored by social scientists. But early and frequent collaborations with engineers during the early design and evaluation stages are critical because this is when the back-end, data acquisition system can be seamlessly integrated with the front-end, user interface. This back-end architecture can prove incredibly useful for researchers and clinicians alike. For example, strong, effectively designed data-acquisition systems can be designed to automatically calculate and quantify real-time in-game (or in-app) play or usage behavior. Information about what parts users interacted with, how long they engaged, when they returned, in what areas they lingered longest, how quickly they acquired skills, and so on can serve as powerful analytic tools for the researcher and clinician alike. Thus, engineers who can build analytic, non-invasive systems can address some of the most pernicious limitations in conventional DMH interventions: participant/client accountability, fidelity and tracking. Technical experts also need to be kept on board past the development and efficacy testing in order to update software continuously (to keep it current and more engaging) and to insure compatibility with changing technology ecosystems (e.g., new operating systems, various platforms such as phones, watches, tablets).

Experimentation

“Design thinking is a misnomer; it is more about doing than thinking.” [84]. It seems peculiar to explain experimentation to researchers, but in the context of DT, it means something different than applying the scientific method in a controlled environment in which one, or very few, factors are manipulated to test a hypothesis. Experimentation in DT refers to a set of processes and practices built around prototyping. A prototype is a simplified version of a product, or part of a product, that is created in minimal time and at minimal cost. It is
used to test the validity of ideas or design assumptions as rapidly and cheaply as possible. Designers often emphasize the massive advantages of “just doing” -- acting out ideas to test their utility before great expense has been invested in a product or service. In the case of DMH interventions, this prototyping phase is often skipped, or applied at such a late stage that little adjustment remains feasible.

Prototyping takes various forms (e.g., paper-and-pencil games, white-boards with sticky notes that depict the flow of a digital experience, storyboards that illustrate the “beats” of a user’s end-to-end experience, PowerPoint mock ups to click through to get the feel of a tool). What is common across these forms is that they are concrete, tangible artifacts that allow hands-on experience and evaluation before any programming starts, and they are usually applied iteratively with a small number of target users. Importantly, prototyping is not meant to take the place of scientifically rigorous experiments or clinical trials; rather it addresses specific design questions. The results of prototyping iteratively and rapidly are action-based insights about the feel and usability of a product. Oftentimes, what emerge are “creative serendipity” and unanticipated insights.

One of the most important lessons we have learned is that throughout the experimentation process (prototyping and later phases), it is crucial to separate and synchronize the goals related to the digital tool versus the intervention. We have studied game design in particular, and we will focus on that domain for articulating our points, but the same principles apply to any interactive app, dynamic website, or other digital media form. As shown in Figure 2, the timelines for game development and intervention development run in parallel. Importantly, these streams iteratively influence one another over time. Each domain has its own set of testing principles and practices, to be applied differentially at each phase.
Figure 2. Separate but interactive development timeline for game and intervention goals.

For example, early in the prototyping phase, two sets of goals are evaluated in parallel (see Figure 3). On the game development level, we evaluate whether the game’s mechanics actually work as they were designed (mechanics are the “verbs” of the game; what players actually do to move through the game towards specified goals; this could also be navigation procedures for a website or app). At this early stage, we test whether players proceed through the intended pathways. Do they know what is being asked of them to solve a puzzle? Do the controls feel natural? Concomitantly, on the intervention development level, this phase is often referred to as piloting and can include tests of whether the game elicits the emotional responses intended. Is the cognitive load overwhelming (a barrier with conventional digital interventions for youth)? Do players respond with reactance (i.e., do they experience the game as didactic or pedantic and quickly turn off)? Figure 3 also shows the relation between the scope of the data collection (e.g., sample size), the timing of evaluations, and the different foci and products, over the course of the development process. All of the prototyping and testing discussed so far falls into Box A in Figure 3. An example from our lab with an applied game that has undergone most of the phases in Figure 3 is presented next.
Figure 3. Timeline and scope of game development in interaction with intervention development.

Example 2: MindLight, an anxiety prevention game for children. During the development of MindLight, a game designed to decrease anxiety symptoms in children, a great deal of prototyping was done to address the two streams of design goals. For example, the game relied largely on exposure techniques to train anxious children to practice facing fears while using relaxation methods. The artists on the project drew several versions of the monsters in the game (see Figure 4), given the importance of these figures for triggering fear, and tested whether children would approach them after a certain period of hesitation (game development goal -- Figure 3). Meanwhile, the psychologists on the project tested children’s fear responses and appraisals of control to overcome their fear to each of these creatures (intervention development goal). Contrary to expectations, most children found the one-eyed monsters humorous and “cute.” Thus, we chose to use the 2-eyed creatures instead, to insure we triggered the fearful responses essential for exposure techniques to work at the
intervention level. Another example of a game mechanic that needed repeated prototyping was neurofeedback. We designed the game so that the calmer children felt while using relaxation techniques during exposure to fearful events (measured by a one-channel EEG system; [89,90]), the brighter the light in the game would shine; the more anxious, the darker it became. A sensitively-tuned threshold for when the light would turn on had to be established: players needed to feel motivated when it was dark to practice relaxation skills and maintain motivation to regain their calm but they could not be so afraid or frustrated that they quit early. Pilot studies helped us identify this threshold, as well as a reasonable pace of increasing this threshold over the course of the game, maintaining challenge and engagement.

Figure 4. Cat concept design for MindLight.

After several iterations to tweak the dynamic adjustment and reward system, a redesigned beta version (full game coded with eight hours of gameplay), was used in a series of RCTs. During this phase (D in Figure 3), the main intervention goals were to use rigorous experimental designs to test the game’s impact on children’s anxiety symptoms. Results from four RCTs were reassuring. The data consistently showed significant decreases in children’s anxiety symptoms, with two of the studies showing similar improvements compared to an
active control [90] and treatment-as-usual [91], and two studies showing improvements equivalent to cognitive-behavioral interventions [89,92], even after long-term follow-up [89].

At the same time, we tested critical elements at the game development level, including replayability, engagement, and how likely children were to recommend the game to others. Data showed that children were equally likely to recommend *MindLight* to a friend as one of the most popular commercial games for this age group [90], and they consistently rated the game as fun and engaging [89], suggesting that our prototyping phase paid off. Mediation studies were also run to examine whether the training mechanics that were designed based on evidence-based techniques (e.g., exposure, light-based neurofeedback) were the action mechanisms that explained outcomes and results confirmed our hypotheses [93]. As expected, children reported feeling fearful of the monsters in the game (i.e., exposure worked). But more importantly, *increases* across game sessions in children’s capacity to shine their “mindlight” (the light indicating relaxation measured with neurofeedback) predicted reductions in anxiety symptoms three months later.

We presented the *MindLight* example to illustrate how the framework in Figure 3 can be concretely applied to the development and research of a digital intervention tool for mental health. We also aimed to highlight how the DT framework was integral to developing not only an effective digital anxiety intervention tool, but one that was eagerly played by children repeatedly. Importantly, this framework should be applicable to a wide range of digital interventions and is certainly not restricted to applied game development.

**Implementation Considerations**

Finally, the last stage of Figure 3 is the implementation phase with the “gold release” version of the DMH product, adjusted with insights from the RCTs and mediation studies and polished for distribution purposes. Related to the second DT tenet, rolling out DMH
interventions requires a multidisciplinary effort [94]. For digital tools in particular, we may need to engage more than stakeholders and policy makers and bring in the unique expertise of marketing experts, business leaders and technical support teams. Of course, there are crucial issues to be considered with commercially oriented partners (e.g., scientific integrity and conflicts of interest). But if scalability and broad impact is what we are aiming for, marketing and business experts may be key to developing optimal models of service delivery. At this final stage, on the game development level, it is important to consider whether young people discover the games we develop on their own, through their own online search initiatives, whether they are interested to engage with our content, whether we can retain that attention and motivate them to practice skills and finally, the extent to which they share these DMH programs with peers and family that might likewise benefit. On the intervention development level, implementation tests may require going beyond RCTs. Current technologies rapidly change in only a small number of years and there is no reason to believe this rate of change will slow. In the midst of this rapidly shifting technological landscape, the traditional research designs that require interventions to remain stable across many years may be less practical, useful and feasible [46,95,96]). Researchers are reconceptualising the scientific framework, methodology, and implementation strategies that might better suit implementation and outcome studies in the DMH context [46,95,96]. DT and its evaluation practices, with their focus on qualitative and participatory studies, seem to have some useful recommendations in this regard.

Conclusions
Several reviews have pointed to the enormous potential to improve effectiveness, efficiency, cost, reach, personalization, and appeal of mental health interventions for young people with the use of technology. Yet, significant challenges including engagement, retention, fidelity, lack of personalization and cognitive load continue to stand in the way of significant progress.
So far, all meta-analyses and reviews have highlighted these barriers but have stopped short of offering avenues for actionable solutions [52-54]. We introduced the three tenets of DT (empathy, multidisciplinary ideation, and experimentation) and showed how these mindsets and practices can inform the development of future digital interventions. We also provided concrete examples from our own work to demonstrate how this new approach can be implemented with young people and provided some preliminary evidence that it can improve outcomes, as well as have an impact on engagement. Ultimately, we argued that integrating DT mindsets and practices with conventional scientific approaches is a promising avenue through which digital tools can address youth mental health. However, we are only at the beginning of merging design and science in the mental health arena. Design as a discipline has been criticized for its lack of quality control, the absence of systems to evaluate that quality, standardization or documentation of the various DT methods [e.g., 54, 97]. Going forward, it will be critical for social scientists and clinical researchers who are interested in appropriating DT to also bring to bear their scientific standards, methods and review outlets to evaluate its contribution.

Conflicts of Interest

None declared.
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