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Special Section: Health Information Technology and Mental Health Services Research: A Path Forward

Behavioral Intervention Technologies: Evidence review and recommendations for future research in mental health

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ABSTRACT

Objective: A technical expert panel convened by the Agency for Healthcare Research and Quality and the National Institute of Mental Health was charged with reviewing the state of research on behavioral intervention technologies (BITs) in mental health and identifying the top research priorities. BITs refers to behavioral and psychological interventions that use information and communication technology features to address behavioral and mental health outcomes.
Method: This study on the findings of the technical expert panel.
Results: Videoconferencing and standard telephone technologies to deliver psychotherapy have been well validated. Web-based interventions have shown efficacy across a broad range of mental health outcomes. Social media such as online support groups have produced disappointing outcomes when used alone. Mobile technologies have received limited attention for mental health outcomes. Virtual reality has shown good efficacy for anxiety and pediatric disorders. Serious gaming has received little work in mental health.
Conclusion: Research focused on understanding reach, adherence, barriers and cost is recommended. Improvements in the collection, storage, analysis and visualization of big data will be required. New theoretical models and evaluation strategies will be required. Finally, for BITs to have a public health impact, research on implementation and application to prevention is required.

A technical expert panel entitled "Health Information Technology and Mental Health: the Way Forward" was convened by the Agency for Healthcare Research and Quality and the National Institute of Mental Health and met several times over 2010, culminating in a multidisciplinary advisory meeting on November 16–17, 2010. The focus of the panel was to review the state of research on health information technology in mental health and identify the top research priorities in the field. This paper reports on the findings of the subgroup charged more specifically with behavioral intervention technologies (BITs).

This paper will provide a brief definition, explain why BITs research is high priority, present an overview of the research to date and outline the research challenges for the field.

1. Definition

BITs are the application of behavioral and psychological intervention strategies through the use of technology features to address behavioral, cognitive and affective targets that support physical, behavioral and mental health [1]. Thus far, BITs have been used to implement change strategies that include self-assessment and self-monitoring, psychoeducation, goal setting, skill building and feedback. To do so, BITs have employed a number of technology media, including, but not limited to, telephone and videoconferencing, Web-based interventions (also called Internet interventions), interventions using mobile devices (also called mHealth interventions), the integration of sensors for patient monitoring, social media, virtual reality and gaming.

BITs should be distinguished as a subset of the far broader field of eHealth, which refers to the use of information and communications technology to support healthcare more generally. Some eHealth technologies not included in the BIT category would include electronic

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health records, clinical decision support programs, use of telemedicine for purely medical care deliver and the use of informatics to support medical education.

2. Why are BITs a research priority?

BITs have the potential to reach populations who otherwise would not be able to access care. Even in urban areas, 75% of primary care patients with depression can identify one or more structural or psychological barriers that substantially interfere with or prevent access to behavioral treatment; these rates are far higher in rural areas [2]. BITs offer the potential to overcome many of those barriers to access, although the objective evidence for this is still largely unavailable (see Clarke et al., this issue).

BITs not only provide new delivery media for mental health treatments, they also open the possibility for entirely new interventions. For example, mobile technologies can harness sensors and ubiquitous computing to provide continuous monitoring and/or intervention in the patient's environment. Virtual reality creates simulated environments that afford a high degree of control in engineering the provision of therapeutic experiences. Gaming may provide teaching methods that are more engaging. These opportunities may also challenge and expand the limits of our knowledge regarding human behavior and behavior change processes.

Industry has begun developing and marketing BITs for a wide variety of mental health problems. These are frequently brought to market with little or no evaluation of their efficacy or utility. Thus, there is a growing need to evaluate these interventions and thereby protect the stakeholders (patients, payers, providers and families), set industry-wide standards of proof of benefit and quality, provide information to stakeholders to guide treatment choice and support the development of new policies and guidelines for the use, development and evaluation of BITs.

3. What has been done in BITs research?

We will review here BITs that include the telephone, Web-based intervention, mobile technologies, social media, virtual reality, virtual humans and gaming. These technologies are mediums for both therapist-delivered and machine-powered interventions that expand the capacity to deliver interventions across space and time. Each section will identify the next steps in that area of research.

3.1. BITs to extend therapist reach: providing psychotherapy via videoconferencing, telephone and instant messaging

Despite the proliferation of evidence-based psychotherapies for numerous mental disorders, the delivery of those treatments to inidividuals who require them is a perennial challenge, given the shortage and uneven geographic distribution of trained providers [3]. A growing number of trials have evaluated using BITs to connect providers and patients in different geographic locations. Current technologies in this subset include delivering psychotherapy via videoconferencing, telephone, instant messaging and e-mail. These resources require professionals to conduct the psychotherapy but overcome access barriers such as limited transportation, medical disabilities or absence of available local services. These interventions generally maintain the standard structure of psychotherapy, but the delivery media reduce the “band-width” of information communicated between the therapist and patient [4,5]. Videoconferencing eliminates immediate presence and some cues, the telephone eliminates visual cues, instant messaging eliminates voice quality and e-mail eliminates synchronous communication. While these communications media can extend care geographically and temporally in the case of asynchronous communication such as e-mail, concerns have been raised that the lack of presence may diminish therapeutic relationships, reduce efficacy, increase risks to privacy and lead to difficulties in managing emergencies and crises [6].

A growing number of studies have examined videoconferencing used to extend specialized care to remote clinics, while newer studies are evaluating the use of videoconferencing with patients in their own homes. These studies have generally found that videoconferencing is effective and acceptable to patients [7]. A large number of studies found that the telephone is an effective medium for delivering psychological care [8–10], is as efficacious as face-to-face treatment and can reduce dropout [9,11,83]. Psychotherapy has also been provided effectively and with reasonable effect sizes via instant messaging [12]. There is no evidence that these delivery media increase risk, as emergent mental health situations for outpatients are often managed at a distance, even in the context of traditional services.

Next steps: Evidence is emerging that psychotherapy delivered by videoconferencing and telephone may be equivalent in efficacy to face-to-face delivered treatment. While these delivery modalities likely extend care geographically, they continue to rely on humans to deliver the content and are therefore limited by the pool of available professionals and the costs associated with their time. These interventions could substantially increase the pool of patients. Accordingly, research evaluating cost-effectiveness and implementation models will be required.

3.2. Web-based intervention

Psychoeducational or intervention content can also be delivered using primarily machine-powered systems with limited (or no) requirement for a professional driving the interaction. Older studies used preloaded desktop computer programs or CD-ROMs that either required patients to come to a provider's office or providers to distribute content to potential users [84]. These interventions are similar in structure to face-to-face therapy where skills and content are taught in sessions with the expectation that patients will apply the newly learned skills in their lives. The predominant mode of dissemination of these treatments currently is through a Website. These Web-based interventions have often used evidence-based psychological treatments as frameworks that are then operationalized and programmed for Web delivery of skills training, other tutorials and promotion of real-life generalization of new skills [13]. The efficacy of Web-based intervention has been demonstrated by a large number of trials for a number of mental health problems, including depression, anxiety disorders, alcohol and substance abuse and insomnia [14–18]. In addition, there are promising results for bipolar disorder [19] and schizophrenia [20]. However, within this growing number of studies, the range of outcomes can vary from virtually no effect to effect sizes that are similar to face-to-face interventions.

Web-based interventions can include a variety of features. Most provide text-based didactic information, much like printed self-help materials [21,22]. These didactic materials can be supplemented by audio, video and animation. Many Web-based interventions also include interactive tools to support learning, such as activity monitoring, thought records or distress ratings. Feedback tools can provide graphic visualizations of the patient's progress. One disadvantage of Web-based interventions, however, is their status as “pull” technologies that rely on the patient's initiative to access the intervention. Thus, many developers include features that “push” information to the user, such as automated e-mail reminders to encourage patients to return to the Website.

Many Web-based interventions are designed to be used over a period of time, requiring decisions about how new content and tools are rolled out. New material is typically rolled out based on time (e.g., weekly or semiweekly), task completion (e.g., after the patient completes specific tasks) or a combination of the two, although

there are also Websites that allow access to all material from the beginning. Web-based interventions vary considerably on the degree to which presentation of lessons and tools is tailored and personalized to meet individual patient needs or characteristics. Some Websites provide the same information and tools to all patients, while others provide specific modules based on presenting problems [23]. Sites can vary considerably in their look and feel, as well as how difficult they are to use and navigate. It is believed that the quality and design of Websites can influence adherence and outcomes [24], although this belief has generally not been rigorously tested.

Web-based interventions can stand alone, or they can be supported by a coach or therapist. Standalone interventions have produced a wide range of outcomes, from small or nonsignificant (e.g., many depression sites, substance abuse) to moderate (some anxiety disorders) to fairly large (insomnia) [14,15,18,25]. Attrition and nonadherence can also range widely from extremely high (>95% for standalone depression sites), modest (many anxiety sites), to minimal (insomnia), depending on the disorder and how participants were sampled or screened.

In general, human support via periodic phone or e-mail contact improves adherence and outcomes when using Internet-based treatments, although this may vary depending on the patient population, disorder or the quality, usability and utility of the program. Outcomes of coach or therapist-supported Internet treatments are moderate to large for depression and have found to be equivalent to face-to-face group intervention for some anxiety disorders [16,17]. One model to explain these coaching effects is supportive accountability [4], which suggests that the mechanism by which coach presence increases adherence is the accountability created by clear adherence goals, monitoring and scheduled contacts in which progress will be reviewed with a supportive coach or therapist. If supportive accountability or other such models are supported, they can provide a framework for developing new and more cost-effective methods of enhancing adherence, as will be described in the Social Media section below.

Next steps: While the potential for Web-based interventions to be effective has been established, little is known about how to optimize their design and implementation. Basic design questions should be investigated, such as the blend of didactic information and interactive tools, effective methods of conveying information and how best to allow patients to progress through interventions. Personalization and tailoring, which have received some attention in Web-based interventions outside of mental health [26,27], remain largely unexamined in mental health. With the growing capacity to collect large amounts of user data from large samples, data mining could be used to identify user preferences and provide patients with content and tools that they are likely to find useful and to use. Adherence to Web-based interventions has been widely acknowledged to be a problem [25,28] and should constitute a standard outcome measure and a focus of new research. As interventions demonstrate efficacy, models for implementation should be examined.

3.3. Mobile technologies

Mobile technologies are pervasive, moving intervention into the real world. Thus, interventions are applied “in-the-moment” using technologies that people carry with them through their days. This offers the potential to provide a ubiquitous connection between a care system and the patient. Older studies used personal digital assistants and handheld computers, while more recent work has shifted to cell phones and smartphones. Trials of mobile BITs have found some positive short-term benefits for anxiety disorders [39], eating disorders [40], bipolar disorder [41] and schizophrenia [42], although others have not been effective at treating depression [43]. Mobile phone interventions have also been used to enhance adherence to psychotropic medications [42] and prevent depression in adolescents [44]. Given that this literature is limited and of variable quality, it is premature to make any definitive conclusions regarding the efficacy of mobile BITs [39].

Most mobile BITs employ short message service (SMS or text) messages or within application notifications, although some use voice messaging or video [45]. Some interventions deliver reminders or informational messages, while other mobile BITs use automated messaging to provide tailored feedback or information. The intervention can initiate such SMS dialogues, but some interventions emphasize or allow patient-initiated dialogue. Most commonly, messaging is only one component of the intervention, which can include Web-based components, brief telephone support by coaches and/or contact with a clinician. The frequency of messaging can range from once weekly to as often as five or more times daily and is commonly linked to the anticipated frequency of the target behavior. Timing of SMS messages may also be tied to the times of day when the patient is particularly vulnerable to difficulties. Another dimension along which mobile BITs vary is personalization and tailoring. Some mobile BITs use highly personalized messages, while others employ generic tips or messages.

A recent trend in mobile BITs is the use of passive data collection to work around patients' reluctance to log information [46]. This allows mobile BITs to detect times at which intervention is needed, without necessitating the patient to log their current state. In passive data collection, sensors automatically collect data that can help to infer the patient state. These sensors can be located within the mobile device itself (e.g., global positioning system (GPS), Bluetooth, accelerometer, etc.) or be external devices available via a wireless connection (e.g., heart rate or galvanic skin response sensors). Intervention delivery can be triggered by the sensor data in two ways. One approach develops algorithms that predict patient states by using predefined algorithms derived a priori from scientific or clinical knowledge [47,48]. The algorithms then make inferences regarding the patient's states by using the sensor data, and the inferred states consequently determine the need for intervention. The second approach uses machine learning techniques [49] that are applied to simultaneously collected sensor data and patient self-reports. In this approach, a model is developed to describe the relationship between the sensor values and the patient's self-reported states. Once reliable models are achieved, the models can be applied to new sensor data and predict patient states in the absence of any self-reported data. The advantage to this second approach is that the models are automatically generated and personalized to each individual patient. This application of machine learning is a new and challenging strategy that has been used to detect physical activity, affective state and social context with differing degrees of accuracy (e.g., [50]).

Steps have also been taken to integrate the real-time data capture capabilities of mobile devices with social networks. For example, the Virtual Environments for Raised Awareness (VERA) mobile phone application enables users to take photos representing their health decisions and share them with other VERA users who can then post comments [51]. Although not designed for healthcare purposes, the CenceMe mobile phone application uses passively collected phone sensor data to make inferences regarding physical activity (e.g., whether the user is sitting or walking) and social states, and then these inferred states are shared with the user's social network via the user's status on Facebook, Twitter or other networking tools [52].

Next steps: Mobile BITs research for mental health remains at an early developmental stage. Considerable work is needed to better understand how patients use mobile phones and how interventions can be integrated into these existing use patterns as seamlessly as possible. Well-designed efficacy trials are required for interventions that have demonstrated initial promise. Continued work developing mobile social media and context sensing systems that harness sensors to evaluate patient states has the potential to create tools that can be weaved into the flow of patients' lives.

3.4. Social media (discussion groups, social networking)

Social media refers to the use of Web-based and mobile technologies to allow for the exchange of user-created content between peers. Social media has been used in the context of mental health BITs primarily in the form of Internet support groups (ISGs). ISGs are often used by patients as a source of information and support [29,30]; however, the quality of many of these studies remains poor. In general, ISGs that are moderated by a clinician tend to show benefits [31]. However, findings of unmoderated support groups have tended to show either no benefits relative to control arms [32,33] or some worsening of symptoms [34,35]. The potential for negative outcomes with ISGs may reflect the effects of social contagion — that negative affective states can be transmitted through online social networks [36,37].

The disappointing effects of unmoderated ISGs to date do not necessarily mean that online peer networks have no role in our treatment armamentarium, particularly given their popularity among some patient groups (e.g., cancer survivors) [30]. One emerging area is the embedding of Web-based intervention tools into social networks that are engineered to encourage peer interactions that align with principals of supportive accountability [4]. Preliminary results, while limited due to small sample sizes, suggest that harnessing peer social networks to encourage collaborative learning and adherence to Web-based interventions may prove useful [38].

Next steps: The use of ISGs has not been rigorously investigated. Understanding the structure of peer interactions and the effects that such interactions have on target outcomes may lead to better engineered ISGs and Websites. Embedding online collaborative learning tools in networks may improve outcomes both by teaching skills and by encouraging communication that is therapeutically beneficial.

3.5. Simulated places and people: virtual reality and conversational agents

A growing body of research indicates that immersive virtual reality exposure therapy may be effective for anxiety disorders [53], as well as pediatric disorders such as attention deficit disorder [54,55]. However, the cost of immersive three-dimensional systems has been a barrier to widespread implementation.

Online virtual worlds such as Second Life have also been proposed as a potential vehicle for delivering mental health treatment [58]. Online virtual worlds have been used primarily to provide informational libraries, interactive educational tools and social media such as chat rooms for health-related issues such as healthy lifestyle, HIV and pediatric disorders [59]. Little mental health research has been conducted in this area to date.

Virtual humans, or conversational agents, are images of humans that are programmed to interact with a user. These characters can be implemented in the context of immersive, virtual reality interventions or as two-dimensional figures on a flat screen. The use of conversational agents in mental health interventions to date is very limited; however, patients rate these agents positively on measures of empathy and alliance [56]. In one example, patients reported high satisfaction with a conversational agent that delivered hospital discharge instructions, and patients with depression and/or low health literacy reported stronger therapeutic alliance with the agent. The agent also elicited more questions from those with lower health literacy, suggesting that such agents may have the potential to provide health information in a supportive, nonthreatening manner [57].

Next steps: More cost-effective methods of delivering virtual reality therapy will be required before it can be widely implemented. The use of conversational agents is just beginning and still requires initial developmental work and evaluation.

3.6. Gaming

Gaming can include both offline video games as well as Web-based games that can use elaborate online worlds that support exploration and therapeutic role playing. Games can be very engaging and thus have the potential to increase patient motivation, to initiate and continue treatment and support successful behavior change. Early work on using games for mental health examined the use of off-the-shelf games within treatment sessions to increase therapeutic alliance and reinforce lessons [60]. A recent shift is the creation of entertaining games with nonentertainment-related goals (such as promoting mental health) encompassed by the serious gaming movement. Games have been examined as treatments for attention deficit hyperactivity disorder, autism spectrum disorders, reduction of aggression in children and for improving behavioral outcomes related to medical issues such as diabetes and cancer. Much of this work remains in early stages [61].

Greater attention has been devoted to using games to support physical health including the promotion of physical activity and adherence to medications. For example, Re-Mission, a computer videogame designed to promote adherence to a treatment regime for cancer, users blast cancer cells and positive self-care practices to achieve mission objectives [62]. This game increased adherence to prescribed oral chemotherapy medication and enhanced psychological resilience such as cancer self-efficacy. Games for mental health that embody therapeutic principles have been developed but lack formal evaluations of their efficacy. For example, Personal Investigator is a computer game designed for children to play alongside their therapist and requires users to hunt for clues to solve a personal problem [63]. In a gaming version of cognitive–behavioral therapy, children solve a mystery by hunting for unhelpful thoughts and replacing them with helpful thoughts [64].

Investigations indicate that gaming may do more than just teach people what to do; the interactivity aspect of playing games might enhance the uptake of interventions. In a study of Re-Mission, only those playing the game experienced activation in reward-related neural circuits when compared with participants who were yoked to watching the same game play [65]. Participants who received a virtual game plus exercise cycling experienced increased cognitive benefits over those who did cycling alone [66]. These findings suggest that a game–play setting can enhance the benefits that people receive from therapeutic interventions.

Next steps: Most games have been developed for children and adolescents, and few trials have evaluated the efficacy of these games for mental health outcomes. More work need to address whether gaming is a reasonable approach for adults and older populations. Trials investigating games also need to control for comparable paradigms to determine if games are merely shells that help teach well-established behavior change principles (i.e., goal setting, competition) or if interactivity improves outcome through different mechanisms.

4. What work is needed?

BITs vary considerably in terms of their level of development and evaluation. Some of the next-step research for specific BITs has been mentioned above. Below, we will discuss larger, cross-cutting research themes that this panel identified as priorities.

4.1. Adherence and engagement

Many BITs, such as Web-based interventions and, in some instances, virtual reality interventions, have high dropout and low utilization rates. Research in this area has been plagued by a lack of a shared definition of what constitutes adherence [25]. For example, Web-based interventions have used number of logins, time on site and number of modules completed to name a few. The relationship of these different metrics to each other and to clinical outcomes can vary

considerably, with logins generally being unrelated or negatively associated with improvement and number of modules typically being positively associated with improvement [67]. Login rate may reflect self-titration of intervention use based on the patients' recognition of their own need [68] while greater use of modules may produce a dose-related response, or may simply reflect user characteristics associated with improvement such as conscientiousness. Improved measurement and understanding of the meaning and implication of adherence metrics is required.

A variety of methods of improving adherence have been proposed and investigated, including improving the quality of the technology (e.g., tailoring content to the user's needs, enhancing the usability, simplifying the interface, etc.) [24,69]; adding human support and adherence promotion via phone, e-mail or other media [4]; using incentives [70,71] and making resources more engaging through gaming elements [72]. Continued research aimed at testing and uncovering new methods of improving adherence will be important to optimize the effectiveness of these interventions, as there is evidence that greater adherence and engagement are often associated with better outcomes. At the same time, however, we should avoid overgeneralized assumptions that increased engagement is necessarily better under all circumstances or with all BITs [68,73]. Some patients may stop using a BIT because they lose interest, but others may stop using because they have received the assistance they sought, because the BIT does not meet their needs or a variety of other reasons. Research is needed to better understand patterns of use and engagement, as well as the determinants and consequences of engagement.

4.2. Accessibility, reach, barriers and cost

Many BITs justify their development in part by claiming that they increase the reach of interventions and reduce barriers to care by decreasing cost (e.g., via reduced time burdens on clinicians), minimizing problems related to time constraints and transportation, overcoming problems in the availability of care, increasing the efficiency of care and/or reducing discomfort associated with traditional face-to-face services [74]. However, researchers have also acknowledged that BITs may create barriers. For example, many patients may be uncomfortable with, or unable to use or access the technologies employed by the interventions. It is also possible that BITs may increase costs by delaying the provision of traditional treatments with greater evidence of efficacy or by increasing the numbers of patients receiving services. Very little work has examined assumptions about the capacity for BITs to reduce barriers and costs. Laying the groundwork for eventual implementation requires an understanding of where and how reach is extended and barriers are overcome or created.

4.3. BITs for prevention

Beyond integration into existing delivery systems, BITs provide promising avenues for creating new streams to deliver resources for the prevention of mental health problems. BITs can improve both the screening and early delivery of interventions to reduce risk factors and build psychological resources. Sensor technology and automated data collection allow for passive monitoring of psychological states that can alert users and providers to acute and chronic stress states that might predispose someone to later clinical disorders. Thus, low intensity interventions can be provided via BITs prior to the need for clinical intervention as a cost-effective approach for prevention [75]. The capability of BITs to reach a vast population allows for the dissemination of universal prevention interventions that are too costly to provide using other resources [44]. Lastly, assistive technologies, those that provide support for better decision making, emotional regulation or interpersonal interactions can provide skills necessary to ensure that psychological, emotional and social deficits do not spiral into clinical disorder. For example, advances in computational approaches for measuring affect through video data can support the creation of wearable technologies to improve recognition of affective cues. This could improve social interactions, which are an important protective factor against mental disorders [76]. Thus, BITs should not only be geared toward treatment but should also be implemented in prevention efforts to reduce the overall burden of mental disorders.

4.4. Big data

Many forms of BITs, such as Web-based and mobile interventions, permit the aggregation of large amounts of data across large numbers of users (e.g., usage data, patient workflow, sensor readings). These data offer the opportunity to improve the quality of interventions and develop deeper tailoring and personalization. However, these datasets, sometimes referred to as “big data,” create difficulties in data capture, storage, cleaning, analytics, visualization and sharing. It is critical to conduct research aimed at developing the capacity to manage big data (e.g., data acquisition, storage and cleaning), identify features that are informative and useful, apply analytic techniques such data mining and machine learning and create visualization methods that allow us to understand the data. Harnessing big data to allow BITs systems to continuously learn from users has the potential to substantially improve the effectiveness of these interventions.

4.5. Theory

Much of the development of BITs to date has either attempted to adapt accepted intervention paradigms such as cognitive behavioral therapy (CBT) through new media, such as Web-based CBT, or has adopted new technologies such as SMS to engage patients based on common sense approaches. While such strategies have yielded benefits, the field is also encountering the limitations of these paradigms. Behavioral and psychological theory may continue to be relevant at the larger level of how behavioral, affective, environmental and cognitive factors interact to affect mental health. However, a growing number of investigators have recognized that current theoretical models are inadequate to inform the development of BITs that can increasingly interact dynamically and adaptively with users [77]. To enhance the design of BITs, theoretical models are necessary to explain how users interact with the technologies and how such interactions can lead to behavior change and improved clinical outcomes. One possible example is control systems engineering, which operationalize inputs, decision rules and outputs. Integrating knowledge from this field into behavioral science could potentially help explain how people use and can benefit from BITs [78]. The adaptation and/or development of such theories will allow larger principals to be tested, thereby allowing the field to move forward more rapidly.

4.6. Need for new evaluation models

BIT research requires new models for development, optimization and evaluation. Developing early BIT prototypes requires a clear understanding of how patients interact with BITs, which can guide the numerous decisions regarding the structure and interface of the technology. Because this emerging area of research lies at the intersection of behavioral science, engineering and clinical science, existing developmental models from engineering can be borrowed and adapted. For example, user-centered design [79] and usability testing [80] are common methods used in product development. These strategies involve systematic problem analysis, design and an iterative process of evaluation to ensure that the BIT is understandable, attractive and usable for the targeted patient population. Human factors and human–computer interaction are disciplines with well-

developed methodologies for design and usability testing [80] that could be adapted for BITs research.

The properties of usability and attractiveness, while necessary for engagement, are not necessarily sufficient for efficacy. Early BIT development often results in multiple features that may or may not contribute to efficacy. Research frameworks to optimize BITs' efficacy will be required. One example of how principles of optimization have been adapted from engineering into a BITs context is the methodological framework called multiphase optimization strategy (MOST) [81]. MOST uses randomized experimentation in a phased approach to identify specific components or features of BITs that contribute to outcomes.

Traditional intervention evaluation models typically require years and can be costly. The rapidity with which new technologies are emerging and developing means that such traditional evaluation methods will result in final validation long after the technology underlying the BIT is obsolete. Furthermore, the continuously evolving nature of technologies and the BITs that use those technologies will require strategies that can continuously evaluate efficacy as new versions and changes are introduced. The traditional differentiation between initial evaluation and implementation will become increasingly arcane due to the ability of many forms of BITs to collect data on use and outcomes, as well as the rapid expansion and availability of these programs entire populations around the world soon after initial program launch. Thus, the field requires methods that can rapidly validate the efficacy of BITs, while at the same time continuously evaluating the incorporation of new developments and innovations for the protection of patients and stakeholders.

4.7. Integration into existing health and mental health delivery systems

BITs can only begin to reach their public health potential if they are integrated into existing healthcare delivery systems. This integration will have to take place on at least four levels: (a) research should identify where BITs fit into the armamentarium of treatment options. Examining stepped care models that incorporate BITs into a care system is an example of this type of research [82]; (b) technological integration is also likely to enhance the impact of BITs. If BITs are integrated into electronic medical records and patient portals, then referrals, treatment monitoring, appropriate follow-up and fuller integration into the patient's overall treatment are more likely to occur; (c) BITs will also have to be integrated economically into our healthcare system. Developing models of costing BITs will support this; (d) BITs will have to be accepted and adopted by healthcare delivery teams as well as patients. The literature on practice adoption of behavioral treatments in general is limited, and this is particularly true for BITs.

5. Conclusion

BITs encompass diverse approaches, including remote provision of psychotherapy, Web-based and mobile interventions, social media, virtual worlds and humans and gaming. These intervention areas are currently in widely varying stages of evaluation and maturity, requiring research that ranges from basic development and evaluation to implementation studies. As a new and evolving field, BITs research is encountering challenges that no single field or specialty can address alone. BITs research will require integration of theoretical and research paradigms from many different disciplines, including behavioral and psychological sciences, engineering, computer science, human–computer interaction, communications and design to name a few. It is critically important to refine our development and evaluation methodologies, as well as develop testable BITs implementation models.

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References

[1] Burns MN, Mohr DC. eHealth, Telehealth, and Telemedicine, in Encyclopedia of Behavioral Medicine. In: Gellman MD, Turner JR, Editors. New York: In Press, Springer.
[2] Mohr DC, et al. Perceived barriers to psychological treatments and their relationship to depression. J Clin Psychol 2010;66(4):394–409.
[3] Kazdin AE. Evidence-based treatment research: advances, limitations, and next steps. Am Psychol 2011;66(8):14p.
[4] Mohr DC, Cuijpers P, Lehman K. Supportive accountability: a model for providing human support to enhance adherence to eHealth interventions. J Med Internet Res 2011;13(1):e30.
[5] Walther JB, Parks MR. Cues filtered out, cues filtered in: computer-mediated communication and relationships. In: Knapp ML, Daly JA, editors. Handbook of Interpersonal Communication. 3rd Ed. Thousand Oaks, CA: Sage Publications; 2002. p. 529–63.
[6] Haas LJ, Benedict JG, Kobos JC. Psychotherapy by telephone: risks and benefits for psychologists and consumers. Prof Psychol Res Pract 1996;27:154–60.
[7] Richardson LK, et al. Current directions in videoconferencing tele-mental health research. Clin Psychol Sci Pract 2009;19:323–8.
[8] Mohr DC, et al. Telephone-administered psychotherapy for depression. Arch Gen Psychiatry 2005;62(9):1007–14.
[9] Mohr DC, et al. The effect of telephone-administered psychotherapy on symptoms of depression and attrition: a meta-analysis. Clin Psychol Sci Pract 2008;15(3):243–53.
[10] Simon GE, et al. Telephone psychotherapy and telephone care management for primary care patients starting antidepressant treatment: a randomized controlled trial. JAMA 2004;292(8):935–42.
[11] Lovell K, et al. Telephone administered cognitive behaviour therapy for treatment of obsessive compulsive disorder: randomised controlled non-inferiority trial. BMJ 2006;333(7574):883.
[12] Kessler D, et al. Therapist-delivered internet psychotherapy for depression in primary care: a randomised controlled trial. Lancet 2009;374(9690):628–34.
[13] Ritterband LM, Tate DF. The science of internet interventions. Ann Behav Med 2009.
[14] Vernon ML. A review of computer-based alcohol problem services designed for the general public. J Subst Abuse Treat 2010;38(3):203–11.
[15] Bewick BM, et al. The effectiveness of web-based interventions designed to decrease alcohol consumption–a systematic review. Prev Med 2008;47(1):17–26.
[16] Andersson G, Cuijpers P. Internet-based and other computerized psychological treatments for adult depression: a meta-analysis. Cogn Behav Ther 2009;38(4):196–205.
[17] Cuijpers P, et al. Computer-aided psychotherapy for anxiety disorders: a meta-analytic review. Cogn Behav Ther 2009;38(2):66–82.
[18] Ritterband LM, et al. Efficacy of an Internet-based behavioral intervention for adults with insomnia. Arch Gen Psychiatry 2009;66(7):692–8.
[19] Smith DJ, et al. Beating bipolar: exploratory trial of a novel Internet-based psychoeducational treatment for bipolar disorder. Bipolar Disord 2011;13(5–6):571–7.
[20] Rotondi AJ, et al. Web-based psychoeducational intervention for persons with schizophrenia and their supporters: one-year outcomes. Psychiatr Serv 2010;61(11):1099–105.
[21] Andersson G, et al. Internet-based self-help for depression: randomised controlled trial. Br J Psychiatry 2005;187:456–61.
[22] Carlbring P, et al. Remote treatment of panic disorder: a randomized trial of internet-based cognitive behavior therapy supplemented with telephone calls. Am J Psychiatry 2006;163(12):2119–25.
[23] Carlbring P, et al. Individually-tailored, internet-based treatment for anxiety disorders: a randomized controlled trial. Behav Res Ther 2011;49(1):18–24.
[24] Ritterband LM, et al. A behavior change model for internet interventions. Ann Behav Med 2009;38(1):18–27.
[25] Christensen H, Griffiths KM, Farrer L. Adherence in internet interventions for anxiety and depression. J Med Internet Res 2009;11(2):e13.
[26] Strecher VJ, Shiffman S, West R. Moderators and mediators of a web-based computer-tailored smoking cessation program among nicotine patch users. Nicotine Tob Res 2006;8(Suppl 1):S95–101.
[27] Couper MP, et al. Engagement and retention: measuring breadth and depth of participant use of an online intervention. J Med Internet Res 2010;12(4):e52.
[28] Eysenbach G. The law of attrition. J Med Internet Res 2005;7(1):e11.
[29] Griffiths KM, Calear AL, Banfield M. Systematic review on Internet Support Groups (ISGs) and depression (1): do ISGs reduce depressive symptoms? J Med Internet Res 2009;11(3):e40.
[30] Bender J, Jimenez-Marroquin M, Jadad AR. Seeking support on facebook: a content analysis of breast cancer groups. J Intern Med Res 2011;13(1):e16.
[31] Winzelberg AJ, et al. Evaluation of an internet support group for women with primary breast cancer. Cancer 2003;97(5):1164–73.
[32] Owen JE, et al. Randomized pilot of a self-guided internet coping group for women with early-stage breast cancer. Ann Behav Med 2005;30(1):54–64.

[33] Hoybye MT, et al. Effect of internet peer-support groups on psychosocial adjustment to cancer: a randomised study. Br J Cancer 2010;102(9):1348–54.
[34] Salzer MS, et al. A randomized, controlled study of internet peer-to-peer interactions among women newly diagnosed with breast cancer. Psychooncology 2010;19(4):441–6.
[35] Kaplan K, et al. Internet peer support for individuals with psychiatric disabilities: a randomized controlled trial. Soc Sci Med 2011;72(1):54–62.
[36] Takahashi Y, et al. Potential benefits and harms of a peer support social network service on the internet for people with depressive tendencies: qualitative content analysis and social network analysis. J Med Internet Res 2009;11(3):e29.
[37] Fowler JH, Christakis NA. Dynamic spread of happiness in a large social network: longitudinal analysis over 20 years in the Framingham Heart Study. BMJ 2008; 337:a2338.
[38] Duffecy, J., et al., Project onward: an innovative e-health intervention for cancer survivors. Psychooncology, 2012.
[39] Heron KE, Smyth JM. Ecological momentary interventions: incorporating mobile technology into psychosocial and health behaviour treatments. Br J Health Psychol 2010;15(Pt 1):1–39.
[40] Treasure J, et al. The use of a vodcast to support eating and reduce anxiety in people with eating disorder: a case series. Eur Eat Disord Rev 2010;18(6): 515–21.
[41] Depp CA, et al. Mobile interventions for severe mental illness: design and preliminary data from three approaches. J Nerv Ment Dis 2010;198(10): 715–21.
[42] Granholm E, et al. Mobile Assessment and Treatment for Schizophrenia (MATS): a pilot trial of an interactive text-messaging intervention for medication adherence, socialization, and auditory hallucinations. Schizophr Bull 2011.
[43] Reid SC, et al. A mobile phone application for the assessment and management of youth mental health problems in primary care: a randomised controlled trial. BMC Fam Pract 2011;12(1):131.
[44] Whittaker R, et al. MEMO–a mobile phone depression prevention intervention for adolescents: development process and postprogram findings on acceptability from a randomized controlled trial. J Med Internet Res 2012;14(1):e13.
[45] Grassi A, Gaggioli A, Riva G. The green valley: the use of mobile narratives for reducing stress in commuters. Cyberpsychol Behav 2009;12(2):155–61.
[46] Lane ND, et al. A survey of mobile phone sensing. IEEE Commun Mag 2010;48(9): 140–50.
[47] Miluzzo, E., et al. Sensing meets mobile social networks: The design, implementation and evaluation of the CenceMe application. in SenSys. 2008. Raleigh, North Carolina: Association for Computing Machinery
[48] Morris M, Guilak F. Mobile heart health: Project highlight. in IEEE Pervasive Computing 2009.
[49] Witten IH, Eibe F. Data mining: Practical machine learning tools and techniques, 2nd edition. 2005, San Francisco: Morgan Kaufman Publishers.
[50] Burns MN, et al. Harnessing context sensing to develop a mobile intervention for depression. J Med Internet Res 2011;13(3):e55.
[51] Baumer EPS, et al. Prescriptive persuasion and open-ended social awareness: expanding the design space of mobile health, in Proceedings of the ACM 2012 conference on Computer Supported Cooperative Work. 2012, ACM: Seattle, Washington, USA. p. 475–84.
[52] Miluzzo, E., et al. Research in the App Store Era: Experiences from the CenceMe App Deployment on the iPhone. in Proceedings of The First International Workshop Research in the Large: Using App Stores, Markets, and other Wide Distribution Channels in UbiComp Research. 2010. Copenhagen, Denmark.: ACM
[53] Meyerbroker, K. and P.M. Emmelkamp, Virtual reality exposure therapy in anxiety disorders: a systematic review of process-and-outcome studies. Depress Anxiety, 2010.
[54] Parsons TD, et al. A controlled clinical comparison of attention performance in children with ADHD in a virtual reality classroom compared to standard neuropsychological methods. Child Neuropsychol 2007;13(4):363–81.
[55] Parsons TD, et al. Virtual reality in paediatric rehabilitation: a review. Dev Neurorehabil 2009;12(4):224–38.
[56] Bickmore T, Gruber A, Picard R. Establishing the computer-patient working alliance in automated health behavior change interventions. Patient Educ Couns 2005;59(1):21–30.
[57] Bickmore TW, et al. Response to a relational agent by hospital patients with depressive symptoms. Interacting Comput 2010;22(4):10p.
[58] Gorini A, et al. A second life for eHealth: prospects for the use of 3-D virtual worlds in clinical psychology. J Med Internet Res 2008;10(3):e21.
[59] Beard L, et al. A survey of health-related activities on second life. J Med Internet Res 2009;11(2):e17.
[60] Ceranoglu TA. Video games in psychotherapy. Rev Gen Psychol 2010;14(2):141–6.
[61] Wilkinson N, Ang RP, Goh DH. Online video game therapy for mental health concerns: a review. Int J Soc Psychiatry 2008;54(4):370–82.
[62] Cole SW, et al. Clinical trial of Re-Mission: a video game for young people with cancer. Cyberpsychol Behav 2006;9(6):665–6.
[63] Coyle D, Doherty G, Sharry J. An evaluation of a solution-focused computer game in adolescent interventions. Clin Child Psychol Psychiatry 2009;14(3):345–60.
[64] Brezinka V. Treasure hunt - a serious game to support psychotherapeutic treatment of children. Stud Health Technol Inform 2008;136:71–6.
[65] Cole SW, Yoo DJ, Knutson B. Interactivity and reward-related neural activation during a serious videogame. PLoS One 2012;7(3):e33909.
[66] Anderson-Hanley C, et al. Exergaming and older adult cognition: a cluster randomized clinical trial. Am J Prev Med 2012;42(2):109–19.
[67] Donkin L, et al. A systematic review of the impact of adherence on the effectiveness of e-therapies. J Med Internet Res 2011;13(3):e52.
[68] Mohr DC, et al. Multimodal e-mental health treatment for depression: a feasibility trial. J Med Internet Res 2010;12(5):e48.
[69] Strecher VJ, et al. Web-based smoking-cessation programs: results of a randomized trial. Am J Prev Med 2008;34(5):373–81.
[70] Khadjesari Z, et al. Impact and costs of incentives to reduce attrition in online trials: two randomized controlled trials. J Med Internet Res 2011;13(1):e26.
[71] Alexander GL, et al. Effect of incentives and mailing features on online health program enrollment. Am J Prev Med 2008;34(5):382–8.
[72] McGonigal J. Reality is broken: why games make us better and how they can change the world. New York: Penguin Press; 2011.
[73] Danaher BG, Seeley JR. Methodological issues in research on web-based behavioral interventions. Ann Behav Med 2009.
[74] Bennett GG, Glasgow RE. The delivery of public health interventions via the Internet: actualizing their potential. Annu Rev Public Health 2009;30:273–92.
[75] Cuijpers P, Beekman AT, Reynolds 3rd CF. Preventing depression: a global priority. JAMA 2012;307(10):1033–4.
[76] Thoits PA. Stress, coping, and social support processes: where are we? What next? J Health Soc Behav, 1995. Spec No: p. 53–79.
[77] Riley WT, et al. Health behavior models in the age of mobile interventions: are our theories up to the task? Transl Behav Med 2011;1(1):53–71.
[78] Rivera DE, Pew MD, Collins LM. Using engineering control principles to inform the design of adaptive interventions: a conceptual introduction. Drug Alcohol Depend 2007;88(Suppl 2):S31–40.
[79] Norman DA. Emotional design: why we love (or hate) everyday things. New York: Basic Books; 2004.
[80] Brinck T, Gergle D, Wood S. Usability for the web: designing web sites that work. San Francisco, CA: Morgan Kaufmann Publishers; 2002.
[81] Collins LM, Murphy SA, Strecher V. The multiphase optimization strategy (MOST) and the sequential multiple assignment randomized trial (SMART): new methods for more potent eHealth interventions. Am J Prev Med 2007;32(5 Suppl):S112–8.
[82] van Straten A, et al. Stepped care for depression in primary care: what should be offered and how? Med J Aust 2010;192(11 Suppl):S36–9.
[83] Mohr DC, Ho J, Duffecy J, et al. Effect of telephone-administered vs face-to-face cognitive behavioral therapy on adherence to therapy and depression outcomes among primary care patients: a randomized trial. JAMA 2012;307(21):2278–85.
[84] Selmi PM, Klein MH, Greist JH, Sorrell SP, Erdman HP. Computer-administered cognitive-behavioral therapy for depression. Am J Psychiatry 1990;147(1):51–6.