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Computer technology-based interventions in HIV prevention: state of the evidence and future directions for research

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Abstract

Computer technology-based interventions (CBIs) represent a promising area for HIV prevention behavioral intervention research. Such programs are a compelling prevention option given their potential for broad reach, customized content, and low cost delivery. The purpose of the current article is to provide a review of the state of the literature on CBIs. First, we define CBIs in HIV prevention and highlight the many advantages of such interventions. Next, we provide an overview of what is currently known regarding the efficacy of CBIs in HIV prevention, focusing on two recent meta-analyses of this literature. Finally, we propose an agenda for future directions for research in the area of CBIs, using the RE-AIM model as an organizing guide. We conclude that with the continued growth of computer technologies, opportunities to apply such technologies in HIV prevention will continue to blossom. Further research is greatly needed to advance an understanding of not only how and under what circumstances CBIs can be efficacious, but also how the reach, adoption, implementation, and maintenance of such programs in clinical and community settings can be achieved.

Keywords

computer technology; HIV prevention; behavioral intervention; theory; condom use; tailoring; targeting; dissemination; computers

Introduction

Scores upon scores of behavioral interventions have been developed and tested since the beginning of the HIV/AIDS epidemic. For example, a comprehensive meta-analysis of HIV prevention behavioral interventions published in 2005 documented 354 interventions and examined their influence on key outcomes such as condom use (Albarracin et al., 2005). While many such interventions have been efficacious, a number of barriers have stood in the way of their widespread dissemination (Kelly, Spielberg, & McAuliffe, 2008; Rietmeijer,

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2007; Solomon, Card, & Malow, 2006). Some of these barriers, such as cost of delivery and maintenance of intervention fidelity, stem in part from the fact that these interventions all require a human facilitator for their delivery.

A promising alternative to human-delivered interventions are computer technology-based HIV prevention interventions (or computer-based interventions; CBIs). The purpose of the current article is to provide a review of the state of the literature in this rapidly growing area. First, we define CBIs in HIV prevention and highlight the many advantages of such interventions. Next, we provide an overview of what is currently known regarding the efficacy of CBIs in HIV prevention, focusing on two recent meta-analyses of this literature. Finally, we propose an agenda for future directions for research in the area of CBIs.

Computer technology-based interventions (CBIs)

CBIs can be defined as those interventions that use computer technology as the primary or sole medium for intervention delivery (Noar, Black, & Pierce, 2009). CBIs that have been developed and evaluated to date can be divided into three types (see Table 1). *Group targeted* interventions are those interventions that have been designed for a particular target audience. They are typically delivered on-screen using a local computer or CD-ROM (Ito, Kalyanaraman, Ford, Brown, & Miller, 2008; Lightfoot, Comulada, & Stover, 2007) or via the Internet (Lau, Lau, Cheung, & Tsui, 2008; Lou, Zhao, Gao, & Shah, 2006). *Individually tailored* interventions are those interventions that tailor content to the individual based upon an assessment of characteristics of that individual. These interventions are delivered via tailored print materials (Scholes et al., 2003) or (increasingly) via local computers or the Internet (Davidovich, de Wit, & Stroebe, 2006; Kiene & Barta, 2006; Redding, Morokoff, Rossi, & Meier, 2008). Finally, *virtual decision-making* interventions (also called *interactive video*) are interventions that simulate dating and sexual situations. These programs allow the user to make choices at various decision points and witness the consequences of various decisions, and they are typically delivered on-screen on a local computer (Downs et al., 2004; Read et al., 2006).

CBIs hold much promise for several reasons, including: (1) the cost of implementing such interventions once they have been developed is minimal compared with those requiring significant human resources; (2) intervention fidelity is maintained through the standardization of content; (3) computerized interventions can *individually* tailor intervention content through the use of computer algorithms; (4) computer technologies include features such as interactivity and multimedia which may aid in the fostering of behavioral change; (5) computerized interventions tend to be brief as well as flexible in terms of dissemination channels, which might include community-based agencies, clinical settings, and the Internet; and (6) with the continued increase in the sophistication of technology as well as the increased use of new technologies (e.g., mobile devices), opportunities to apply computer-based technologies in HIV prevention will only grow (Bull, 2008; Cassell, Jackson, & Cheuvront, 1998; Fotheringham, Owies, Leslie, & Owen, 2000; Swendeman & Rotheram-Borus, 2010).

Efficacy of computer technology-based interventions (CBIs)

Recently, we conducted a series of meta-analytic projects to synthesize the effects of numerous randomized controlled trials designed to examine the efficacy of CBIs in HIV prevention. One meta-analytic project focused on the effects of CBIs on theoretical mediators of safer sex while the other project focused on the effects on behavioral outcomes. We now discuss each of these meta-analyses in detail.

Efficacy of computer technology-based interventions (CBIs) to change theoretical mediators

The first meta-analysis was undertaken to examine the potential efficacy of CBIs in changing theoretical mediators of safer sex (Noar, Pierce, & Black, 2010). Both the published and unpublished literatures were searched for studies that evaluated the ability of a CBI (relative to a comparison condition) to change theoretical mediators of safer sex. A total of $k = 20$ studies met criteria and were included in the meta-analysis.

Populations studied in this literature included men who have sex with men (MSM) (15%) and heterosexually active adolescents (55%) and young adults/adults (30%). The most common intervention type was a group targeted intervention (65%). This was followed by individually tailored interventions (15%), virtual decision-making interventions (10%), and multiple type interventions (10%). Most interventions were delivered via the Internet (55%) or on-screen using a computer located on site (40%). One intervention (Scholes et al., 2003) was delivered via a computer-generated magazine (5%). Just over half of the interventions (55%) were theory-based, and just under half of the studies were conducted outside the USA (45%).

Analyses were conducted on all theoretically oriented outcome variables measured in the studies, one at a time. The results indicated that CBIs significantly improved the three outcome variables most often reported in studies, including HIV/AIDS knowledge ($d = 0.276, p < 0.001, k = 15$), sexual/condom attitudes ($d = 0.161, p < 0.001, k = 12$), and condom self-efficacy ($d = 0.186, p < 0.001, k = 10$). Interventions also significantly improved perceived susceptibility ($d = 0.131, p < 0.01, k = 4$), condom communication ($d = 0.119, p < 0.01, k = 6$), and condom intentions ($d = 0.110, p < 0.05, k = 5$). No significant effects were found on refusal self-efficacy ($d = 0.056, p = 0.31, k = 4$).

Many of the mean effect sizes listed above were found to be heterogeneous, suggesting the presence of moderator variables that impacted study outcomes. Analysis of moderator variables revealed some significant differences. For example, interventions were significantly ($p < 0.05$) more likely to have improved sexual or condom attitudes if they (1) targeted MSM (versus heterosexuals); (2) were delivered online; or (3) utilized individualized tailoring.

Efficacy of computer technology-based interventions (CBIs) to change behavior

A second meta-analysis was undertaken to examine the ability of CBIs to impact safer sexual behavior (Noar, Black et al., 2009). Again, both the published and unpublished literatures were searched for studies that evaluated the ability of a CBI (relative to a

comparison condition) to change safer sexual behaviors. A total of $k = 12$ studies met criteria and were included in the meta-analysis.

Populations studied included MSM (17%) as well as heterosexually active adolescents (33%) and young adults/adults (50%). The most common intervention type was an individually tailored intervention (50%), followed by group targeted (25%), virtual decision-making (17%), and mixed type interventions (8%). Most interventions were delivered on-screen using a computer located on site (67%), while the remainder were delivered over the Internet (25%), or via a computer-generated magazine (8%). Most of the interventions (83%) were theory-based, with a stages of change model being the most popular theoretical perspective applied (50% of the theory-based interventions). Virtually all of the studies (92%) were conducted in the USA, with the exception of one study conducted in the Netherlands (Davidovich et al., 2006).

Results of the meta-analysis indicated that CBIs had a statistically significant effect on condom use, $d = 0.259$, $p < 0.001$, $k = 12$. While fewer studies measured other behavioral outcomes, the existing data suggested that interventions reduced numbers of sexual partners ($d = 0.422$, $p < 0.01$, $k = 2$), frequency of sexual activity ($d = 0.427$, $p < 0.001$, $k = 3$), and incident STDs, ($d = 0.140$, $p < 0.01$, $k = 3$). Given that the effect size for condom use was heterogeneous, moderator analyses were conducted to examine this variability in relation to key study characteristics. Interventions were found to be significantly more efficacious when they (1) were targeted to a single gender ($p < 0.01$); (2) applied individualized tailoring ($p < 0.001$); (3) used a stages of change model ($p < 0.001$); and (4) had a “high” intervention dose (3+ contacts; $p < 0.05$).

Significance of meta-analyses

The above meta-analyses suggest that CBIs are efficacious in changing theoretical mediators of safer sex and safer sexual behaviors. They also point to features, in particular the use of message targeting and tailoring, which may enhance the efficacy of such interventions. In both projects, publication bias analyses were conducted and in both cases suggested that it is unlikely that these observed effect sizes were inflated by publication bias. Moreover, both projects compared observed effect sizes to effect sizes from meta-analyses of human-delivered behavioral interventions, and in both cases effect sizes were (remarkably) found to be similar (Noar, Black et al., 2009; Noar et al., 2010).

An emerging research agenda for computer technology-based interventions (CBIs)

Given the great promise of these interventions as demonstrated by these meta-analyses, a number of critical questions in this area remain. The RE-AIM framework (Glasgow, Lichtenstein, & Marcus, 2003) provides a useful organizing guide for future research directions in this area. This framework is important because it provides a guide for not only the usual “efficacy” focus of research, which addresses the question of whether a program has its intended effects, but also on several other dimensions that inform whether a program will ultimately have public health impact. That is, the central argument of RE-AIM is that

with so much focus on *whether* programs work (i.e., efficacy), we have not focused enough on broader issues that affect whether programs can be disseminated and have lasting public health impact. These broader dimensions include reach (R), adoption (A), implementation (I), and maintenance (M), and they (along with efficacy – E) make up the RE-AIM model (Glasgow et al., 2003). While a central implication of RE-AIM is that researchers should better consider and report on these issues in efficacy and effectiveness trials, such dimensions are also useful as areas for future research. Table 2 presents the RE-AIM dimensions and corresponding questions and implications for further research on CBIs. We now briefly discuss each of these dimensions in turn.

Reach

The first dimension is focused on *who* can be reached by CBIs as well as how they can be recruited and retained. That is, for what populations are CBIs most appropriate, and what proportion of those populations can be reached? Will large proportions of younger at-risk populations engage with CBIs, and will older populations also engage with CBIs? Will interventions need to be developed differently for populations with more or less advanced computer skills?

Also, given the many studies that have documented MSM using the Internet to find (often high risk) sexual partners (Bull, McFarlane, & Rietmeijer, 2001; McFarlane, Bull, & Rietmeijer, 2000), how can CBIs be best applied to reach these men? What proportion of high-risk MSM can be reached? While some research in this area exists (Bowen, Horvath, & Williams, 2007; Bull, McFarlane, Lloyd, & Rietmeijer, 2004; Rosser et al., 2009), further work is needed.

Moreover, while some trials of CBIs have used samples recruited online (Bull, Lloyd, Rietmeijer, & McFarlane, 2004; Davidovich et al., 2006), many such studies have suffered from low retention. How can we best reach particular populations online? What factors might motivate them to engage in a CBI? And, how can samples recruited online be retained over the longer term?

Finally, we should also consider for whom CBIs may *not* be appropriate. While being careful to not stereotype any particular population, there may be some populations and settings where CBIs are not the best fit. Thus, understanding both the potential and limits to the reach of CBIs is critical as this area moves forward.

Efficacy

The second dimension is focused on whether CBIs can have impact. While the existing meta-analytic data strongly suggest that CBIs can be *efficacious*, equally important is the fact that the potential low cost to deliver these interventions may be the most important contributor to *effectiveness*. That is, many consider the real world impact of interventions (i.e., effectiveness) to be a function of both efficacy and reach. Thus, if CBIs are efficacious (even with small effects) and are capable of broad reach, then their ultimate impact could be significant. This underscores the fact that research questions listed under “reach” above are as important as questions regarding efficacy.

In addition, as this area moves forward to larger efficacy and effectiveness studies, RE-AIM dimensions should be considered, assessed, and reported on in such studies. These important areas can speak to the external validity of an intervention trial and can have important implications for ultimate dissemination of CBIs.

There are also other important efficacy questions in this area. Given the relatively small number of CBI evaluations to date, further research is needed on the efficacy of CBIs. Studies should consider comparing different types of CBIs head to head and manipulating elements of CBIs in carefully designed studies to tease out what features account for their efficacy. For instance, how can CBI modules for skills training be optimized? While skills training is common in HIV prevention interventions (Edgar, Noar, & Murphy, 2008), it is not clear what the most fruitful approach to skills training in the CBI context may be.

In addition, the existing studies to date have tended to evaluate CBIs as standalone interventions, but there are likely to be contexts where they could be applied as adjuncts to other (human-delivered or mass media) interventions. In what circumstances might this be a good model? Is a CBI capable of enhancing the effects of a short human-delivered intervention? Also, given that mass media campaigns are still widely used in HIV prevention (Bertrand, O'Reilly, Denison, Anhang, & Sweat, 2006; Noar, Palmgreen, Chabot, Dobransky, & Zimmerman, 2009), understanding how to use Internet websites and CBIs effectively as a part of campaign efforts should be a key priority (Noar, 2009; Noar, Palmgreen et al., 2009).

Finally, studies are needed to evaluate CBIs that take advantage of newer technologies such as mobile devices (e.g., smart phones) and social media (e.g., Facebook and MySpace) (Lefebvre, 2009; Swendeman & Rotheram-Borus, 2010). Such technologies are quickly becoming more widespread, and they may offer the opportunity to intervene with participants more frequently and at a lower cost when compared to more traditional CBIs. However, CBIs will need to be carefully developed for each of these newer platforms, as (for several reasons) they will not easily translate from one computerized platform to another.

Adoption

This third dimension is focused on the following question: under what circumstances will CBIs be adopted? No matter how efficacious a given CBI is, if it is not adopted in practice it will fail to have real public health impact. While the literature on human-delivered behavioral interventions for HIV prevention is vast (Noar, 2008), most studies have focused solely on efficacy. In the area of CBIs, an early focus on dissemination is needed in order to heed the lessons learned from the human-delivered intervention literature (Rietmeijer, 2007).

CBI developers should, if possible, have a setting in mind for ultimate dissemination of a program, as this will make issues related to adoption more salient and will bring greater clarity to the issues. Then, when the CBI is being developed, issues of adoption can be considered. Still, even with a setting in mind, CBIs should be developed to be as flexible as possible to increase the chances of adoption in a variety of potential settings. For instance,

CBIs developed for only a Macintosh platform might have trouble at the dissemination stage in a setting that uses PC computers. A CBI developed as a three-session intervention may not “fit” the needs of a clinic where one-session interventions are needed. In the end, the more flexible a program can be, the greater are the chances that it will be adopted.

Also, studies of the gatekeepers and stakeholders at agencies, clinics, and organizations that are in a position to make decisions about what interventions are offered are critical. What are such individuals’ views of CBIs? What are their perceptions and misperceptions about such programs? An understanding of both the barriers and facilitators to the adoption of CBIs in these settings is needed, as this knowledge may ultimately increase the chances of such programs being adopted (Eke, Neumann, Wilkes, & Jones, 2006; Harshbarger, Simmons, Coelho, Sloop, & Collins, 2006; Kelly, Heckman et al., 2000).

Implementation

The fourth dimension is implementation. In a formal research study, interventions are typically implemented by research staff who are 100% dedicated to a project. In a practice-based setting, however, this is unlikely to be the case. Rather, staff with multiple, competing demands are most likely to be responsible for implementing a program. Thus, a consideration here is how CBIs can be packaged for easy implementation. Given the work of the Centers for Disease Control and Prevention’s (CDC) Diffusion of Effective Behavioral Interventions (DEBI) project, which has aimed to diffuse a variety of human-delivered HIV behavioral interventions into practice (Collins, Harshbarger, Sawyer, & Hamdallah, 2006), many examples of such “packaged for use” interventions exist (Eke et al., 2006; Hamdallah, Vargo, & Herrera, 2006). The new question raised here, however, is how to package a CBI for easy implementation and use.

Also, it is important to consider who at a given organization would be responsible for overseeing the implementation of a CBI. For instance, some have suggested that CBIs may be well suited to ultimately take the place of human-delivered prevention counseling in STI clinics (Rietmeijer, 2007), but several questions about this remain. For example, whose job would it be to oversee the CBI? Who would be the appropriate staff person for this task? How much time would this take each day and each week? And, who would be called in the case of technical problems? These are all questions that deserve further consideration and investigation in the STI clinic setting and other settings.

Maintenance

The final dimension in the RE-AIM model is that of maintenance. While it is one thing for an organization to try out a new program, it is quite another for that organization to maintain that program over the long term. Thus, even if all of the previous dimensions are fulfilled, a program may not be carried through over the long term. Why would this be the case? There are a variety of problems that could result in the discontinuation of a new program. To avoid this, studies might examine what types of resources and support systems would be needed to keep a CBI running over the long term. Clearly, CBIs require some resources – including computer technology, staff time, and technical support. Over the long term, updates and improvements to a computer-based program will be needed, as computer technologies

change over time and the needs of the particular setting may change as well. Thus, research can and should focus on how these kinds of supports could be achieved in practice-based settings as well as what the optimal level of support is to maintain a program. Such research might mimic the approach of studies that have been taken in the area of human-delivered interventions (Fuller et al., 2007; Harshbarger et al., 2006; Kelly, Sogolow, & Neumann, 2000).

Conclusion

CBI represents a relatively new area of research with much future promise. The meta-analytic projects described in the current article demonstrate that CBIs are efficacious in improving both mediators of safer sex and safer sexual behaviors in a manner that is not unlike more traditional human-delivered interventions. With the continued growth of computer technologies (including smart phones, social media, etc.), opportunities to apply such technologies in HIV prevention will continue to blossom. Further research is greatly needed to advance an understanding of not only how and under what circumstances CBIs can be efficacious, but also how the reach, adoption, implementation, and maintenance of such programs in clinical and community settings can be achieved.

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Table 1

Definitions and examples of different types of computer technology-based interventions.

Intervention type	Definition	Example
Group targeted	Intervention designed for a particular target audience; may include a variety of content, activities, and/or multimedia designed with that particular audience in mind. Typically delivered on-screen, using a local computer (e.g., CD-ROM) or via the Internet.	Ito et al. (2008) developed an interactive CD-ROM for female adolescents, called "Let's Talk About Sex: A Girl's Guide to Sexually Transmitted Infections." The program allowed each young woman to choose among six videotaped actors to be their "host." It included four major sections with several activities, including a six-item quiz on HIV/STD facts, cartoon on condom instruction, game demonstrating how you cannot tell by looking if one has an STD, bulleted text addressing safer sex norms and attitudes, and several video clips of teens discussing issues related to STDs, negotiating sex, and the media. The intervention was based on the Integrative Model of Behavioral Prediction.
Individually tailored	Intervention which tailors content to each individual, based upon an assessment of characteristics of that individual; traditionally, these interventions used computers to generate tailored print materials, but increasingly these types of interventions are delivered on-screen using local computers or via the Internet.	Kiene and Barta (2006) developed an intervention consisting of several content modules based upon the Information-Motivation-Behavioral Skills (IMB) model of behavioral change. In the first component of the intervention, individuals were assessed on IMB constructs and in cases where they scored low, received that particular content. For example, if an individual scored high on information but low on behavioral skills, they would receive the behavioral skills content but not the information content. In the second component, individuals were presented with several possible safer sex "goals" based on their stage of change and were asked to choose one of the goals to work on. They were also asked to list anticipated benefits of achieving that goal.
Virtual decision-making (Interactive video)	Intervention that simulates dating and sexual situations and allows the user to make choices at various decision points and witness the consequences of various (good and/or bad) decisions. Typically delivered on-screen on a local computer.	Downs et al. (2004) used a Mental Models Theory approach to develop an interactive video intervention delivered on-screen, which covered four content domains: safer sex negotiation, obtaining condoms and condom efficacy reproductive health knowledge, and STD knowledge. The intervention depicted video storylines about young women such as Keisha and her relationship with her boyfriend. At various points, such as in sexual situations, the program offered choices for the user to make (choices that clearly lead either toward or away from unsafe sexual behavior). An emphasis was also put on "cognitive rehearsal," with the screen freezing at various points so young women could think about what they might say or do in a particular situation.

Table 2

Research questions to be addressed in the area of computer technology-based interventions.

RE-AIM dimensions	Research questions	Implications
Reach	<p>Who can be reached with CBIs? Who cannot?</p> <p>What proportion of target populations can be reached?</p> <p>For whom are CBIs most appropriate?</p> <p>For whom are they least appropriate?</p> <p>How can samples be recruited and retained offline and online?</p> <p>What factors predict engagement with CBIs?</p>	These research questions will help researchers understand the most appropriate audiences for CBIs, as well as the best ways to recruit and retain participants.
Efficacy	<p>What types of CBIs are most efficacious with what populations?</p> <p>What features of CBIs make them more or less efficacious?</p> <p>What do assessments of reach, adoption, implementation, and maintenance in efficacy trials show?</p> <p>How can interactive technologies be best applied for effective skills training?</p> <p>How can newer technologies (e.g., mobile devices and social media websites) be applied and evaluated for efficacy in HIV prevention?</p> <p>In what cases are CBIs best used as standalone interventions vs. supplements to human-delivered or media-based interventions?</p>	These research questions will help researchers understand the kinds of effects that CBIs are capable of, as well as what their role in larger HIV prevention efforts can and should be.
Adoption	<p>How can CBIs be developed to allow for flexibility in adoption?</p> <p>What are practitioners, clinicians, and community partners' views about CBIs?</p> <p>In what settings will the above stakeholders adopt CBIs?</p> <p>What are the barriers and facilitators to adoption of CBIs in various settings?</p>	These research questions will help researchers understand how adoption of CBIs by various organizations can be achieved, including from both programmatic and organizational standpoints.
Implementation	<p>How might CBIs best be packaged for easy implementation in clinical and community settings?</p> <p>How would CBIs be implemented and overseen in practice? By whom?</p> <p>How might technical issues with CBIs best be handled?</p>	These research questions will help researchers understand how the implementation of CBIs in practice settings would unfold, including who would oversee such interventions as well as how technical support would be provided.
Maintenance	<p>Once implemented, how could the use of CBIs over time be best ensured?</p> <p>What kind of technical and other support would be necessary to support the maintenance of a CBI?</p> <p>What factors predict the institutionalization of a CBI?</p>	These research questions will help researchers understand how the use of CBIs could be maintained over the long term.