Current HIV/AIDS Reports (2024) 21:152–167
https://doi.org/10.1007/s11904-024-00693-1

REVIEW

"Your Package Could Not Be Delivered": The State of Digital HIV Intervention Implementation in the US

Dennis H. Li[1,2,3,4] · Kathryn Macapagal[1,2,4] · Melissa Mongrella[2] · Rana Saber[2] · Brian Mustanski[1,2,4]

Accepted: 26 February 2024 / Published online: 19 March 2024

Abstract

Purpose of Review Despite continuous innovations and federal investment to create digital interventions addressing the HIV prevention and care continua, these interventions have not reached people in the U.S. at scale. This article reviews what is known about U.S. implementation of digital HIV interventions and presents a strategy to cross the research-to-practice chasm for these types of interventions.

Recent Findings We conducted a narrative review of U.S.-based original research on implementation of digital HIV interventions and identified few studies reporting on implementation determinants, strategies, processes, or outcomes, particularly outside the context of effectiveness trials. To supplement the literature, in 2023, we surveyed 47 investigators representing 64 unique interventions about their experiences with implementation after their research trials. Respondents placed high importance on intervention implementation, but major barriers included lack of funding and clear implementation models, technology costs, and difficulty identifying partners equipped to deliver digital interventions. They felt that responsibility for implementation should be shared between intervention developers, deliverers (e.g., clinics), and a government entity. If an implementation center were to exist, most respondents wanted to be available for guidance or technical assistance but largely wanted less involvement.

Summary Numerous evidence-based, effective digital interventions exist to address HIV prevention and care. However, they remain "on the shelf" absent a concrete and sustainable model for real-world dissemination and implementation. Based on our findings, we call for the creation of national implementation centers, analogous to those in other health systems, to facilitate digital HIV intervention delivery and accelerate progress toward ending the U.S. epidemic.

Keywords eHealth · mHealth · Intervention technology · Digital intervention · HIV prevention · HIV care · Implementation · Dissemination

Introduction

As articulated in the U.S. Ending the HIV Epidemic (EHE) Plan, for the past decade, we have had the biomedical tools to effectively eliminate HIV transmission—highly sensitive tests to diagnose HIV infection, interventions to prevent and treat infection, and cutting-edge technologies to identify and respond to outbreaks and individuals out of care [1]. Yet over much of the past decade, overall HIV diagnoses in the U.S. did not decline. In fact, rates among many key populations, such as young men who have sex with men (MSM), trended upwards—a pattern that just shifted in 2021 with the first evidence of declines among young MSM [2]. This is largely because these effective interventions did not reach the people who needed them. For example, adolescent MSM have a high HIV incidence [3–5] but poor HIV

Dennis H. Li and Kathryn Macapagal are co-first authors.

✉ Brian Mustanski
brian@northwestern.edu

1 Department of Psychiatry and Behavioral Sciences, Feinberg School of Medicine, Northwestern University, Chicago, IL, USA

2 Institute for Sexual and Gender Minority Health and Wellbeing, Northwestern University, Chicago, IL, USA

3 Center for Dissemination and Implementation Science, Institute for Public Health and Medicine, Feinberg School of Medicine, Northwestern University, Chicago, IL, USA

4 Department of Medical Social Sciences, Feinberg School of Medicine, Northwestern University, Chicago, IL, USA

status awareness due to low rates of testing (e.g., only 23% have ever had an HIV test [6]), limited use of PrEP [7, 8], and lower rates of viral suppression [9], indicating need for improving services across the HIV prevention and care continua. Profound racial inequities also exist in HIV incidence, prevention, and care. This is an implementation challenge that will be solved not with more investment in better tests and medications but with research on effective and equitable implementation strategies.

Solely relying on a medical model for intervention delivery will not work due to needs around awareness, skills, motivation, adherence, retention, and engagement that exceed the capacities of a brief medical appointment. Instead, we need strategies that increase consumer demand and support effective utilization: *Adjunctive interventions* augment and enhance health interventions' effectiveness by supporting initial uptake, adherence, and/or continued engagement with the intervention [10•]. In the HIV sphere, adjunctive interventions have historically been limited to behavioral interventions to increase condom use through individual, couple, small-group, and community programming; more recently, they have also aimed to increase HIV testing, PrEP uptake and adherence, and HIV care engagement. Such evidence-based behavioral interventions have typically been delivered by health departments and community-based organizations (CBOs) [11–13] but reach only one quarter of urban MSM [14], 13% of heterosexuals [15], 32% of people who inject drugs [16], and 63% of transgender women [17]. Research also suggests these interventions are not always implemented with fidelity [18–20], which can produce a "voltage drop" in effectiveness [21].

In recent years, these intensive behavioral interventions have been deprioritized into optional elements in federal HIV prevention funding [22], thereby limiting resources to cover the costs of implementation. The National Institutes of Health (NIH) and other agencies have thus invested substantial funds into developing digital adjunctive interventions for HIV [23•], with the hope of tapping into the promise of wide-scale delivery with high fidelity at low cost [24]. Evidence from systematic reviews and meta-analyses indicate that digital programs have significant effects on reducing HIV risk and increasing protective behaviors comparable to in-person programs [25••, 26–31]. Agencies like the U.S. Community Preventive Services Task Force [32], United Nations Programme on HIV/AIDS, and World Health Organization [33] have issued recommendations for digital HIV interventions. However, guidance from these agencies on how to implement or even access these interventions is missing. Some examples of real-world utilization of evidence-based digital HIV interventions in the U.S. do exist, primarily in support of HIV care services (e.g., telehealth [34], text message reminders [35]), but over two decades since the first computer- and Internet-based applications for HIV were tested, wide-scale implementation of such programs remains at a near standstill nationally.

In this paper, we sought to understand why effective digital HIV interventions are not being implemented. Our approach was framed using implementation science (IS), a field dedicated to the "study of methods to promote the systematic uptake of research findings and other evidence-based practices into routine practice" [36]. IS disentangles the complexities of introducing and integrating a new intervention into a system into several interrelated components [37, 38]: (1) *Determinants of implementation* are the multilevel conditions or characteristics of a given system or setting that may facilitate or be a barrier to implementing a given innovation. Examples for digital HIV interventions include recipients' broadband Internet access, organizations and their staff's technological capacities, and levels of HIV stigma in communities. (2) *Implementation strategies* are the specific and replicable actions taken by external and internal agents to deliver the innovation, often by mitigating or leveraging specific determinants. Examples include training HIV service providers to deliver the digital HIV intervention, building technological capacity at implementing sites, and marketing interventions on mobile dating applications. (3) The *implementation process* describes the order and timing in which strategies are conducted, and (4) *implementation outcomes* are indicators of implementation success, such as the proportion of the target population reached by the intervention and the cost of delivery. Together, these components form the pillars for understanding the current state of digital HIV intervention implementation.

Narrative Review of Digital HIV Intervention Implementation

Review Methods

We conducted a literature search of PubMed for original research focused on digital (i.e., "ehealth," "mhealth," "digital," "web," "smartphone," "internet," "text message," "social media") HIV or sexual health intervention or program implementation (i.e., "implement," "deliver," "barriers," "determinants," "adoption," "fidelity"). We limited the search to the U.S./Canadian context because implementation approaches would not generalize due to the countries' unique demographic makeup, HIV epidemiology, and fragmented healthcare system. Of 132 results returned, we excluded development, digitization, interest/preference, protocol, and purely efficacy/effectiveness studies as well as studies of digital implementation strategies of non-digital interventions, leaving 22 published articles of relevance. We also searched gray literature and health agency websites for additional articles and reports using similar keywords.

Review Results

What Do We Know About Determinants of Implementing Digital HIV Interventions?

Before identifying what contextual factors influenced digital HIV intervention implementation, we needed to first identify the contexts in which these interventions were implemented. Many studies reported delivering the intervention directly to consumers (DTC; e.g., [39, 40]), but there were also examples of fully or partially digital HIV interventions being integrated into schools (e.g., [41–43]), clinics (e.g., [44–46]), and other settings (e.g., [47–50]). Among studies testing intervention effectiveness, which comprise most of the published research, the intervention was often delivered by the research team (e.g., [51–55]) in an environment that was more controlled and favorable to implementation than the real world. It was not always clear then, particularly for DTC delivery, who would be the eventual deliverers besides researchers. Some studies tackled this question by supplementing the effectiveness trial with exploratory implementation research [56] with potential implementers. For example, within a DTC-delivered type I hybrid effectiveness–implementation study [57, 58], Ventuneac et al. [59] interviewed HIV service agencies about their attitudes toward potentially implementing a self-guided HIV prevention program for adolescent MSM and found that agencies felt the digital intervention fell outside their organizations' current technical capacities. Other studies included deliverers as part of their effectiveness evaluations (e.g., [42, 44, 57, 58, 60, 61]); while these types of studies had the benefit of getting feedback from real-world deliverers in process evaluation, other important implementation questions—e.g., who maintains the technology after the research is over—remain.

Given the dearth of studies involving real-world deliverers of digital HIV interventions, research on the determinants of implementation is limited. Studies primarily reported on facilitating characteristics of interventions themselves, including recipient-level acceptability and usability of the applications (e.g., [55]) and how the interventions filled a gap in services (e.g., [44, 62]). The needs of recipients (e.g., challenges accessing HIV testing and/or care, problems with adherence) were also commonly presented as support for digital adjunctive interventions [45, 50]. Cost and complexity, which are known significant barriers in the broader implementation literature [63, 64], were not frequently discussed. Findings are mixed regarding how the technological aspect of digital HIV interventions affected implementation. Decker et al. [42] reported that technological issues greatly affected implementation but improved over time, and both they and Cohn et al. [45] identified issues with recipients' access to technology (e.g., smartphone and WiFi access, data storage, battery life) as major barriers. Ventuneac et al. [59] identified technical capacity as a limitation at HIV CBOs, but staff at those agencies also described their lack of experience serving adolescents as a strong barrier to adopting the specific intervention. In contrast, Harshbarger et al. [44] found that a web-based HIV counseling tool was generally feasible to implement in clinics, and clinic workflows and the physical environment were more substantial determinants. For Faccio et al. [43], it was not the technology but teens' relationship with it—namely "Zoom fatigue"—that became a barrier. More research like these latter studies is needed to identify the salient contextual factors, particularly at the inner setting (e.g., implementation climate [65]) and outer setting (e.g., funding) levels [64], that will impede translation of digital HIV interventions from research to practice so that appropriate implementation strategies to address them can be developed (see Table 2).

What Do We Know About Strategies for Implementing Digital HIV Interventions?

Because most studies on digital HIV interventions have focused on evaluating the interventions' effectiveness, almost no research has systematically evaluated the effectiveness of the implementation strategies supporting those interventions. As one exception, Witte et al. [66] evaluated the simultaneous digitization of a couples-based HIV prevention program and its training and technical assistance supports against the original manual-based versions among 80 HIV CBOs. They found that program adoption between arms did not differ but that CBOs receiving web-based support reached significantly fewer couples. In another example, Mustanski et al. [67••] compared DTC versus CBO-based delivery of a web-based intervention in a county-randomized head-to-head implementation trial; however, results from their study are not yet published. This same *Keep It Up!* intervention had previously been shown excellent implementation outcomes when delivered by a CBO as a service, with the university-based creators serving as the technology and evaluation partner [68]. Several other studies conducted more formative work on strategies. In the context of a university-based service implementation of a clinic-deployed mobile application, Cohn et al. [45] analyzed determinants to refine their package of strategies, which included a manual, onsite staff training, a learning management system, and on-demand implementation support. Zulkiewicz et al. [46] similarly mapped implementation barriers to 19 strategies used in their pilot implementation, noting the importance of having both strategies with generalized effects (e.g., training) and specific strategies that target barriers not otherwise

addressed. Asking HIV CBOs about what they would need to deliver a web-based application, Ventuneac et al. [59] identified technical capacity building, training for staff, and partnering with a coordinating center that provides support for the technology as key asks. To bring digital HIV interventions to scale, far more studies are needed on designing and evaluating implementation strategies.

What Do We Know About the Process for Implementing Digital HIV Interventions?

No studies we could find explicitly examined implementation processes for digital HIV interventions, though several described adaptation as a key step to ensure fit with a population, health outcome, and/or geography [69–71]. Li et al. [72•] presented case examples from interventions using different digital platforms (web application, text messaging, social media, smartphone application) to highlight the importance of directly involving deliverers, as it can accelerate implementation by eliminating additional time and resource costs for building out the backend of an intervention. They also noted that because HIV care, technology, and society's relationship with technology evolve constantly and rapidly, adaptability within the intervention itself is critical for long-term sustainability. Beyond adaptation, however, specific steps for getting a digital HIV intervention adopted and implemented are largely unknown.

What Do We Know About the Outcomes from Implementing Digital HIV Interventions?

A common framework for understanding implementation success is RE-AIM [73], which comprises the domains of reach, effectiveness, adoption, implementation, and maintenance. As previously noted, many studies have demonstrated the effectiveness of specific digital HIV interventions [25••, 26–28]. And while all effectiveness studies report the number of individuals they enrolled, and many break down the demographics of enrollees [48], reach—defined as the proportion of potential individuals in a given setting that are offered an intervention—is rarely if ever captured due to the non-pragmatic eligibility criteria and capped sample sizes of effectiveness research. Two implementation studies [66, 74] did report reach of their digital HIV interventions; however, results were poor, suggesting the need for better dissemination and implementation strategies. We also found few examples of research reporting on deliverer- or setting-level adoption [66], implementation fidelity and cost [49, 75], and maintenance/sustainment.

In summary, although enthusiasm for digital HIV interventions from potential recipients and deliverers has been documented (e.g., [41, 53, 59, 76, 77]), the scientific literature is still sparse with information about how to implement these technologies in practice. Given the time lag in publication as well as potential for publication bias, we sought to supplement published research with first-hand accounts from developers of digital HIV interventions. Their implementation experiences and challenges could help identify what contextual factors to address, what strategies to use and in what ways, and what outcomes to expect to ensure research investments in digital HIV interventions make an impact on individuals' lives.

Survey of Creators of Digital HIV Interventions

Survey Methods

Sample and Procedure

Sampling focused on developers of interventions listed in Muessig et al.'s 2015 review of digital HIV interventions ($N = 53$) [23•] and digital interventions listed in the Centers for Disease Control and Prevention's (CDC) Compendium of Evidence-Based Interventions ($N = 47$) [78]. We selected the former source because those interventions would have potentially had enough time to reach the implementation phase, even accounting for an additional 5-year effectiveness study. The latter source represented interventions traditionally considered "ready for use" in practice. We sent personalized e-mail invitations to 81 individuals who were listed as the principal investigator and/or contact person for each intervention and had a valid email address. Invitations asked them to complete a brief online survey about the progress of their intervention implementation to date. Respondents completed surveys between September 26 and October 20, 2023, and did not receive incentives. The study received a non-human-subjects determination from the Northwestern University Institutional Review Board.

Measures

Drawing on multilevel IS determinants frameworks (e.g., Consolidated Framework for Implementation Research (CFIR; 64)) that consider individual, organizational, external, and process-related factors and contextualized with our own technology development and implementation experience, we designed the survey to assess implementation progress/processes, strategies, barriers, and facilitators of the interventions that respondents had developed. Respondents

who indicated they had attempted to implement or disseminate their intervention after the completion of their effectiveness study were asked what implementation or dissemination strategies they used and in what settings they attempted to implement their intervention. Open-ended items asked respondents to describe adaptations made to facilitate intervention implementation and the most significant barriers to implementation. Another section asked questions about technology maintenance, licensing, and sustainment. Respondents could report on more than one digital HIV intervention they created. The survey closed by asking if there was anything else they thought researchers and intervention developers should know about implementation of digital HIV interventions.

Data Analysis

We used Microsoft Excel to calculate descriptive statistics of quantitative items and manage open-ended survey responses. Using rapid qualitative analysis [79], a method commonly used in implementation research, a lead coder (MM) thematically summarized the qualitative data for each question (domain), and a secondary coder (KM) reviewed the themes.

Survey Results

Forty-seven respondents began and 44 completed the survey. Most respondents described one intervention, with 16 reporting more than one, for a total of 64 unique digital interventions. Respondents reported on a variety of types of digital interventions, most commonly web and social media, text message, smartphone apps, and videos. Fewer interventions related to telehealth, electronic medical records, virtual reality and gaming, and other computer- or device-based activities. Table 1 presents frequencies and proportions of the closed-ended items. Except where otherwise noted, we present subsequent results in terms of numbers of unique interventions. Table 2 summarizes the major determinants identified from the review and the survey, organized by the five domains of CFIR [64].

Importance of and Responsibility for Implementation

Seventy percent of respondents reported that it was extremely or very important that their intervention was widely implemented, and 57% said they felt completely or very responsible for its implementation. A subsequent open-ended item asked participants to elaborate on who else they felt should be responsible for intervention implementation. One respondent noted that it was not important to implement because their intervention was not found to be effective. The remaining responses were evenly divided among three entities: research teams that developed the interventions; funders and government agencies such as the NIH, CDC, and health departments; and specific settings such as clinics, schools, CBOs, and service agencies who would deliver the intervention. Many emphasized that the responsibility does not rest on one entity and instead should be a collaborative effort, suggesting this may result in greater implementation complexity due to these dependencies:

> It takes a village... It isn't one person or one agency. "Real world" implementation requires… many champions, resources to make the intervention available, and advertising or other means of spreading the word that the program is available and is worthwhile. Additionally, as the science grows, continued implementation requires revisions to ensure information is contemporary. Someone needs to make all of that happen and most researchers don't have the training or the funding to make that happen. – no. 16

Steps Taken to Implement or Disseminate Intervention

Respondents were asked to select from a checklist any implementation or dissemination strategies that they employed for their interventions, which we have described thematically. Nine respondents indicated that no steps were taken to implement their interventions.

The most frequently endorsed strategies related to *applying for additional funding* to either research or implement the intervention. This was predominantly through federal research funding mechanisms like NIH/NSF and less frequently through local health departments, CDC, Substance Abuse and Mental Health Services Administration (SAMHSA), or Health Resources and Services Administration (HRSA) or through specialized mechanisms like small business innovation research and technology transfer (SBIR/STTR) grants. Three respondents reported seeking funds from investors. The second most endorsed strategies related to *intervention dissemination*, including making content freely available and writing an intervention manual. These two broad categories of options are illustrated by this participant's response: "Original research funded by NIH involved disseminating virtual game intervention over the web nationally. Publications resulted from this work. I have provided copies of game to researchers" (no. 8).

These were distantly followed by other types of strategies, such as copyrighting, partnering with health technology companies, and licensing to brokers who would then disseminate the intervention. A subsequent open-ended item

Table 1 Descriptive statistics of the implementation experiences of creators of digital HIV interventions ($N=64$)

	n	%
What is/was your role(s) with this intervention (e.g., developer, coordinator, collaborator, mentor)?[(M)]		
Principal investigator	53	83%
Collaborator	3	5%
Developer	3	5%
Staff	1	1%
Other	4	6%
How important is it to you that this intervention is widely implemented?[(M)]		
Extremely important	25	40%
Very important	24	38%
Moderately important	10	16%
Slightly important	1	1%
Not at all important	3	5%
How much responsibility do you feel you have for this intervention's implementation?[(M)]		
Completely responsible	8	13%
Very responsible	28	44%
Moderately responsible	14	22%
Slightly responsible	6	10%
Not at all responsible	7	11%
What steps have you taken to implement or disseminate this intervention in any setting, including subsequent research?[(A)]		
Applying for NIH/NSF or other research grants (NOT SBIR/STTR grants)	22	34.92%
Making intervention content freely available to public	22	34.92%
Writing an intervention manual	21	33.33%
Other	18	28.57%
Obtaining local/regional funding (e.g., health department)	12	19.04%
Applying for CDC, SAMHSA, or HRSA grants	9	14.28%
No steps have been taken to implement or disseminate the intervention beyond scientific publications	9	14.28%
Seeking copyrights	9	14.28%
Partnering with a health tech company	7	11.11%
Making intervention code freely available to public	3	4.76%
Seeking funds from angel investors/venture capital	3	4.76%
Applying for SBIR/STTR grants	2	3.17%
Licensing to broker (e.g., having an organization implement or disseminate the intervention for you)	3	4.76%
Seeking patents	0	0%
What settings was your intervention implemented in?[(A)]		
Community-based organizations	27	50.94%
Public health departments	22	41.51%
Hospitals	14	26.41%
Schools	12	22.64%
Other	6	11.32%
Who owns the license to this intervention?[(A)]		
I do (as an individual)	12	19.67%
My university/institution	14	22.95%
I don't know	15	24.59%
Other	24	39.34%
If this intervention were part of a national repository/implementation center for delivering digital HIV interventions, what involvement would you want to have in the maintenance, enhancement, and dissemination of this intervention?[(A)]		
Consultation in implementation support (e.g., you train the repository to provide technical assistance to implementers)	31	51.66%
Approval of content maintenance, adaptations, and enhancements (but someone else handles the updates)	23	38.33%
Approval over how it is priced or licensed	22	36.66%

Table 1 (continued)

	n	%
Responsibility over content maintenance, adaptations, and enhancements (i.e., you/your developers update content and/or platform and redeposit in the repository)	19	31.66%
Approval over how it is used in future research	17	28.33%
No/minimal involvement	15	25%
Direct involvement in implementation support (e.g., you train or provide technical assistance to implementers, you provide protocols and manuals)	13	21.66%
Approval over how it is marketed (e.g., advertisements)	11	18.33%
Approval over where it is implemented (e.g., settings, geographic locations)	10	16.66%
Other	5	8.33%
If this intervention were part of a national repository/implementation center for delivering digital HIV interventions, what would you want to receive back?(A)		
Regular reports on dissemination/implementation status (e.g., reach, enrollment)	38	63.33%
Attribution	29	48.33%
Funding to maintain or adapt the content and/or platform	26	43.33%
First rights to conduct further research on this intervention	23	38.33%
Funding to produce implementation supports (e.g., manuals, implementation guides)	20	33.33%
Staff time to produce implementation supports (e.g., manuals, implementation guides) on your behalf	19	31.66%
Royalties/profit from licensing fees	12	20%
Access to aggregate user data	13	21.66%
Access to individual user data	11	18.33%
Nothing	9	15%
Other	5	8.33%
Which software developer or software development group originally wrote the code for the underlying software of this intervention?(A)		
Commercial partner	32	53.33%
Used open-source or already-built software (no software developer needed)	8	13.33%
Developers within my own lab	6	10%
University IT group	4	6.66%
External non-profit	3	5%
Software development group at another university	2	3.33%
Other	8	13.33%
Is the same software developer or software development group still maintaining (i.e., making technical updates, providing technical support) this intervention?(M)		
Yes	22	37%
No	15	25%
Unsure	6	10%
My software is not being maintained	17	28%
Who is currently maintaining the software (i.e., making technical updates, providing technical support) for this intervention?(A)		
Developers within my own lab	1	7.14%
Commercial partner	2	14.29%
Unsure	2	14.29%
Other	11	78.57%

*N*s vary due to branching logic and incomplete survey responses

(M) indicates item responses were mutually exclusive. (A) indicates respondents could select all that apply

that allowed them to describe other steps taken yielded a variety of responses, such as creating a start-up company; having discussions with the CDC, clinical directors, and funders about future pathways to implementation; and getting the intervention designated as a CDC Evidence-Based Intervention.

Settings, Licensing, and Technology

We asked respondents to indicate all the settings in which their interventions were implemented. Interventions were predominantly implemented in CBOs and health departments, with fewer implemented in hospitals/clinics,

Table 2 Determinants of implementing digital HIV interventions identified from a narrative review and survey of creators, organized by domains from the Consolidated Framework for Implementation Research (CFIR) 2.0

CFIR domain	Review	Survey
Outer setting	• Constantly evolving scientific (intervention content), technological, and sociotechnical landscape (–)* o Technology (e.g., Zoom) fatigue among recipients (–)	• Lack of continuous funding for development, adaptation, deployment, refinement, redeployment (–)* o Target audience is too small to secure investors (–) • Slow and fragmented pace of research relative to technological innovations and commercial models (–)* • Uncertainty around ownership of the intervention and ability to license (?)*
Inner setting (including technology and implementation partners)	• Not always clear what the right delivery settings are (–) • Lack of technical capacity (–)* • Challenges integrating technology into workflows and physical environment (–) • Uncertainty around who should maintain the technology (–)*	• Implementation requires complex collaboration among researchers, settings, and government/funders (–)* • Difficulty finding appropriate and long-term technology partners (–)* • Difficulty forming and maintaining implementation partnerships (–)* o Lack of partner staff and financial resources (–) o Competing priorities (–) o Lack of partner interest (–)
Individuals	• Deliverers' enthusiasm for digital interventions (+) • Recipients' need for support to utilize and/or adhere to HIV interventions (+) • Recipients' acceptability (in research contexts) of digital interventions (+) • Recipients' limited access to technology, especially broadband and high data capacity (–)	• Developers feel it is important to implement (+)* • Developers feel responsible for implementation (+)* • Limited attempts by developers to implement outside research (–)* • Recipients' limited access to technology (–)
Innovation	• Interventions have high usability (in research contexts) (+) • Digital interventions fill gaps in services (+) • Intervention technology is adaptable to scientific, technological, and sociotechnical changes (+/–)* • Technological issues, bugs (–)*	• Intervention technology is difficult to maintain and update (–)* o Ongoing need for adaptations for content, context, usability, and/or age (+/–)* • Software typically not maintained after the research study (–)*
Implementation process (including strategies)	• Adapting to local contexts (+)* • Involving deliverers from the design phase (+) • Unknown processes for adoption and implementation (–)* • Delivering direct to consumer versus through an organization (?) • Building technical capacity (+)* • Training (+)* • Providing external implementation support (+)* o Digitizing supports (?) • Outsourcing technological support (+)*	• Designing with implementation in mind (+)* • Having intervention designers involved in the software development process (+)* • Investing ongoing resources in technology (+)* • Lack of models for and guidance on how to implement digital interventions (–)* • Disseminating intervention through manuals and websites (?) • Seeking various sources of additional funding (?)* • Identifying technology and implementation partners (+)* o Partnering with health technology companies (?) o Licensing to brokers (?) o Creating a start-up company (?) o Engaging funders and policymakers about pathways for implementation (+)* o Outsourcing technology maintenance to external entity (+/–)* o Getting external support for implementation (+)* • Seeking copyrights and designation as a CDC evidence-based intervention (?)

(+) = evidence or suggestion that this is/would be a facilitator. (–) = evidence or suggestion that this is/would be a barrier. (?) = reported as a characteristic or process but with unclear valence or outcome. * = potentially addressed/leveraged by the proposed national infrastructure

schools, and solely online. Of note, implementation may have occurred still in the context of a research study; few respondents had attempted implementation outside research altogether.

Regarding ownership of the intervention license, respondents were divided among their institution/university, themselves as an individual, and "I don't know." Those who provided write-in responses largely indicated that the intervention was not licensed, with fewer stating that the intervention was in the public domain or licensed by a software company. Over half of interventions' software platforms were initially developed by a commercial partner, distantly followed by open-source or pre-existing software. When asked whether the same developer was still

maintaining the intervention, most said no or that their software was not being maintained at all. Of the former, 78.5% indicated that other individuals or entities were maintaining the intervention.

Adaptations

An open-ended item asked what adaptations were made to facilitate intervention implementation after the research study, as many digital HIV interventions in effectiveness evaluations may not be developed with sustained implementation in mind. Several interventions did not make any adaptations after study completion ($n = 15$). Content adaptations ($n = 18$) included for new populations (e.g., adapting content originally designed for Chileans to Latinas in the U.S.) or contexts (e.g., low-to-middle-income countries). Software and technology adaptations were endorsed at a similar frequency ($n = 17$), which included migrations to web, SMS, Wordpress, and Canvas and moving to an open-science format. These two types of adaptations (i.e., content and technology) are illustrated by this respondent's quote: "Videos are used in the intervention and they do NOT age well. So groups choose different videos that I approve. In one of the interventions there was technology used that is difficult to implement in community settings, so groups have adapted these activities with my approval" (no. 84).

Implementation Barriers

When we asked respondents to name the most significant barriers that interfered with their ability to implement their intervention, *lack of funding* was overwhelmingly, and unsurprisingly, cited as a significant barrier. This respondent also highlighted the discrepancy between the speed of innovations in the technology world and the slower pace of science and research funding, which can hamper implementation of interventions that are developed in a research setting:

> The biggest barriers… securing sufficient continuous funding to develop, adapt, deploy, refine, redeploy in a timely way – nature of research funding world and cycles do not match with pace/speed of tech development nor do they match with commercial models and (domestic) HIV realm is just not a large enough audience segment to be able to secure investors. – no. 39

Respondents noted a variety of challenges related to *software and technology*, such as a target population's access to technology; difficulty maintaining and updating intervention technology; and difficulty finding appropriate and long-term technology partners. Some of these concerns were described by this respondent: "The fact that the technology that was used to program the intervention became outdated and we needed to update the technology; this created additional costs which stalled dissemination of the intervention" (no. 38).

Respondents also cited difficulties forming and maintaining *implementation partnerships*, including establishing interventions within partner organizations, in part because of lack of staff and financial resources, time due to competing priorities, and organizational or user interest in the intervention that led to difficulties recruiting and retaining people into the intervention. One respondent summarized multiple implementation barriers common among the sample, including another theme reflecting a *lack of models for and guidance on how to implement a digital intervention*: "No national model for funding the technology delivery; CBOs have limited experience with eHealth so need a lot of capacity building; CBOs are often unaware of these interventions and they are not called out in FOAs [funding opportunity announcements] from funders as eligible for delivery" (no. 67).

Advice for Other Researchers and Developers

We asked participants an open-ended question about what others should know about implementing digital HIV interventions. Several respondents emphasized that those who design the interventions should also be more *involved in intervention software developmen*t, including having a working knowledge of the software development process, logistics, and costs of developing and maintaining a digital intervention over time. Relatedly, others spoke to the importance of developers *investing substantial resources in technology* on an ongoing basis to ensure implementation success, including finding reliable and experienced tech partners: "Cost associated with the development software/IT aspect. As researchers we may know how to develop an intervention (front-end) but the software aspect (back-end) is costly and also time consuming to understand as a researcher. Also important that researchers are involved and understand the software component so that they maintain control over the whole process of development and implementation" (no. 2).

Respondents also encouraged individuals to *consider implementation from the beginning*, rather than waiting until after a digital intervention has established effectiveness, including anticipating end-user and prospective implementer needs up front. Similarly, several participants noted the absence of a clear path forward for implementing digital HIV interventions and called for *formal guidance and support for implementation*, such as infrastructure or "roadmaps" for sustaining digital interventions and increased availability of grants focused on real-world intervention

implementation (cf. solely researching efficacy or effectiveness). This is underscored by two respondents who expressed sentiments common among the sample: "There's not enough information on implementation of these types of interventions" (no. 21), and "No real plans or framework for the CDC or other govt organizations to support tech-based interventions" (no. 22).

Of note, several respondents shared the sentiment that dissemination and implementation of digital HIV interventions is difficult; one mentioned that because of these issues, it seemed easier to implement traditional face-to-face or workbook-type interventions.

Perspectives on a Centralized Implementation Model

We asked respondents what involvement they would want to have in the maintenance, enhancement, and dissemination of their intervention if it were administered through a centralized implementation center or national repository charged with delivering digital HIV interventions. Over half of respondents wanted to offer consultative services in support of implementation, such as training implementation center staff to provide technical assistance to implementers. A third of respondents wanted to approve content adaptations and enhancements and how the intervention is priced or licensed, with the implementation center handling the execution of these activities. A quarter of respondents wanted minimal to no involvement.

A second question asked what respondents would want to receive back from the implementation center. The most frequently selected option was regular reports on the status of dissemination and implementation, such as reach and enrollment in the intervention. Other commonly selected options were attribution, funding for further maintenance, adaptations, implementation supports, and first rights to conduct future research on the intervention.

Discussion

There remains great, but largely untapped, potential in digital adjunctive interventions that address the HIV prevention and care continua in the U.S. Numerous effective programs already exist, but without clear processes and strategies for their implementation, they will continue to sit on a metaphorical shelf, never to reach those whom they were meant to benefit. Furthermore, continued investment in the development and testing of new digital HIV interventions without simultaneous and aggressive investment in infrastructure and resources to house and deliver them afterwards will only end in the same result.

Fig. 1A depicts the current state of digital HIV intervention implementation, based on our review, survey of developers, and two decades of experience in this field. We use the metaphor of delivering physical products to consumers, known in IS as recipients. At the top left is intervention science, which develops and tests digital HIV interventions and has thus far comprised nearly all federal research dollars in this area. Interventions found to be effective enter a compendium, such as those maintained by the CDC [78] and HRSA [80]. After that, there is a long and winding road toward preparing for implementation, filled with obstacles identified in our review and survey such as post-research needs to integrate with real-world health delivery systems, costly technological modifications and maintenance, and insufficient partnerships with deliverers. These challenges arise not only due to the scarcity of implementation-focused research and guidance but also from uncertainty surrounding the next steps after demonstrating effectiveness. Yet, such barriers are surmountable with time, resources, and individual capacity and motivation. There is a point in the current state, however, that researchers simply cannot move forward to implementation, as the lack of technological infrastructure to deposit interventions, the lack of funding to implement digital HIV interventions, and the lack of support for deliverers to integrate and use these technologies create an ocean uncrossable by the trucks carrying their interventions, preventing any handoff to deliverers waiting to receive and use these technologies. Our belief is that these trucks continue to pile up and that only structural interventions by federal agencies can traverse this chasm

Lessons from IS and more implementation research can help bypass some initial barriers and shorten the time to prepare interventions for implementation. For example, researchers can build in time and money to design for implementation from the beginning to avoid costly adaptations down the line [72•]. However, digital interventions need a "home" that can support their maintenance, adaptation, and delivery over time, and it is impractical and inefficient for individual teams to provide this in the context of single studies. Respondents mentioned difficulties in staying abreast with rapid changes in the software landscape that may require complete overhauls of platforms due to advances in technology, such as when Adobe Flash—a go-to platform for content delivery—became discontinued several years later. This speaks to the need for a repository where researchers could deposit their tested interventions, not just the research evidence, to curate and maintain. Our respondents also pointed to the need for strategies to systematically get digital interventions to those who need them and to offer technical assistance to organizations who want to implement these interventions but lack the technology, expertise, or staffing to do so successfully, both of which require substantial infrastructure to support. Together with dedicated funding for implementation, these pillars can support a way to move past the current impasse and support researchers and deliverers collectively getting these effective interventions to communities in need (Fig. 1B).

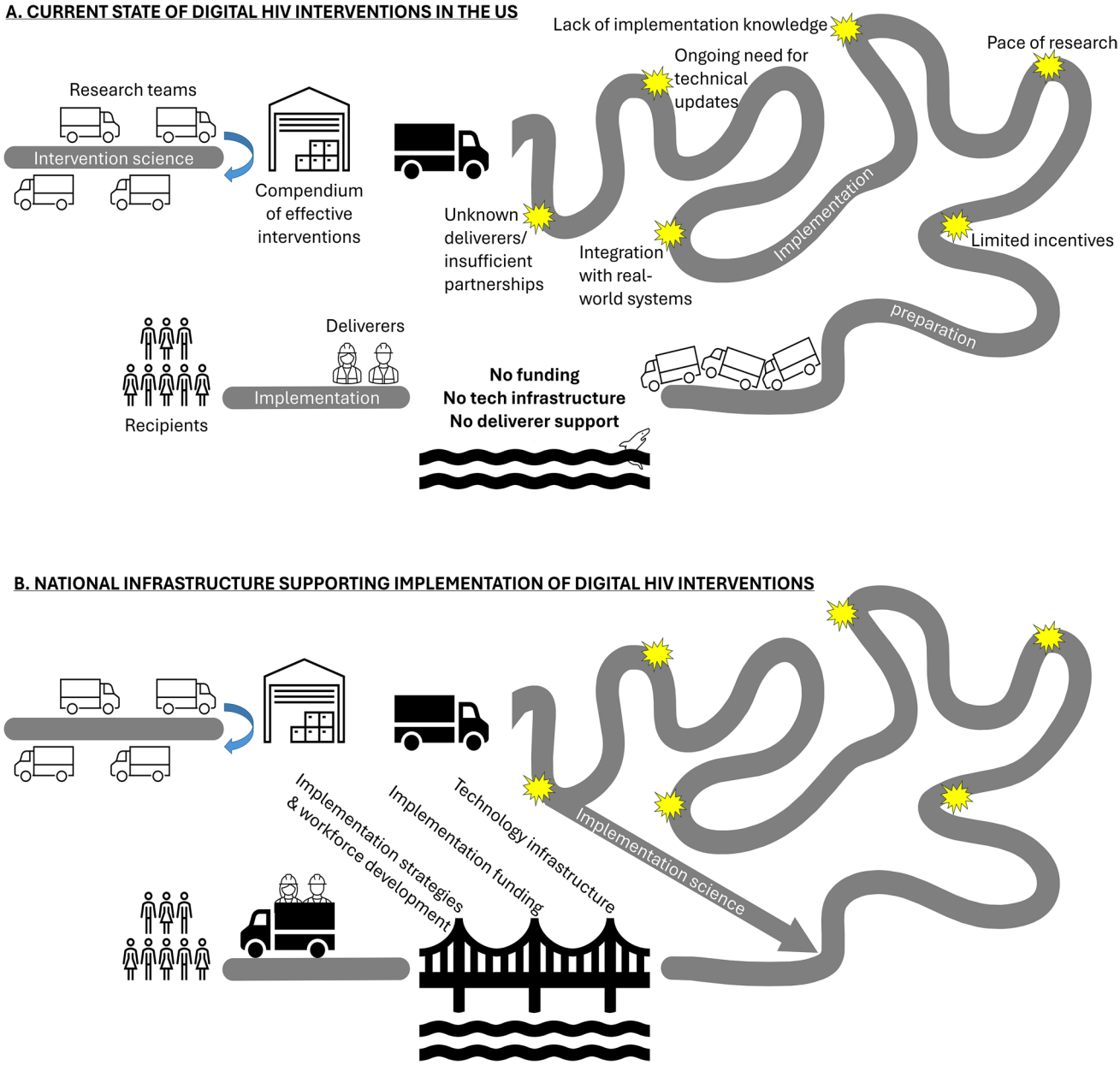

Fig. 1 Current and potential future states of digital HIV intervention implementation in the U.S. In the current state (**A**), preparing evidence-based digital HIV interventions for implementation is a long and arduous path for research teams (trucks) that is fraught with challenges (explosions). Even overcoming those, researchers have no way to get the interventions to deliverers (workers) and recipients (people) because of insurmountable barriers related to lack of funding, infrastructure, and implementation support (water). In a proposed future state (**B**), a national infrastructure comprising technological infrastructure and coordination, implementation funding, and deliverer-centered implementation strategies (bridge) supports both researchers and deliverers in implementation. Implementation science also helps shorten the route from intervention science to implementation

A Path Forward for Digital HIV Intervention Implementation

We envision that these solutions could come together efficiently and cost-effectively in the form of a national distribution system tailored to the implementation and dissemination of digital HIV interventions (represented by the bridge in Fig. 1B and asterisks in Table 2). One or more technology centers could serve as national hubs for hosting, maintaining, and delivering interventions, addressing many of the implementation barriers cited by our respondents. The system could streamline operations by consolidating resources, expertise, and technological infrastructure and could harmonize a diverse array of stakeholders vital to the

success of these interventions, including program managers, IT specialists, user support, and data analysts. Centers could host essential digital resources, software applications, databases, and websites while ensuring the necessary security of the underlying technology infrastructure, addressing challenges associated with maintaining and updating technology. Moreover, they could relieve the need for investigators to find appropriate and stable technology partners and funding by providing technical support that includes troubleshooting, maintenance, and updates. After demonstrating the effectiveness of a digital HIV intervention, creators could license the content to the system for distribution under an agreement that would allow for appropriate credit and other desirables for the creator, as informed by our survey data.

At a higher level, such a system could spearhead the promotion and establishment of standardization and interoperability to enable data exchange across different interventions, platforms, and devices more easily. In addition to supporting the technology, centers could uniformly address content adaptation needs in response to advances in clinical HIV research (e.g., adding injectable PrEP as an option to existing content on oral PrEP). They could also serve as hubs for harmonized data collection and analysis, identifying emerging trends and best practices and facilitating data-driven decision-making that optimizes the collective impact of all programs within the system. It is important to note that these centers would need to deploy robust security measures to safeguard sensitive data and ensure the privacy and confidentiality of health information, since simply placing interventions online without ongoing maintenance will result in their eventual malfunction and potential for security breaches.

Delivery of digital interventions to recipients could be performed by technology centers directly to consumers or mediated by local community and clinical organizations, with the appropriate expertise housed internally. Whereas a DTC approach might require more knowledge about advertising, user engagement, and shipping logistics (if materials such as HIV self-test kits are being distributed), a CBO approach might need to provide more technological support to agencies, as noted in our findings. Both models are viable [67••], but the differences in necessary skills further supports divorcing those responsibilities from individual research teams and deliverers.

Regardless of the selected approach, funding is critical for implementing digital HIV interventions and was cited as the most significant barrier among survey respondents. Although health insurance reimbursement policies and coverage may play a role in facilitating the adoption of some digital interventions [81], not all digital products may be reimbursed at a rate sufficient to sustain effective implementation [82] or even at all [83]. Therefore, a synchronized collaboration with national funding sources and local organizations to create a funding schema for effective interventions could help ensure their sustainability. Given their scope of responsibilities, CDC is the obvious funder for interventions focused on HIV prevention and HRSA for digital interventions related to HIV care. However, given that some digital interventions are generalizable (e.g., text messaging medical reminders for PrEP or ART) and the increased focus on status-neutral services, technology centers that use braided funding support both prevention and care would be ideal.

There are exemplars of widespread, coordinated scale-up of digital HIV interventions outside the U.S., such as the QuickRes Online Reservation and Case Management App [33, 84, 85] implemented in multiple African and Asian countries. Features of this impressive implementation include local tailoring of implementation strategies and field support and centralized technology hosting, training, and technical assistance. Our proposed pathway could replicate this approach across interventions. Several countries are already actively strategizing to embed digital tools into their healthcare systems, driven by the overarching goals of enhancing patient care, streamlining operations, and improving healthcare accessibility. Examples include the United Kingdom's National Health Service, which has positioned its digital transformation strategy as a pivotal facet of its goals to bolster patient access to digital services by enabling the digitization of healthcare records and harnessing technology to improve patient care. Similarly, Australia has begun to integrate digital tools into its healthcare landscape, with a focus on initiatives encompassing digital health records, telehealth services, and the utilization of technology to augment healthcare delivery and accessibility. In the U.S., the Department of Veterans Affairs has taken the lead in the adoption of digital tools through its "Connected Care" program, which employs technology to enhance veterans' access to healthcare services, including telehealth and electronic health records. Notably, Kaiser Permanente, one of the largest healthcare providers in the U.S., has seamlessly integrated digital tools into its ecosystem and successfully developed its own technology infrastructure to offer a wide array of digital services to its patients, including telemedicine, patient portals, mobile applications, and data analytics, all aimed at improving patient care and operational efficiency.

Conclusion

In the U.S., there have been huge investments of taxpayer dollars in the creation and testing of digital HIV interventions, but without the mechanisms for implementation we lay out in this article, these effective adjunctive interventions will not impact the epidemic. To invest in demonstrating

proof-of-concept but not in their ultimate implementation makes the government "run the risk of becoming a kitchen that prepares exquisite dishes that are never enjoyed by the public who paid for their preparation" [86]. However, the issues we have presented here are solvable. The necessary strategies for implementation success include a national system of technology coordinating centers that can house, maintain, and support the delivery of these interventions; funding for delivery to and engagement of recipients either directly or mediated by local organizations; and plans and templates for technology creators (often researchers) to deposit their interventions into the coordinating centers. Scientists can be encouraged to do all they can to plan for dissemination and implementation during their studies (we have offered suggestions for doing elsewhere [72•], but the primary responsibility for conditions necessary for implementation rests with federal agencies such as the CDC and HRSA, and we urge them to take action to gain the return on large prior investments.

Author contributions All authors contributed to the design, data collection, literature review, writing, and editing of the manuscript.

Funding This publication was supported by grants from the National Institutes of Health: R01MH118213 (Mustanski), P30AI117943 (Mustanski & D'Aquila), R01MH129207 (Macapagal), and P30AI117943 Supplement (Mustanski & Benbow).

Declarations

Competing interests The authors declare no competing interests.

Human and Animal Rights and Informed Consent This study includes surveys of humans but was designated not human subject research by the IRB. All participants were provided information about the study before they opted to participate.

Disclaimer The content of this article is solely the responsibility of the authors and does not necessarily reflect the views of the National Institutes of Health.

References

Papers of particular interest, published recently, have been highlighted as:
- • Of importance
- •• Of major importance

1. Fauci AS, Redfield RR, Sigounas G, Weahkee MD, Giroir BP. Ending the HIV epidemic: a plan for the United States. JAMA. 2019;321(9):844–5.
2. Centers for Disease Control and Prevention. Estimated HIV incidence and prevalence in the United States, 2017–2021. HIV Surveillance Supplemental Report. 2023;28:3. Available from: https://www.cdc.gov/hiv/library/reports/hiv-surveillance/vol-28-no-3/index.html.
3. Balaji AB, An Q, Smith JC, Newcomb ME, Mustanski B, Prachand NG, et al. High human immunodeficiency virus incidence and prevalence and associated factors among adolescent sexual minority males-3 cities, 2015. Clin Infect Dis. 2018;66(6):936–44.
4. Garofalo R, Hotton AL, Kuhns LM, Gratzer B, Mustanski B. Incidence of HIV infection and sexually transmitted infections and related risk factors among very young men who have sex with men. J Acquir Immune Defic Syndr. 2016;72(1):79–86.
5. Mustanski B, Ryan DT, Newcomb ME, D'Aquila RT, Matson M. Very high HIV incidence and associated risk factors in a longitudinal cohort study of diverse adolescent and young adult men who have sex with men and transgender women. AIDS Behav. 2019;24(6):1966–75.
6. Mustanski B, Moskowitz DA, Moran KO, Rendina HJ, Newcomb ME, Macapagal K. Factors associated with HIV testing in teenage men who have sex with men. Pediatrics. 2020;145:3.
7. Yusuf H, Fields E, Arrington-Sanders R, Griffith D, Agwu AL. HIV preexposure prophylaxis among adolescents in the US: a review. JAMA Pediatr. 2020;174(11):1102–8.
8. Huebner DM, Mustanski B. Navigating the long road forward for maximizing PrEP impact among adolescent men who have sex with men. Arch Sex Behav. 2020;49(1):211–6.
9. Centers for Disease Control and Prevention. Monitoring selected national HIV prevention and care objectives by using HIV surveillance data—United States and 6 dependent areas, 2020. HIV Surveillance Supplemental Report. 2022;27:3. Available from: https://www.cdc.gov/hiv/library/reports/hiv-surveillance/vol-27-no-3/index.html.
10.• Smith JD, Li DH, Keiser B, Mustanski B, Benbow N. Adjunctive interventions are change methods directed at recipients that support uptake and use of health innovations. Implement Sci. 2024;19:10. **This article describes the importance of adjunctive interventions, a category of behavior change methods that are designed to enhance uptake and use of health interventions by recipients, in HIV care. It also demonstrates the need and benefit of distinguishing adjunctive interventions from health interventions and implementation strategies based on function.**
11. Centers for Disease Control and Prevention. High-impact HIV prevention: CDC's approach to reducing HIV infections in the United States. Division of HIV/AIDS Prevention, National Center for HIV/AIDS, Viral Hepatitis, STD, and TB Prevention, Centers for Disease Control and Prevention. 2011. Available from: https://www.cdc.gov/hiv/pdf/policies_nhpc_booklet.pdf.
12. Kegeles SM, Hays RB, Coates TJ. The Mpowerment Project: a community-level HIV prevention intervention for young gay men. Am J Public Health. 1996;86(8):1129–36.
13. Jones KT, Gray P, Whiteside YO, Wang T, Bost D, Dunbar E, et al. Evaluation of an HIV prevention intervention adapted for Black men who have sex with men. Am J Public Health. 2008;98(6):1043–50.
14. Centers for Disease Control and Prevention. HIV infection risk, prevention, and testing behaviors among men who have sex with men – National HIV Behavioral Surveillance, 13 U.S. Cities, 2021. HIV Surveillance Special Report. 2023;31. Available from: https://www.cdc.gov/hiv/library/reports/hiv-surveillance-special-reports/no-31/index.html.
15. Centers for Disease Control and Prevention. HIV infection, risk, prevention, and testing behaviors among heterosexually active adults at increased risk for HIV infection—National HIV Behavioral Surveillance, 23 U.S. Cities, 2019. HIV

Surveillance Special Report. 2021;26. Available from: https://www.cdc.gov/hiv/library/reports/hiv-surveillance.html.
16. Centers for Disease Control and Prevention. HIV infection risk, prevention, and testing behaviors among persons who inject drugs—National HIV Behavioral Surveillance: Injection Drug Use, 23 U.S. Cities, 2018. HIV Surveillance Special Report. 2020;24. Available from: https://www.cdc.gov/hiv/library/reports/hiv-surveillance.html.
17. Centers for Disease Control and Prevention. HIV infection, risk, prevention, and testing behaviors among transgender women-National HIV Behavioral Surveillance, 7 U.S. Cities, 2019–2020. HIV Surveillance Special Report. 2021;27. Available from: https://www.cdc.gov/hiv/library/reports/hiv-surveillance.html.
18. Bell SG, Newcomer SF, Bachrach C, Borawski E, Jemmott JB 3rd, Morrison D, et al. Challenges in replicating interventions. J Adolesc Health. 2007;40(6):514–20.
19. Neumann MS, Sogolow ED. Replicating effective programs: HIV/AIDS prevention technology transfer. AIDS Educ Prev. 2000;12(5 Suppl):35–48.
20 Kegeles SM, Rebchook G, Tebbetts S, Arnold E. Team T Facilitators and barriers to effective scale-up of an evidence-based multilevel HIV prevention intervention. Implement Sci. 2015;10:50.
21. Glasgow RE, Eckstein ET, Elzarrad MK. Implementation science perspectives and opportunities for HIV/AIDS research: Integrating science, practice, and policy. J Acquir Immune Defic Syndr. 2013;63(Suppl 1):S26-31.
22. Centers for Disease Control and Prevention. Comprehensive high-impact HIV prevention programs for community-based organizations: CDC-RFA-PS21–2102 2020 [Available from: https://www.cdc.gov/hiv/pdf/funding/announcements/ps21-2102/cdc-hiv-nofo21-2102-rfa.pdf.
23.• Muessig KE, Nekkanti M, Bauermeister J, Bull S, Hightow-Weidman LB. A systematic review of recent smartphone, Internet and Web 2.0 interventions to address the HIV continuum of care. Current HIV/AIDS Reports. 2015;12(1):173–90. **This article provides a historic snapshot of digital HIV intervention studies published or ongoing in 2013–2014. Interventions from this article contributed to the sample we surveyed to understand investigators' experiences with implementation after the research projects ended.**
24. Schueller SM, Munoz RF, Mohr DC. Realizing the potential of behavioral intervention technologies. Curr Dir Psychol Sci. 2013;22(6):478–83.
25.•• Noar SM. Computer technology-based interventions in HIV prevention: state of the evidence and future directions for research. AIDS Care. 2011;23(5):525-533. **This article presents the state of evidence on digital HIV interventions from 2011, demontrating that many efficacious digital programs already existed. Even then, the author declared a need for and provided a framework to guide more research on dissemination and implementation of these interventions.**
26. Guse K, Levine D, Martins S, Lira A, Gaarde J, Westmorland W, et al. Interventions using new digital media to improve adolescent sexual health: a systematic review. J Adolesc Health. 2012;51(6):535–43.
27. Bailey J, Mann S, Wayal S, Hunter R, Free C, Abraham C, et al. Sexual health promotion for young people delivered via digital media: a scoping review. Public Health Res. 2015;3:13.
28. Noar SM, Pierce LB, Black HG. Can computer-mediated interventions change theoretical mediators of safer sex? A Meta-Anal Human Commun Res. 2010;36(3):261–97.
29. Xin M, Viswanath K, Li AY, Cao W, Hu Y, Lau JT, et al. The effectiveness of electronic health interventions for promoting HIV-preventive behaviors among men who have sex with men: meta-analysis based on an integrative framework of design and implementation features. J Med Internet Res. 2020;22(5):e15977.
30. Maloney KM, Bratcher A, Wilkerson R, Sullivan PS. Electronic and other new media technology interventions for HIV care and prevention: a systematic review. J Int AIDS Soc. 2020;23(1):e25439.
31. Mayer JE, Fontelo P. Meta-analysis on the effect of text message reminders for HIV-related compliance. AIDS Care. 2017;29(4):409–17.
32. Guide to Community Preventive Services. HIV prevention: digital health interventions to improve adherence to HIV pre-exposure prophylaxis. Community Preventive Services Task Force; 2022. Available from: https://www.thecommunityguide.org/findings/hiv-prevention-digital-health-interventions-improve-adherence-hiv-pre-exposure-prophylaxis.html.
33. United Nations Programme on HIV/AIDS, World Health Organization. Innovate, implement, integrate: virtual interventions in response to HIV, sexually transmitted infections and viral hepatitis. Geneva: World Health Organization; 2022. Available from: https://www.unaids.org/sites/default/files/media_asset/policy-brief_virtual-interventions_en.pdf.
34. Centers for Disease Control and Prevention. Telehealth for HIV Prevention and Care Services 2023 [Available from: https://www.cdc.gov/hiv/effective-interventions/treat/telehealth/index.html.
35. Idelson L. Oregon Reminders: Technology to Engage Rural Oregon Communities in HIV Care: AIDS Education & Training Center Program; 2020 [updated April 27, 2023. Available from: https://aidsetc.org/blog/oregon-reminders-technology-engage-rural-oregon-communities-hiv-care.
36. Bauer MS, Damschroder L, Hagedorn H, Smith J, Kilbourne AM. An introduction to implementation science for the non-specialist. BMC Psychol. 2015;3:32.
37. Nilsen P. Making sense of implementation theories, models and frameworks. Implement Sci. 2015;10:53.
38. Smith JD, Li DH, Rafferty MR. The implementation research logic model: a method for planning, executing, reporting, and synthesizing implementation projects. Implement Sci. 2020;15:84.
39. Mustanski B, Saber R, Macapagal K, Matson M, Laber E, Rodrgiuez-Diaz C, et al. Effectiveness of the SMART Sex Ed program among 13–18 year old English and Spanish speaking adolescent men who have sex with men. AIDS Behav. 2023;27(2):733–44.
40. Mustanski B, Parsons JT, Sullivan PS, Madkins K, Rosenberg E, Swann G. Biomedical and behavioral outcomes of Keep It Up!: an eHealth HIV prevention program RCT. Am J Prev Med. 2018;55(2):151–8.
41. Shegog R, Peskin MF, Markham C, Thiel M, Karny E, Addy RC, et al. It's Your Game–Tech: toward sexual health in the digital age. Creat Educ. 2014;5(15):1428–47.
42. Decker MJ, Harrison S, Price M, Gutmann-Gonzalez A, Yarger J, Tenney R. Educators' perspectives on integrating technology into sexual health education: implementation study. JMIR Hum Factors. 2022;9(1):e31381.
43. Faccio B, McClay A, McConnell K, Gates C, Finocharo J, Tallant J, et al. Comparing virtual and in-person implementation of a school-based sexual health promotion program in high schools with large Latino populations. Prev Sci. 2023;24(Suppl 2):251–61.
44. Harshbarger C, Burrus O, Zulkiewicz BA, Ortiz AM, Galindo CA, Garner BR, et al. Implementing web-based interventions in HIV primary care clinics: pilot implementation evaluation of positive health check. JMIR Form Res. 2019;3(2):e10688.
45. Cohn WF, Canan CE, Knight S, Waldman AL, Dillingham R, Ingersoll K, et al. An implementation strategy to expand mobile

health use in HIV care settings: rapid evaluation study using the consolidated framework for implementation research. JMIR Mhealth Uhealth. 2021;9(4):e19163.
46. Zulkiewicz BA, Burrus O, Harshbarger C, Ortiz A, Garner BR, Lewis MA. Identifying implementation strategies that address barriers and facilitate implementation of digital interventions in HIV primary care settings: results from the pilot implementation of positive health check. AIDS Behav. 2021;25(1):154–66.
47. Horvath KJ, Lammert S, LeGrand S, Muessig KE, Bauermeister JA. Using technology to assess and intervene with illicit drug-using persons at risk for HIV. Curr Opin HIV AIDS. 2017;12(5):458–66.
48. Uhrig Castonguay BJ, Cressman AE, Kuo I, Patrick R, Trezza C, Cates A, et al. The implementation of a text messaging intervention to improve HIV continuum of care outcomes among persons recently released from correctional facilities: randomized controlled trial. JMIR Mhealth Uhealth. 2020;8(2):e16220.
49. Ladapo JA, Elliott MN, Bogart LM, Kanouse DE, Vestal KD, Klein DJ, et al. Cost of talking parents, healthy teens: a worksite-based intervention to promote parent-adolescent sexual health communication. J Adolesc Health. 2013;53(5):595–601.
50. Middleton M, Somerset S, Evans C, Blake H. Test@Work Texts: mobile phone messaging to increase awareness of HIV and HIV testing in UK construction employees during the COVID-19 pandemic. Int J Environ Res Public Health. 2020;17:21.
51 Mustanski B, Madkins K, Greene GJ, Parsons JT, Johnson BA, Sullivan P, et al. Internet-based HIV prevention with at-home sexually transmitted infection testing for young men having sex with men: study protocol of a randomized controlled trial of Keep It Up! 20. JMIR Res Protoc. 2017;6(1):e1.
52. Mustanski B, Moskowitz DA, Moran KO, Newcomb ME, Macapagal K, Rodriguez-Diaz C, et al. Evaluation of a stepped-care eHealth HIV prevention program for diverse adolescent men who have sex with men: protocol for a hybrid type 1 effectiveness implementation trial of SMART. JMIR Res Protoc. 2020;9(8):e19701.
53. Trujillo D, Turner C, Le V, Wilson EC, Arayasirikul S. Digital HIV care navigation for young people living with HIV in San Francisco, California: feasibility and acceptability study. JMIR Mhealth Uhealth. 2020;8(1):e16838.
54. Tanner AE, Song EY, Mann-Jackson L, Alonzo J, Schafer K, Ware S, et al. Preliminary impact of the weCare social media intervention to support health for young men who have sex with men and transgender women with HIV. AIDS Patient Care STDS. 2018;32(11):450–8.
55. Westergaard RP, Genz A, Panico K, Surkan PJ, Keruly J, Hutton HE, et al. Acceptability of a mobile health intervention to enhance HIV care coordination for patients with substance use disorders. Addict Sci Clin Pract. 2017;12(1):11.
56. Lane-Fall MB, Curran GM, Beidas RS. Scoping implementation science for the beginner: locating yourself on the "subway line" of translational research. BMC Med Res Methodol. 2019;19(1):133.
57. Curran GM, Bauer M, Mittman B, Pyne JM, Stetler C. Effectiveness-implementation hybrid designs: combining elements of clinical effectiveness and implementation research to enhance public health impact. Med Care. 2012;50(3):217–26.
58. Landes SJ, McBain SA, Curran GM. An introduction to effectiveness-implementation hybrid designs. Psychiatry Res. 2019;280:112513.
59. Ventuneac A, Li DH, Mongrella MC, Moskowitz DA, Weingardt KR, Brown CH, et al. Exploring potential implementation barriers and facilitators of the SMART program: a stepped-care package of eHealth HIV prevention interventions for adolescent men who have sex with men. Sex Res Soc Policy. 2020;17(3):378–88.
60. Aladin B, Thompson M, Addison D, Havens J, McGowan J, Nash D, et al. The YgetIt? Program: a mobile application, PEEP, and digital comic intervention to improve HIV care outcomes for young adults. Health Promot Pract. 2023;24(4):658–68.
61. Caldwell S, Flickinger T, Hodges J, Waldman ALD, Garofalini C, Cohn W, et al. An mHealth platform for people with HIV receiving care in Washington, District of Columbia: qualitative analysis of stakeholder feedback. JMIR Form Res. 2023;7:e48739.
62. Mustanski B, Garofalo R, Monahan C, Gratzer B, Andrews R. Feasibility, acceptability, and preliminary efficacy of an online HIV prevention program for diverse young men who have sex with men: The Keep It Up! intervention. AIDS Behav. 2013;17(9):2999–3012.
63. Damschroder LJ, Aron DC, Keith RE, Kirsh SR, Alexander JA, Lowery JC. Fostering implementation of health services research findings into practice: a consolidated framework for advancing implementation science. Implement Sci. 2009;4:50.
64. Damschroder LJ, Reardon CM, Widerquist MAO, Lowery J. The updated Consolidated Framework for Implementation Research based on user feedback. Implement Sci. 2022;17(1):75.
65. Garner BR, Burrus O, Ortiz A, Tueller SJ, Peinado S, Hedrick H, et al. A longitudinal mixed-methods examination of positive health check: implementation results from a type 1 effectiveness-implementation hybrid trial. J Acquir Immune Defic Syndr. 2022;91(1):47–57.
66. Witte SS, Wu E, El-Bassel N, Hunt T, Gilbert L, Medina KP, et al. Implementation of a couple-based HIV prevention program: a cluster randomized trial comparing manual versus Web-based approaches. Implement Sci. 2014;9:116.
67.•• Mustanski B, Saber R, Jones JP, Macapagal K, Benbow N, Li DH, et al. (2023) Keep It Up! 3.0: study protocol for a type III hybrid implementation-effectiveness cluster-randomized trial. Contemp Clin Trials. 2023;127:107134. **This article describes a head-to-head implementation trial of a digital HIV intervention that utilized a coordinating center model to support direct-to-consumer and community-based organization delivery.**
68. Greene GJ, Madkins K, Andrews K, Dispenza J, Mustanski B. Implementation and evaluation of the Keep It Up! online HIV prevention intervention in a community-based setting. AIDS Educ Prev. 2016;28(3):231–45.
69. Black KJ, Morse B, Tuitt N, Big Crow C, Shangreau C, Kaufman CE. Beyond content: cultural perspectives on using the Internet to deliver a sexual health intervention to American Indian youth. J Prim Prev. 2018;39(1):59–70.
70. Li DH, Moskowitz D, Macapagal K, Saber R, Mustanski B. Using intervention mapping to developmentally adapt an online HIV risk reduction program for adolescent men who have sex with men. Prev Sci. 2020;21(7):885–97.
71. Budhwani H, Kiszla BM, Hightow-Weidman LB. Adapting digital health interventions for the evolving HIV landscape: examples to support prevention and treatment research. Curr Opin HIV AIDS. 2022;17(2):112–8.
72.• Li DH, Brown CH, Gallo C, Morgan E, Sullivan PS, Young SD, et al. Design considerations for implementing eHealth behavioral interventions for HIV prevention in evolving sociotechnical landscapes. Curr HIV/AIDS Rep. 2019;16(4):335–48. **This article provides developers of digital interventions with a list of questions to think through during the development phase, with the goal of helping them create interventions that are more implementable and sustainable outside of research contexts.**
73. Glasgow RE, Harden SM, Gaglio B, Rabin B, Smith ML, Porter GC, et al. RE-AIM planning and evaluation framework: adapting

to new science and practice with a 20-year review. Front Public Health. 2019;7:64.
74. Wright CJC, Leinberger K, Lim MSC. Challenges to translating new media interventions in community practice: a sexual health SMS program case study. Health Promot J Austr. 2016;27(1):70–3.
75. Campbell AR, Kinvig K, Cote HC, Lester RT, Qiu AQ, Maan EJ, et al. Health care provider utilization and cost of an mHealth intervention in vulnerable people living with HIV in Vancouver, Canada: prospective study. JMIR Mhealth Uhealth. 2018;6(7):e152.
76. Montgomery TM, Mays VM, Heilemann MV, Nyamathi A, Bauermeister JA, Koniak-Griffin D. Acceptability and feasibility of a sexual health intervention for young adult Black women. J Obstet Gynecol Neonatal Nurs. 2018;47(6):862–73.
77. Williamson A, Barbarin A, Campbell B, Campbell T, Franzen S, Reischl TM, et al. Uptake of and engagement with an online sexual health intervention (HOPE eIntervention) among African American young adults: mixed methods study. J Med Internet Res. 2021;23(7):e22203.
78. Centers for Disease Control and Prevention. Compendium of evidence-based interventions and best practices for HIV prevention Atlanta, GA: Division of HIV/AIDS Prevention, National Center for HIV/AIDS, Viral Hepatitis, STD, and TB Prevention, Centers for Disease Control and Prevention; 2023 [Available from: https://www.cdc.gov/hiv/research/interventionresearch/compendium/index.html.
79. Taylor B, Henshall C, Kenyon S, Litchfield I, Greenfield S. Can rapid approaches to qualitative analysis deliver timely, valid findings to clinical leaders? A mixed methods study comparing rapid and thematic analysis. BMJ Open. 2018;8(10):e019993.
80. HRSA Ryan White HIV/AIDS Program. TargetHIV: best practices compilation: HRSA, HIV/AIDS Bureau; 2023 [Available from: https://targethiv.org/bestpractices/search.
81. van Kessel R, Srivastava D, Kyriopoulos I, Monti G, Novillo-Ortiz D, Milman R, et al. Digital health reimbursement strategies of 8 European countries and Israel: scoping review and policy mapping. JMIR Mhealth Uhealth. 2023;11:e49003.
82. Mkuu R, Harle CA, Andreadis K, Muellers KA, McDonnell C, Goede D, et al. Financial factors that influenced telemedicine delivery during the COVID-19 pandemic. Am J Accountable Care. 2023;11(2):7–14.
83. Mantovani A, Leopaldi C, Nighswander CM, Di Bidino R. Access and reimbursement pathways for digital health solutions and in vitro diagnostic devices: current scenario and challenges. Front Med Technol. 2023;5:1101476.
84. FHI 360. Online reservation app for HIV service delivery programs. Technical Implementation Brief. 2019. Available from: https://www.fhi360.org/sites/default/files/media/documents/resource-linkages-ora-technical-brief.pdf.
85. EpiC. QuickRes technical guide: a global online reservation and case management tool for HIV programs. Durham, NC: FHI 360; 2021. Available from: https://www.fhi360.org/sites/default/files/media/documents/resource-quickres-technical-guide-march-2021.pdf.
86. Mustanski B, Smith JD, Keiser B, Li DH, Benbow N. Supporting the growth of domestic HIV implementation research in the United States through coordination, consultation, and collaboration: how we got here and where we are headed. J Acquir Immune Defic Syndr. 2022;90(S1):S1–8.