

A Systematic Review of Recent Smartphone, Internet and Web 2.0 Interventions to Address the HIV Continuum of Care

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Abstract eHealth, mHealth and “Web 2.0” social media strategies can effectively reach and engage key populations in HIV prevention across the testing, treatment, and care continuum. To assess how these tools are currently being used within the field of HIV prevention and care, we systematically reviewed recent (2013–2014) published literature, conference abstracts, and funded research. Our searches identified 23 published intervention studies and 32 funded projects underway. In this synthesis we describe the technology modes applied and the stages of the HIV care cascade addressed, including both primary and secondary prevention activities. Overall trends include use of new tools including social networking sites,

provision of real-time assessment and feedback, gamification and virtual reality. While there has been increasing attention to use of technology to address the care continuum, gaps remain around linkage to care, retention in care, and initiation of antiretroviral therapy.

Keywords mHealth · eHealth · Internet · HIV · Mobile phone · Smartphone · Social media · Intervention · Prevention

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Introduction

In recent years, HIV prevention has been reframed by the dual, related concepts of the HIV care continuum – or treatment “cascade” [1, 2] – and “Treatment as Prevention” (TasP) [3, 4]. Both concepts draw on scientific advances that demonstrate the ability of antiretroviral therapies (ART) to prevent HIV acquisition in the form of Pre-Exposure Prophylaxis (PrEP), and reduce forward transmission via earlier initiation of ART among those who are HIV-positive [5–7]. In practice, the success of these biomedical strategies will depend on integrated prevention and care systems and sustained behavioral modification. To aid the rapid and cost-effective application of these new advances, researchers and health practitioners are testing a variety of technology-based approaches.

eHealth (using information and communication technologies for health), and more recently mHealth (using mobile devices for health), strategies provide opportunities to reach and engage key populations in HIV prevention across the testing, treatment, and care cascade [8, 9, 10••]. Equivalent outcomes have been found comparing therapist and computer-based interventions (CBI) focused on the promotion of a range of health behaviors; two meta-analyses found that CBIs can change mediators of safer sex (e.g. HIV/AIDS knowledge,

condom use self-efficacy) as well as behavioral and biomedical outcomes (e.g. condom use, incident sexually transmitted infections (STIs) [11, 12]. Since the early 1990s, the range and complexity of tools available for CBIs have grown to include serious gaming (using gaming principles and mechanics to achieve a specific health or education outcome), interactivity, simulation, and virtual reality (VR). These tools are being leveraged to address the need for innovative and high-fidelity technologies within health-related interventions [13–21]. Given the rapid expansion of the mobile web, social media, and user-driven content—so called “Web 2.0”—these technologies are highly scalable and relatively cost-effective once developed.

Mobile phone ownership is widespread across the world. In the US, 90% of adults own a mobile phone and 58% own smartphones [22]. Usage statistics are variable in other parts of the world, but a recent Pew Internet Research survey found that over 50% of respondents in each of 24 included countries owned a mobile phone with rates as high as 91% in South Africa and 95% in Jordan and China [23].

Expanded access to smartphones has fundamentally changed how we engage with mobile technologies. Mobile applications, “apps”, are computer programs designed to run on smartphones, tablet computers and other mobile devices. While apps were originally offered for general productivity and information retrieval, they have expanded to include games, location-based services, and more recently, mobile medical apps, though use within HIV prevention and care is still in its infancy [24, 25, 26].

A concurrent evolution of web technologies has transformed internet utilization. In contrast to static web sites where consumers are limited to passive viewing of content, a Web 2.0 site allows users to interact and collaborate via social media platforms as co-creators of user-generated content in virtual communities (e.g. Facebook, Twitter). The popularity of these new forms of engagement is evidenced in the exponential growth of social and sexual networking sites (sites where people explicitly seek others for sex) over the past decade. Seventy-three percent of online adults now use a social networking site of some kind, and 42% use multiple sites [27]. Thus, interventions delivered via social media have the potential to reach large numbers of participants “where they are”. Sexual networking sites like Grindr among men seeking men, and more recently Tinder for heterosexuals, are increasingly popular and create new opportunities for finding sex partners. Grindr boasts five million users in 192 countries [28] while Tinder is suspected to have as many as 10 million active daily users [29].

While social media sites may facilitate sexual risk behaviors in certain contexts, they also create opportunities for health promotion [30]; interventions can be delivered at the times and places most relevant for individuals, utilizing technologies they already own and are familiar with. We

conducted a review of recent advances and current trends in the use of electronic and mobile health technologies for primary and secondary HIV prevention. As technological development often out-paces academic research, we include emerging technologies and interventions that are still under development.

Methods

We searched PubMed, Web of Science, and NIH Reporter, using the dates 1/1/2013 to 9/1/2014 and the following key words in combination: HIV, eHealth, mHealth, smartphone, mobile phone, cell phone, mobile health, internet, online, app, application, social media, web, and Web 2.0. We also searched select conference databases for 2013 and 2014, including *Conference on Retroviruses and Opportunistic Infections (CROI)*; *International AIDS Society (IAS2013 and AIDS2014)*, *US Conference on AIDS (USCA)*, *STD Prevention Conference*, and *Youth+Tech+Health (YTH)*. Among articles and abstracts identified through these searches, we included for review those which reported the development, pilot test, or randomized controlled trial (RCT) of an HIV primary or secondary prevention intervention that utilized internet and/or smartphone-based technology as a primary component of the intervention. We excluded publications that: 1) did not include a clear intervention, 2) exclusively used text-based technologies such as mobile phone text messaging (SMS), or CD-ROM-based technologies (independent of internet connection), or 3) did not include an HIV-specific outcome (e.g. focused exclusively on other STIs).

We abstracted the following information into a Microsoft Excel database: author; publication/funding year(s); citation/grant number; institution; study population; sample size; study location; study description (intervention and control conditions) and primary and secondary outcomes. We categorized the technology mode(s) applied as: “web-only” (website-based, no explicit mobile phone component); “mobile web” (explicit design for use via a smartphone or tablet with internet connectivity); “app” (stand-alone application, able to operate on a mobile device independent of internet connectivity); “web+phone” (utilizes a combination of internet and mobile phone based elements); and “Web 2.0” (employs tools or platforms of social media in conjunction with internet or mobile phone, e.g. use of Facebook to spread HIV education).

Lastly, we categorized each included intervention by the stage(s) of the HIV cascade primarily addressed defined as: 1) preventing primary acquisition (e.g. condom promotion, STI care, pre-exposure prophylaxis); 2) increasing HIV testing; 3) supporting linkage to care; 4) supporting retention in care; 5) supporting initiation of ART; 6) supporting adherence to ART and/or increasing viral suppression; 7) preventing secondary transmission. We applied categorization 7 to

interventions which focused on reducing risk behaviors among diagnosed HIV-infected persons (prevention for positives). ART-based strategies can also be considered as preventing secondary transmission; in this categorization model, these activities are captured by categories 3 through 6.

Results

We identified 26 relevant published articles and conference abstracts describing 21 intervention studies (Table 1) and 14 systematic reviews and meta-analysis studies (not presented in Table form). Searches within the NIH Reporter database identified an additional 31 studies currently underway (Table 2).

For each prevention approach, we begin by highlighting evidence from randomized controlled trials (RCTs). In the absence of data from RCTs, we describe results from pilot trials and study protocols. Following the continuum of care framework, we organize the results in terms of mode of delivery (e.g. web based, mobile, smartphone app) and point of intervention along the care continuum. As noted throughout, and displayed in Table 3, a number of interventions target more than one area along the continuum and/or use multiple modes of technology.

I. Web-Based Interventions

Within peer-reviewed published literature, the web continues to be the predominant mode for intervention delivery. Overall, ten published studies [31•, 32–40] and eight studies underway applied web-based interventions. Focus areas across the HIV continuum of prevention and care included eight primary prevention interventions, five testing interventions, two for linkage to care, two focused on retention, four focused on ART initiation, four focused on ART adherence, and five for secondary prevention (Table 3).

Prevention of Primary Acquisition and/or Secondary Transmission

The majority of the interventions completed in the last year have focused on prevention of primary HIV acquisition. Danielson et al. developed a web-based adaptation of the evidence-based intervention, Sistas, Informing, Healing, Living, and Empowering (SiHLE). The pilot study demonstrated increases in HIV/STI knowledge, risk reduction, and condom use self-efficacy [41•]. Ybarra et al. conducted a large pilot trial of CyberSenga, an internet-based intervention informed by the Information-Motivation-Behavior model for HIV prevention among 366 secondary school students in Uganda to increase abstinence and condom use, and teach about healthy

relationships, communication and decision-making skills. While there was an increased level of abstinence at the three month follow-up between the intervention and control (81% vs. 74%, $p=0.08$), there were no significant differences in the main outcomes at 6 months [32, 33]. This type of intervention decay has been seen in other behavioral interventions delivered online and in person [42, 43].

Milam et al. presented results from their controlled trial of an internet-based risk reduction intervention in HIV-positive men who have sex with men (MSM) who reported recent unprotected sex or STIs. Participants at three US HIV clinics were randomized (1:1) to either a monthly behavioral risk survey instrument alone or combined with tailored internet-based prevention messages based on their self-reported risk of HIV transmission. Intervention arm messages targeted condom use, ART use, disclosure of HIV status, and reducing substance use. Syphilis, gonorrhea and Chlamydia were assessed at baseline and every 3 months. The internet-based risk reduction intervention showed no evidence for efficacy in reducing incident STIs among these subjects [39].

HIV Testing

Despite recommendations to increase and routinize HIV testing, an estimated 15% of persons in US [44] and 54.3% of persons worldwide [45] are unaware of their HIV-positive serostatus. Bauermeister et al. presented findings of an intervention designed to provide young MSM (age 15–24) with tailored, motivational content around HIV/STI testing alongside a testing locator. Those who received the intervention (compared to the testing locator only) were more likely to visit an HIV/STI testing clinic and report higher testing self-efficacy. The intervention also saw decreases in reports of the number of overall sex partners as well as the number of condomless anal sex partners in the prior 30 days [36].

II. Mobile Web/Smartphone Apps

Our review identified four published studies [37, 38, 46, 47] and 14 studies underway utilizing smartphone-based interventions for HIV prevention and care. These include seven interventions focused on primary prevention, six addressing testing, three for linkage to care, four for retention in care, four for initiation of ART, ten for ART adherence, and two for secondary prevention (Table 3). Of note, all interventions identified for retention in care and secondary prevention were still in the development phase.

Table 1 eHealth prevention interventions for HIV

Author, publication year	Population, sample size	Location	Study Description Intervention (I) vs. Control (C)	Results	eHealth mode	Cascadestage
Miranda et al. 2013 [40]	HIV+ MSM; $n=60$	US	Study protocol: Internet-based intervention to increase condom use compared to list of websites with HIV prevention information	Outcomes: improving condom use, self-efficacy, and intentions to use condoms. <i>NOTE: study not yet conducted.</i>	web	Prevent secondary transmission
Ybarra et al. 2013, 2014 [32, 33]	Secondary school students; $n=366$	Uganda	Pilot: CyberSenga five 1-hour online modules (+ booster module), tailored for gender and culture. Aim: to increase abstinence and/or condom use.	3-month FU: Abstinence, I vs C: 81% vs. 74%, $p=0.08$; unprotected sex: no difference. 6-month FU: no significant differences in main outcomes. Abstinence, I booster group vs. I no booster vs. C: (80% vs. 57% vs. 55%). 91.9%: very satisfied with website content and activities. 67.6%: information was easy-to-find on the site, 70.3%: website features were very good.	web	Prevent primary acquisition
Villegas et al. 2014 [34]	Women, age 18–24; $n=40$	Chile	Pilot: I-STIPI, online adaptation of successful in-person interventions (Mano a Mano-Mujer & SEPA). Modules, quizzes, activities, 1 month.		web	Prevent primary acquisition
Bauermeister, 2014 YTH [36]	MSM, age 15–24; $n=130$	Michigan, US	I: HIV education and HIV/STI test locator. Content tailored for demographics, values and prior HIV risk and testing behaviors. C: Test locator only.	Intervention: more likely to visit HIV/STI testing clinic (past 30 days), and reported higher self-efficacy around testing behaviors. I and C: significantly reduced sex risk behaviors, no difference by treatment condition.	web	Prevent primary acquisition Increase HIV testing
Fakhouri, 2014 YTH [35]	“teens”; $n=199$	US	I: PlayForward, 12-session (75–90 min each) online game to improve sexual health decision-making, 6 weeks. C: attention/ time control games.	Positive association trend between greater progress through the game and sexual health knowledge score at 6 months.	web	Prevent primary acquisition
Milam et al. 2014 CROI [39]	HIV+ MSM with recent UAI or STI; $n=181$	Southern California, US	I: Monthly risk survey+tailored internet-based prevention messages targeting condoms, ART use, status disclosure, and reducing substance use. C: monthly behavioral risk survey.	12-month follow-up: I vs C, at least one new STI: 27 (30%) vs. 22 (27%) ($p=0.38$). Similar non-significant results found in sensitivity analyses.	web	Support ART initiation Improve ART adherence Prevent secondary transmission
Christensen et al. 2013 [31•]	HIV-neg MSM, UAI, age 18–24; $n=921$	National online	I: Socially Optimized Learning in Virtual Environments (SOLVE): web-based modules to reduce UAI via reduced stigma. C: wait-list control.	I vs C at 3 month follow-up: significant shame reduction, $p<0.001$; significant decrease in UAI: (point estimate -0.10 , 95% CI $[-0.01$ to $-0.23]$ 6 month follow-up data (also significant) forthcoming.	web	Prevent primary acquisition
Jones et al. 2013 [46]	Urban African American women, age 18–29; $n=238$	New Jersey, US	I: “Love, Sex, & Choices” streaming 12-episode weekly soap opera video episodes to smartphones. C: weekly HIV prevention text messages	Video was rated popular, relevant, and identifiable. Episodes of UVI, past 3 months dropped significantly in both study arms from 21–22 episodes to 5–6 episodes. No statistical differences in effect for text vs. video.	mobile web	Prevent primary acquisition
Phillips et al. 2013 [47]	Opioid-dependent drug users, age 18–75; $n=24$	Baltimore, US	Pilot: smartphone based intervention with 3 modules that each consisted of a 10-minute video on HIV risk reduction	All 3 videos met a priori criteria for acceptability and feasibility. On average, participants answer 92% of HIV/STI knowledge questions correctly post-video (pre-post difference not measured).	mobile web	Prevent primary acquisition

Table 1 (continued)

Author, publication year	Population; sample size	Location	Study Description Intervention (I) vs. Control (C)	Results	eHealth mode	Cascade/stage
Bonnet Rivera et al. 2014 USCA [37]	High-risk Latino young MSM	Puerto Rico	Projecto Nosotr@s: venue-based testing staff support linkage to care via SMS, email, calls, social media and apps.	The project has identified 260 HIV positive MSM (159 ages 13 to 29).	web+phone	Support linkage to care
Jones & Green, 2014 USCA [38];	Providers and their HIV+ patients	United States	A mobile app and four e-learning modules adapted from evidence-based CDC interventions: Project HEART (Helping Enhance Adherence to Anti-retroviral Therapy), SMART (Sharing Medical Adherence Responsibilities Together) Couples, Partnership for Health – Medication Adherence, and Peer Support.	Outcomes: ART initiation, medication adherence among PLWH <i>NOTE: study not yet conducted.</i>	Web+App	Support ART initiation Improve ART adherence
Danielson et al. 2013 [41]	African American women, age 13–18; n=41	Southeast, US	Pilot: web adaptation of CDC evidence-based intervention Sistas, Informing, Healing, Living, and Empowering. 4 one-hour modules: interactive video-based design, health educator, activities, “near peer”, real-time tailored feedback.	63% completed all four modules. Pre-post study: significant increases in: HIV/STI risk knowledge and condom use self-efficacy. No significant change in: ethnic and gender pride, partner communication, healthy relationships and self-care, or self-esteem.	web 2.0	Prevent primary acquisition
Anand et al. 2013 LAS [51]	MSM	Indonesia	TemanTeman.org: information on MSM- friendly healthcare and services in Indonesia. Over 40 expert advice videos on sexual health. Male fashion photography is linked to HIV/STI information and campaign is affiliated with an HIV/STI testing clinic in Jakarta and in Bali.	Outcomes: HIV and STI testing. <i>NOTE: Intervention not yet evaluated</i>	web 2.0 /social media	Prevent primary acquisition Increase HIV testing
Pachankis et al. 2013 [48]	Adult MSM with recent UAI and substance use	NYC, US	I: online adaptation of Young Men’s Health Project (using motivational interviewing in 4 one-hour sessions), specifically using the unique features of Facebook.	Outcomes: reduce substance use and sexual risk-taking <i>NOTE: Study not yet conducted</i>	web 2.0	Prevent primary acquisition
Gaynsnsky et al. 2014 [59]	HIV+ participants in a Facebook support group, age 16–27; n=43	NYC, US	Evaluation of a private Facebook group established for members of an HIV clinic’s young adult program, 16 month study period.	3838 posts and comments. Content analysis: 42% of content was classified as “administrative/ engagement in group” and functioned to enhance the operations of the program as a whole. Positive interactions were common: socializing (25%), banter (20%), and offers of social support (15%). Emotional support most frequent type of support requested, esteem support most commonly provided form of support.	web 2.0	Support retention in care Support ART initiation Improve ART adherence
Lelutiu-Weinberger et al. 2014 [49]	High-risk MSM, age 18–29, n=41	United States (online)	I: 8 one-hour motivational interviewing and cognitive behavioral skills-based online live chat intervention sessions	Pre-post reductions in past 30 days: days of drug (5.52 vs. 3.30, p=0.073) and heavy alcohol use (10.7 vs. 8.52, p=0.082), and episodes of UAI (8.96 vs.	web 2.0	Prevent primary acquisition

Table 1 (continued)

Author, publication year	Population, sample size	Location	Study Description Intervention (I) vs. Control (C)	Results	eHealth mode	Cascade/stage
Young et al. 2013, 2014 [53–56, 57••]	MSM (85% African American); <i>n</i> =112	Los Angeles, US	delivered on Facebook. Pre/post study design. Project HOPE: 16 peer leaders randomly assigned to (I) deliver HIV information and promote free home-based HIV tests or (C) provide general health information, via Facebook groups over 12 weeks. I: two volunteers promoted VCT using active (instant messaging, chat rooms, mobile phones, email) and passive (website banner ads) methods. Those who came for testing completed a survey and HIV/syphilis tests.	3.11, <i>p</i> =0.042), and UAI+substance use (6.89 vs. 0.81, <i>p</i> <0.001). Significant increases in HIV risk knowledge. I vs. C: communication via the social platform: 95% vs 73%; requested home-based HIV testing kits: 44% vs. 20%; took and returned test kit: 36% vs. 18%. 12 week retention >93%, 1 year retention: 82%. 12.9% of men contacted (<i>n</i> =429) were tested at designated VCT clinics. Instant messaging was most effective mode for promotion (1 out of 4 men). Email was least effective (1:140). Active recruitment yielded men who were significantly younger and more likely to have never tested for HIV or tested less frequently.	web 2.0	Prevent primary acquisition Increase HIV testing
Zou et al. 2013 [58]	MSM; <i>n</i> =3332	China	I: iPOL, online adaptation of CDC's Popular Opinion Leader intervention. iPOLs are trained to disseminate information about HIV, risk reduction, behavior change; and ask and respond to questions and discussions via Facebook. C: informational website.	369 iPOLs reached 959,088 persons on Facebook in 6 months. I vs. C: receive HIV-related information (25% vs 10%), discuss HIV issues with others (42% vs 24%), review articles about HIV (91% vs 80%), be asked about or discuss HIV-related questions (51% vs 32%), have HIV test within 6 months (44% vs 22%), no UAI with online sex partners (34% vs 26%). All participants had improvements (psychological improvements, safer sex practices and partner disclosure) after engaging with The STD Project.	web 2.0	Prevent primary acquisition Increase HIV testing
Marie, 2014 STD Prevention [50]	Youth, age 15-25	US	I: The STD Project (thestdproject.com) online storytelling to address STD stigma by advocating for awareness, education, and acceptance. Readers submit personal stories and engage via the forum or contact form. Pilot study: video-conferencing based intervention, HR-VG: six two-hour sessions led by two facilitators, and used structured activities and video-clips to build HIV status disclosure and safer sex skills.		web 2.0	Prevent primary acquisition Prevent secondary transmission
Marheka et al. 2013 [60]	HIV+ women; <i>n</i> =4	US	Participants and facilitators reported feeling either “very comfortable” or “completely comfortable” with the technology and the overall intervention. Participants reported high levels of unity and togetherness among the group.		web 2.0	Prevent secondary transmission

I intervention; C control; CDC Centers for Disease Control; VCT voluntary counseling and testing; UAI unprotected anal intercourse; MSM men who have sex with men; FU follow-up

Prevention of Primary Acquisition and/or Secondary Transmission

Jones et al. tested the use of smartphones for the delivery of HIV prevention messages to women in an RCT, comparing 12 weekly videos of the educational soap opera *Love, Sex, and Choices* to 12 weekly HIV prevention messages [46]. Base-line and follow-up interviews at 3 and 6 months were completed by an audio computer-assisted self-interview (ACASI). The primary study outcome measure of unprotected vaginal and anal sex with a high-risk partner was significantly lower at follow-up for both treatment arms ($p < .001$) compared to baseline. These reductions were dramatic with median risk behavior falling from about 21 to 22 unprotected vaginal sex act equivalents in the prior 3 months at pre-intervention to five to six such acts post intervention. The authors concluded that both smartphone interventions were viable for HIV prevention [46].

Phillips et al. evaluated the feasibility and acceptability of the *Safe in the City* intervention modified for “on-demand” delivery on a handheld device among opioid-dependent patients in methadone maintenance therapy [47]. The interactive mobile HIV Risk Reduction modules consisted of three components: videos, questions about videos’ acceptability, and questions about videos’ perceived effectiveness. All three videos met a priori criteria for acceptability and feasibility and participants answered 92% of HIV/STI knowledge questions correctly post-video [47].

III. Web 2.0/Social Media

Numerous studies employed innovative demonstration of Web 2.0 and social media website and apps including the use of Facebook, gamification, and interactive graphical interfaces (discussed in more detail in section IV, below). We found 10 published interventions [41•, 48–56, 57••, 58–60] and 17 studies underway utilizing Web 2.0 technologies. These include 19 focused on primary prevention, eight addressing testing, one for linkage to care, four for retention in care, three for initiation of ART, five for ART adherence, and four for secondary prevention (Table 3).

Prevention of Primary Acquisition and/or Secondary Transmission

Lelutiu-Weinberger et al. tested the feasibility, acceptability and preliminary efficacy of a live chat intervention delivered on Facebook for reducing condomless anal sex and substance use within a group of high risk young MSM (YMSM) in a pre-post-test design with no control group [49]. Participants ($N = 41$; 18–29 years old) completed up to eight one-hour

motivational interviewing and cognitive behavioral skills-based online live chat intervention sessions. Analyses indicated that participation in the intervention ($n = 31$) was associated with reductions of days of drug and alcohol use in the past month and instances of anal sex without a condom (including under the influence of substances), as well as increases in knowledge of HIV-related risks at three-month follow-up [49].

HIV Testing

Within Project Hope, 16 peer leaders were randomly assigned to deliver either HIV information and promote free home-based HIV tests (intervention) or general health information (control) over 12 weeks through closed Facebook groups [55]. The intervention was delivered to 112 MSM (85% African American). Compared to the control group, those in the intervention were more likely to request home-based HIV testing kits: 44% vs. 20%; and take and return test kits: 36% vs. 18% [57••]. Retention in this study was very high: 93% at 12 weeks and 82% at 12 months [61].

While Facebook has been the primary site of most Web 2.0 interventions to date, researchers in China used a combination of active (instant messaging, chat rooms, mobile phones, email) and passive (website banner ads) methods to promote voluntary counseling and testing (VCT) among 3332 MSM. Overall, 12.9% of men contacted ($n = 429$) were tested at designated VCT clinics. Instant messaging was the most effective mode for promotion: one of four men contacted went in for testing, while email was least effective (1:140). Compared to passive recruitment, active recruitment mechanisms yielded men who were significantly younger and more likely to have never tested for HIV or tested less frequently [58].

There have been a number of online interventions that resulted from adaptation of existing in-person evidence-based or evidence-informed interventions to be delivered online [34, 38, 41•, 52]. For example, Ko et al. adapted CDC’s Popular Opinion Leader (POL) intervention to develop an online version (iPOL) which trained peers to disseminate information about HIV, risk reduction, and behavior change; and to ask and respond to questions via Facebook [52]. 369 iPOLs reached 959, 088 persons on Facebook in 6 months. At six-month follow-up, those in the intervention arm were more likely than those in the information-only control to: receive HIV-related information (25.5% vs 10.5%, $p < 0.001$), discuss HIV issues with others (41.9% vs 23.8%, $p < 0.001$), review articles about HIV (90.6% vs 79.7%, $p < 0.001$), be asked about or discuss HIV-related questions (51.1% vs 31.8%, $p < 0.001$), have HIV tested within 6 months (43.9% vs 22.3, $p < 0.001$), and to avoid condomless anal intercourse with partners met online (34.2% vs 26.2%, $p = 0.004$) [52].

Table 2 Currently funded eHealth for HIV Prevention studies (NIH Reporter and conference abstracts)

Primary Investigator Organization Name	Funding period	Project Abstract	Target population	eHealth mode(s)	Cascade stage
Cohen MIRIAM HOSPITAL	2011–13	Vigorous Mind 4.0 uses a computerized system to promote treatment adherence for those with substance use disorders via enhanced cognitive functioning (cognitive exercises, organizational tools) training. 3 month pilot study ($n=50$) will compare intervention with standard of care control.	HIV+ with substance use disorders	Web	ART adherence
Boyer UNIV OF MASSACHUSETTS MED SCH WORCESTER	2011–15	iHAART delivers personalized adherence interventions with content and “dose” that adapt in real time to variable medication adherence in HIV+ stimulant users (methamphetamine, cocaine, MDMA). 3 month pilot study to test functionality and acceptability.	HIV+ stimulant users	Smartphone App	ART adherence
Brown RHODE ISLAND HOSPITAL	2012–15	Medication monitoring device (Vitality Cap) integrated with an interactive app/game. Opening the medication bottle gives access to the app game. The game integrates health information (knowledge about HIV treatment), motivation, and skill-building. Intervention will be tested in a pilot RCT ($n=60$). Primary outcomes: medication adherence and biological measures.	HIV+ youth	Smartphone App, gaming	ART adherence
Gonzalez CUNY GRADUATE SCH AND UNIV CTR	2012–15	Pilot testing of a smartphone app for sexual and reproductive health information and push messages versus self-directed app use for increasing dose. Primary outcomes: increased knowledge and utilization of services such as PEP, Plan B, HIV, STD, and pregnancy testing, and to other social services, such as substance abuse treatment.	Black and Latina women, age 18-25	Smartphone App	Primary acquisition HIV testing
Kirk JOHNS HOPKINS UNIVERSITY	2012–15	eMOCHA: (electronic Mobile Open-source Comprehensive Health Application) app assists peer navigators (former IDUs currently in HIV care) to deliver individually-tailored interventions to HIV+ IDUs out of care for >1 year. Ecologic momentary analysis assesses clinic attendance, adherence, drug cravings, and stress then triggers either: phone call/visit from a peer navigator or automated, context-specific text message	HIV+ IDU, out-of-care	Smartphone App	Linkage to care Retention in care ART adherence
Himmelhoch UNIVERSITY OF MARYLAND	2013–15	HEART to HAART (Helping Enhance Adherence to Retroviral therapy using Technology): provides real-time information on adherence, periodic assessment of medication side effects, depressive symptoms and drug use and tailored education, recommendation and encouragement. Participant and adherence team jointly adherence in real-time. 6 month pilot test planned ($n=50$) comparing intervention with smartphone control.	HIV+ drug users	Smartphone	ART adherence
Reback COG ANALYTICS, LLC	2013–15	Project aims to translate “Getting Off: A Behavioral Treatment Intervention for Gay and Bisexual Male Methamphetamine Users” into a computerized app to reduce methamphetamine use and HIV sexual risk behaviors and increase antiretroviral therapy (ART) medication adherence. Study will pilot test the intervention prototypes	Gay and Bisexual Male Methamphetamine Users	Smartphone App	Primary acquisition ART adherence Secondary transmission
Horvath UNIVERSITY OF MINNESOTA	2013–16	ART adherence intervention app: tailored informational messages, a motivational personal intervention guide, medication reminders,	HIV-positive stimulant-using MSM	Smartphone App	ART adherence

Table 2 (continued)

Primary Investigator Organization Name	Funding period	Project Abstract	Target population	eHealth mode(s)	Cascade stage
Horvath UNIVERSITY OF MINNESOTA	2014–17	ART and drug use self-monitoring, self-reflection and strategy rehearsal. Pilot RCT testing ($n=76$) with primary outcomes: app component use, percent of ART doses taken, rating of suggested strategies to overcome adherence barriers, experiences of drug cravings, and use of stimulants. App to facilitate regular HIV testing through: regular assessment of risk behaviors via personal profile, recommended HIV test frequency based on individual's risk patterns and profile, GPS-enabled HIV testing location finder, and motivational messages addressing critical barriers to testing. Pilot RCT test ($n=120$) to assess primary outcome: increased HIV testing. Smartphone app to promote HIV care and prevention services. Will be pilot tested with target population in Baltimore.	HIV-negative/ unknown MSM	Smartphone App	HIV testing
Pillai CAPITAL TECHNOLOGY INFORMATION SERVICES	2014–15	Smartphone app to promote HIV care and prevention services. Will be pilot tested with target population in Baltimore.	Urban young MSM	Smartphone App	(unclear) Mentions all stages of the cascade
McNulty CAKTUS CONSULTING	2014–16	“Epic Allies” is a mobile phone app that utilizes game mechanics and social networking features to improve and optimize linkage to HIV care and ART uptake and adherence. App will be tested in a RCT through 14 sites of the Adolescent Trials Network ($n=300$). Outcome measures: engagement with medical providers, medical appointment consistency, ART uptake, adherence, viral suppression, CD4 count.	HIV+ MSM, age 18–30 MSM	Smartphone App, interactive gaming, social networking	Retention in care ART initiation ART adherence
Cruess UNIVERSITY OF CONNECTICUT STORRS	2010–14	This study will develop and pilot RCT test an internet-delivered risk reduction intervention for HIV-positive MSM who use the Internet to meet potential sex partners. Primary outcomes: behavioral risk and Internet use outcomes.	HIV+ MSM	Web	Secondary transmission
Mustanski NORTHWESTERN UNIVERSITY AT CHICAGO	2012–17	Keep It Up! (KIU!), an online HIV prevention program tailored to ethnically diverse YMSM. KIU! is based on the Information-Motivation-Behavior Skills model of HIV risk behavior change and informed by principals of E-learning. Pilot RCT had high retention and a significant 44% decrease in UAI. This study will test KIU! in a multisite RCT ($n=750$) for primary outcomes: UAI and STD incidence.	Young MSM	Web	Primary acquisition
Hirshfield PUBLIC HEALTH SOLUTIONS	2014–16	Online videos for HIV prevention about UAI, HIV disclosure, and testing partnered with POZ.com. RCT found significantly reduced UAI and significant increases in HIV status disclosure. Current RCT ($n=1500$) will edit the 3 HIV prevention videos into 10 short online sessions (including boosters), improve retention with incentives and a proven online platform, and conduct cost-effectiveness analyses for averted HIV infections.	Virally unexpressed HIV+ MSM	Web	Secondary transmission
Hightow-Weidman UNIVERSITY OF NORTH CAROLINA	2012–16	“healthMpowerment.org”: a mobile phone and internet-based intervention that provides information, resources, tailored feedback, gamification, and platforms for social support. Currently undergoing a state-wide RCT in North Carolina ($n=474$).	Black MSM and TW, age 18–30	Mobile optimized web, gaming, social networking	All stages of cascade

Table 2 (continued)

Primary Investigator Organization Name	Funding period	Project Abstract	Target population	eHealth mode(s)	Cascade stage
Koblin NEW YORK BLOOD CENTER	2013–17	Outcomes: reduced UAI past 3 months (primary), depression, social support, viral load/CD4, adherence, testing, HIV knowledge, substance use. Internet-based testing intervention optimized for mobile devices to provide men with a tailored recommendation of their optimal HIV testing approach. Pilot RCT to assess primary outcome of increased HIV testing.	Young, Black MSM	Mobile optimized web	HIV testing
Tulsky UNIVERSITY OF CALIFORNIA, SAN FRANCISCO	2011–16	Teach and train newly diagnosed HIV infected individuals to utilize deployed internet and cellular technologies and develop novel applications to assist with linkages to care and improve treatment outcomes. Primary outcomes: referrals and follow through with appointments, retention in care and the initiation and sustaining of ART.	Newly HIV diagnosed in safety net care settings	Web+App	Linkage to care Retention in care ART initiation ART adherence
Mitchell UNIVERSITY OF MIAMI SCHOOL OF MEDICINE	2014–16	Web-based prevention toolkit: modules to guide creation of an explicit sexual agreement that integrates interval testing for HIV/STDs and prevention messaging, interactive website and smartphone app with GPS resources for HIV/STD testing and free safer sex supplies. Pilot RCT ($n=160$) to assess primary outcomes of: forming and adhering to a sexual agreement, increased HIV/STD testing, decreased UAI with casual partners.	HIV-negative male-male couples practicing UAI	Web+App	Primary acquisition HIV testing
Sullivan EMORY UNIVERSITY	2014–16	Development of support for home-based HIV testing system in support of PrEP including specimen self-collection using mail-in kits; online smartphone or SMS assessment of medication adherence and sexual behavior risk; and video/telephone counseling support.	MSM	Web+App	Primary acquisition HIV testing
Rosser UNIVERSITY OF MINNESOTA	2010–15	Men's Internet Study - MINTS-III - aims to increase the long-term effectiveness of MINTS-II (Sexpulse, an online, HIV prevention intervention for Men who use the Internet to seek Sex with Men) by strengthening the dosage of Sexpulse via tailored feedback on individual risk behavior; integrated research surveys; and follow-up boosters and test Sexpulse 1.1 in two RCTs ($n=1000$ high-risk MSM and $n=500$ no/low-risk MSM)	Men who use the Internet to seek Sex with Men	Web 2.0/social media	Primary acquisition
Young UNIVERSITY OF CALIFORNIA LOS ANGELES	2010–15	Intervention to test the use of online social networks to scale peer community leader models to increase HIV prevention. Pilot study primary outcomes: increased testing and HIV prevention behaviors. "CyBER/testing" is a chat room intervention to increase HIV testing. Primary outcome: self-reported HIV testing at immediate post-intervention.	African-American and Latino MSM	Web 2.0/social media	Primary acquisition HIV testing
Rhodes WAKE FOREST UNIVERSITY HEALTH SCIENCES Washington CALIFORNIA STATE UNIV. LONG BEACH	2011–15	Exploring an HIV Testing Intervention Model (TIM project): Facebook "like" site will feature videos to encourage HIV testing plus social networking features to host discussions among the intervention group about HIV testing uptake and testing sites, drug use and sexual risk behavior. Will be tested in a pilot RCT.	MSM	Web 2.0/social media	HIV testing
Clark	2014–17		Black MSM, age 18–30	Web 2.0/social media	HIV testing
				Web 2.0/social media	Primary acquisition

Table 2 (continued)

Primary Investigator Organization Name	Funding period	Project Abstract	Target population	eHealth mode(s)	Cascade stage
UNIVERSITY OF CALIFORNIA LOS ANGELES		“TransPREP”: Social network intervention to promote PrEP adherence via individual counseling, group workshops, adherence support tools. Structured social media platforms to educate, motivate, and promote discussions of PrEP adherence, unstructured participant-generated interactions to reinforce new social norms within the network. Pilot RCT ($n=8$ social network-based clusters) primary outcome PrEP adherence.	Transgender women in Lima, Peru		
Blackstock ALBERT EINSTEIN COLLEGE OF MEDICINE	2014–19	“Sisters-GPS”: intervention to improve ART adherence adapted from the group clinical visit model and incorporating social media. Pilot RCT with primary outcome of ART adherence; secondary outcomes HIV viral load and health care utilization.	HIV+ African American and Latina women	Web 2.0/social media	Retention in care ART adherence
Patel ALBERT EINSTEIN COLLEGE OF MEDICINE	2014–19	“E-PrEP”: a social media-based peer-led intervention to promote PrEP uptake via online messaging and discussions directed by peer leaders to provide education on PrEP, increase interest in PrEP use, and facilitate access to PrEP. Pilot RCT to assess feasibility and preliminary efficacy for increasing self-reported intention in and uptake of PrEP.	Men of color who have sex with men, age 18–29	Web 2.0/social media	Primary acquisition
Merchant RHODE ISLAND HOSPITAL	2014–16	Study aims to evaluate use of a social-networking website to facilitate HIV testing and dissemination through an RCT. Primary outcomes: testing uptake, time to initiation of testing, and whether participants invite their ‘online’ or ‘offline’ contacts to use this new type of test.	Black, Hispanic, and white MSM, age 18–24	Web 2.0, social networking	HIV testing
Miller UNIVERSITY OF SOUTHERN CALIFORNIA	2008–15	SOLVE (Socially Optimized Learning in Virtual Environments) integrates cognitive approaches with affect-based and reactive risky decision-making processes, providing experience with risk cues in a safe, virtual environment. RCT being conducted online: testing and risk situations using Intelligent Agent and Gaming technologies. Primary outcomes: UAI change with casual partners. Significant 3- and 6- month findings to date.	MSM, age 18–24	Virtual reality	Primary acquisition HIV testing
Fiellin YALE UNIVERSITY	2009–15	Retro-Warriors’ study will adapt existing software for an interactive video game designed to decrease HIV risk by teaching sex, drug and alcohol negotiation and refusal skills. Intervention will be tested in an RCT ($n=330$) with primary outcome: initiation of sexual activity; secondary outcomes: HIV risk behavior knowledge, social competency, self-efficacy, drug/alcohol use behaviors and overall risk-taking behaviors.	Minority youth, age 9–14	Interactive gaming	Primary acquisition
Enah UNIVERSITY OF ALABAMA AT BIRMINGHAM	2012–15	Study will develop a prototype for an individually tailored, electronic HIV prevention adventure game designed to improve decision-making and learn behavioral strategies that assist with avoiding sexual risk behaviors. Intervention prototype will be tested ($n=40$) for acceptability and relevance.	African American rural youth, age 12–14	Interactive gaming	Primary acquisition
McLaughlin RADIANT CREATIVE GROUP, LLC	2012–15	It’s Your Game- Family’: online game intervention provides age-appropriate sexual health life skills education and training for children and to enhance parents’ skills in support of this training.	Children, age 11–14 and their parents	Interactive gaming	Primary acquisition

Table 2 (continued)

Primary Investigator Organization Name	Funding period	Project Abstract	Target population	eHealth mode(s)	Cascade stage
McDaniel VIRTUALLY BETTER, INC.	2014–16	Supports ongoing pregnancy and HIV/STD prevention education. Study will develop and test IYG-F in a pilot RCT in 80 homes. Primary outcomes: children: intentions for abstinence, psychosocial determinants of sexual behavior, adults: psychosocial determinants regarding parent-child sexual health communication and parental monitoring, beliefs about youth sexual behavior, both: increased sexual health communication. "Tough Talks" will be an internet-delivered software program with intelligent virtual character-driven scenarios focused on increasing skills associated with disclosure of HIV status.	HIV+ young MSM	Virtual reality	Secondary transmission

IDU Injection drug user; *RCT* randomized controlled trial; *HIV+* HIV-infected; *MSM* men who have sex with men; *STD* sexually transmitted infections; *UAI* unprotected anal intercourse

Linkage and Retention in Care

Gaysynsky et al. describe the integration of Facebook into an HIV treatment program serving adolescents and young adults infected with HIV (Young Adult Program – YAP). Content analysis was applied to 3838 posts and comments that appeared on the YAP Facebook wall over a 15-month period (3/1/11 -7/1/12). Most of the interactions on the Facebook page during the course of the study period were positive, and a substantial amount of social support was observed. Of the 3838 posts and comments analyzed, 6.6 % (255) sought some kind of social support and 15.1% (578) provided (or offered to provide) some type of social support, demonstrating that social networking sites may offer effective ways for health organizations to communicate with young adults [59].

IV. New Trends and Developments in mHealth Interventions

The US National Institutes of Health (NIH) has recently funded a number of new HIV prevention and care interventions that apply mHealth and eHealth technologies (Table 2). While some employ established technologies, there is a noteworthy trend toward greater integration of individual user tailoring via interactive and role-playing elements. We highlight these interventions as examples of what the field can expect to see in the published literature over the next few years.

Provision of Real-time Feedback

Several interventions attempt to monitor behaviors over time and offer real-time feedback at key moments in order to influence positive behavior change (also called Ecological Momentary Assessment [28]) [41•]. One newer intervention under development, iHAART, delivers personalized adherence interventions with content and “dose” that adapt in real time to variable medication adherence in HIV-infected stimulant users (methamphetamine, cocaine, MDMA). A three-month pilot study is planned to test functionality and acceptability (PI: Boyer). In another example, eMOCHA (electronic Mobile Open-source Comprehensive Health Application), investigators are developing an app to assist peer navigators deliver individually-tailored interventions to HIV-infected injection drug users who are out of care. Ecologic momentary analysis is being used to trigger either phone call or visit from the peer navigator or automated, context-specific messages (PI: Kirk).

Gaming and Gamification

Gamification uses game-related design components and principles along with psychology in non-traditional gaming

Table 3 eHealth interventions across the HIV continuum of prevention and care: published and under development

Published studies	Primary Prevention	HIV Care cascade					Secondary Prevention
		Testing	Linkage	Retention	Initiation	Adherence	
Christensen et al. 2013 [31]							
Ybarra et al. 2013, 2014 [32, 33]							
Villegas et al. 2014 [34]							
Fakhouri 2014 [35]							
Jones et al. 2013 [46]							
Phillips et al. 2013 [47]							
Danielson et al. 2013 [41]							
Pachankis et al. 2013 [48]							
Lelutiu-Weinberger et al. 2014 [49]							
Marie 2014 [50]							
Bauermeister 2014 [36]							
Anand et al. 2013 [51]							
Ko et al. 2013 [52]							
Young et al. 2013, 2014 [53-57]							
Zou et al. 2013 [58]							
Bonnet Rivera et al. 2014 [37]							
Gaysynsky et al. 2014 [59]							
Jones & Green 2014							
Milam et al. 2014 [39]							
Miranda et al. 2013 [40]							
Marhefka et al. 2013 [60]							
In development							
PI: Reback, 2013-2015							
PI: Rosser, 2010-2015							
PI: Rhodes, 2011-2015							
PI: Washington, 2012-2015							
PI: Clark, 2014-2017							
PI: Patel, 2014-2019							
PI: Fiellin, 2009-2015							
PI: Enah, 2012-2015							
PI: McLaughlin, 2012-2015							
PI: Mustanski, 2012-2017							
PI: Mitchell, 2014-2016							
PI: Sullivan, 2014-2016							
PI: Gonzalez, 2012-2015							
PI: Miller, 2008-2015							
PI: Young, 2010-2015							
PI: Hightow-Weidman, 2012-2016							
PI: Koblin, 2013-2017							
PI: Horvath, 2014-2017							
PI: Merchant, 2014-2016							
PI: Kirk, 2012-2015							
PI: Tulskey, 2011-2016							
PI: McNulty, 2014-2016							
PI: Blackstock, 2014-2019							
PI: Cohen, 2011-2013							
PI: Boyer, 2011-2015							
PI: Himmelhock, 2013-2015							
PI: Horvath, 2013-2016							
PI: Brown, 2012-2015							
PI: Cruess, 2010-2014							
PI: Hischfield, 2014-2016							
PI: McDaniel, 2014-2016							

Web-based Web2.0, Social Media, Gaming Smartphone based

Note: Pillai 2014-15 excluded from Figure 1 as stage of cascade addressed in intervention is unclear

contexts and represents a unique opportunity for meaningful and sophisticated ways to engage participants in online health behavior interventions [62, 63]. Components of gamification may enhance the degree and depth of participant interaction, increase behavior change learning opportunities and improve intervention appeal for youth. We draw attention to two interventions focused on youth (ages 9–14) that address prevention of primary acquisition of HIV/STIs delivered using two popular gaming systems (e.g. Playstation, Wii). *Retro-Warriors* is an interactive video game in development designed to decrease HIV risk by teaching sex, drug and alcohol negotiation and refusal skills to youth, aged 9–14 (PI: Fiellin). In a second example, investigators at the University of Alabama are developing an unnamed individually tailored, electronic HIV prevention adventure game designed to improve decision-making and learn behavioral strategies that assist with avoiding sexual risk behaviors among African American rural adolescents, age 12–14 (PI: Enah).

Another intervention that uses game-based principles is healthMpowerment.org (HMP). HMP is a mobile-phone-optimized internet-based intervention for young black MSM that provides information, resources, tailored feedback, and social networking platforms for social support. As participants engage with material on the site (e.g. read articles, submit posts), they acquire points to spend on real items in the HMP store (e.g. water bottles, sweatshirts) and they move up status levels on the site. Pilot studies supported the feasibility and acceptability of this intervention [64–66]. A state-wide RCT is currently underway in North Carolina ($n=474$) and outcomes include reduced unprotected anal intercourse (UAI) in the past 3 months (primary), depression, social support, viral load/CD4, adherence, testing, HIV knowledge, and substance use (PI: Hightow-Weidman).

We also highlight two interventions in development that focus on increasing medication adherence through gamification. *Epic Allies*TM is a mobile phone app that utilizes game mechanics and social networking features to improve and optimize ART uptake and adherence among YMSM. This app will be tested in an RCT ($n=300$) through 14 sites of the Adolescent Trials Network. Outcome measures include engagement with medical providers, medical appointment consistency, ART uptake, medication adherence, viral suppression, and CD4 count (PI: McNulty).

In an intervention being developed by Brown, participants will gain smartphone access to an engaging and immersive gaming app each time they open their medication bottle (via wireless connection between the pill bottle cap and participant's smartphone). While gaming, participants will gain information about their health, improve motivation for ART and medical appointment adherence, and practice healthy behaviors. The intervention will be tested in a pilot RCT ($n=60$) with medication adherence and viral load measures as primary outcomes.

Virtual Reality

Virtual Reality (VR) scenarios are computerized, interactive role-playing games that can yield engaging, ecologically valid, and user-centric content. Within the field of HIV, these interventions are designed to increase mastery of important skills associated with sexual health promotion, effectively address affect management, and provide more robust situation-specific intervention techniques (e.g. practicing HIV status disclosure or condom negotiation skills). VR can supplement or take the place of traditional in-person role-playing exercises, which are limited by numerous factors including the prior relationship between the health provider and participant, appropriate ethical constraints, and scalability [67]. These limitations make for highly artificial “practice” that is unlikely to elicit the actual reactions, both emotional and physiological that individuals encounter in real life.

“Tough Talks” is a disclosure intervention for HIV-infected YMSM, which aims to create an internet-delivered software program that will offer intelligent virtual character-driven scenarios focused on increasing mastery of important skills associated with disclosure of HIV status. The intervention will address sexual health communication with sex partners in the context of disclosing HIV status using artificially intelligent technology (e.g. avatars) and natural language processing.

Another example, “SOLVE: Socially Optimized Learning in Virtual Environments (SOLVE)”, has created “virtual date” narratives based on extensive formative research with MSM. In a national online survey among HIV-uninfected MSM ($n=921$) they found significant shame reduction and decrease in UAI compared to a wait-list control group [31•]. Significant effects were maintained at 6 months follow-up (author personal communication).

Conclusion

The advantages of internet and mobile-based interventions include the potential to provide consistency in the delivery of an intervention, potential low cost once developed, and the ability to disseminate the intervention to a wider population. Advances in technology offer a wide range of approaches, from the most straightforward use of mobile phones to send reminders or track information to a full suite of capabilities within smartphones (e.g. GPS, sensors) and beyond. While there has been significant progress over the past year, there is still a lack of long term and large-scale efficacy outcome studies. Given the many pilot studies and studies in development, we can expect to see a substantial increase in available results in the coming years. Importantly, as shown in the bottom half of Table 3, the pipeline of interventions appears to acknowledge the importance of the HIV Care

Continuum and the necessary combination of behavioral and biomedical interventions across the various stages. The middle of the care continuum (i.e. link, retain, initiate ART) remains an area open for further development.

Confirming what others have noted, our review identified a predominant number of completed and planned interventions conducted within the United States (U.S.) and focused on MSM [68•]. This leaning, in part, reflects the defined nature of this review which excluded text-based interventions, a number of which have been conducted in non-US settings (see [69–72] for recent reviews of SMS-based HIV/AIDS interventions). This pattern also reflects the unequal distribution of technology worldwide, the American HIV epidemic, and MSM's early adoption of new technologies and social media, including geosocial smartphone apps to meet sex partners [73, 74].

Smartphone uptake is increasing globally and changing the way we access the internet. More than 1.75 billion people are expected to own and use smartphones by the end of 2014, up more than 25% over 2013 [75]. Users in Western Europe and the Asia-Pacific region make up the greatest number of users, with consumers in Asia-Pacific accounting for more than half of all smartphone users in 2014 [75]. Expansion of smartphone penetration in non-industrialized countries will impact our ability to affect HIV outcomes globally in a meaningful way. A critical first step requires local assessments to understand a target population's technology access and use (e.g. hardware ownership, development platforms, subscription plans, usage patterns and preferences). For example, while Android and iOS (Apple) continue to be the top two mobile operating systems globally (holding over 80% and 10% of market share in the second quarter of 2014, respectively) [76], usage among key demographics may favor one or the other. This information is a critical starting point for appropriately tailored app development and dissemination. Throughout intervention development and implementation, research teams need to continue monitoring the local market and have a flexible intervention approach that can adapt to changes in technology uptake and usage within diverse populations and geographies.

Working in developing countries, particularly among MSM, requires a high sensitivity and awareness of safety, security, and privacy issues. MSM face high levels of stigmatization in many settings: In five countries and in parts of two others, homosexuality is still punishable with the death penalty, while a further 70 countries may imprison citizens because of their sexual orientation [77]. In addition, government monitoring and restrictions on technology access can pose problems including lack of trust and the ability to design engaging, explicit and appealing content. For example, the Chinese government maintains strict control over the internet through a variety of censoring, blocking, and monitoring tactics [78, 79]. At the same time, web-based technologies may offer

more discrete access to health information (as compared to clinic settings) in countries where sexuality, sexual behaviors and HIV/STI are highly stigmatized. Regardless of the setting, in-depth assessment and qualitative research are needed to ensure protection of individuals and position programs for better success [80].

There are a number of lessons we can learn from researchers who have tried to use smartphone and Web 2.0-based technologies for HIV prevention and care. First, future interventions will need to be mindful of eHealth literacy inequities in the population, as well as account for constant changes in the popularity and emergence of social media platforms and devices themselves. Second, challenges exist between different “languages” spoken and overall goals of programmers, researchers, and end-users. Aims of app development and definitions of success may differ between researchers and programmers, and each may be responding to different perceived needs of end users. Teams can address some of these differences through continuous formative research with the target population during intervention development and creating very explicit deliverables, timelines, and division of labor within the development team. These first and second points emphasize the importance of designing technology-based interventions with the end user constantly in mind to create something that is intuitive, useful, engaging and fun [80].

Lastly, a number of funding challenges are inherent to this research. Investigators may have difficulty devoting sufficient money to design, programming and/or dissemination either due to budget limitations, inexperience, or unexpected technology challenges. In addition, the required development process for technology projects is not necessarily well-aligned with standard federal funding mechanisms and timelines; The accelerated pace of technology evolution is driven by commercial markets, and is often at odds with the typical speed of funding application, review and reward cycles, as well as with typical research timelines. Technology interventions that are tested through this cycle run the risk of being outdated by the time intervention results are ready for dissemination. Additional funding may need to be explicitly earmarked to expedite the technology transfer pipeline from prototype to pilot trial and efficacy trial if we are to be responsive to the rapid changes in technology.

Going forward, we foresee HIV care and prevention intersecting with novel technology advances such as quantified self-movement and geolocation, self-monitoring of physiological and emotional states (e.g. mood, arousal), and performance (mental and physical) in the near future. These advances will be vital to ensure the success of integrated sustained, behavioral modification and biomedical strategies for prevention and care. Additionally, while establishing efficacy is of course critical, many of these studies have yet to demonstrate effectiveness through scale-up, a key issue in increasing access and dissemination for HIV prevention. As

with biomedical interventions, we need to explore ways to ensure that “what works” within eHealth, mHealth, and Web 2.0 can be accessed and widely utilized by populations at risk for HIV.

Compliance with Ethics Guidelines

Conflict of Interest Kathryn E. Muessig, Manali Nekkanti, Jose Bauermeister, and Sheana Bull report that they have NIH-funded grants.

Lisa B. Hightow-Weidman reports personal fees from Gilead Sciences and personal fees from Janssen Therapeutics.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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