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Paradata: Measuring Engagement in Digital HIV Interventions for Sexual and Gender Minorities

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Abstract

Purpose of Review The goal of this review was to examine online engagement using *paradata* (i.e., intervention usage metrics) as part of the reporting of online behavioral HIV prevention and care interventions' findings. We underscore the importance of these data in examining intervention engagement and effectiveness.

Recent Findings We focused on studies indexed in PubMed and published between April 1, 2017, and June 30, 2023, that reported the development and testing of online behavioral interventions for HIV prevention and/or care. Of the 689 extracted citations, 19 met the study criteria and provided engagement data — only six studies tested the association between engagement and intervention outcomes. Of these, four studies found a positive association between participants' engagement and improvements in HIV-related outcomes.

Summary Increasing attention is being paid to the collection and reporting of *paradata* within HIV online behavioral interventions. While the current evidence suggests a dose-response relationship due to user engagement on HIV outcomes, greater efforts to systematically collect, report, and analyze paradata are warranted.

Keywords mHealth · Online · Digital interventions · HIV · Prevention and care

Introduction

Compared to human immunodeficiency virus (HIV) prevention and care interventions delivered in-person, online-delivered interventions provide greater reach, accessibility, and flexibility regarding when and where they might be used [1]. These interventions are delivered using diverse channels (e.g., websites, mobile-adapted websites, social media, and/or native applications [apps]). However, compared to traditional in-person settings where researchers can have greater control over participants' engagement with the intervention content, researchers delivering online interventions have more uncertainty regarding whether participants will use the online tool as designed and, in turn, receive the intended "dose" proposed to achieve a desired behavioral outcome [2]. As a result, monitoring participant engagement takes on heightened importance [3, 4]. As a response to this challenge, researchers have increasingly turned to the use of *paradata* to measure engagement levels in digital HIV interventions.

Paradata refers to supplementary data that capture intricate details concerning the process of interaction with an online intervention [5], including where, when, and how users access, participate, and use these online interventions. As noted by Hightow-Weidman and Bauermeister [3], the collection and analysis of *paradata* can help conceptualize users' engagement in online interventions across four domains: amount (i.e., quantification of users' actions within an online intervention; e.g., number of activities completed), frequency (i.e., rate of event occurring; e.g., number of log-ins), duration (i.e., time spent on the intervention or its features; e.g., participants' total number of minutes engaged with the intervention content), and depth (i.e., extent to which users engaged with a given feature and/or content, e.g., proportion of participants who engage with intervention content related to pre-exposure prophylaxis [PrEP]).

Engagement can also play a significant role in the effectiveness of digital health interventions. Inadequate

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levels of engagement can diminish the impact of an intervention on behavioral changes, whereas adequate levels of engagement can increase the intervention effect. For instance, a recent digital health intervention designed to assist sexual and gender minority youth in coping with minority stress found that greater engagement with the intervention (≥ 5 log-in sessions, > 10 min of use, or > 10 content pages viewed) was linked to greater improvements in coping appraisals among participants assigned to the treatment group [6]. As a result, it is crucial that researchers collect engagement data and take it into account when assessing the efficacy of their interventions. This consideration provides valuable insights for strategies to maximize the interventions' effectiveness and enhance their efficiency.

A prior review of digital health intervention trials for HIV prevention and care published between January 2016 and March 2017 found that only one published intervention provided data on participants' engagement with the intervention [4]. In this review, we examine whether researchers' reporting of engagement data in their HIV prevention and care interventions has changed over the past 6 years. Moreover, recognizing that greater user engagement has been posited to result in stronger intervention effects, we examine the extent to which researchers are examining the association between *paradata* metrics and HIV prevention and care outcomes within these interventions.

Methods

Guided by a scoping review methodology [7], we considered peer-reviewed publications reporting outcomes of randomized controlled trials or clinical trials focusing on HIV prevention and care among sexual and gender minority populations. We collaborated with a biomedical librarian and refined our approach by building on the methods employed in Bauermeister et al.'s 2017 review [4] focused on *paradata* in online HIV prevention and care interventions.

Our search strategy specifically targeted digital interventions for HIV prevention and care in PubMed. We intentionally excluded engagement-related terminology from the search terms due to its varying usage and definitions among researchers, making it challenging to establish a common search terminology. Instead, during the full-text review, we examined whether the articles contained engagement metrics (see Table 1). We utilized a query that combined controlled vocabulary (e.g., Medical Subject Headings), keywords, and filters to search for the titles and abstracts of clinical trials published between April 1, 2017, and June 30, 2023. This timeframe was selected to follow up on the previous 2017 review. While we acknowledged the potential presence of relevant content in gray literature, local publications, organizational bulletins, and conference proceedings, we limited our scope to peer-reviewed studies published in the literature.

The final literature search was concluded in August 2023 and identified a total of 689 distinct articles (see Fig. 1). We managed these articles using the Covidence platform

Table 1 PubMed search strategy

Overview of search strategy	A PubMed search was conducted to retrieve articles by employing a combination of MeSH terms and a keyword-based exploration of titles and abstracts. The search incorporated two sets of terms: the first pertained to "HIV prevention and control," while the second revolved around "digital interventions." These sets were merged using the logical operator "AND," ensuring that only articles containing at least one term from each set were included. Additionally, the search results were refined by applying filters based on publication date (between April 1, 2017, and June 30, 2023) and article type (i.e., clinical trials and randomized controlled trials)
HIV prevention and care-related terms	("HIV"[MeSH] OR "HIV"[tiab] OR "Human immunodeficiency virus"[tiab] OR (("unprotected"[tiab] OR "condomless"[tiab] OR "high-risk"[tiab] OR "unsafe"[tiab]) AND ("sex"[tiab] OR "intercourse"[tiab] OR "coitus"[tiab] OR "anal intercourse"[tiab])) OR "pre exposure prophylaxis"[MeSH] OR "PrEP"[tiab] OR "post exposure prophylaxis"[MeSH] OR "pep"[tiab] OR "antiretroviral therapy, highly active"[MeSH] OR "HAART"[tiab] OR "medication adherence"[MeSH])
Digital intervention–related terms	("Behavior Therapy"[MeSH] OR "behaviour therap*"[tiab] OR "behavioural therap*"[tiab] OR "behavioral therap*"[tiab] OR "digital intervention*"[tiab] OR "telemedicine"[MeSH] OR "telemedicine"[tiab] OR "internet"[MeSH] OR "mhealth"[tiab] OR "digital health"[tiab] OR "Cell Phone"[MeSH] or "Internet-Based Intervention"[MeSH] or "Mobile Applications"[MeSH] or "virtual"[tiab] or "digital"[tiab] or "eHealth"[tiab] or "Mobile phone"[tiab] or "online"[tiab] or "technology-based"[tiab] OR "app-based"[tiab])
Publication date	2017/04/01–2023/06/30
Filters	Clinical trial, randomized controlled trial
Final yield	689

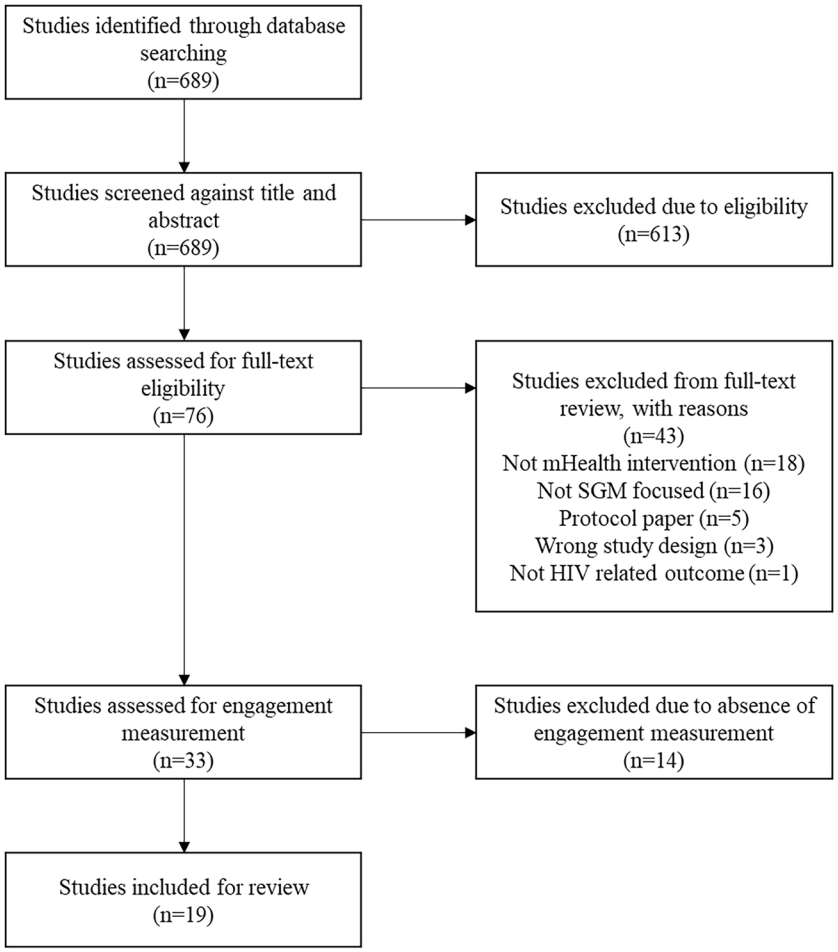

Fig. 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) diagram for our scoping review

(Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia; accessible at www.covidence.org). Our inclusion criteria encompassed studies that (1) assessed HIV prevention or care outcomes, (2) incorporated internet and/or smartphone-based technology as a central component of the intervention, and (3) included sexual and gender minority populations. Conversely, exclusion criteria encompassed studies that (1) lacked a clear intervention description, (2) did not focus on HIV-specific outcomes (e.g., exclusively addressing pregnancy or other sexually transmitted infections (STIs), (3) solely presented study protocols without reporting findings, (4) did not address sexual and gender identities, or (5) relied solely on text-based technologies (e.g., SMS).

During the initial title and abstract screening, 613 studies were excluded as they did not meet our inclusion criteria (e.g., did not measure relevant outcomes, focused on mother–child HIV transmission or pregnancy, targeted only cisgender women, relied solely on SMS). Subsequently, two independent reviewers assessed the full text of the remaining 76 studies to determine final eligibility. The two reviewers met to discuss any discrepancies and achieve consensus. Out of these, 43 articles were disqualified for various reasons, including not being digital interventions ($n=18$), lacking inclusion or mention of sexual and gender diverse populations ($n=16$), representing protocol papers without reported outcome results ($n=5$), adopting a study design other than RCT or Clinical Trials ($n=3$), or addressing outcomes not related to HIV ($n=1$).

Thirty-three articles were extracted from Covidence for further evaluation to determine whether they measured or collected engagement metrics. Of these, 19 articles [8, 9••, 10••, 11••, 12••, 13, 14, 15••, 16–24, 25••, 26] reported engagement data. We provide a brief description of the characteristics of the reviewed articles (Table 2) and present a synthesis of the main findings from these studies (Table 3).

Results

Digital HIV Interventions

Table 2 provides a detailed overview of the study objectives and sample characteristics of the 19 clinical trials included in this review. Among these studies, 18 were randomized controlled trials: 12 were parallel randomized controlled

Table 2 Descriptions of digital HIV intervention studies included in the review ($n=19$)

Intervention name	Author	Goal of the intervention	Study design	Recruitment period; study period	Population; sample size; location	Sex and gender	Race and ethnicity
MyChoices	Biello (2022)	Increase HIV testing and PrEP uptake among young MSM	Parallel randomized controlled trial (2:1 allocation ratio)	Nov 2018 to Apr 2019; 6-month	Young MSM aged 15–24 years old; $N=60$; U.S. (Boston, MA; Bronx, NYC; Chapel Hill, NC)	Cisgender men 100%	Hispanic 15%; Black 5%; Asian 11.7%; White 58.3%
MyDEx	Choi (2022)	Promote HIV prevention behaviors and mechanisms of change associated with HIV risk	Stratified block randomized controlled trial (2:1 allocation ratio)	Nov 2016 to Jan 2017; 90-day	Single young MSM aged 18 to 24; $N=180$; U.S	Gay 89%; bisexual 7.1%; Queer 3.9%	Hispanic 29.2%; Black 15%; Asian 8.3%; White 74.2%
The app-based intervention	Fan (2023)	Increase uptake of case management service	Parallel randomized controlled trial	Mar 2019 to Jan 2020; 1-month	HIV-positive MSM aged ≥ 18 years; $N=344$; China (Guangzhou)	Homosexual or bisexual 88.7%	Chinese 100%
HealthMpowerment.org (HMP)	Hightow-Weidman (2019)	Reduce sexual risk behaviors among HIV-positive and HIV-negative young Black MSM	Parallel randomized controlled trial	Nov 2013 to Oct 2015; 3-month	Young Black MSM and transgender women aged 18–30; $N=474$; U.S. (North Carolina)	Gay 66.7%; bisexual 20%	Black 100%
Epic Allies	Hightow-Weidman (2021)	Increase engagement in care, ART uptake, and ART adherence among young MSM with HIV who have detectable viremia	Parallel randomized controlled trial	Oct 2015 to Sept 2016; 26-week	HIV-positive young MSM aged 16 to 24; $N=146$; U.S. (South Florida, FL; Chicago, IL; Bronx, NY; New Orleans, LA; Chapel Hill, NC; Charlotte, NC)	Gay 77.4%	Hispanic 19.9%; Black 80.9%; White 8.8%
APP+	Horvath (2019)	Promote self-reported ART adherence and reduce stimulant use	Parallel randomized controlled trial	Aug 2016 to Mar 2017; 6-month	MSM living with HIV who use stimulants; $N=90$; U.S	Gay 88.9%	Hispanic 23.4%; Black 24.4%; White 44.4%
PATHS	Huebner (2023)	Improve communication about HIV and increase behaviors supportive of sexual health among young MSM	Parallel randomized controlled trial	June 2019 to Jan 2020; 6-month	Parents having a cisgender son aged 14–22; $N=61$; U.S	Gay 55.7%; bisexual 34.4%; Queer/Other 8.2%	Hispanic 6.6%; Black 4%; White 54.1%

Table 2 (continued)

Intervention name	Author	Goal of the intervention	Study design	Recruitment period; study period	Population; sample size; location	Sex and gender	Race and ethnicity
Youth-Friendly Services (YFS) plus the use of the Raincoat app	Kawichai (2022)	Support HIV PrEP adherence	Parallel randomized controlled trial	Mar 2018 to June 2019; 6-month	HIV-negative young MSM and young transgender women aged 15–19; $N=200$; Thailand (Bangkok)	MSM 73.5%; transgender women 26.5%	Thai 100%
PrEPmate	Liu (2021)	Improve retention and adherence to PrEP among young MSM initiating PrEP	Parallel randomized controlled trial (2:1 allocation ratio)	Apr 2015 to Mar 2016; 9-month	HIV-negative MSM aged 18–29; $N=121$; U.S. (Chicago, IL)	Male 95%; transgender/genderqueer 5%	Hispanic 35.5%; Black 27.3%; Asian 6.6%; White 24.8%
Keep It Up!	Madkins (2019)	Increase HIV knowledge, motivate and teach safer behaviors, and instill self-efficacy for HIV prevention strategies	Parallel randomized controlled trial	May 2013 to Dec 2015; 12-month	HIV-negative MSM aged 18–29; $N=1{,}113$; U.S. (Atlanta, GA; Chicago, IL; New York City, NY)	Gay 86.5%; bisexual and other 13.5%	Hispanic 30.3%; Black 23.8%; White 37.1%
The Young Men and Media	Nelson (2022)	Promote HIV prevention outcomes and develop pornography literacy skills	Block randomized controlled trial	Mar 2020 to May 2020; 3-month	HIV-negative adolescent sexual minority males aged 14–17; $N=154$; U.S	Gay 53%; bisexual 39%; heterosexual 5%	Hispanic 26%; Black 11%; White 52%
+Approp	Puig (2021)	Manage clinical outcomes (adherence to treatment and quality of health care) of older HIV-Infected patients	Parallel randomized controlled trial	June 2017 to Dec. 2017; 48-week	HIV-infected patients aged ≥ 60 years; $N=100$; Spain (Barcelona)	MSM 46%	100% Spaniards
weCare	Rhodes (2022)	Reduce rates of missed HIV care appointments and increase HIV viral suppression	Block randomized controlled trial	Sept 2016 to May 2018; 12-month	Racially/ethnically diverse gay, bisexual, and other MSM and transgender women living with HIV; $N=198$; U.S	Cisgender men 93.9%; transgender women 6.1%	Hispanic 12.6%; Black 64.1%; White 14.1%
VIP-HANA	Schnall (2021)	Improve symptom burden among people living with HIV	Parallel randomized controlled trial	Jan 2018 to Oct 2018; 6-month	People living with HIV with HIV-associated non-AIDS (HANA) conditions; $N=100$; U.S. (New York City, NY)	Male 52%; female 44%; transgender female 3%; genderqueer 1%	Hispanic 30%; Black 65%; White 10%

Table 2 (continued)

Intervention name	Author	Goal of the intervention	Study design	Recruitment period; study period	Population; sample size; location	Sex and gender	Race and ethnicity
MyPEEPS	Schnall (2022)	Reduce sexual risk behavior in same-sex attracted young males	Block randomized controlled trial	June 2018 to Apr. 2020; 3-month	HIV-negative same-sex attracted adolescent males aged 13–18; $N=763$; U.S. (Birmingham, AL; New York, NY; Seattle, WA; Chicago, IL)	Male 97%; gender-queer 0.8%; Nonbinary 1.7%	Hispanic 40.9%; Black 20.8%; Asian 9.5%; White 37.4%
WiseApp	Schnall (2023)	Improve ART adherence and viral suppression	Parallel randomized controlled trial	July 2017 to Apr. 2021; 6-month	People living with HIV; $N=200$; U.S. (New York, NY)	Homosexual 28.8%; heterosexual 55.1%; bisexual 11.1%; queer 0.5%; asexual 0.5%	Hispanic 25.8%; Black 73.7%; White 6.6%
JomPrEP	Shrestha (2023)	Deliver HIV prevention services for MSM in Malaysia	Single-arm trial	Mar 2022 to Apr 2022; one- month	HIV-negative cisgender MSM; $N=50$; Malaysia (Greater Kuala Lumpur)	Cisgender men 100%	Malaya 52%
M-cubed	Sullivan (2022)	Increase HIV prevention and care behaviors in diverse gay, bisexual, and other MSM	Stratified randomized controlled trial	Jan 2018 to Oct 2019; 3-month	Gay, bisexual, and other MSM; $N=1,226$; U.S. (Atlanta, GA; Detroit; MI; New York City; NY)	Cisgender men 100%	White 41.8%; color 58.11%
WeTest	Zhu (2019)	Deliver app-based information regarding the use of and interpretation of HIV self-testing kits, HIV transmission, risk for other STIs, behavioral risk reduction, and the importance of regular HIV testing	Parallel randomized controlled trial	Sept 2017 to June 2018; 6-month	HIV-negative MSM; $N=100$; China (Hefei)	Gay 78%	100% Chinese

Table 3 Engagement of the digital HIV interventions ($n = 19$)

Intervention	Author	Technology	Intervention/Control	Outcome of Interest	Engagement Metrics	Engagement Results
Studies reporting relationships between engagement metrics and outcomes						
MyDEx	Choi (2022)	Web app	I: 6 sessions; addressing distinct cognitive and affective content areas C: Attention control	Sexual risk behavior; HIV testing behavior; PrEP uptake; mechanisms of change	Number of log-ins; the number of sessions viewed	Number of sessions viewed was negatively associated with changes in internalized homophobia ($\beta = -06$; $P < .001$)
The app-based intervention	Fan (2023)	App	I: 1) Web-based communication with case managers, educational articles delivery, supportive service information retrieval, and hospital visit reminders; 2) standard case management service C: Standard case management service	Adherence to ART medication	Amount of intervention component delivered; extent of interaction with delivered resources or materials	Number of educational articles accessed was associated with adequate adherence in the intervention group (odds ratio 1.08, 95% CI 1.02–1.15; $P = .009$)
HealthMpowerment.org (HMP)	Hightow-Weidman (2019)	Web app	I: HMP — an interactive theory-based website to increase safer sex behaviors C: Information-only control website	Self-reported condomless anal intercourse	Total time spent; number of total log-ins	25% used HMP over 60 min during the 3-month. Intervention group who used the app for more 60 min had fewer CAI than expected in the control (95% CI 2.15, 7.53)
Epic Allies	Hightow-Weidman (2021)	App	I: Self-management tools, gamification, and social support to improve engagement in care and antiretroviral adherence C: Weekly phone-based notifications to encourage participants to review educational information in control app	VL suppression (either < 20 copies/ml or < 40 copies/ml, depending on assay used)	Daily app login; number of daily articles read	Regular users (a total of 52 log-ins or more per 13 weeks) in the intervention had a 56% higher viral suppression (ARR = 1.56, 95% CI 1.10–2.23)

Table 3 (continued)

Intervention	Author	Technology	Intervention/Control	Outcome of Interest	Engagement Metrics	Engagement Results
Youth-Friendly Services (YFS) plus the use of the Raincoat app	Kawichai (2022)	App	I: 1) YFS — monthly engagement and access to counselor; 2) raincoat mobile app — risk assessment, reminders, and rewards to support — PrEP adherence C: YFS — monthly engagement and access to counselor	PrEP adherence	Number of log-ins; risk assessment	Median frequency of 6 log-ins and risk assessments; 22% of YFS + APP arm participants were frequent users (log-ins and risk assessment ≥ 10) PrEP adherence was higher in frequent app users (log-ins and risk assessment ≥ 10) than in infrequent app users (NS)
M-cubed	Sullivan (2022)	App	I: Prevention messages in 6 domains of sexual health and offered ordering of at-home HIV and sexually transmitted infection test kits, receiving preexposure prophylaxis (PrEP) evaluations and navigation, and service locators C: No access to intervention app at baseline visit but continued to receive quarterly surveys	HIV testing and PrEP uptake	Time spent on the mobile app over the 3-month intervention	No significant differences in outcomes between the control and intervention groups who used more than 30-min over the 3-month intervention
Studies reporting engagement metrics only						
MyChoices	Biello (2022)	App	I: 1) Thought processes, goal setting, self-regulation, and self-efficacy, and addresses cognition, behavior, and environmental influences to improve HIV testing and PrEP uptake; 2) standard of Care C: Standard of care — CDC factsheets on HIV testing and PrEP uptake, access to standard of care services	HIV testing and PrEP uptake	Number of session viewed; total time spent	96.8% used the test plan feature; 83.9% used the app to locate nearby testing centers or PrEP providers. The most popular feature: supply ordering (1370 views)

Table 3 (continued)

Intervention	Author	Technology	Intervention/Control	Outcome of Interest	Engagement Metrics	Engagement Results
APP+	Horvath (2019)	App	I: APP+ C: No intervention. Email for assessment only	Self-reported ART adherence and stimulant use	Number of days used the app; the number of times sessions viewed	Median of 110 days of app access; 21 intervention participants utilized Choose Your Own Adventure component 268 times; 29 participants tracked their medication at least once in active intervention period
PATHS	Huebner (2023)	Web app	I: All content in a single session lasting 30–60 min or multiple sessions C: Lead with Love — a 35-min documentary-style intervention film	HIV information sharing; Condom access; Condom use; HIV testing; PrEP knowledge and interest	Time spent; completion of optional module	Parents spent an average of 40 min engaged with PATHS; 4 parents (13%) spent less than 10 min; Of parents randomized to PATHS 16 (52%) entered the optional PrEP module, and nine (29%) engaged with the content for more than 2 min
PrEPmate	Liu (2021)	Web	I: 1) Weekly "check in" SMS; 2) interactive online content through website C: Standard of care	PrEP adherence tenofovir diphosphate (TFV-DP) concentrations $\geq$ 700 fmol/ punch (consistent with $\geq$ 4 doses/week)	Weekly check-in completion; count of activities consumed	100% completion of weekly check-ins; 65% opting into continued daily SMS reminders after 2 weeks; 58% accessed information on website; 44% watched at least 1 video; 35% participated in forum; 76% requested support through SMS via PrEPmate
Keep It Up!	Madkins (2019)	Web	I: Seven modules that are completed across three sessions at least 24 h apart C:	Unprotected anal sex; Incident STIs	Time spent	Mean total time spent = 65 min; Time spent in the intervention correlated with an average star rating ($r = 0.11$, $p = .03$), and engagement factor ($r = 0.12$, $p = .02$)

Table 3 (continued)

Intervention	Author	Technology	Intervention/Control	Outcome of Interest	Engagement Metrics	Engagement Results
The Young Men and Media	Nelson (2022)	Web	I: Nine interactive modules C: Links to the CDC HIV prevention and the national HIV and STD testing resource websites	HIV knowledge; STI knowledge; aware of PrEP; condom knowledge	Percentage of those who logged in to the website; number of reminders required for logging in; number of modules completed; percentage of who completed each module	84% logged into the intervention website; Of those who logged in, 88% completed at least one module; The median number of completion = 9 ($M = 7$, SD = 2.7); Of those who logged in, the majority (57/65, 88%) completed the pornography set scavenger hunt game, 52/65 (80%) completed HIV/STI jeopardy, and 51/65 (78%) completed the anal health/anatomy animated video
+ Approp	Puig (2021)	App	I: 1) + Approp; 2) standard clinical management C: Standard clinical management	Adherence to treatment and quality of health care	Number of screens visited; number of days used; the total number of sessions; the mean session time; The most frequently used fields	Patients used the app for a mean of 23.7 (±2.84) days; The most popular screens were health counseling (24.8%) and medical records (22.2%)
weCare	Rhodes (2022)	App (Facebook, texting, and dating apps)	I: Cyberhealth educators, trained interventionists delivering the intervention, sent messages to each enrolled participant C: Usual-care	HIV care appointment and viral load	Number of messages exchanged	Each participant had a mean of 3.1 (SD 0.95; range: 1–9) conversations with a cyberhealth educator per month
VIP-HANA	Schnall (2021)	App	I: Report symptoms every week and receive tailored self-management C: App to report their symptoms every week	Symptom burden	Average times participants used app; average time spent each session	The intervention group spent more time vs the control group (5.9 min vs 3.9 min), while the control group used more often compared to the intervention group (28.2 times vs. 25.3 times)
MyPEEPS	Schnall (2022)	App	I: 21 online psychoeducational and skill-building modules C: Delayed intervention	Condomless anal sex acts	Module completion	91.5% of participants were given access to the app, and 81.7% completed all app modules

Table 3 (continued)

Intervention	Author	Technology	Intervention/Control	Outcome of Interest	Engagement Metrics	Engagement Results
WiseApp	Schnall (2023)	App	I: 1) Videos and health surveys on medication adherence and managing HIV; 2) daily app notification reminders C: Attention control — access to mHealth app	ART adherence	The mean number of days that each participant used the app	At 3 months, intervention group participants used the app for a mean of 57.8 days as compared to the control group, which used the app for a mean of 46.4 days
JomPrEP	Shrestha (2023)	App	I: Virtual platform, access to a range of HIV prevention materials (i.e., HIV testing and PrEP), and other support services (i.e., referral to mental health support)	HIV testing and PrEP uptake	Number of log-ins; session duration; pages viewed; frequency and duration of use of app components	Participants used JomPrEP for an average of 8 (SD 5.0) times during 30 days of testing, with each session lasting an average of 28 (SD 38.9) minutes
WeTest	Zhu (2019)	App (WeChat)	I: Two weekly messages — informational articles about HIV, STIs, and HIV testing; first-person stories of people diagnosed and living with HIV; local data about HIV and STI infections among MSM; HIV-related national news; and stories of general MSM health concerns C: general baseline procedures	HIV self-testing	The number of messages read; the most frequently read message	Approximately 80% of messages delivered to participants via WeChat (63 of 79 messages) were read by > 20% of participants and 15% of the messages (12 of 79 messages) were read by > 50% of participants. The most frequently read WeTest messages included content concerning MSM diagnosed and living with HIV, drug use, and case studies about HIV infection

trials, four were block randomized controlled trials, and one was stratified randomized controlled trial. Additionally, one study [24] was categorized as a single-arm trial. The sample sizes across these studies varied, ranging from 50 to 1113 participants, and the trials followed participants from 1 to 12 months.

Half of the studies ($n = 10$; 52.6%) were designed for HIV-negative participants, while 6 (31.6%) were tailored for participants living with HIV. Two studies [12••, 25••] were status-neutral. Additionally, it is worth noting that Huebner's study [14] specifically targeted parents with cisgender sons aged 14 to 22, rather than directly focusing on sexual and gender minority individuals. However, they assessed outcomes from both parents and their sons. Not all studies recruited sexual and gender minority individuals exclusively. Three studies [19, 21, 23] focused on individuals living with HIV and had between 4 and 46% of individuals who also identified as sexual and gender minorities.

Nine of the studies (47.4%) had a specific focus on adolescent and/or young adult populations, with age ranges typically spanning from 14 to 30 years. Geographically, the majority of these studies ($n = 14$; 73.7%) were conducted in the United States (U.S.), with two studies conducted in China [10••, 26] and one in Thailand [15••], Spain [19], and Malaysia [24]. Among the studies conducted in the U.S., nine studies [11••, 13, 16, 17, 20–23, 25••] predominantly sampled participants from racial/ethnic minority backgrounds and one study [12••] specifically targeted Black/African American populations.

In Table 3, we provide details of the digital HIV intervention studies and their engagement. The format of intervention delivery across these studies exhibited variability and encompassed web apps (i.e., mobile-optimized websites) in three cases [9••, 12••, 14], websites in three cases [16–18], and smartphone apps in 13 cases. Among the 13 interventions utilizing smartphone apps, a small subset ($n = 2$) made use of existing apps. For instance, Rhodes et al. [20] employed existing social media platforms, including Facebook and dating apps, to disseminate messages delivered by trained educators. Likewise, Liu et al. [16] utilized WeChat, a Chinese instant messaging social media and mobile payment app, to convey app-based messages containing concise informational articles about HIV and HIV testing, along with referrals to HIV-related health services.

Engagement Operationalization

The most commonly collected *paradata* metrics were related to the amount ($n = 12$; e.g., number of sessions viewed, daily articles read, message exchanges, and module completions), followed by frequency ($n = 9$; e.g., the number of log-ins, number of days used) and duration ($n = 7$; e.g., total time spent). However, only two cases have collected in-depth engagement metrics, specifically whether participants engaged with a particular intervention feature or module. Nelson et al. studied specific content consumption patterns, finding that a majority (88%) of participants completed the pornography set scavenger hunt game, 80% completed HIV/STI jeopardy, and 78% completed the anal health/anatomy animated video.

Most of the studies ($n = 18$; 94.7%) explicitly presented descriptive statistics of engagement metrics using measures such as mean and percentage. For example, in Nelson's study [18], it was reported that 84% of participants accessed the intervention website. Among those who logged in, 88% completed at least one module, and the median number of module completions reached nine, which is the total number of available modules. In Puig's study [19], patients used the app for an average of 23.7 days over a 48-week period, and the most frequently accessed screens were "health counseling" and "medical records," which were accessed by over 20% of participants. Additionally, in Schnall's study [21], the average time spent on individual app session was described and compared between the intervention group and the control group. The intervention group spent 1.5 times more time on the app than the control group.

Four studies (21.1%) categorized raw *paradata* metrics into categories such as "regular," "frequent," and "compliant" users, while the remaining studies reported raw *paradata* metrics. For instance, Hightow-Weidman [12••] defined "compliant users" as those who used the app for more than 60 min over the 3-month intervention period. Similarly, Sullivan [25••] employed 30 min of app usage over 3 months as a threshold to define an engaged group. In another study by Hightow-Weidman [11••], "regular users" were characterized as individuals who logged in a total of 52 times or more within a 13-week period (an average of four or more times per week). Kawichai [15••] defined "frequent users" as those with more than 10 log-ins and engagement in a risk assessment.

Impact of Engagement on Digital HIV Intervention Effectiveness

Out of the 19 studies that collected *paradata* metrics, six (31.6%) examined the impact of engagement on their study outcomes [9••, 10••, 11••, 12••, 15••, 25••]. Four of these studies found significant correlations between engagement and their primary or secondary outcomes. For instance, in Choi's study [9••], the number of sessions viewed was negatively associated with changes in internalized homophobia, a secondary outcome not directly related to the intervention's primary goals. In Fan's study [10••], the number of articles accessed was associated with greater adherence to antiretroviral therapy (ART) medication in the intervention group. In Hightow-Weidman's study [12••], participants who engaged

with the intervention for more than 60 min over a 3-month period reported a lower frequency of condomless anal intercourse (CAI) compared to the control group. In another study of Hightow-Weidman [11••], regular users (defined as having a total of 52 log-ins or more per 13 weeks) in the intervention group had a 56% higher rate of viral suppression compared to those in the control group.

Two studies did not report statistically significant associations between engagement and intervention outcomes. For instance, in Kaiwichai's study [15••], PrEP adherence was slightly higher among frequent app users compared to infrequent users, but this difference did not reach statistical significance. Similarly, Sullivan's study [25••], which utilized a 30-min engagement threshold, did not discover a significant link between engagement levels and the outcomes of the intervention, HIV testing, and PrEP uptake.

Discussion

In recent years, researchers have dedicated significant efforts to the development of digital HIV prevention and care interventions tailored for sexual and gender minority populations. Alongside these advances, efforts to conceptualize and measure participants' engagement with these online interventions have received greater attention given their potential impact on their effectiveness, scalability, and sustainability. Since the prior 2017 review examining the inclusion of *paradata* metrics in HIV prevention trials [4], our review found a substantive increase in the reporting of *paradata* metrics across online intervention trials. We identified a total of 33 digital HIV interventions designed for sexual and gender minority populations and published in the prior 5 years. Among these, 19 studies (58%) provided a variety of engagement metrics in their reporting of their results. This represents a substantial shift in the field over the past 6 years, highlighting that researchers are increasingly gathering and analyzing *paradata* to enhance the evidence base for technology-driven interventions. Consistent with other standardized metrics that are often reported as part of a clinical trial, we recommend the inclusion of *paradata* reporting as a key component when reporting digital intervention outcomes.

Given the role that engagement can play in the efficacy of digital interventions, it is imperative that researchers explore how engagement influences their trial outcomes. For example, Hightow-Weidman [12••] observed a more robust intervention effect in reducing CAI among participants who engaged with the intervention for over 60 min during a 3-month web-based HIV prevention and care intervention targeting young Black men who have sex with men. Regrettably, only six of the 19 studies included in the review examined how engagement influenced their outcomes. In four studies, we observed a positive association between greater engagement and desired intervention outcomes. The inclusion of these analyses is important to understand whether digital interventions that may be considered at first glance as having negligible or small effect sizes are dependent on participants engaging sufficiently with the digital tool to receive the optimal "intervention dose." As more studies characterize and report engagement in these dose–response relationships, opportunities to use in meta-analytic strategies to answer these questions will also become more feasible.

It is noteworthy that researchers, when assessing the impact of engagement in their digital HIV interventions, have employed varying criteria to categorize participants as "complied," "frequent," or "regular" users. For instance, Hightow-Weidman [12••] deemed users who engaged for a minimum of 60 min as "complied" users, whereas Sullivan [25••] established a 30-min threshold for the same intervention period. Additionally, two studies [11••, 15••] have chosen to define thresholds based on the number of log-ins (such as a total of 52 log-ins or more over a 13-week period and 10 or more log-ins and risk assessment over 6-month) instead of considering engagement duration. The choice of different thresholds can be attributed to the specific outcomes being measured in the intervention. For instance, in digital health interventions that monitor daily adherence, a common practice is to consider seven consecutive days of adherence in a week as equivalent to 100% engagement. However, it is important to note that there is currently no established literature that defines or investigates the appropriate thresholds indicative of a "good" level of engagement, one that ensures participants derive the benefit from these online tools. Therefore, future studies should delve into the determination of what level of engagement is necessary to achieve behavioral changes through various digital HIV interventions.

Researchers may also benefit from using *paradata* to pinpoint the core components of the intervention that are linked to behavior change. We observed that studies are reporting a mix of quantity, frequency, and duration of engagement metrics. Undoubtedly, the selection of *paradata* to collect and report is dependent on the features of the digital intervention (e.g., forums, interactive activities, or tailored content) and its mode of delivery (e.g., social media app, stand-alone app, or website). While amount, frequency, and duration are important engagement metrics, we also encourage the exploration of the depth of engagement as an important *paradata* metric. Depth of engagement within an online intervention can offer valuable insights into how features within a digital intervention are linked to changes in the intended outcomes. For example, Bauermeister et al. [27] found that participants who had engaged in a greater set of forum conversations with peers regarding stigma through an online forum were more likely to report decreases in their

HIV and sexuality-related stigma over time. However, in this review, only two out of the 19 cases in our review collected data on the depth of engagement, which limits our understanding of how core features of a digital tool are driving the observed behavioral changes. Efforts to collect and analyze various engagement metrics, including the depth of engagement, will enable researchers to pinpoint which intervention components are most effective for different intervention outcomes and various sexual and gender minority groups. Ultimately, this targeted approach will enhance efficiency by alleviating the burden on users and reducing associated costs. Future meta-analyses may help us examine how engagement across different *paradata* domains (e.g., amount, frequency, duration, and depth) and features are associated with an intervention's effectiveness.

In summary, the collection and examination of *paradata* to evaluate participants' engagement patterns in digital HIV intervention studies is an essential practice for all researchers. However, it is equally important to investigate how engagement impacts intervention outcomes. The influence of engagement on the effectiveness of digital interventions cannot be overlooked, and researchers must consider variations in participants' engagement when analyzing outcomes. Furthermore, it is essential to explore various *paradata* metrics, including quantity, frequency, duration, and depth, simultaneously to measure engagement. Multiple testing, which raises the risk of Type 1 errors, is a common challenge in research [28]. When evaluating engagement in digital HIV prevention, inflating the risks of Type 1 errors may arise when testing numerous *paradata* metrics and multiple outcomes in a single study. Among studies included in our review, we did not observe a systematic approach across studies regarding potential Type 1 errors when examining the association between engagement and its outcomes. Future research examining how to address multiple testing issues by controlling the family-wise error rate [29] or applying the false discovery rate [30] to maintain an acceptable level of Type I error is warranted.

Conclusion

Strengthening the evidence of digital interventions for HIV prevention and care will require a systematic and rigorous approach to collecting, reporting, and analyzing engagement data through *paradata* metrics. These *paradata* will help us understand how digital interventions work and what the optimal engagement is in order to achieve the intended effect. Understanding these engagement processes will also help us facilitate the reproducibility of intervention trials and inform population health efforts to scale these tools beyond the clinical trial setting. Continued attention and incorporation of *paradata* into the analysis of digital health interventions for HIV prevention and care are warranted.

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Declarations

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