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# Smartphone Self-Monitoring to Support Self-Management Among People Living With HIV: Perceived Benefits and Theory of Change From a Mixed-Methods Randomized Pilot Study

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**Background:** Self-monitoring by mobile phone applications offers new opportunities to engage patients in self-management. Self-monitoring has not been examined thoroughly as a self-directed intervention strategy for self-management of multiple behaviors and states by people living with HIV (PLH).

**Methods:** PLH (n = 50), primarily African American and Latino, were recruited from 2 AIDS services organizations and randomly assigned to daily smartphone (n = 34) or biweekly Web-survey only (n = 16) self-monitoring for 6 weeks. Smartphone self-monitoring included responding to brief surveys on medication adherence, mental health, substance use, and sexual risk behaviors, and brief text diaries on stressful events. Qualitative analyses examine biweekly open-ended user-experience interviews regarding perceived benefits and barriers of self-monitoring, and to elaborate a theoretical model for potential efficacy of self-monitoring to support self-management for multiple domains.

**Results:** Self-monitoring functions include reflection for self-awareness, cues to action (reminders), reinforcements from self-tracking, and their potential effects on risk perceptions, motivations, skills, and behavioral activation states. Participants also reported therapeutic benefits related to self-expression for catharsis, non-judgmental disclosure, and in-the-moment support. About one-third of participants reported that surveys were too long, frequent, or tedious. Some smartphone group participants suggested that daily

self-monitoring was more beneficial than biweekly due to frequency and in-the-moment availability. About twice as many daily self-monitoring group participants reported increased awareness and behavior change support from self-monitoring compared with biweekly Web-survey only participants.

**Conclusions:** Self-monitoring is a potentially efficacious disruptive innovation for supporting self-management by PLH and for complementing other interventions, but more research is needed to confirm efficacy, adoption, and sustainability.

**Key Words:** self-monitoring, self-management, HIV/AIDS, chronic conditions, mobile phones, mHealth

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## INTRODUCTION

Self-management is a fundamental component of HIV treatment and prevention as HIV/AIDS has transitioned to a chronic illness with the advent of effective treatments.<sup>1</sup> A major challenge for all chronic conditions is engagement of patients in active self-management during their daily routines and between clinical and behavioral intervention visits.<sup>2–4</sup> The nearly ubiquitous integration of mobile phones into our daily routines is creating many novel opportunities to enhance engagement in self-management through common functions, such as medication reminders,<sup>5,6</sup> and informational and motivational messaging.<sup>7,8</sup> Self-monitoring, that is, the active observation and recording of behaviors, states, and their determinants and effects, is a core element of self-regulation and self-management<sup>9–11</sup> that can be easily implemented and scaled through mobile phones. Self-monitoring is a self-directed intervention activity that does not entail the costs and provider burdens associated with traditional counseling interventions and may be a massively scalable disruptive innovation in which even small effects can have significant impacts at scale.<sup>12</sup>

Self-monitoring has been identified as a core element of evidence-based interventions for a variety of conditions,<sup>13,14</sup> although reviews of the self-management literature in general,<sup>2,3,15</sup> and for HIV specifically,<sup>1,16</sup> rarely mention self-monitoring. Similarly, the evaluation of multicomponent evidence-based

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intervention packages has resulted in “black box” barriers to understanding specific intervention components’ efficacy and mechanisms of change.<sup>12,17</sup> Elaborating causal mechanisms of behavior change and identifying the impacts of specific behavior change tools is a new priority focus for the National Institutes of Health (NIH) through the Science of Behavior Change (SOBC) program.<sup>18</sup> The efficacy and causal mechanisms of self-monitoring, in particular, have not been well elaborated to date in general,<sup>14,19</sup> nor for multiple HIV-related self-management domains of medical adherence, mental health, substance use, and sexual behaviors. This article aims to help fill this gap in the literature and bring renewed attention to self-monitoring as a behavior change intervention strategy that is made more feasible by the integration of mobile phones into our daily routines.

Early research on self-monitoring suggests that it is integral to self-regulation and self-management through processes involving response to feedback from self-observation, such as reflection in comparison with criteria (eg, perceived norms or personal standard), self-correction, and reinforcement through self-reward or critique.<sup>10,11</sup> There is modest meta-analytic evidence for the efficacy of self-monitoring diet, physical activity, and weight to support self-management of diabetes<sup>20</sup> and obesity.<sup>21</sup> Notably, meta-analytic evidence does not support the efficacy of self-monitoring blood glucose alone for diabetes self-management,<sup>22</sup> which suggests the importance of self-monitoring behaviors, rather than biomarkers alone, for behavior change and maintenance. Evidence also emerges for the potential efficacy of self-monitoring from alcohol, tobacco, and drug (ATOD) abuse intervention research identifying “assessment effects” in which control groups experience improvements in targeted outcomes.<sup>23,24</sup> There is similar evidence for sexual risk reduction on the order of 15% to up to 30% in control groups in some HIV prevention trials with both HIV-negative<sup>17,25,26</sup> and HIV-positive participants.<sup>27</sup> Qualitative process studies of ATOD intervention trials find that participants recognize the impact of assessments on their behaviors and that more frequent monitoring might result in greater effects.<sup>23</sup>

There are a number of studies using phone- and Web-based diary methods for capturing data with people living with HIV (PLH)<sup>28–32</sup>; however, only a handful of studies have examined self-monitoring as an intervention tool for self-management of HIV-related health and risk behaviors. One small randomized controlled trial compared self-monitoring by pill diary for 2 weeks after baseline to a single session behavioral intervention (based on motivational interviewing, cognitive-behavioral, and problem-solving techniques), finding similar improvements in antiretroviral therapy (ART) adherence at 12-week follow-up for both interventions.<sup>33</sup> Two other small-scale efficacy studies examining self-monitoring by interactive voice response and smartphone application have identified potential enhancements to engagement and efficacy of motivational interviewing for reducing ATOD use among PLH in clinical settings.<sup>34,35</sup> A larger randomized controlled trial of computer-based self-monitoring at routine medical visits compared with standard care found some support for reducing sexual risk behaviors by PLH over time.<sup>36</sup> The study also found

that improvements positively correlated with the number of assessments completed, indicating that self-monitoring frequency and intersecting motivational factors may moderate self-monitoring effects.<sup>36</sup> Another recent study of reactivity (ie, behavior changes) in response to Web-based daily diary assessments by gay and bisexual men found a heterogeneity of effects based on motivational factors, suggesting that different mechanisms of self-monitoring function at various stages of activation and motivation.<sup>37</sup> Although these studies suggest the efficacy of self-monitoring as an intervention strategy and some potential mediating or moderating factors (eg, motivation), the theoretical and causal pathways of the impacts of self-monitoring on multiple HIV-related health behaviors and states have not been thoroughly elaborated. This study aims to begin to fill this gap in the literature.

This article presents qualitative results from a pilot study of daily self-monitoring through smartphone and biweekly Web surveys by PLH for multiple HIV-related domains over 6 weeks. The primary aim of this article is to elaborate a theoretical model for the potential benefits of self-monitoring in supporting self-management of medication adherence, mental health, substance use, and sexual risk behaviors by PLH, through analysis of open-ended user-experience interview responses. Secondary aims explore potential differences in efficacy of daily versus biweekly self-monitoring as well as barriers and challenges reported, to inform application of self-monitoring for future research, intervention, and practice.

## METHODS

### Recruitment, Eligibility, Screening, and Randomization

Details on study design were published previously.<sup>38</sup> Briefly, in accordance with the UCLA Institutional Review Board requirements, fliers listing eligibility criteria, study purpose (ie, “to help develop a mobile phone application for PLH”), and a contact phone number were posted at 2 AIDS service organizations in Los Angeles. Clients interested in participation called the contact phone number and completed an eligibility screening, which included taking any medicine daily (antiretroviral or other drugs); ATOD use at least once a week; sexually active at least once a week; daily mobile phone and internet use; and English speaking. If eligible, participants completed informed consent, baseline interviews, and a review of study instructions at an on-site appointment.

Participants were randomized into one of the 3 study groups using randomization lists balanced across self-reported ethnic (African American, Latino, white, Asian/other) and gender categories (male, female, and transgender). Two mobile phone groups with daily self-monitoring had minor variations in framing the study purpose, with 2 paragraphs in consent forms framing the study as either developing a new research tool (group A “Assessment,” n = 14) or behavior change tool (group B, “Behavior Change,” n = 20). This framing reflects 2 of the study aims, in addition to examining the reliability and validity of smartphone surveys reported previously.<sup>38</sup> The variation in framing was designed to

preliminarily assess potential impacts on participation and self-monitoring efficacy, as suggested by a review of reactivity and behavior change in diary and ecological momentary assessment studies.<sup>39</sup>

The biweekly Web-survey only condition (group C, “Comparison,”  $n = 16$ ) was included to preliminarily assess efficacy of daily versus biweekly self-monitoring. Because of the small sample size and short duration of this pilot study, and variability in risk levels (ie, many participants were adherent, not engaging in risk), preliminary statistical analyses did not detect statistically significant differences between daily smartphone and biweekly Web-survey conditions on any single self-report outcome in the biweekly Web surveys. Therefore, this article also explores potential differences in efficacy of daily versus biweekly self-monitoring based on qualitative reports.

## Procedures

Eligible participants met with a research assistant (RA) and completed a baseline retrospective computer-assisted self-interview on Survey Monkey (ie, the Web survey) at their first in-person appointment. The RA trained participants in using the Web survey and smartphone applications by reviewing surveys together and providing written instructions with screen shots of the smartphone application (Ohmage, [www.ohmage.org](http://www.ohmage.org)). Training included customizing time-based alarms for surveys at schedules convenient to participants’ daily routines (eg, during breaks, meals, or before bed). Participants could receive additional training by calling the RA and during follow-up interviews. Participants were scheduled to complete Web surveys with 14-day recall assessments at baseline, and end of weeks 2, 4, and 6. E-mail reminders were sent with personalized survey links. If Web surveys were not completed within 3 days of due date, the RA made follow-up phone calls. Brief, qualitative, user-experience interviews were conducted by phone at the end of weeks 2 and 4, and in-person at the final 6-week meeting.

Mobile phone group participants (groups A and B) received a study-assigned mobile phone (a first-generation Android G1 smartphone, valued at \$50). Participants were instructed to complete mobile phone surveys once daily on alcohol, tobacco, and other drug (ATOD) use, sexual behaviors, and medication adherence; 4 times per day on physical and mental health-related quality of life to capture and reflect high variability in symptom experiences throughout a day; and to self-initiate stressful event reports or a text diary entry at any time. Participants were instructed to complete phone surveys at times they programmed the application alarm to trigger (ie, time-based reporting) as well as at any time when relevant experiences occurred (event-based reporting). A Web-based visualization portal was also available to mobile phone group participants, which was capable of displaying their personal phone survey responses over time, by location (using a Google map of phone survey geolocation stamps), and associations between variables. This prototype visualization tool was difficult to use and interpret and was rarely accessed by participants.<sup>40</sup>

Participants were compensated \$25 for in-person meetings at baseline and 6 weeks, \$10 for each of the 3 follow-up Web surveys, and \$10 for each of the 2 phone interviews.

Phone surveys were compensated on a cumulative scale as follows: \$5 for completing 25%, \$15 for 50%, \$20 for 75%, and \$30 for 100% (ie, \$70), for a grand total of up to \$170 maximum per participant for all surveys and interviews. Incentives were provided based on 7 total phone assessments per day. Many participants opted to complete stressful event and text diary surveys to meet their daily survey quotas in lieu of daily ATOD or sexual behavior surveys, which were completed about every other day on average.<sup>38</sup>

A prior article from this study specifically examines the validity and reliability of daily versus biweekly recall reports and provides more extensive details on survey question content.<sup>38</sup> A brief overview is provided below along with details of the open-ended qualitative interview questions that are the focus of the current analysis.

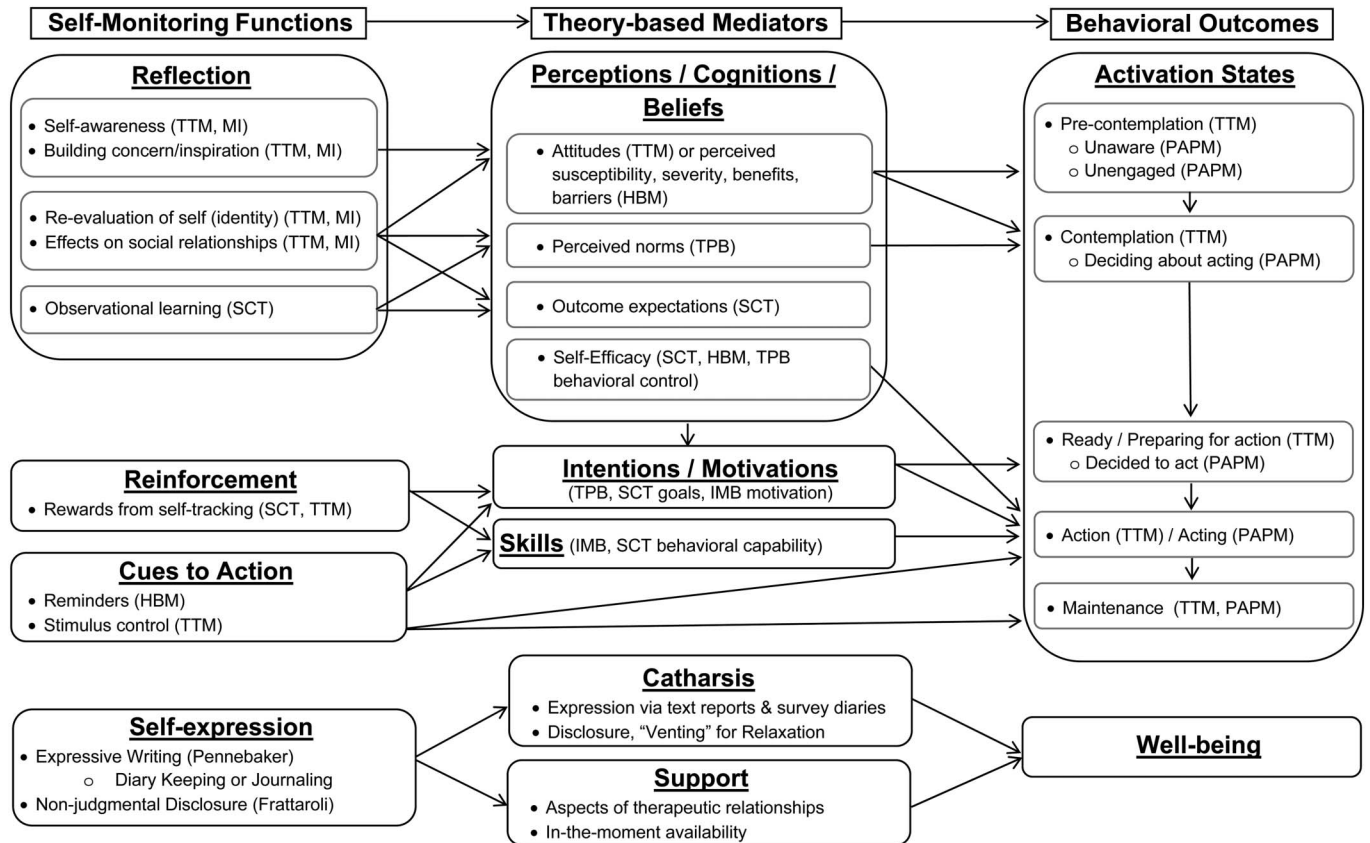
## Biweekly Web Surveys and Daily Smartphone Surveys

Demographics assessed at baseline included age, gender, sexual orientation, race/ethnicity, and education. Smartphone surveys were adapted from Web-survey questions to assess daily or in-the-moment periods. Smartphone surveys were organized in the smartphone app by the 4 categories outlined below.

Medication adherence was reported using the AIDS Clinical Trial Group adherence questionnaire,<sup>41</sup> which was modified to also assess the prior 14 days for Web surveys. Participants were instructed to report on medications in general, and ART specifically if they were being treated. Phone surveys included 8 items (prompted 1×/d) on whether a medication was missed or taken, the timeliness, and reasons for late or missed medications. The final item instructed participants to repeat the survey for each medication taken.

Mental health and physical health symptoms were reported using the brief health-related quality of life (CDC-HRQOL) measure.<sup>42</sup> Web-survey questions were adapted to assess number of days felt depressed, anxious, fatigued, energetic, and activity limitations in the past 14 days. Phone surveys were prompted 4 times a day, adapted to cover the past several hours, and rated on a 0–3 scale as follows: “Not at all,” “A little,” “Somewhat,” or “Extremely.” The 4-times-per-day schedule was used to capture expected variability in symptom experiences throughout a day. Phone surveys also included separate Stressful Event and Photo Diary surveys. The stress survey (4 items; participant initiated) included a question on the stress level (on a 1–10 scale), and optionally, to provide a text annotation, take a photo related to the event, and/or edit the date/time of the event. A Photo Diary (2 items; participant initiated) provided the option to report non-stressful events by taking a photo and providing a brief text annotation.

ATOD use was reported using measures from prior studies with PLH.<sup>43</sup> Web surveys assessed the number of days participants used alcohol, tobacco, marijuana, cocaine, crack, methamphetamine/stimulants, hallucinogens, and heroine/opiates over the prior 2 weeks. Phone surveys included 12 items (including skip options; prompted 1×/d). A single stem question asked participants to check all applicable alcohol, tobacco, marijuana, cocaine, methamphetamine, or “other



**FIGURE 1.** Self-monitoring theory of action. TTM, Trans-theoretical Model<sup>48</sup>; HBM, Health Belief Model<sup>46</sup>; TPB, Theory of Planned Behavior<sup>47</sup>; SCT, Social Cognitive Theory<sup>9</sup>; IMB, Information, Motivation, Behavior<sup>47</sup>; MI, Motivational Interviewing<sup>58</sup>; PAPM, Precaution Adoption Process Model<sup>49</sup>; Expressive Writing<sup>50</sup>; Nonjudgmental Disclosure.<sup>51</sup>

drug” use “since last report” (ie, prior day ideally). This framing was used to anticipate missed daily reports and event-based reporting trends for some ATOD use that may not occur daily, and which was observed in the data.<sup>38</sup>

Sexual behaviors were reported using a slightly modified version of the NIMH Multisite Prevention Trial Protocol.<sup>25</sup> Web surveys included questions regarding total number of sex partners and partner-level reports for up to 5 recent sex partners on numbers of sex acts, unprotected sex acts, and unprotected sex acts with HIV-negative or unknown status partners, also over the prior 2 weeks. Phone surveys included 17 items (including skip options; prompted 1x/d) on partner type (eg, 1 time or regular), gender, HIV and sexually transmitted infection (STI) status, and nickname for repeat reports; time since encounter ended; anal, vaginal, or oral intercourse; active or receptive partner; condom use; safe sex discussions; and ATOD use during the encounter. The final item instructed participants to repeat the survey for each sexual encounter.

Web surveys also assessed goals and supports with a series of yes/no and open-ended follow-up questions for each of the 4 domains: medication use (adherence), mental health, ATOD use, and sexual risk behaviors. The first question asked, “Are you currently trying to make any changes related to your...” and if yes, “Is anyone helping

you with this?” Open-ended follow-up questions asked for details on the goals, sources of support, and frequency of support (not examined in this analysis).

### Qualitative User-Experience Interviews

Brief, semi-structure, open-ended qualitative interviews were conducted by telephone at 2 and 4 weeks, and in-person at 6 weeks after baseline, to gather user-experience feedback on the Web and mobile phone tools. The opening question was nondirective, “Please tell me about your experiences and thoughts on using the Web survey (and cell phone surveys, for groups A and B) over the past 2 weeks.” Three follow-up questions (or probes) were then asked for each of the 3 technology tools (Web surveys, cell phone surveys, and Web-based visualizations): (1) concerns about sensitive information; (2) what was “helpful or useful”; and (3) what was “annoying, tedious, or not useful.” No additional probes were used to elicit further responses or detailed elaborations.

### Analytic Methods

Qualitative user-experience interview responses were coded in iterative rounds using a grounded approach, which

**TABLE 1.** Demographic Characteristics and Assessment Completion Rates, by Study Arm

	Daily Mobile A “Assessment”		Daily Mobile B “Behavior Change”		Biweekly Web Only C		Total	
	N = 14		N = 20		N = 16		N = 50	
	n	%	n	%	n	%	n	%
Gender*								
Female	1	7.1	4	20.0	1	6.7	6	12.2
Male	11	78.6	15	75.0	14	93.3	40	81.6
Transgender	2	14.3	1	5.0	0	0.0	3	6.1
Race								
Black	7	50.0	8	40.0	9	56.3	24	48.0
Latino	1	7.1	3	15.0	4	25.0	8	16.0
Native American	0	0.0	1	5.0	0	0.0	1	2.0
White	4	28.6	6	30.0	3	18.8	13	26.0
Mixed†	2	14.3	2	10.0	0	0.0	4	8.0
Sexual orientation*								
Bisexual	3	23.1	3	15.0	0	0.0	6	12.2
Gay	8	61.5	13	65.0	13	81.3	34	69.4
Heterosexual	2	15.4	4	20.0	3	18.8	9	18.4
Medication adherence‡								
ART (miss <3 of 14 d)	8	80.0	13	81.3	10	83.3	31	81.6
ART (miss 0 in last 3 d)	7	77.8	11	73.3	11	91.7	29	80.6
Mental health								
Anxious (5+ d/14 d)	6	75.0	5	62.5	4	40.0	15	57.7
Sad (5+ d/14 d)	3	37.5	4	44.4	5	50.0	12	44.4
Substance use (>0/14 d)								
Alcohol	13	92.9	18	90.0	15	93.8	46	92.0
Cocaine	4	28.6	5	25.0	5	31.3	14	28.0
Crack	8	57.1	8	40.0	4	25.0	20	40.0
Marijuana	10	71.4	14	70.0	12	75.0	36	72.0
Tobacco	9	64.3	11	55.0	10	62.5	30	60.0
Methamphetamine	6	42.9	9	45.0	7	43.8	22	44.0
Sexual behaviors								
Casual or 1-time sex partner (past 14 d)	6	42.9	8	40.0	9	56.3	23	46.0
Unprotected sex with HIV-negative/unknown (14 d)	4	28.6	5	25.0	2	12.5	11	22.0
Web-survey retention, wk								
2	13	92.9	17	85.0	16	100	46	92.0
4	13	92.9	16	80.0	15	93.8	44	88.0
6	11	78.6	13	65.0	14	87.5	38	76.0
Qualitative interview retention, wk								
2	13	92.9	17	85.0	11	68.8	41	82.0
4	12	85.7	12	60.0	9	56.3	33	66.0
6	6	42.9	6	30.0	4	25.0	16	32.0

\*Overall N = 49 due to missing information for 1 participant.

†Group A (Latin/Native American, Latin/Safartio); group B (Latin/Native American, French/Spanish-Indian).

‡Denominator only includes those who responded to the question.

involves working from the data to identify key themes or descriptive codes and subthemes within the data.<sup>44</sup> The lead author and RA initially reviewed the data and generated 3 primary codes: (1) benefits related to increased awareness of behaviors, states, or their associations; (2) benefits related to supporting behavior change, broadly categorized to include initiating, maintaining, or adhering to healthy behaviors<sup>18</sup>; and (3) barriers or concerns around smartphone and Web-based self-monitoring. Two other RAs then coded the data independently,

with the lead author reviewing results, clarifying constructs, and developing code trees for subsequent rounds of coding. After each round of coding, grounded themes were compared with common and complementary behavior change theory constructs from an integrative framework.<sup>45</sup> Theories include Social Cognitive Theory (SCT),<sup>9</sup> the Health Belief Model (HBM),<sup>46</sup> the Theory of Planned Behavior and Reasoned Action (TPB/TRA),<sup>47</sup> the Trans-theoretical Model (TTM)<sup>48</sup> and the related Precaution Adoption Process Model (PAPM),<sup>49</sup> and the

Information, Motivation, Behavioral Skills meta-theory (IMB).<sup>47</sup> In addition, an independent pathway of benefits emerged from the data regarding self-expressive functions of self-monitoring as having a therapeutic benefit, which was referenced by participants in relation to journaling, diary keeping, and their cathartic effects (eg, “venting”) through functions, such as expressive writing<sup>50</sup> and nonjudgmental disclosure.<sup>51</sup> These theories guided coding in subsequent rounds to elaborate the theoretical model on the mechanisms, mediators, and potential impacts of self-monitoring. Figure 1 shows the theoretical model, which is further discussed in reference to participants’ responses in the results below.

The 2 higher order outcome codes of perceived self-monitoring benefits for improving awareness and supporting behavior change were confirmed through comparison with the behavioral activation subcodes of precontemplation and contemplation for awareness, and maintenance, action, and preparing/decided to act for change. Inter-rater reliability between the 2 independent RA coders on these outcome codes was calculated using Cohen kappa and range from 0.41 to 0.79, corresponding to agreement rates of 82%–100%, indicating moderate to good agreement.<sup>44</sup> The lowest agreement rates were for middle categories of contemplation and preparing/deciding to act, whereas the rest of the categories were at 90% or higher agreement. Exploratory aims around hypothesized variability in perceived benefits across study arms were assessed by examining proportions of participants reporting awareness and change benefits for each domain of medication adherence, mental health, ATOD use and sexual behavior, and for general nonspecific references. These data were also integrated<sup>52</sup> with the corresponding goal and support response data to explore their potential associations in cross tabulations.

## RESULTS

Over a 9-month recruitment period, 126 calls were received and 118 individuals screened, with 53 eligible and 50 consented and enrolled into the study. Table 1 presents baseline information on key demographic variables, medication adherence, mental health symptoms, substance use, sexual risk behaviors, and assessment retention. The majority of participants were male, gay, or bisexual, with an average age in the mid 40s. The sample was diverse in ethnicity (about 50% African American and 25% Latino) and education level. Most participants (about 80%) taking ART reported >90% adherence rates. About 58% of participants reported 5+ days experiencing anxiety symptoms in the 14 days before baseline, and 44% reported 5+ days of depressive symptoms. Past 14-day use of alcohol, marijuana, and tobacco were common, whereas use of other drugs was modest (see Table 1). About one quarter of participants reported unprotected sexual intercourse with HIV-negative or unknown status partners in the prior 14 days.

The 3 study groups were fairly well balanced across demographic and risk factors, although the randomization was not perfectly balanced due to small sample size and balancing points in randomization lists. Web-survey completion rates were high, around 90% except for the final follow-up (76%).

Group B (behavior change framed, mobile phone) had lowest follow-up rates, but this is also the result of 3 participants being lost to follow-up during the first week of the study (and phones not returned); excluding these participants makes follow-up rates more similar to other groups. Qualitative follow-up interview participation rates were lower than Web-survey rates, particularly for group C (Web-survey only, control). Completion rates for mobile phone surveys in groups A and B are reported in a prior publication,<sup>38</sup> but in general, were modest with an average of 7–10 days of reporting per 2-week reporting periods for each domain, and about 90% completing 2 weeks, 74% 4 weeks, and 50% completing 6 weeks of smartphone self-monitoring.

Figure 1 presents the theoretical framework that emerged from the data in conjunction with iterative comparisons to an integrative theoretical model for behavior change.<sup>45</sup> The model specifically focuses on elaborating constructs related to self-monitoring mechanisms, their mediators, and outcomes of activation states and well-being embedded in participants’ responses. The arrows in Figure 1 suggest potential relationships between the specific theoretical constructs as elaborated below, although not every construct in the model is directly referenced in participant responses. Representative responses on the general functioning and benefits of self-monitoring are presented in the following narrative. More specific responses referring to medication adherence, mental health, ATOD use, and sexual risk behaviors are presented in Tables 2 and 3, and discussed below in terms of potential variability across domains for self-monitoring functions, mechanisms, and outcomes.

The primary outcomes outlined in Figure 1 are Activation states, which refer to the “stages of change” in the TTM and Precaution Adoption Process Model, but reframed here to refer to behavioral activation rather than stages, in acknowledgment of the lack of evidence for impacts of stage-tailored interventions<sup>53,54</sup> and that people may move through multiple activation states with each behavior change challenge.<sup>54,55</sup> Self-monitoring mechanisms include processes of reflection, cues to action, reinforcement, and self-expression. Self-monitoring is posited to impact activation states indirectly through multiple theory-based mediators, and directly through cues or reminder functions, as elaborated below.

Reflection is a core element of MI and the linked TTM, which describe how reflective processes build self-awareness, concern or inspiration, reevaluation, and awareness of effects on social relationships. Observational learning from SCT is applied here to self-observation. These reflective processes are theorized to shift multiple theory-based mediator constructs, such as attitudes or perceived risks, benefits, and norms from the Health Belief Model (HBM); outcome expectancies from SCT; and self-efficacy or behavioral control beliefs from multiple theories. These perceptions and cognitions are posited to primarily influence precontemplation and contemplation of action, as well as intentions or motivations more closely linked to behaviors. For example, several participants mentioned self-reflective benefits of self-monitoring that indicated moving from an unengaged to engaged state of precontemplation of change:

Helps me check in with my behavior and think about it (group B; age: 59 years; female; Latino)

Makes you think about how you are living your life (group B; age: 38 years; male; white)

It made me think about what I'm doing. My behaviors (group C; age: 44 years; female; black)

Other participants' responses suggested benefits related to risk perceptions:

Made me more aware of my bad habits (group C; age: 46 years; transgender; white)

It's not often a person is forced to think about what they do and the possible consequences (group C; age: 58 years; male; black)

Self-monitoring also was reported to support contemplation for action:

Shows me what I need to work on in my life (group A; age: 51 years; female; black)

Helped me realize what I need to work on (group B; age: 31 years; male; Latino)

For some participants, self-monitoring was credited with supporting behavioral changes:

I started changing my behavior once I started taking the surveys—I have been thinking about it for a while but the surveys make me concentrate on certain areas of my life that I wasn't focusing on (group A; age: 52 years; male; black)

It's good for anyone to have as many opportunities as they can to self-reflect. It's beneficial. It can help you make better decisions (group C; age: 58 years; male; black)

Reinforcement or rewards from self-tracking is another self-monitoring function, which is posited to enhance motivations or intentions and skill mastery for action and maintenance. As 1 participant stated:

It's a reality check a couple times a day—it makes you look at the things you do and then makes you learn and change your behavior for next time. It's like a learning tool (group B; age: 38 years; male, white)

Cues to action (ie, reminders) in the HBM, and the related "stimulus control" construct in TTM, are posited to have direct impacts on behaviors, but are also dependent on having intentions and skills for the behavior. Some participants recognized benefits of these functions for the mobile phone surveys in particular, for example:

Surveys helped me be more in control and responsible in doing what I need to be doing—it gave me something to do every day... (group B; age 39 years; male; Native American)

Taking the surveys makes me more focused. Helps me concentrate on my health and stay aware (group A; age: 52 years; male; black)

Self-expression through journaling and nonjudgmental disclosure is another set of related self-monitoring functions noted by participants, and supported by theory and research.<sup>50,51</sup> Self-expression functions are theorized to provide opportunities for catharsis and to mimic elements of social support and therapeutic relationships, such as nonjudgment and confidentiality, as outlined at bottom of Figure 1. For example, in regards to journaling, 1 participant noted succinctly:

Writing about my habits keeps me from doing the bad habits (group C; age: 33 years; male; Latino)

Others noted nonjudgment and aspects of social support:

Makes a difference feeling like I have someone to talk to—I feel like I can tell the researchers anything and they won't shun me (group B; age: 41 years; female; white)

Don't feel judged on cell phone... More truthful because you are talking to a machine rather than speaking to a live person (group A; age: 38 years; male; Latino)

The majority of responses on these self-expressive functions and benefits are noted in reference to mental health-related therapeutic benefits for general well-being, detailed in Table 2 and discussed below.

## Domain-Specific Results: Adherence, Mental Health, ATOD Use, and Sexual Behaviors

Representative responses referring to specific domains of behavior change are shown in Tables 2 and 3, including codes for functions, mediators, and outcomes of activation states and well-being. Table 2 presents results for health-related domains of medication adherence and mental health. Table 3 presents results for risk behaviors of ATOD use and sexual behaviors. Results are discussed below in terms of potential variability in functions, mediators, and outcomes for each domain.

Results presented in Table 2 suggest that trends in responses for benefits of self-monitoring specific to medication adherence are primarily linked to the reminder functions of the surveys and their alarms (ie, cues to action) as well as reinforcement of habits or routines. Reflective processes also supported a few participants in recognizing the extent of missed doses and lack of routines for adherence, although the majority of responses refer to maintenance of adherence due to the large proportion of adherent participants in the sample.

Responses regarding mental health (ie, mood, stress) are further illustrated in Table 2. Responses suggest impacts on precontemplation and contemplation states based on reflective processes, similar to other outcome domains. In



**TABLE 2.** Perceived Benefits of Self-Monitoring for Health: Medication Adherence and Mental Health

	Self-Monitoring Mechanism	Mediators	Outcomes
<b>Medication adherence</b>			
I realized that I don't actually have a set schedule for my meds (31, male, Latino, B)	Reflection—self-awareness		Contemplation
Helped me think about how many times I actually miss my medication—I never thought about it before (50, male, white, C)	Reflection—self-awareness	Perceptions—susceptibility	Precontemplation
Reminds me to take my meds. (39, male, Native American, B)	Cues to action		Maintenance
Reminds me to take my meds, and helps me keep my medicines in order. (56, male, white, A)	Cues to action, reinforcement		Maintenance
The alarm reminded me to take my medication on time—I am now accustomed to taking it at that time every day. (40, male, black, B)	Cues to action, reinforcement		Maintenance
Got me into a better routine with my medicine. (34, male, Latino, B)	Reinforcement		Maintenance
Helped me not miss my medicine (61, male, black, C)	Cues to action		Maintenance
Made me more adherent to my medications (46, not reported, white, C)	Reinforcement		Maintenance
<b>Mental health</b>			
Helped me realize my emotional state and my sleep patterns (23, male, black, B)	Reflection—self-awareness		Precontemplation
The survey questions aren't questions that you would ask yourself or even talk about with friends- so it really makes you think about things (ie, mood, sexual behavior) (52, male, black, A)	Reflection—self-awareness		Precontemplation
Mood questions got me to reflect on my various moods throughout the past 2 wk (60, male, white, C)	Reflection—self-awareness		Precontemplation
Helped me realize exactly what I am stressing about and what I need to work on (31, male, Latino, B)	Reflection—inspiration	Intentions	Contemplation
Liked general feeling surveys—recently started seeing a psychiatrist and started taking medication so it was helpful to keep track of my mood (depression, energy levels). The surveys helped me keep track of how I was getting better each day (40, male, Latino, A)	Reinforcement—self-reward		Maintenance
Acts like a diary—can express myself when I'm feeling down, can express myself, and write down my emotions which helps calms me down (38, male, Latino, A)	Self-expression	Catharsis	Well-being
Sometimes you don't say everything to your therapist and it helps to write down how you are feeling—not to get feedback, but it just feels good to let it out (38, male, Latino, A)	Self-expression	Nonjudgmental, Catharsis	Well-being
Helpful to get things off my chest when I'm stressed—something to talk to (47, transgender, black, A)	Self-expression	Catharsis	Well-being
Therapeutic—I can express how I feel at that moment (49, male, Latino, B)	Self-expression, in-the-moment	Catharsis	Well-being
Felt like I could talk freely- like having a therapist (41, female, white, B)	Self-expression	Nonjudgmental	Well-being
I feel free to vent to the phone about things that I can't talk to my partner about—I can really express how I feel (30, male, black, B)	Self-expression	Catharsis, Nonjudgmental	Well-being

addition, general well-being was reported to be supported by self-expression for catharsis (eg, “venting”) and other aspects of therapeutic relationship processes, such as nonjudgmental disclosure (eg, “something to talk to”). One participant also referred to self-monitoring being beneficial in reinforcing progress made from recent initiation of treatment with a psychiatrist (Table 2).

Results presented in Table 3 illustrate self-monitoring benefits noted by participants in reference to risk behaviors. Themes regarding perceived benefits of self-monitoring for ATOD use tended to focus either on reflective processes for risk perceptions and contemplation of change, or on reinforcement and cue functions for maintenance (eg, “keeping in

check”). A few participants also noted how self-monitoring multiple domains increased their awareness of the relationships between their substance use, sexual behaviors, and other triggers (eg, boredom, thinking about illness).

Themes regarding sexual behavior illustrated in Table 3 also centered on impacts of self-monitoring on condom use, reducing numbers of partners, and disclosure and discussions of STI status. Self-monitoring functions included reflective processes for altering risk perceptions, intentions, and contemplating decisions for action. Participants also noted that self-monitoring functioned as a reminder cue for taking action to reduce risks and as reinforcement through self-reward by tracking progress after initiating change (Table 3).

**TABLE 3.** Perceived Benefits of Self-Monitoring for Risk Behaviors: Alcohol, Tobacco, Drugs, and Sexual Behaviors

	Self-Monitoring Mechanism	Mediators	Outcomes
<b>ATOD use</b>			
I saw that when I got bored, wasn't feeling healthy, or when I think about my illness, it triggers me to do drugs (49, male, black, A)	Reflection—self-awareness	Perceptions—susceptibility	Contemplation
Made me start thinking about my actions—cutting down on drinking and smoking weed (44, female, black, C)	Reflection—concern	Intentions	Contemplation
Made me take a closer look at my drug usage and my desire to stop (50, male, black, C)	Reflection—concern	Intentions	Contemplation
I realized how much I was smoking and that I need to quit (31, male, Latino, B)	Reflection—inspiration	Intentions	Contemplation
Helps me look at my behavior and think about what I should keep doing to stay clean (33, male, Latino, C)	Reinforcement, reflection	Intentions	Maintenance
Helps me stay on track with not smoking (52, male, black, A)	Reinforcement	Intentions	Maintenance
Keeps me in check and helps me think about not drinking alcohol (61, male, black, A)	Reinforcement, cues to action	Intentions	Maintenance
Keeps me in check, monitoring sexual encounters and drug activities (38, male, Latino, A)	Reinforcement		Maintenance
Made me think about not drinking and taking my medicine at the same time (44, female, black, C)	Reflection—reevaluation	Intentions	Contemplation
Helped me realize that we usually smoke weed to get intimate (31, male, Latino, B)	Environmental reevaluation	Intentions	Precontemplation
<b>Sexual Behaviors</b>			
Make me think about my actions with my partner to be safe or not (61, male, black, C)	Reflection	Intentions	Contemplation
Now I have to reflect on my behavior and possibly make better decisions, specifically about being conscious about being safe with protection (58, male, black, C)	Reflection—self-awareness, concern/inspiration	Perceptions, intentions	Contemplation
Opened my eyes in terms of speaking up about STD status (31, male, Latino, B)	Reflection—reevaluation	Intentions	Preparation
More open with partner about my STD status (31, male, Latino, B)			Action
Reminds me to ask the questions about safe sex and find out the status of my partner (61, male, black, C)	Cues to action		Action
Useful for helping me stop my sexual activity—I want to be single for now (44, female, black, C)	Reinforcement	Intentions	Action
I talked to my boyfriend about safe sex after taking the survey (26, male, black, C)			Action
I saw my own track record. I didn't realize how many people I was sleeping with until I saw the numbers in front of me. By the end of the study, my number was down (40, male, black, B)	Reflection—concern; Reinforcement—Self-reward	Perceptions—severity	Action

### Benefits of Daily Smartphone Self-Monitoring Versus Biweekly Web Surveys

Participants' responses also suggested potential for greater benefits from daily smartphone self-monitoring compared with biweekly Web surveys alone. In general, participants in group C (biweekly, Web only) reported fewer benefits when queried about useful aspects of completing surveys, and those reports tended to be less elaborate and centered around reflective processes, as shown in responses in Tables 2 and 3. In addition, a few participants noted benefits specific to daily mobile self-monitoring related to in-the-moment availability and daily routines:

Cell phone is more helpful than the Web survey at keeping me on track because it's always there (group B; age: 39 years; male; Native American)

The surveys are time sensitive so I can say how I feel in a particular moment of the day (group A; age: 51 years; female; black)

Helps me keep a "log," like therapy—but can do it every day instead of waiting for a week to see your therapist... Nice to do it throughout the day, multiple times a day, on a daily basis. Life happens daily—not weekly like when you see a therapist (group A; age: 38 years; male; Latino)

The proportions of mobile phone groups' (A and B) participants reporting awareness and change benefits was about twice that of biweekly only group (C) for all domains except sexual behaviors. Among mobile phone group participants, about two-thirds reported awareness benefits and roughly a quarter reported change benefits compared with the biweekly group C with about one quarter reporting awareness benefits and only a few participants reporting change for ATOD use only and none for adherence or mental health. General proportion estimates are used here due to limitations of the data related to small sample sizes, variable retention rates and numbers of repeat assessment, as well as

variability in proportion calculations depending on different assumptions around missing data (ie, represents participants disengagement so can be included in denominator, or was not probed extensively in open-ended interviews).

Study groups were similar in sexual behavior awareness benefits reported (about 40% of participants) but behavior change benefits were reported by about half as many mobile group participants as biweekly group participants (about 15% compared with 30%). The groups had similar proportions of participants reporting sexual risk reduction goals (about 60%) and about one-third reporting supports. These results should be interpreted with caution but suggest the possibility that sexual risk self-management does not benefit more from daily compared with biweekly self-monitoring, and possibly that the lack of benefits in other domains for biweekly Web-survey only participants (group C) made the perceived benefits around sexual behaviors more salient for reporting. Again, there were no statistically significant impacts on standardized self-report outcome measures so these results only suggest hypotheses for further testing.

Proportions of participants reporting goals and supports did not vary across groups for mental health, ATOD use, or medication adherence. Almost all, about 90% of participants, reported goals for mental health and ATOD use, with about two-thirds reporting support for mental health and just under half for ATOD use. Less than half, about 40%, reported goals for medication adherence and about one quarter reported support. Exploratory examination of associations between reports of having goals and reports of benefits from self-monitoring had some trends for higher proportions of reports of self-monitoring benefits when goals were reported, but none were statistically significant, except for sexual behavior change benefits reported by 28% with goals versus 0% without (Fisher exact test  $P = 0.037$ ). Again, results should be interpreted as exploratory due to the many limitations of these data. Participants reporting having support for goals (professional or social) tended to report benefits from self-monitoring less frequently than those without support, suggesting that self-monitoring may compensate for lack of social support, although none of the associations were statistically significant.

### Negative Feedback on Self-Monitoring

Participants identified a number of negative qualities of the surveys, such as being repetitive, too long, confusing, and intrusive. About one-third of participants described the surveys as “repetitive,” “redundant,” “monotonous,” or “tedious,” including participants in the biweekly Web-survey only group. About one quarter of participants reported that surveys were too long or too frequent, with all but 1 participant being from the mobile phone groups. Some participants suggested improvements, for example:

I like it, but I wish it was more than the same questions every day (group A; age: 61 years; male; black)

About 20% of participants across the 3 study groups reported that the surveys were intrusive or were concerned

about privacy, primarily around the sexual behavior surveys and the detailed partner-level reports. In 1 extreme example, likely in reference to geolocation tagging of phone survey responses, 1 participant responded:

I felt like a wild animal being tracked (group A; age: 47 years; male; Latino/Native American)

This response emphasizes the importance of privacy protections around mobile technologies (participants were trained to use the application settings to turn off geolocation if they wished). Only 5 participants (about 10%) stated that the self-monitoring questions were confusing or reported technical challenges, and none were in the Web-survey only group. Four participants requested more in-depth questions to better reflect their experiences.

### DISCUSSION

This article makes a modest but novel contribution to elaborating the potential efficacy and causal mechanisms of self-monitoring to support self-management generally, and specifically for multiple domains for PLH. The results of this pilot study illustrate how the multiple self-monitoring functions of reflection, reinforcement, and cues to action can influence risk perceptions, motivations, and skills to support behavioral activation states ranging from contemplation to action and maintenance. Participants also described how self-monitoring functioned for self-expression to provide opportunities for catharsis through journaling, aspects of social support from nonjudgmental disclosure, and in-the-moment availability, to improve their sense of well-being. The latter result was surprising given the brief text responses supported by the smartphone application, as opposed to longer narrative writing processes identified in prior research.<sup>50</sup> Participants’ feedback suggests that the frequency and in-the-moment nature of the brief text-based responses may account for their potential impacts. Results also suggest that perceived benefits from self-monitoring were greater for daily mobile phone monitoring compared with biweekly self-monitoring alone, which is consistent with some prior process research on assessment effects in ATOD abuse intervention studies.<sup>23</sup> The exploratory results of this pilot study also suggest moderating effects of having goals or supports on impacts of self-monitoring, similar to prior studies’ findings on motivations and risk perceptions<sup>36,37</sup>; however, this result could also be explained by those with goals simply being more aware of self-monitoring benefits. Much more rigorous research is needed to test the hypotheses suggested by the results of this study around self-monitoring frequency, intensity, duration, and sustainability, and efficacy as both an independent intervention and as an adjunct to other interventions.

The results of this pilot study should be interpreted with caution given the many limitations of these data. The small sample size made statistical analyses for group comparisons infeasible. The specificity of quantitative estimates across study groups was also limited by small

sample sizes, varying and low retention rates for the qualitative interviews, uncertain assumptions about missing data, and some degree of uneven randomization. Open-ended reports were brief, and participants were not prompted to elaborate their responses, which suggests the salience of the perceived benefits reported but also likely under-identified the frequency of themes reported and more specific details of self-monitoring functions and mediators on outcomes. In addition, some of the specific constructs and pathways suggested in the theoretical model may not be fully represented in participants' brief responses with limited prompting for elaboration. Only about one-third of participants completed the qualitative interview at 6-week follow-up compared with about 3 quarters completing the Web survey. This limitation presents further bias in the qualitative data, and so more detailed analyses of longitudinal trends were not viable. Similarly, only half of the mobile phone groups' participants completed 6 weeks of daily self-monitoring, indicating the burden and burnout suggested by negative feedback in this study about long, detailed, and frequent self-monitoring. Follow-up periods longer than 6 weeks are warranted for many real-world applications such as between clinical visits yet prior research has found that even 2 weeks of daily self-monitoring results in improved ART adherence at 3-month postassessment, similar to a single session intervention comparison.<sup>33</sup> Future research and application of self-monitoring for self-management support should anticipate patients engaging in several weeks of daily self-monitoring interspersed with longer periods of weekly self-monitoring, for example. Patients engaged in more intensive behavioral interventions with weekly visits might be more open to, or better served by, daily self-monitoring, particularly when first initiating behavior changes.

Although self-monitoring has long been noted as a key self-management strategy,<sup>10</sup> it is rarely highlighted in reviews of the self-management literature generally<sup>2,3,15,56</sup> nor for HIV specifically.<sup>1</sup> Similarly, Social Cognitive Theory<sup>9</sup> notes self-monitoring as a primary self-regulation strategy, in addition to self-efficacy, and yet it seems that most interventions emphasize targeting self-efficacy and perhaps assume that self-monitoring functions sufficiently as a passive and internal process. This trend also runs parallel to the emphasis on the stages of change in the TTM while there is relatively little attention paid to the TTM's 10 processes of change,<sup>48</sup> which are primarily self-reflexive and are incorporated into to the theoretical model in this article. Despite longstanding theoretical emphasis, self-monitoring as a more actively engaged self-management tool has not been consistently incorporated into interventions for PLH. For example, the Los Angeles County Department of Public Health, Division of HIV/STD Programs recently funded medical care coordination (MCC) programs (ie, patient-centered medical homes) in HIV treatment settings, based on a model arising from work in San Francisco.<sup>57</sup> The primary goal of MCC is supporting patients to achieve a "self-managed" state for medical adherence, sexual risks, mental health, and substance abuse by incorporating brief behavioral interventions into clinical care teams.<sup>57</sup> Although MCC emphasizes monitoring by care

providers at quarterly or semiannual visits, and the use of assessments for brief motivational interviewing, patient self-monitoring is not noted in the MCC protocol, consistent with much of the literature on self-management.<sup>3,15</sup> Research in progress with MCC providers in Los Angeles has identified that a key challenge is patients' lack of participation in self-management activities between clinical and behavioral intervention visits.

Most self-management interventions for PLH focus on increasing patients' knowledge, self-efficacy, and self-management skills by providing feedback, problem-solving support, and achievable goal setting.<sup>1</sup> Self-monitoring potentially complements these strategies by accelerating and reinforcing their effects. Mobile phone applications offer novel opportunities to engage patients in self-monitoring and self-management between clinical visits, in real-time and during daily routines. A key challenge will be making self-monitoring applications engaging for patients and making data useful for providers, to maximize benefits of the data provided by patients. Although self-monitoring is not a new concept, mobile phones are enabling self-monitoring at a scale and level of engagement that warrants further investigation as both an independent intervention and an intervention adjunct.

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