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Calendaring and Alarms Can Improve Naturalistic Time-based Prospective Memory for Youth Infected with HIV

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Abstract

Individuals with HIV disease often evidence deficits in prospective memory (PM), which interfere with daily functioning and increase the risk of suboptimal health behaviors. This study examined the benefits of simple encoding and cueing supports on naturalistic time-based PM in 47 HIV-positive young adults. All participants completed a naturalistic time-based PM task in which they were instructed to text the examiner once per day for seven days at a specified time. Participants were randomized into (1) a Calendaring condition in which they created a calendar event in their mobile telephone for the specified texting time; (2) an Alarm condition in which they programmed an alarm into their mobile telephone for the specified texting time; (3) a Combined calendaring and alarm condition; and (4) a Control condition. Participants in the Combined condition demonstrated significantly better naturalistic PM performance than participants in the Control and Calendaring conditions. Findings indicate that HIV-positive youth may benefit from a combined calendaring and alarm supportive strategy for successful execution of future intentions in daily life.

Keywords

Infectious disease; neuropsychological rehabilitation; episodic memory; cue salience; AIDS dementia complex

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Introduction

Individuals with HIV commonly endorse failures of prospective memory (PM), or "remembering to remember," in their daily lives (Woods et al., 2007), and demonstrate mild-to-moderate impairments on laboratory-based measures of PM (Carey et al., 2006; Martin et al., 2007). PM is a complex cognitive process in which an intention (e.g., I will take my medication) is paired with a cue, which can be time-based (e.g., taking medication at 2 pm) or event-based (e.g., taking medication when an alarm rings, or when experiencing migraine symptoms). Once individuals have learned the cue-intention pairing, they must monitor the environment for the cue during a delay interval in which they are engaging in ongoing activities that preclude overt rehearsal (e.g., normal daily activities). During the delay interval, time- and event-based tasks require slightly different cognitive processes for proper cue detection, with time-based tasks being more reliant on strategic, self-initiated cognitive processes than event-based tasks, which are thought to be more reliant on spontaneous/automatic processes (Einstein & McDaniel, 2005). Once the target cue has been encountered and identified, individuals must recall the paired action and execute it properly (Kliegel et al., 2008).

PM has great relevance for a myriad of real-world and health-related outcomes in HIV disease. At the level of real-world outcomes, HIV-associated deficits in PM are related to higher rates of unemployment (Woods et al., 2011) and increased dependence on others for completing instrumental activities of daily living (Woods et al., 2008a). Common health-related examples of PM include attending prescheduled medical appointments, adhering to medication regimens, and refilling prescriptions before running out. Thus, PM deficits confer greater risk of suboptimal adherence to antiretroviral medications (Woods et al., 2009), which in turn predicts poorer health-related outcomes, including viremia (Catz et al., 2000), development of viral resistance (Bangsberg, Kroetz, & Deeks, 2007; Harrigan et al., 2005), and disease progression (Bangsberg et al., 2001).

Suboptimal adherence is also associated with greater risk of viral transmission (e.g., Cohen et al., 2011). As young adults living with HIV disease are particularly susceptible to suboptimal adherence (Murphy et al., 2003; see Reisner et al., 2009 for a review), and are at higher risk for engaging in risky sexual behaviors per the typical developmental trajectory of adolescence and adulthood (e.g., Battles & Wiener, 2002), it is worthwhile to consider the profile of HIV-associated deficits in PM with an eye toward developing effective interventions that might improve both individual and public health-related outcomes. Individuals with HIV tend to evidence larger deficits in the strategic, as opposed to automatic, aspects of PM. Accordingly, HIV tends to be more strongly associated with deficits in time-based PM than event-based PM. For example, HIV-positive individuals show larger effect sizes for deficits in laboratory-based time-based PM compared to event-based PM (Martin et al., 2007; Zogg et al., 2011), and produce more errors on naturalistic time-based PM tasks (Woods et al., 2009). Individuals with HIV also show deficits in strategically demanding event-based PM tasks (e.g., Woods et al., 2010). HIV-associated PM deficits tend to reflect decrements in successful self-directed monitoring and cue detection; for example, HIV-positive individuals perform fewer clock checks during time-based PM tasks (Doyle et al., 2013), and perform worse over long delay intervals that are more strategically demanding (e.g., Loftus, 1971).

The reliable pattern of HIV-associated deficits in PM suggests that interventions designed to decrease reliance on self-directed monitoring could support PM for HIV-positive individuals. Reliance on self-monitoring in PM can be alleviated or supported by multiple methods, as demonstrated by three recent studies from our research group that have focused on event-based PM. The first study revealed that slowing the pace of a strategically demanding PM task improved PM accuracy among HIV-positive young adults by reducing the self-monitoring demands of the task (Loft et al., 2014). Another study demonstrated that instructions emphasizing the importance of the PM task compared to the ongoing task reduced the strategic demands of the PM task and improved PM accuracy among HIV-positive individuals with neurocognitive impairment and substance use disorders (Woods et al., 2014). In the third study, Faytell and colleagues (2015) found that brief visualization of successful PM performance at receipt of task instructions improved PM for HIV-positive participants with impairments in the strategic aspects of PM, suggesting that visualization reduced the strategic demands of the PM task.

External memory aids have also been used to decrease reliance on self-directed monitoring and thus bolster PM performance across numerous patient and healthy populations (e.g., Cicerone et al., 2005). Given the high frequency of mobile telephone use among young adults (e.g., Faulkner & Culwin, 2005; Fjeldsoe, Marshall, & Miller, 2009), the present study sought to investigate two supportive strategies for time-based PM that employ external memory aids available in most mobile telephones. The first strategy involved programming the mobile telephone alarm to function as a highly salient PM cue. Highly salient PM cues have perceptual characteristics that stand out against the surrounding environment, thus attracting attention more automatically and thereby reducing self-monitoring demands (e.g., Mahy, Moses, & Kliegel, 2014). Highly salient cues are associated with better PM performance among seronegative children (Kliegel et al., 2013; Mahy, Moses, & Kliegel, 2014), older adults (e.g., McDaniel et al., 1999), and individuals with Korsakoff's syndrome (e.g., Altgassen, Ariese, Wester, & Kessels, 2015), as well as HIV-positive populations (e.g., Garofalo et al., 2016). For example, Garofalo et al., (2016) conducted a randomized two-way personalized daily text messaging intervention over a six-month period with a sample of 105 poorly adherent HIV-positive adolescents and young adults. On average, participants who received the daily text messaging intervention were more than twice as likely to reach ≥90 percent adherence over the six-month study trial, and to maintain ≥90 percent adherence over the six-month post-intervention follow-up period (OR=2.12; Garofalo et al., 2016). Notably, highly salient cueing does not require personalization or content related to the PM task to be effective. For example, one study trained 20 participants with brain injury and impaired PM to connect the cue phrase "STOP!" with pausing current activities to review their intentions (Fish et al., 2007). Later, when participants were administered a 10-day telephone PM task (in which they were instructed to place calls to a voicemail service four specified times daily for 10 consecutive days), PM was significantly better on the days that participants received the highly salient "STOP!" text messages.

The second supportive strategy employed the calendaring function of the mobile telephone to bolster PM performance. Manual calendaring has been implemented as one of the strategies employed by Compensatory Cognitive Training (CCT; Twamley et al., 2012) and Cognitive Symptom Management and Rehabilitation Therapy (CogSMART; Twamley et al., 2015), interventions designed to support PM and other cognitive domains for individuals with schizophrenia (e.g., Twamley et al., 2012) and traumatic brain injury (e.g., Twamley et al., 2015). Such manualized interventions have been associated with improved PM performance in these clinical populations (e.g., Twamley et al., 2012; Twamley et al., 2015). Electronic calendaring has also been used to support PM. One example is the use of Google Calendar, which a recent study found to be more effective for supporting PM than a standard diary among 12 adults with acquired brain injury (McDonald et al., 2011). The Google Calendar intervention was also rated as more popular by the participants than the standard diary. However, the prior study permitted the use of Google Calendar's active reminders, which are highly salient cues that reduce need for self-directed monitoring. Thus, it is unclear whether the benefit of Google Calendar use in the study was due to the calendaring or cueing elements, or both. The current study therefore sought to compare the effectiveness of electronic calendaring and salient alarm cues for naturalistic time-based PM performance among young adults with HIV infection. Given the findings of the prior literature, our general prediction was that use of one or both strategies would improve PM compared to the control condition. We also predicted there would be a stair-step effect of condition, such that the combined alarm and calendaring condition would improve PM over either condition alone.

Method

Participants

This study was approved by the human research protections programs at Wayne State University and at the University of California, San Diego. The eligible sample was comprised of 47 young adults (age range: 19 – 24 years) with HIV infection recruited from urban HIV clinics in Detroit (n=30) and San Diego (n=17). The sample was a subset of study participants described in detail elsewhere (e.g., Faytell et al., 2015; Loft et al., 2014; Woods et al., 2014), but the naturalistic PM alarm/calendar intervention data have not heretofore been reported. Inclusion criteria for the sample included diagnosis of HIV infection, the ability to provide consent on the day of the study evaluation, and current possession of a mobile telephone. HIV serostatus was confirmed via chart review. We excluded potential participants with psychotic disorders or neurological conditions that negatively affect cognition (e.g., seizure disorder, traumatic brain injury with loss of consciousness greater than 15 minutes). Potential participants with estimated verbal IQ scores below 70 (based on the Wechsler Test of Adult Reading [WTAR]; Psychological Corporation, 2001) were also excluded. All participants were randomized into one of four conditions: Control (n=14), Calendaring (n=9), Alarm (n=11), or Combined (n=13). Descriptive clinicodemographic characteristics of the study participants are presented by condition in Table 1.

Materials and Procedure

After obtaining written informed consent, we administered a semi-structured clinical interview to gather relevant clinicodemographic information, a brief neurocognitive battery (see Faytell et al., 2015), and a series of questionnaires to assess participant self-ratings of busyness, adherence to routine, mood, substance use, and cognitive complaints (see below). HIV infection and treatment variables were obtained from clinic medical records.

Naturalistic PM Experiment

Participants were assigned a naturalistic time-based PM task at the beginning of the study evaluation. All participants were prescribed the intention to text the examiner the number of hours they slept the previous night, once per day for seven days at a pre-specified time. Participants in the Control condition received only these instructions. Participants in the Calendaring-alone condition created a daily entry in their mobile telephone calendars for the correct dates and time of the prescribed intention, along with text that displayed task instructions (e.g., “text examiner # of hours slept”). All future calendar event notifications were disabled during the creation of daily entries to avoid confluence with the Alarm-alone intervention. Additionally, participants were not required or reminded at any point to check their mobile telephone calendars at a future date. Thus, the format of the Calendaring-alone intervention was categorized as encoding-only. Participants were permitted to choose the calendaring applications, provided that the application included: (1) the ability to program a daily calendar entry as described above; and (2) the ability to disable calendar alerts associated with the programmed entries. Participants in the Alarm-alone condition programmed a daily alarm in their mobile telephone alarm applications for the correct dates and time of the intended action, but they were not allowed to include any text with instructions (i.e., alarms were content-free). Alarms were programmed to ring until silenced at the intended time for each date. Participants were also permitted to select the alarm applications, provided that the application permitted users to program daily alarms as described above. The sound and volume of alarms were selected by the participants. Finally, participants in the Combined calendaring and alarm condition worked with the examiner to program both a calendar event and an alarm into their mobile telephone in the same formats described above. Thus, the Combined condition was comprised of an encoding intervention (i.e., Calendaring) followed by content-free cueing (i.e., Alarm) during the delay interval. All participants in the Calendaring, Alarm, and Combined conditions received examiner support as needed and successfully completed the assigned task prior to leaving the experimental session.

The range of potential naturalistic time-based PM texts for the weeklong experimental period was 0 to 7. Consistent with other clinical and laboratory-based PM tasks (e.g., the Memory for Intentions Screening Test; Raskin et al., 2010), we coded these responses using a 3-point system that ranged from 0 to 2. Participants were awarded 2 points if they sent the text at the correct time (i.e., ± 30-min of target), 1 point if they either sent the text at the wrong time or completed another action (e.g., called the examiner) at the correct time, and 0 points if they did not text the examiner (or performed another action at the wrong time). Thus, the total range of possible scores was 0 to 14, with higher scores indicating better naturalistic time-based PM performance. We also coded scores of 1 and 0 for specific error types in a manner consistent with our prior studies (e.g., Woods et al., 2008b) in order to better understand the nature of any observed PM failures. Relevant error types for this study included omissions (i.e., no response), task substitutions (e.g., calling instead of texting), and loss of time errors (i.e., texting the examiner outside of the 30-minute window). Errors were coded as either present or absent for each day, so the range of possible scores was 0–7 for each error type, with higher values representing a greater number of failures.

Prospective Memory Ability

All participants completed the research version of the Memory for Intentions Screening Test (MIST; Raskin et al., 2010; Woods et al., 2008b), a standardized performance-based measure in which participants are prescribed four time-based and four event-based PM tasks over approximately 30 minutes, during which time they are engaged in a word-search puzzle that serves as an ongoing distractor task. Tasks are balanced across delay intervals (i.e., two-minute or 15-minute delay) and response modalities (i.e., verbal or physical). The MIST provides a summary score that ranges from 0 to 48, with higher scores reflecting better PM ability (see Woods et al., 2008b). Among HIV-positive samples, performance on the MIST is associated with validated clinical measures of retrospective memory and executive functions (e.g., Carey et al., 2006). Poor performance on the MIST predicts employment status (e.g., Woods et al., 2011) and non-adherence to antiretroviral medications (e.g., Woods et al., 2009), and is associated with increased risk of dependence on others for completing activities of daily living (e.g., Woods et al., 2008a).

Assessment of Neuropsychiatric Symptoms

Participants also completed the Brief Symptom Inventory-18 (BSI-18; Derogatis, 1993), and the Alcohol, Smoking, and Substance Involvement Screening Test (ASSIST; World Health Organization, 2002) as a brief neuropsychiatric assessment. Comprised of 18 items, the BSI-18 is a short self-report questionnaire that assesses general psychological distress (Meijer, de Vries, & van Bruggen, 2011). The BSI-18 provides three subscale scores (i.e., somatization, depression, and anxiety) as well as a Global Severity Index score. The ASSIST is another brief screening questionnaire comprised of eight questions that evaluate the frequency of use and associated problems for each of ten substances: tobacco, alcohol, cannabis, amphetamine-type stimulants, cocaine, sedatives, opiates, inhalants, hallucinogens, and ‘other drugs.’

Data Analysis

We employed a prospective, four-group randomized control design to compare the effects of brief planning and cueing interventions on performance on a naturalistic time-based PM task. The four study groups were Control, Calendaring, Alarm, and Combined. Despite the randomization procedure, the four study groups differed significantly on self-reported depression and anxiety, nadir and current CD4 T-cell counts, and AIDS status (*p*s $< .05$; see Table 1). To determine whether these group differences should be included as covariates, we evaluated their relationships with naturalistic time-based PM performance across the entire study sample. None of these potentially confounding variables were significantly associated with naturalistic time-based PM performance (all *ps*$>.05$). Thus, no covariates were included in our statistical models. Given the non-normal distribution of the PM outcome ($W=0.74$,

p<.0001), we used simple between-subjects (nonparametric) Wilcoxon rank sums tests to compare naturalistic time-based PM performance across the study conditions. To compare frequencies of error types (i.e., omissions, loss of time, and task substitutions), we used omnibus between-subjects Wilcoxon rank sum tests. Individual group differences were then examined with planned post hoc nonparametric comparisons for all pairs using the Steel-Dwass method. The critical alpha was set at .05 and effect sizes were estimated using Cohen's *d*. We also used nonparametric (Spearman ρ) correlational analyses to compare naturalistic time-based PM performance to the MIST summary score across experimental conditions. All analyses were run with JMP (Jones & Sall, 2011) software.

Results

Overall Naturalistic Time-based PM Performance

Figure 1 displays the naturalistic time-based PM scores across the four conditions. Using an omnibus Wilcoxon rank sum test, we observed an overall effect of experimental condition on PM performance (χ^2=7.91, p=.048). One-way individual paired Wilcoxon rank sum tests revealed a significant positive benefit of the Combined condition for PM compared to the Control condition (χ^2=6.01, p=.0142, d=1.2). The Combined condition also conferred a trend towards superior performance for PM compared to Calendaring alone (χ^2=3.43, p=.0641, d=1.1). PM performance in the Combined conditions was not significantly different from PM in the Alarm condition (p=.261, d=.51). The Alarm condition conferred a trend towards superior performance compared to Controls (χ^2=2.94, p=.0862, d=1.1) but not compared to Calendaring (p=.286). PM performance did not differ significantly between the Calendaring and Control conditions (p=.575).

Frequency of Naturalistic PM Error Types

Figure 2 displays the frequencies of error types across the four conditions. We observed an overall effect of experimental condition on the frequency of omissions (χ^2=9.33, p=.025). Planned post hoc comparisons revealed a modest difference between the Combined condition and Controls (p=0.053) that was associated with a medium effect size (Cohen's d=.66). Specifically, participants in the Combined group made fewer PM errors than the Controls (See Figure 2). No other significant differences in PM error frequency were observed between conditions (all ps>.05). The overall effect of experimental condition on loss of time error frequency approached significance (p=.055); however, planned post hoc comparisons revealed no significant differences in loss of time error frequency between conditions (all ps>.1). No significant effect of experimental condition on error frequency was observed for task substitution errors (p=.868).

Laboratory-based PM as a Potential Correlate of Naturalistic Time-based PM

Taken together, the above-described pattern of findings appeared to indicate a main effect of cueing. Careful inspection of the data revealed relatively larger variances in PM performance in the Alarm-alone and Combined strategies. Based on results of prior studies in our lab (e.g., Faytell et al., 2015), we hypothesized that performance on a laboratory-based PM task (i.e., the MIST summary score) may account for some of these difference. To maximize the limited power of our data, we dichotomized our sample into Cueing (i.e., Alarm and

Combined; n=24) and Non-Cueing (i.e., Calendaring and Control; n=23) conditions. Thus, each group also included a subset of participants who received the Calendaring intervention. We then evaluated the MIST summary score as a potential covariate of naturalistic time-based PM performance across the Cueing and Non-Cueing conditions. No significant relationship was observed between the MIST summary score and naturalistic time-based PM within or across the Cueing and Non-Cueing conditions (all *p*s>.05).

Discussion

The profile of PM impairment in HIV disease is often characterized by performance decrements on strategically demanding PM tasks (e.g., Zogg et al., 2011), which confer greater risk of worse real-world and health-related outcomes, including suboptimal adherence to antiretroviral medications (e.g., Woods et al., 2009). The present study investigated the potential benefits of brief alarm and electronic calendaring strategies for supporting naturalistic PM performance among young adults with HIV infection. Despite modest or trend-level statistical significance, our data show large positive effects of the alarm-alone and combined conditions for naturalistic PM performance in a sample of HIV-positive young adults. The benefits of highly salient cueing on a strategically demanding PM task among HIV-positive young adults are commensurate with prior studies in samples of healthy children (e.g., Mahy, Moses, & Kliegel, 2014), older adults (e.g., Cohen, Dixon, Lindsay, & Masson, 2003), and clinical samples (e.g., Fish et al., 2007). The current study extends that work by assessing the effects of cue salience on time-based PM in a relatively understudied HIV-positive subpopulation (i.e., young adults) at high risk for poor adherence. These findings also complement prior studies showing that other methods that reduce self-directed monitoring demands (e.g., Woods et al., 2014) or support cue detection (e.g., Loft et al., 2014) ultimately improve PM accuracy on laboratory-based PM tasks among seropositive samples. The differential effects of the Alarm and Combined conditions on naturalistic PM were independent of clinicodemographic factors, including education, neuropsychiatric comorbidity, and severity of HIV disease.

Notably, the Alarm-alone and Combined conditions afforded the greatest benefits to naturalistic PM performance for HIV-positive young adults, with effect sizes of those benefits ranging from large to very large. Specifically, participants who utilized both calendaring and alarm strategies upon receipt of the PM task instructions performed significantly more correct PM responses than participants who did not use any strategies, or used the calendaring strategy alone. The effects of the Combined condition were considerable, as participants in the Combined condition on average produced five and six times as many correct PM responses as participants in the Calendaring-alone and Control conditions, respectively. The Alarm-alone condition also produced a large benefit for PM compared to the Control condition, with participants in the Alarm condition producing an average of nearly four times as many correct PM responses as Controls. While PM performance did not differ significantly between the Alarm-alone and Calendar-alone conditions, effect size analysis revealed a large positive effect of the Alarm strategy on PM compared to the Calendar strategy. Given the magnitude of the observed effect size, the lack of significance may have been a product of the limited size of the study sample. Together, these findings suggest a large main effect of mobile alarm use on naturalistic time-based PM performance.

This large main effect of alarm use on naturalistic PM performance supports the hypothesis that reducing the self-directed strategic monitoring demands of the naturalistic PM task would improve PM performance. Specifically, the large main effect of alarm suggests that the high salience of the alarm as a PM cue successfully increased the automaticity of cue detection and facilitated an attentional shift toward cue detection and retrieval of the intended action. The effect of the mobile alarm strategy on PM is unlikely to be due to a direct effect of the alarm on the retrieval stage of PM, due to the content-free design of the alarm cue. In other words, because the alarm cue contained no information relevant to the PM-task, it is unlikely to have benefited PM by functioning as a retrospective memory cue.

In contrast, the calendaring strategy provided only a modest additive benefit to naturalistic PM performance when used in combination with the alarm strategy. Alone, the calendaring strategy did not confer significant or substantial positive effect in PM performance over the control condition. Conversely, when combined with the alarm strategy, the calendar strategy conferred a medium positive effect on PM compared to the alarm-alone condition, though this difference was not statistically significant. The lack of statistical significance may be due to the limited size of the study sample, and may not accurately reflect the presence or absence of a significant additive effect of calendaring on PM. Taken together, these data suggest that while the calendaring strategy alone does not confer benefit for PM in this sample, when combined with the alarm strategy, calendaring provides a medium-sized additive benefit to PM over the alarm strategy alone. These data support an interactive relationship between alarm and calendaring strategies for PM, such that sole use of the calendaring strategy is not sufficient to bolster PM, but calendaring provides a modest benefit for PM when used in combination with the alarm strategy.

Further support for an underlying combined effect of alarm and calendaring strategies on naturalistic PM is provided by the observed pattern of PM task errors. Error type analysis revealed a medium benefit of the Combined condition on the number of task omissions compared to those observed in the Control condition. Specifically, participants who utilized both the calendaring and alarm strategies produced half as many omission errors on average as Control participants. If the alarm strategy was the only strategy driving this decrease in errors, a similar effect of the Alarm-alone condition on number of omissions would be expected. However, the expected benefit of the Alarm-alone condition was not observed, as participants using the alarm strategy alone produced about the same number of omissions on average as Control participants.

Conceptually, the additive benefit of calendaring for PM when combined with alarm use may also reflect reduced self-monitoring PM demands. Calendaring may support the benefits of alarm use on PM by strengthening the encoding of the cue-intention pairing, which in turn may increase the possibility that that the cue-intention pairing is consolidated properly into retrospective memory and later more easily retrieved upon cue detection (e.g., Faytell et al., 2015), which in turn has been made more automatic by implementation of the highly salient alarm cue. Another, not necessarily mutually exclusive, possibility is that calendaring at encoding bolsters the effects of alarm on PM by reducing cognitive load during the delay interval and/or increasing the salience of the cue-intention pairing (e.g., Faytell et al., 2015), thus supporting self-directed monitoring in a manner additive to that of the alarm strategy. Future studies aimed at identifying the mechanisms underlying the putative interaction between the alarm and calendar strategies are necessary to better understand how and why the strategies provide the greatest benefit to PM when used in combination. Such research could be applied to the development of mobile-based interventions for improving PM among HIV-positive young adults.

Finally, careful inspection of the data revealed relatively larger variances in PM performance in the Alarm-alone and Combined strategies, suggesting that alarm use may support PM for some but not all HIV-positive young adults. Based on the findings of prior studies in our lab (e.g., Faytell et al., 2015), we hypothesized that performance on a laboratory-based PM task (i.e., the MIST) may also account for some of these differences. To investigate, we evaluated laboratory-based PM as a potential covariate of naturalistic PM across the cueing (i.e., Alarm-alone and Combined) and non-cueing (i.e., Control and Calendaring-alone) conditions. We found no significant relationship between laboratory-based PM and naturalistic PM within or across experimental conditions. This finding dovetails with other studies comparing laboratory-based and naturalistic measures of PM (e.g., Schnitzspahn et al., 2011), and is thought to highlight the discrete mechanisms that underlie performance within each setting. For example, personality and lifestyle factors disproportionately affect self-report of daily life PM failures compared to laboratory-based PM performance (e.g., Uttl & Kibreab, 2011). Unfortunately, investigation of other participant differences across experimental conditions that could account for the differential support of supportive strategies for PM was precluded by the limited sample size, which did not provide enough power to support any interpretations that could be gleaned from analyses. Thus, future experimental work is needed to identify potential differences between participants who appeared to benefit from strategy use and those who did not appear to benefit.

In summary, our data show that use of a daily alarm, either alone or in combination with electronic calendaring, produced the greatest improvements in naturalistic time-based PM accuracy for HIV-positive young adults compared to controls. Combined use of the alarm and calendaring strategies also decreased the number of omissions on the naturalistic PM task compared to controls. Future studies may wish to focus on potential mechanisms that account for the relative benefits of the alarm and calendaring strategies, both together and separately. Clinically, these data suggest that mobile alarm use is a viable strategy for supporting daily PM functioning, either alone or in conjunction with use of the calendar function. These strategies may be particularly useful for supporting daily PM functioning among younger HIV-positive populations, given that younger adults are generally less likely to use external strategies to support PM (e.g., Weber et al., 2011), but are identified as having high rates of mobile telephone use (e.g., Fjeldsoe, Marshall, & Miller, 2009) and are more likely to rely on mobile telephones for multiple functions beyond sending and receiving calls or texts (e.g., Zickuhr, 2011). Future studies may wish to determine whether use of these mobile telephone-based strategies can benefit adherence, particularly among HIV-positive young adults. Additionally, investigation of participant characteristics that are associated with observed benefits of the respective strategies would be warranted.

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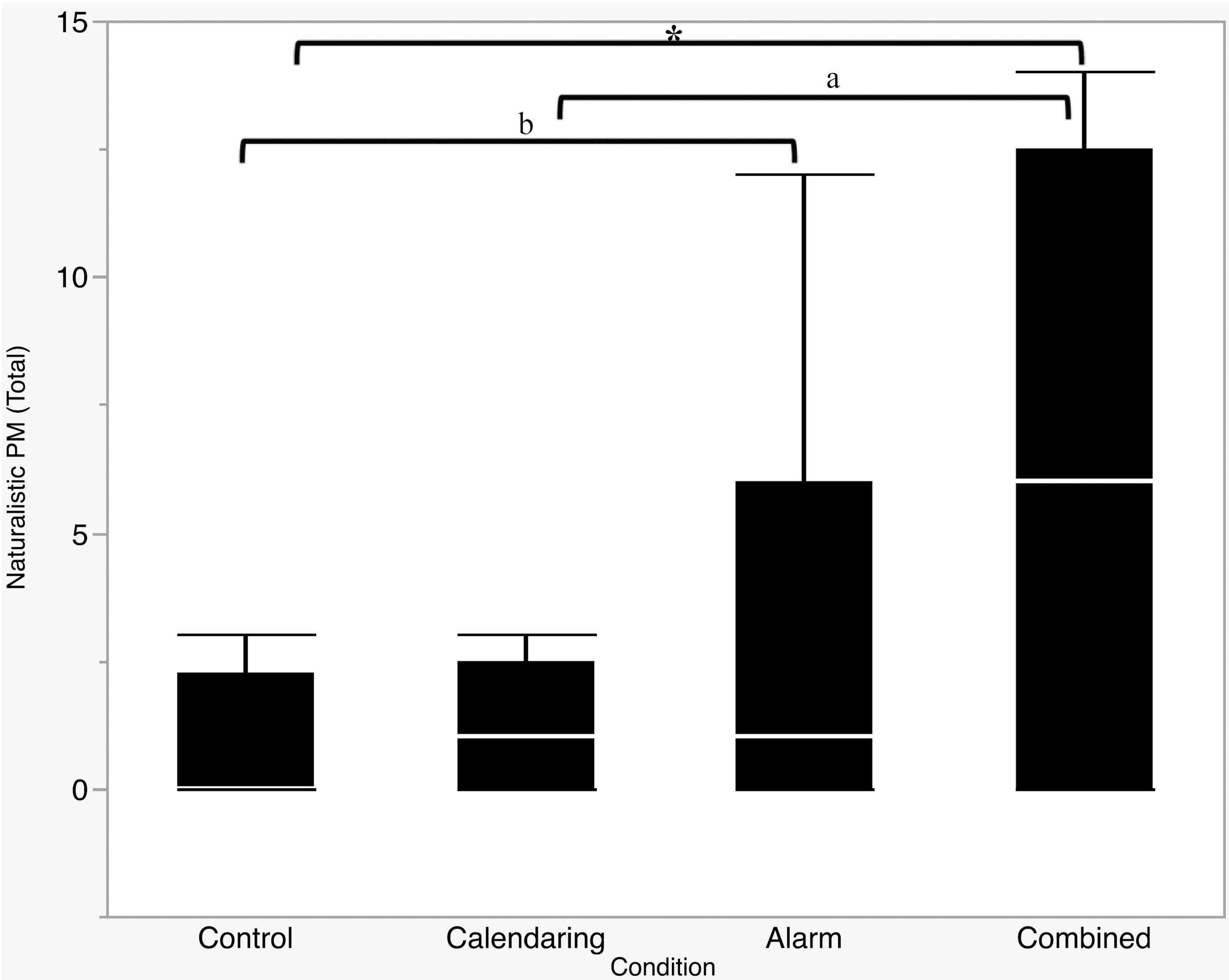

Figure 1.
Effect of Condition on Naturalistic Time-Based PM Performance. *p=.0142, Cohen's d=1.2. [a]p=.0641, Cohen's d=1.1. [b]p=.0862, Cohen's d=1.1.

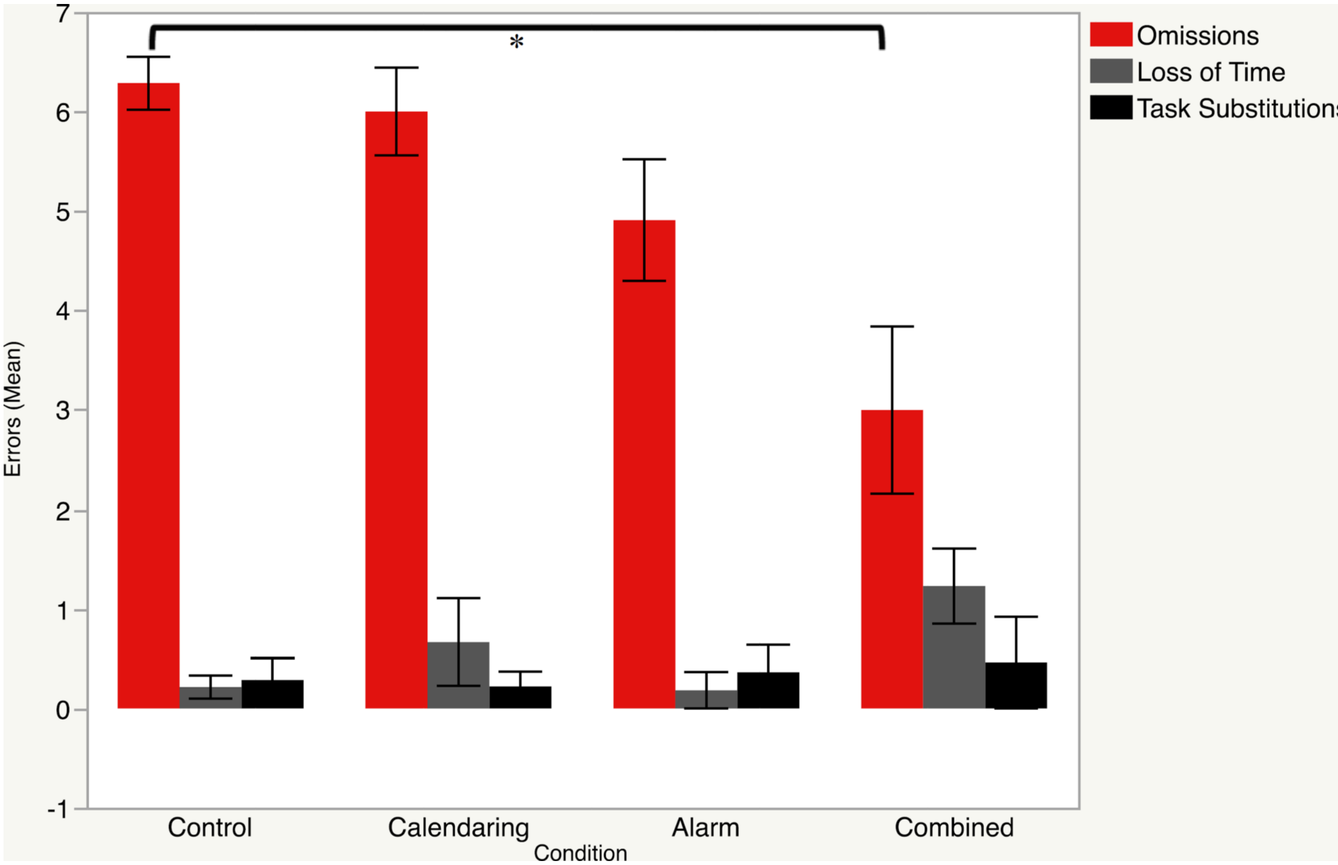

Figure 2.
Errors Recorded on the Naturalistic Time-based PM Task across Study Conditions. Error bars represent one standard error from the mean. *Cohen's d=.66, p=0.053.

Table 1

Characteristics of the Study Participants by Condition

Characteristic	Control (N=14)	Calendaring (N=9)	Alarm (N=11)	Combined (N=13)	p
Demographics					
Site (UCSD/WSU)	6/8	2/7	3/8	6/7	.568
Age (years)	22.6 (1.2)	23.1 (1.1)	22.5 (1.3)	22.6 (1.3)	.732
Education (years)	12.5 (1.2)	12.4 (1.4)	12.1 (1.1)	11.6 (1.4)	.304
Estimated verbal IQ (WTAR)	91.6 (10.5)	89.3 (20.6)	82.8 (11.2)	87.2 (13.6)	.462
Sex (% male)	85.7	77.8	90.9	76.9	.772
Ethnicity (%)					.520
Caucasian	14.3	11.1	0.0	15.4	
African-American	57.1	77.8	81.8	61.5	
Hispanic	28.6	11.1	9.1	23.1	
Other	0.0	0.0	9.1	0.0	
Brief Symptom Inventory[a,b]	53.1 (12.6)	67.1 (11.1)	52.9 (9.8)	54.6 (10.0)	**.018**
Somatization	53.1(12.9)	64.7 (11.2)	53.9 (10.0)	51.8 (11.0)	.060
Depression[c]	52.6 (11.9)	66.0 (11.6)	48.2 (8.4)	55.5 (11.7)	**.007**
Anxiety[d]	50.0 (13.2)	64.7 (10.4)	52.7 (11.2)	53.1 (9.1)	**.027**
Problematic Substance Use (%)[e]					
Alcohol	28.6	44.4	27.3	23.1	.754
Non-Alcohol	35.7	66.7	72.7	46.2	.219
HIV Disease					
Estimated duration of infection (mos.)	36 (16, 57)	43 (18, 69)	65 (42, 88)	30 (8, 52)	.161
Nadir CD4 T-cell count (cells/μl)[f]	407 (312,501)	286 (168,403)	236 (130,342)	456 (358,554)	**.013**
Current CD4 T-cell count (cells/μl)[g]	581 (459,703)	500 (348,652)	380 (243,517)	701 (575,827)	**.010**
AIDS status (% Yes)[h]	7.14	11.1	54.6	0.0	**.003**
Plasma HIV RNA (%	50.0	66.7	45.5	46.2	.761

Characteristic	Control (N=14)	Calendaring (N=9)	Alarm (N=11)	Combined (N=13)	p
detectable)					
ART Use (% ON)	85.7	88.9	72.7	84.6	.785
MIST Summary Score (of 48)[i]	36.4 (7.6)	36.3 (5.9)	32.5 (12.6)	37.4 (5.8)	.516

Note.

[a]Derogatis, 1993.

[b]*Calendaring* > *Control* (p=.023) and > *Alarm* (p=.031).

[c]*Calendaring* > *Control* (p=.033) and > *Alarm* (p=.005);

[d]*Calendaring* > *Control* (p=.019).

[e]Based on the Alcohol, Smoking, and Substance Use Involvement Screening Test (ASSIST v. 3.0).

[f]*Alarm* < *Combined* (p= .019).

[g]*Alarm* < *Combined* (p=.006).

[h]*Alarm* > *Combined* (p<.05).

[i]Based on the Memory for Intentions Screening Test (MIST; Raskin, 2010). Data are presented as means and standard deviations or 95% confidence intervals except where indicated. ART = Antiretroviral therapy. WTAR = Wechsler Test of Adult Reading.