

Mental Health Support and Crisis Detection for Veterans Using Opioids: Evaluating Predictive Modeling and Peer Support Through a Mobile App

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ABSTRACT

Veterans with Post-Traumatic Stress Disorder (PTSD) face heightened risks of opioid misuse due to the interplay between chronic pain management and psychological distress. The combination of PTSD and opioid use disorder (OUD) creates a complex clinical challenge, contributing to increased rates of overdose, suicide, and healthcare burden. Traditional interventions often fall short due to barriers such as stigma and fragmented treatment approaches. Peer support programs have emerged as a promising intervention strategy, leveraging lived experiences to improve engagement and adherence to treatment. This study evaluates the integration of predictive modeling techniques and peer mentorship through the BattlePeer mobile application, designed to support veterans with PTSD. We apply machine learning algorithms and rule-mining techniques to detect early indicators of mental health crises among veterans who use opioids. Our results suggest that a hybrid approach combining machine learning-based crisis detection with structured peer support can optimize mental health outcomes for veterans with PTSD and OUD.

Keywords

Opioids, PTSD, Peer Support, Veterans, Crisis Detection, Machine Learning

INTRODUCTION

Mental illness remains a growing public health crisis among U.S. veterans, driven in large part by the psychological impact of military service. The U.S. Department of Veterans Affairs (VA) estimates that by 2036, more than 14 million veterans will be living, with approximately 75% having served in a war or conflict era (Gade & Wenger, 2011). This population faces a heightened risk of co-occurring mental health conditions, such as Post-Traumatic Stress Disorder (PTSD) and opioid use disorder (OUD), which complicate recovery and reintegration into civilian life.

The opioid epidemic has intensified these challenges. In 2021 alone, opioid-related overdoses claimed over 80,000 lives in the United States (CDC, 2022). A significant challenge in addressing the OUD crisis is that overdoses frequently take place in isolation, reducing the likelihood of immediate intervention. Unlike other medical emergencies where early symptoms may prompt individuals to seek help, opioid users may not recognize the warning signs of an impending overdose or may hesitate to call for assistance due to stigma or legal concerns (Wakeman & Barnett, 2018).

Veterans are especially vulnerable due to high rates of chronic pain and PTSD, which often result in prolonged opioid use and elevated risk of OUD (Seal et al., 2012; Nahin, 2017; U.S. Department of Veterans Affairs, 2018). Research shows that long-term opioid use may further exacerbate PTSD symptoms by altering neural stress and emotion regulation pathways (Bernardy & Montaña, 2019). Recognizing the urgency of this crisis and the barriers to effective treatment, recent research has explored innovative interventions aimed at mitigating opioid misuse among veterans. One such approach is peer-delivered opioid prevention programs, which leverage veterans with lived experience to provide mentorship, education, and support to those at risk. Efforts to address these dual challenges are increasingly turning to technology.

Recent advances in mobile health (mHealth) applications, wearable sensors, and machine learning have enabled real-time tracking of physiological signals related to opioid use and relapse risk (Salgado García et al., 2022; Chapman et al., 2022). Tools such as ecological momentary assessment (EMA) have also emerged as valuable for capturing real-time patient experiences (Piot et al., 2022; Walz et al., 2014), while GPS-integrated systems allow for contextual analysis of substance use behaviors, allowing for more timely and contextualized intervention.

Despite these promising advancements, empirical validation remains limited, particularly for veteran-focused applications. There is a critical need for evidence-based, user-centered technologies to detect, manage, and ultimately prevent opioid misuse among veterans with PTSD. The Milwaukee PROMPT (Prevention of Opioid Misuse through Peer Training) project, a community-academic partnership, developed a peer mentor training curriculum designed to address OUD among veterans.

This initiative demonstrated the effectiveness of peer mentoring in fostering trust, addressing trauma, and improving access to recovery resources (Pazdera et al., 2021). Such community-engaged research efforts highlight the need for comprehensive strategies that integrate mental health screenings, alternative pain management techniques, and substance use interventions to improve outcomes for veterans. Addressing PTSD and OUD among veterans is essential not only to enhance the individual well-being of veterans but also to mitigate broader societal impacts, including rising mental healthcare costs and the loss of workforce productivity. Given the complex relationship between PTSD and opioid use, interdisciplinary and community-based approaches remain critical to developing sustainable solutions for this vulnerable population.

BACKGROUND

Early detection of mental health disorders is critical for reducing the economic burden of disease and alleviating strain on mental health systems (Ozonoff, 2015). For veterans living with mental health disorders, early detection

of their triggers would help initiate a support system and allow for timely intervention, strengthen prevention strategies, and improve treatment outcomes. Peer support programs have emerged as effective interventions in this space. By fostering trust and reducing stigma, peer mentors, often veterans with lived experience, help individuals navigate recovery, encourage treatment adherence, and offer practical strategies for coping with PTSD symptoms and substance withdrawal (Hundt et al., 2015; Chinman et al., 2014; Pfeiffer et al., 2011). Additionally, peer mentors play a critical role in crisis response by identifying signs of distress and guiding peers toward timely care (Fortuna et al., 2020).

Digital platforms such as the BattlePeer App are increasingly used to enhance access to peer support, particularly in underserved or rural areas. These tools enable real-time communication, support on demand, and the potential for crisis alerting (Franco et al., 2023). However, peer mentors often operate with limited data and may miss subtle or cumulative warning signs of relapse or emotional deterioration. This underscores the need for technology that can surface meaningful patterns such as changes in language, mood, or self-reported stress levels while supporting mentor well-being and reducing burnout.

This work aims to augment peer support through a mobile application that leverages veteran self-report data to assist mentors in detecting potential crises early. While smartphone-based strategies show promise, further development is needed to integrate them effectively into PTSD and OUD management frameworks.

Mobile Mental Health Peer Support Systems

Mobile peer support systems extend the beliefs of traditional peer mentorship by leveraging technology to increase access, reduce stigma, and enhance engagement. For veterans navigating PTSD and substance use disorders, these systems offer an inclusive, confidential space that encourages connection while minimizing barriers to care (Roscoe, 2021; Botero Jr. et al., 2020).

Unlike conventional clinical care, mobile platforms empower users to take an active role in their recovery, enabling greater autonomy and responsiveness to individual needs (Rizia et al., 2014). Beyond the individual benefits of peer support systems, technology-enabled systems can also enhance collective resilience by strengthening bonds among veterans who understand and validate each other's experiences. This networked support not only enhances the peer mentor model but also expands its reach, enriching the overall mental health recovery process (Kahn et al., 2016).

Predictive Modeling Techniques for Optimizing Mental Health Outcomes

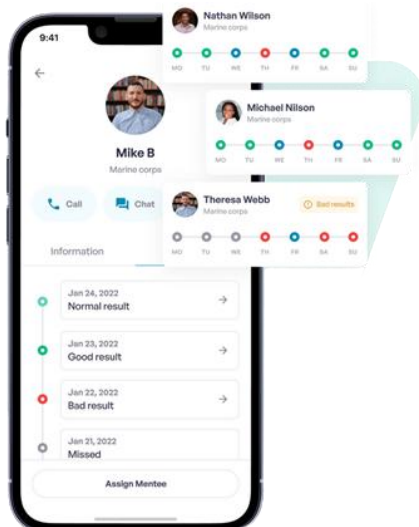
Predictive modeling using data produced by smartphone applications supporting peer mentor programs also offers a promising solution to optimize health outcomes for veterans with PTSD and OUD. By leveraging machine learning algorithms and biometric data, predictive models can increasingly forecast mental health crises and allow for early intervention (Yang, 2022). For example, wearable devices have been used to predict mental health conditions based on sleep patterns and lifestyle habits (Saito et al., 2022). Furthermore, machine learning techniques, such as decision trees and logistic regression, have been applied to assess mental health states in real time (Srividya et al., 2018). These advancements collectively underscore the transformative potential of predictive modeling in mental healthcare, specifically among veterans using opioids and experiencing PTSD, offering valuable tools for early diagnosis, prevention, and personalized intervention strategies.

METHODS

Prior Work

Previous research efforts on the design of the Battle Peer App (formerly known as QRF+) leveraged a co-design process and Community-Based Participatory Research (CBPR) principles. These efforts involved collaborations

between veteran community partners at DryHootch, behavioral health specialists at the Medical College of Wisconsin, and computer science faculty at Marquette University. This multidisciplinary approach aimed to identify and define indicators of impending PTSD crises among veterans, as detailed in prior studies (Franco et al., 2015; Franco et al., 2018).



The BattlePeer Smartphone Application for Veteran Mental Health Peer Support

The BattlePeer mobile application was initially developed to support a peer mentorship program for U.S. military veterans faced with mental health challenges such as PTSD due to previous military job experiences and reintegration into civilian life. The app was designed in partnership with DryHootch a veteran-led peer-mentor initiative using a community-based collaborative design process and was initially named “Quick Reaction Force”, detailed information on design history has been published elsewhere see (Franco et al., 2021; Rizia et al., 2014; Franco et al., 2016; Franco et al., 2018). The Battle Peer App is designed to work with existing peer mentorship programs, and its features are adaptable to meet any organization's mental health peer support needs. With the primary goal of making peer-based mental health support and interventions readily accessible and convenient, through the app, mentees and mentors communicate seamlessly through

one-touch options for calls, text messaging, or in-person meetings. The apps are now commercially available via university tech transfer and support both Apple and Android systems.

Earlier work based on the BattlePeer intervention and mHealth app highlighted the integration of behavioral health principles to enhance the appropriate application of peer support within the app, specifically through the mentor-mentee approach. Studies by George et al. (2019) and Hossain et al. (2020) explored how real-time, community-based feedback from peer mentors and mentees could improve communication and response options. These studies demonstrated how much interaction facilitated the early detection of an incoming or ongoing mental health crisis.

Current Study

Using a peer mentor mental health intervention approach similar to our prior research but applied to a dual diagnosis population, we provided 12 weeks of structured peer-to-peer support for veterans to evaluate its impact on PTSD and OUD to 29 veterans actively using or in recovery. The intervention approach, including mental health training for peer mentors and the community-academic partnership for this work, was facilitated through are detailed elsewhere (Ahmed, et al, 2020). The primary focus of this study is an examination of the quantitative data available pre-, mid-point, and post-intervention, as well as Ecological Momentary Assessment (EMA) data available specific to an OUD population. We attempted to replicate prior crisis predictive analysis work performed with a non-OUD population using an associative classifier approach, but extending it to address this more complex, dual-diagnosis population using somewhat different psychometric assessment tools.

For each of the studies, a similar intervention and assessment approach was used. A longer survey was administered at baseline, 6-week mid-point, and 12-week discharge. The PROMPT study used the PCL-5 and DRRI-2 used in the prior Quick Reaction Force studies but extended these measures to also include psychometrically validated instruments focused on housing stability, addiction severity, and trauma exposure. The specific instruments are detailed in **Table 1**. Additionally, using the EMA approach, each participant was delivered a brief 10-item survey by email every week. These EMA items focused on dynamic “state-based” factors as described in **Table 2** below, and response scales varied by item (e.g., *Yes/Maybe/No, Less/Same/More, or compared to last week, etc*).

Table 1. Instruments used in Assessment Battery

Table 2. EMA Survey Items

EMA Items	Theoretical Framework
Are you feeling good about yourself overall this week?	Self-esteem, a question originally posed by a female peer mentor to address esteem issues in female veterans, but also globally applicable.
Have you engaged in any risky behavior (as you define it) this week?	Dynamic risk assessment
How strong were your cravings this week?	OUD-focused EMA item
How stressful has this week been?	An increase in stressors also increases the risk for MH crisis
Has your health changed this week?	Peer mentors have noted that short-run changes in health can exacerbate mental health problems
How well did you sleep this week?	While nightmares are a known issue in PTSD, this question broadness to sleep as a whole
My peer mentor's approach is a good fit for me:	Therapeutic alliance/Session Alliance Inventory/Feedback-Informed Treatment
Did your Dryhooch peer mentor talk to you this week?	Mutual accountability and intervention fidelity check
We talked: Face to face Phone Text Social media	Increased information about channels of communication, recognizing that the workflow for peer mentors making contact with veterans occurs in several formats at changes based on factors for both the peer mentor and the veteran

RESULTS

Changes in PTSD Outcome:

To understand changes in depression outcomes, the PTSD Checklist for DSM-5 (PCL-5) was measured for each participant at baseline (Week 1), midpoint (Week 6), and discharge (Week 12). An overall reduction in PTSD scores was observed, with a mean decrease of **3.5** (Cohen's $d = 0.16$). A PCL-5 score greater than 33 is considered indicative of high risk (Forkus et al., 2023). For participants classified as high risk at baseline (PCL-5 ≥ 33), the reduction was greater, with a mean decrease of **5.33** (Cohen's $d = 0.44$). Among the 12 participants with baseline PCL-5 scores ≥ 33 , 8 showed a reduction in their scores by discharge. Additionally, 2 participants had their scores decrease to below 33, indicating a shift out of the high-risk category.

Changes in Drug Use Outcome:

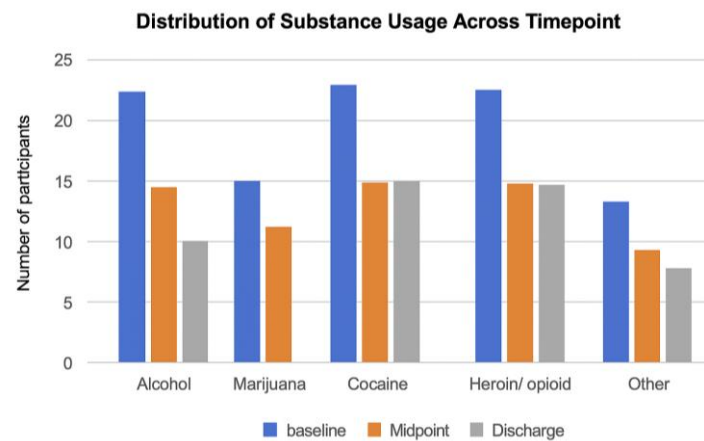


Figure 1. Veterans' Substance Use Across Study Time Points

The most used substances were alcohol, marijuana, cocaine, and heroin. Overall, drug use declined from baseline to discharge (**Figure 1**). Drug use outcomes were assessed using the Drug Use Disorders Identification Test (DUDIT). An overall reduction in DUDIT scores was observed, with a mean decrease of **1.82** (Cohen's $d = 0.15$). For participants classified as high risk at baseline (PCL-5 ≥ 33), the reduction was greater, with a mean decrease of **3.08** (Cohen's $d = .41$). These changes are shown in **Figure 2**.

At the individual level, if a participant's DUDIT score increased at either the midpoint or discharge, they were considered to be at increased risk (Hildebrand, 2015). From this perspective, 9 participants were classified as high risk, while the remaining participants remained stable or showed a decline in symptoms.

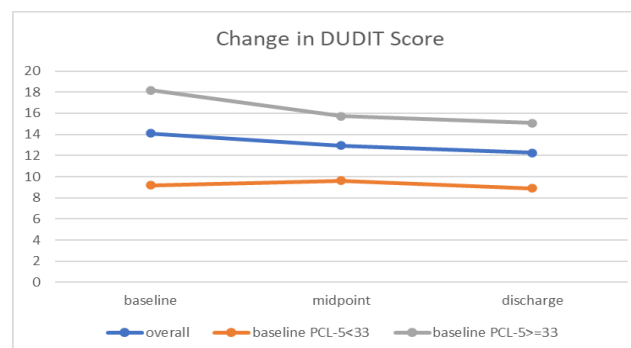


Figure 2. Changes in Veterans' Drug Use by PTSD Risk Severity (Low vs. High Risk) Across Study Time Point

Short-term crisis:

We asked five questions in the EMA questionnaire related to health, craving, self-worth, sleep quality, and stress. According to our previous study, a **short-term crisis** is considered present if:

- a) **Three or more symptoms** are elevated within a single week, OR
- b) **Two symptoms** are elevated across any pair of two-week periods.

When determining whether a participant experienced a short-term crisis, **stress** and **sleep quality** were the most critical indicators, followed by **health** and **craving**. Notably, **no participant reported worsening in the self-worth question**. We received completed EMA responses from 22 participants. Among them, 9 participants experienced a short-term crisis.

At discharge,

- 11 participants with high PCL scores experienced a short-term crisis, while 2 participants with high PCL scores did not.
- 7 participants with high drug risk experienced a short-term crisis, while 5 participants with high drug risk did not.

Discharge PCL-5 scores based on Short-Term Crisis:

We compared PTSD and drug outcomes at discharge between two groups: nine participants who experienced a short-term crisis and thirteen who did not. Participants experiencing a short-term crisis had higher mean scores on both the PCL-5 and the DUDIT at discharge. The difference in PCL-5 scores was statistically significant. **These findings suggest that if mentors can identify short-term crises using EMA responses, they could implement additional support measures**, such as increased contact with mentees, to potentially reduce PCL-5 scores at discharge. These results are shown in **Table 3** and **Figure 4 boxplots**.

Table 3. Short Term Crisis Indicators Based on Veterans' Drug Use & PCL-5 scores at Discharge

	No Short-Term Crisis (n=13)	Short-Term Crisis Present (n=9)	Wilcoxon Rank Sum Test Statistics	p-value
Mean (SD) PCL-5 Score	19.22 (17.12)	43.27 (20.81)	-2.33	0.02*
Mean (SD) DUDIT Score	8.9 (12.25)	15.3 (10.77)	-1.66	0.09

(* $p < 0.05$ indicates statistical significance)

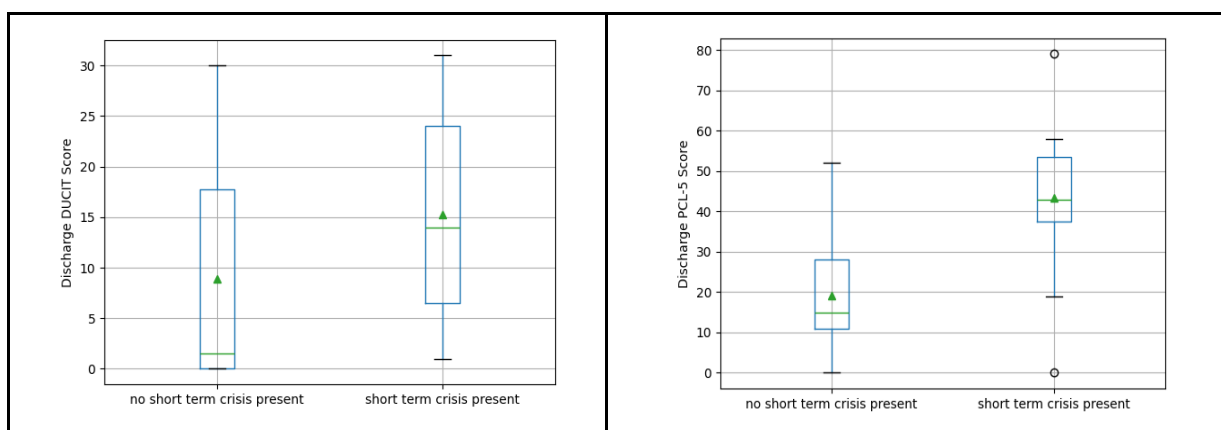


Figure 4. Boxplots of Short-Term Crisis Indicators Based on Veterans' Drug Use & PCL-5 Scores at Discharge

Relationship between Mentor Match and Depression and Drug Use Outcomes:

The EMA weekly survey included three questions regarding mentor-mentee contact: perceived mentor match, whether contact occurred that week, and the communication method used. Due to the small sample size and limited variability in responses (few participants reported a poor mentor match or a lack of contact), statistically analyzing

the relationship between these variables and PCL-5 or DUDIT scores was not feasible. However, a manual review of the data revealed a potential trend. Five participants had limited mentor contact (typically 3-5 weeks out of 12), and of these, four exhibited early warning signs. One participant showed a decrease in PCL-5 scores during the first six weeks, a period marked by regular mentor contact. Conversely, when mentor contact decreased during four of the final six weeks, this participant's PCL-5 scores subsequently increased at discharge.

Relationship between Depression Outcomes and Short-Term Crisis:

We applied logistic regression to examine the relationship between baseline PCL-5 scores (a measure of PTSD symptom severity) and the likelihood of experiencing a short-term crisis (**Figure 5**). Given the statistically significant p-value (0.0303) and the odds ratio greater than 1 (1.0582) for baseline PCL-5, we can conclude that baseline PCL-5 score is a significant predictor of experiencing a short-term crisis. Specifically, higher baseline PCL-5 scores are associated with increased odds of experiencing a short-term crisis. The odds ratio of 1.0582 suggests that for each one-unit increase in baseline PCL-5, the odds of experiencing a crisis increase by about 5.8%. The confidence interval further supports this conclusion as it lies entirely above 1. V B

Model Fit					
Chi-Square = 6.0530 $df = 1$ $p\text{-value} = 0.0139$					
Variable	Coefficient	Standard Error	p-value	Odds Ratio	95% Confidence Interval
baseline PCL-5	0.0566	0.0261	0.0303	1.0582	(1.0054, 1.1137)
Constant	-1.7305	1.0200	0.0898		

Figure 5. Logistic Regression Examining the Relationship Between Veterans' Baseline PCL-5 Scores and Likelihood of Experiencing a Short-term Crisis.

Summary of Findings:

- Participants with high baseline PTSD scores showed significant reductions in symptoms after participating in the intervention.
- Drug use declined over the 12-week program, especially among those classified as high risk at baseline.
- EMA responses revealed that short-term crises (defined by elevated stress, poor sleep, health changes, or cravings) were strongly associated with higher PTSD and substance use scores at discharge.
- Participants with limited mentor contact during the intervention were more likely to show worsening symptoms, indicating the critical role of consistent peer engagement.
- Baseline PTSD severity significantly predicted the likelihood of experiencing a short-term crisis, suggesting a need for proactive monitoring and support.

DISCUSSION

The findings of this study underscore the potential of peer mentor interventions to enhance mental health outcomes among veterans with PTSD and OUD. By leveraging the lived experiences of peer mentors, the intervention facilitated increased engagement and adherence to treatment but also provided a critical support mechanism for crisis intervention. The results reinforce prior evidence highlighting the effectiveness of peer-based interventions in mental health management. Moreover, the incorporation of predictive modeling and ecological momentary assessment (EMA) within the intervention framework holds promise not just for analysis, but also for real-time early detection and response to crises in this vulnerable population. Despite important first steps toward

developing OUD-specific dynamic risk assessment, several challenges must be addressed to improve the scalability and sustainability of such interventions.

For example, one consideration of this study is the complexity of dual-diagnosis populations, which introduces variability in treatment response and intervention effectiveness. Unlike our prior predictive modeling studies that focused on a single diagnosis of PTSD, this study adapted existing crisis prediction methodologies to a population with both PTSD and OUD. While the associative classifier approach demonstrated potential, further refinement is needed to improve accuracy and reliability in predicting crisis events with this population and diagnostic mix. Future research should explore the integration of additional biometric and behavioral data sources to enhance predictive validity.

Additionally, the study's reliance on self-reported EMA data presents both strengths and limitations. While EMA offers the advantage of capturing dynamic, state-based fluctuations in mental health status, self-report measures may be subject to response biases, particularly among individuals experiencing cognitive impairment or distress. Individuals who are struggling with drug addiction and recovery also experience significant stigma, which may adversely impact their willingness to provide accurate self-report data. Future work should consider complementing self-reported data with passive monitoring strategies, such as physiological tracking via wearables, to provide a more comprehensive assessment of mental health trajectories.

Despite these challenges, the study highlights significant opportunities for advancing the integration of peer support with data-driven predictive interventions, and it takes the first steps toward applying previous rule-based strategies to isolate possible early warning signs specific to OUD markers.

Implications for Battlepeer and similar technologies

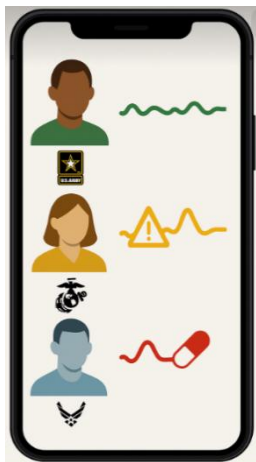
Real-time Crisis Detection and Intervention

Weekly EMA responses in our study captured fluctuations across five key domains: stress, sleep quality, craving, health, and self-worth. A short-term crisis was defined as three or more elevated symptoms in one week or two elevated symptoms sustained over a two-week period. Stress and sleep disturbances emerged as the most consistent early indicators of crisis, while no participant reported a decline in self-worth. These findings suggest that EMA data can support real-time crisis detection within mHealth apps. For instance, when multiple elevated symptoms are detected, the app could notify mentors or trusted contacts to initiate timely, just-in-time interventions. However, real-time detection systems come with limitations (Mansoor et al., 2024). Challenges such as incomplete data, algorithmic errors (“hallucinations”), and latency in system responses can impact the accuracy (Sun et al., 2024) and timeliness of alerts (Haque et al., 2024). Despite these constraints, we have recognized that when these systems are designed with cultural sensitivity and human oversight, these systems can offer powerful, scalable solutions for high-risk populations (Mansoor et al., 2024, Haque et al., 2023). Our study provides culturally contextualized insights into early crisis detection among veterans, a population frequently affected by shared experiences of trauma. A human-in-the-loop strategy can ensure that automated alerts are supplemented with informed, compassionate responses. For instance, when elevated symptoms are detected, the system could alert peer mentors, prompting personalized check-ins. Access to a dashboard displaying symptom trends over time would further equip mentors to make informed, timely decisions, strengthening the responsiveness and effectiveness of peer support.

Tailored Mentor Engagement using Predictive Modeling

Baseline PTSD severity was a strong predictor of short-term crisis risk in our modeling. Incorporating this information into the app can enable adaptive engagement strategies based on each user's risk profile. Veterans with high baseline PTSD scores, for instance, could receive more frequent prompts for mentor check-ins, while mentors would be nudged to maintain closer contact with higher-risk mentees. Risk profiles derived from both static (e.g., PTSD severity) and dynamic (e.g., symptom fluctuation) data can be used to personalize mentor

engagement intensity. This ensures that support resources are directed where they are most needed, enabling scalable care delivery without overburdening the system.



Advancing Real-time Visualization of Substance Use Patterns

The current version of the app collects weekly EMA data to track mentees' substance cravings. Future iterations could incorporate real-time reporting of actual substance use events. Adding a visual dashboard to display longitudinal trends in cravings and use would help mentors and researchers identify escalating risk patterns earlier. A number of other HCI considerations, including embedding visual cues for peer mentors to be able to rapidly tell the type of issue causing an alert, may assist para-professionals to tailor their response or intervention approach, providing important contextual information that can drive their clinical decision making. A notional example of this is offered here, for further consideration and development. This example shows that the visual alerting strategy can be tied to multi-factor and real-time analysis. Based on feedback from peer mentors, alerting for cravings would optimally be tied to the individual's baseline craving level, emphasizing deviations from this rather than simple increases. This enhancement could strengthen the app's predictive capabilities and enable more effective, timely interventions.

Support for Peer Mentors and Burnout Prevention

Our study found that mentors sometimes missed early warning signs of crisis, highlighting the need for better decision-support tools. Future versions could include dashboards that synthesize mentee data, flag concerning patterns, and recommend appropriate actions. Additionally, offering self-care tips and workload management support could help reduce cognitive load and prevent burnout among mentors (Haque et al., 2023). By enhancing both usability and well-being, these tools would contribute to more sustainable and impactful mentoring relationships.

CONCLUSION

This study demonstrates the benefits of peer-mentor interventions integrated with EMA-informed crisis monitoring to address the comorbid occurrence of OUD and PTSD in veterans. Despite a relatively modest sample size of 29 participants, our findings reveal critical insights: reductions in drug use and stabilization or decline in symptom severity among participants underscore the significant benefits of the intervention, while the association between short-term crises and elevated PTSD (PCL-5) and drug risk (DUDIT) scores emphasize actionable intervention points. Specifically, the ability to detect crises via EMA and the subsequent opportunity to deploy targeted solutions to individuals could prevent acute symptom escalation. Although dual diagnosis complexity introduces potential variability, this study advances methodologies for predictive modeling in understudied, high-risk populations like U.S. veterans. Our inclusion of veterans with both OUD and risk of PTSD, although methodologically challenging, fills a crucial gap in existing literature and underscores the need for targeted, tailored, and dynamic approaches for mental health crisis prevention. Future studies should expand sample sizes, integrate multimodal behavioral data, and refine crisis prediction algorithms to enhance utility. To conclude, these findings contribute foundational evidence for more effective and scalable, peer-supported interventions in comorbid mental health and substance use care.

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