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TITLE: Does Evidence-Based PTS Treatment Reduce PTS Symptoms and Suicide in Iraq and Afghanistan Veterans Seeking VA Care?

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14. ABSTRACT We succeeded in developing a Natural Language Processing (NLP) System with excellent performance characteristics for determining the type of psychotherapy described in VA clinical notes. We found that positive predictive value was greater than .91 and sensitivity was greater than .92 for all types of posttraumatic stress (PTS) evidence-based treatment (EBT), including Cognitive Processing Therapy (CPT) individual and group, and Prolonged Exposure (PE) individual therapy. We completed seven major annotation projects resulting in over 11,935 documents, 1,297 of which were annotated by four people (quadruple-annotated) and 7,226 of which were double annotated. We also developed an NLP system to extract PTS Checklist (PCL) scores from clinical notes with excellent accuracy (98% positive predictive value). We were also able to obtain preliminary numbers related to psychotherapy utilization among Iraq and Afghanistan Veterans as well as information about their use of PTS evidence-based psychotherapies. Descriptive analyses of psychotherapy utilization (2005-2014), based on NLP output, showed that although the absolute number patients with PTS increased substantially (~18-fold) between 2005-2014 (Figure 1), the proportion engaged in any psychotherapy remained below 50%, and the number engaged in EBT remained below 10% by 2014(Figure 2).					
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1. INTRODUCTION:

Posttraumatic stress (PTS) is among the most common mental health problems among Service Members and Veterans returning from recent deployments, and despite the availability of evidence-based treatments (EBT), many of those with mental health problems do not seek or postpone seeking EBT for PTS, defined here as Prolonged Exposure Therapy (PE) and/or Cognitive Processing Therapy (CPT). This study will improve clinical care for the large number of Warfighters and Veterans who suffer from PTS by determining if Veterans receiving EBT outside of research trials demonstrate PTS symptom improvement in a clinical setting, whether these EBTs for PTS impact suicidality in a clinical setting, what factors are associated with PTS symptom improvement in those that benefit from EBT, and whether all Veterans benefit equally from EBTs for PTS.

2. KEYWORDS:

Posttraumatic stress
Cognitive Processing Therapy
Prolonged Exposure Therapy
Evidence based treatment

3. ACCOMPLISHMENTS:

a. What were the major goals of the project?

The major goals of this project are to determine the effectiveness of evidence-based therapies for posttraumatic stress (PTS) applied naturalistically in a clinical setting; factors associated with PTS symptom improvement; and optimal treatment trajectories for Veterans with PTS and complex comorbidities.

In order to accomplish these goals, we will need to update and merge several datasets from the Veterans Health Administration, drawn from electronic medical records, each one containing pertinent information that will be needed to complete the study. Part of acquiring relevant data will include defining the sample so that we can obtain relevant clinical notes, and then using clinician coding and natural language processing (NLP) in order to determine those who received EBT for PTS and those who did not. Data analytic tasks will involve a series of complex analyses that will best answer our research questions.

The project work has been divided into four main tasks:

TASK 1. Update and Merge Existing Data and Datasets—100% completed

TASK 2. Use NLP to Evaluate Clinical Notes—100% completed.

TASK 3. Data Analysis—10% completed

TASK 4. Finalize study requirements, prepare for future funding, and dissemination of findings—0% completed

Progress on subtasks is described in detail in the following section.

b. **What was accomplished under these goals?**

Each of the subtasks described below are serving to help us determine whether Iraq and Afghanistan Veterans that receive EBT for PTSD demonstrate improved symptoms (Aim 1). In order to do this, we first needed to create the algorithm that identifies these therapies and validate it, as well as merge the datasets for analysis. Each of these tasks are also in service of determining the percentage of Veterans who complete EBTs for PTSD (Aim 2) and setting up treatment profiles (Aim 3).

In summary, we have performed seven annotation projects and annotated over 11,935 documents, 1297 of which were annotated by four people (quadruple-annotated) and 7,226 were double annotated. We created an NLP system to analyze narrative text of the psychotherapy notes to determine the type of psychotherapy that the documents describe. We also developed an NLP system to extract PCL scores which potentially has a broader impact as it results in previously unavailable data for a range of other studies.

The goal of manual annotation was to review each note in the selected set and assign a label that reflects the type and format of psychotherapy that the clinical note described. We used the following 8 labels: 1) CPT individual, 2) CPT group, 3) PE individual, 4) PE group, 5) other individual psychotherapy, 6) other group psychotherapy, 7) other family or couple's psychotherapy, and 8) not psychotherapy.

Two practicing VA psychologists and two professional clinical chart annotators performed multiple rounds of annotation (**subtasks 2b and 2c**). The psychologist and professional clinical chart annotation team collaborated to iteratively create an annotation guideline describing the code definitions. All four annotators completed the first two rounds of annotation on the same document set to evaluate inter-annotator agreement. Once an acceptable level of agreement was achieved ($\kappa=0.88$; 95% CI: 0.85-0.90), the professional clinical chart annotators reviewed additional documents.

The final annotated set of 3,467 clinical documents was randomly split into two parts; two thirds of the set ($N=2,960$) was used for training a support-vector machine (SVM) model, and one third of the set ($N=1,507$) was used for validation of the model. Building a set of features for a machine learning classifier is typically the first step in applying machine learning. One of the simplest but highly effective methods of representing a document is a binary bag-of-words approach. This method encodes a document as an unordered set of words with a value of one if the word is present in the

document and zero if the word is absent. We amended this set by removing most frequently used irrelevant words (e.g. 'a', 'an', 'is', 'was', and 'the'). We also removed irrelevant phrases that contained words that could potentially be relevant. For example, the phrase “CPT Code” (Current Procedural Terminology, which is used to classify clinical visits) contains the word “CPT,” which can also stand for “Cognitive Processing Therapy,” a highly relevant phrase related to EBT. By removing the phrase “CPT Code” the word “CPT” would only be included in the feature vector if it is not a part of this phrase. We also created a set of features representing salient phrases, which are indicative of one of the categories. The values for these features were set to two to give them a larger weight. For example, the phrase “prolonged exposure” is more important for determining if the document reports on a PE session than the words “prolonged” and “exposure” on their own. After developing the machine learning model, we validated the system on the test document set. The system accuracy was analyzed for each category separately and for the system as a whole (**subtask 3a; see Table 1**). As can be seen from Table 1 below, we met performance standards of .90 or above on the two evidence based treatments (**subtask 2e**); we used positive predictive value (PPV) and sensitivity to calculate performance (analogous to recall, precision and f-measure). We did not need to further hone our algorithm, given that we met all the performance standards (**subtask 2f**).

The document level validation paved the way for the next validation step at the patient-level. We selected a group of 120 patients who had a substantial number of visits (>3) of one or more types of EBT (CPT individual/CPT group/ PE) based on NLP results. We set the index date to first session of EBT and reviewed all psychotherapy notes from 30 days prior to 24 weeks after the index date (N notes=7227). The annotation is complete and overall accuracy equals 88.5%. We are currently using these annotated results to calculate performance of NLP at the patient level, including accuracy of the “dose” of therapy received (**part of subtask 2h**).

Table 1 outlines the performance characteristics of the developed system.

Document Classes	TP	Total NLP	Total Test set	PPV	Sensitivity
CPT_Group	303	328	319	0.924	0.950
CPT_Individual	301	329	326	0.915	0.923
Not_Psychotherapy	241	260	267	0.927	0.903
Other	221	260	269	0.850	0.822
PE	315	330	326	0.955	0.966

Another accomplishment in this period involves the PTS Checklist (PCL) that we are using as one of our main outcome measures. Theoretically, each EBT visit should have a PCL score associated with it recorded in a structured database called Mental Health Assistant (MHA); however, we found that often clinicians were recording PCL scores in body of note text rather than in MHA, which was causing missing data. However, we realized that this could easily be remedied through an extra NLP step. We developed an NLP system to extract these PCL scores from the text documents. It was validated to reach 98% positive predictive value. PCL values were found in 333, 558 (out of 8,173,027) documents for 108,996 patients, which represents 35% of the patients in the set. We will combine these PCL results with the set of PCL scores recorded in structured data and repeat our previous analyses (**subtasks 1h, 1j, 1k**). This will not only be helpful for our study, but we are already getting requests to use these procedures in other projects, which can greatly benefit DoD and VA health research.

Given that we met our performance standards for the algorithm, we were able to apply it to all the notes to determine which Veterans have completed EBT for PTS (**subtask 2g**). We then further refined the PTS cohort to the set of patients who will be included in main analyses, i.e., post-deployment mental health outpatient (MHO) visit at least one year prior to end of our study period with non-compensation and pension psychotherapy clinical notes available in VA data; n=216,598 (**subtasks 2h and 3b**). This is part of the process of combining the administrative and NLP-derived datasets to create the analytical cohort, which we are now updating with even more recent data, bringing us up to date (**subtask 3b**). We then carried out descriptive analyses of psychotherapy utilization (2005-2014), including total annual PTS patients actively engaged in psychotherapy (Figure 1) and prevalence of psychotherapy among all PTS patients (Figure 2). Although the absolute number of PTS patients increased substantially (~18-fold) between 2005-2014 (Figure 1), the proportion engaged in any psychotherapy was below 50%, and the number engaged in EBT remained below 10% by 2014 (Figure 2).

Figure 1. Total annual PTS patients engaged in psychotherapy

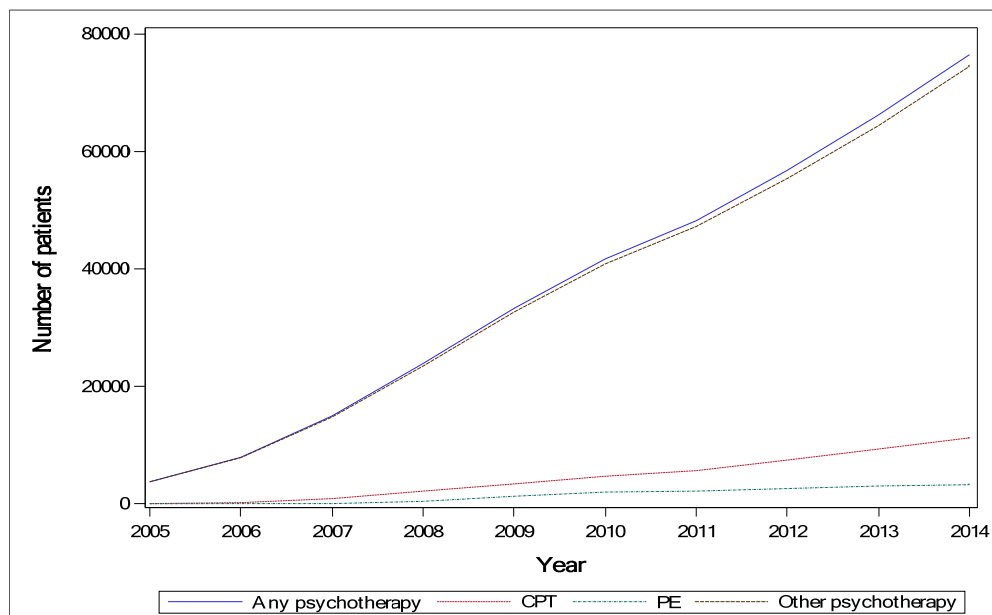
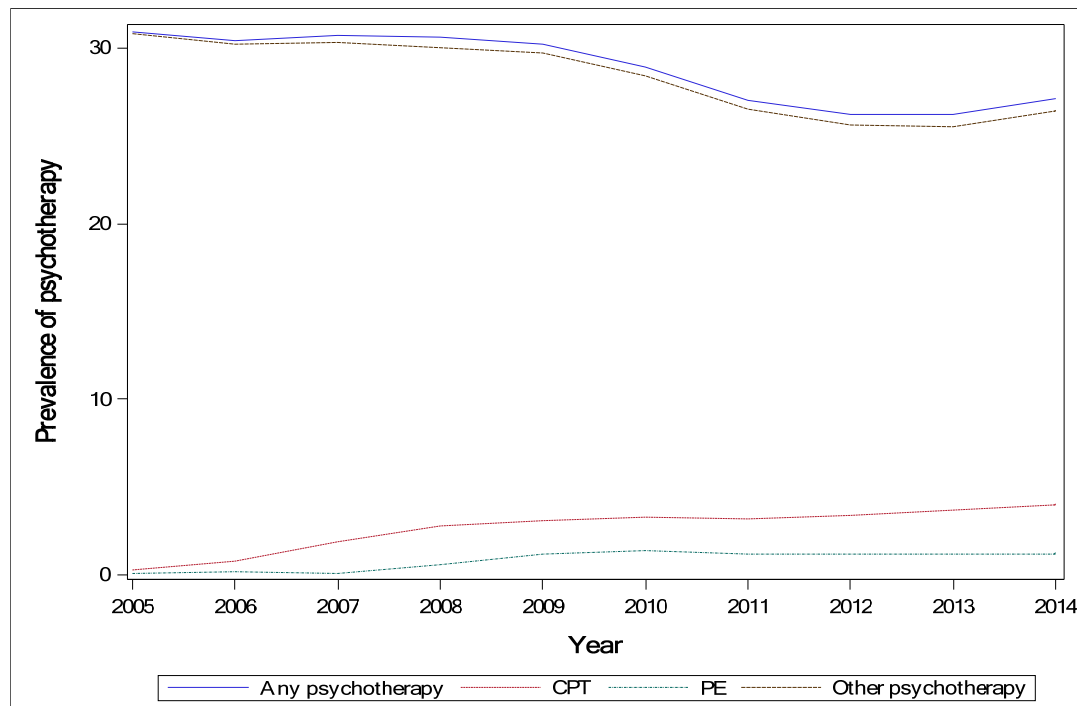


Figure 2. Prevalence of psychotherapy among cumulative PTS mental health outpatient patients



Data analysis is now well underway and we will soon begin working on using a mixed model regression of PTS symptoms (**next steps: subtask 3c**) and using a matching approach based on propensity (**next steps: subtask 3d**).

What opportunities for training and professional development has the project provided?

Nothing to report (not a goal of this study).

c. **How were the results disseminated to communities of interest?**

Nothing to report (not yet at dissemination phase).

d. **What do you plan to do during the next reporting period to accomplish the goals?**

Currently, we are evaluating the algorithm for measuring the “dose” of evidence based psychotherapy. Analysis of the Receiver Operator Characteristic (ROC) Curve will be used to

determine optimum number of visits labelled by NLP as EBT (Area under the ROC curve). Then we will apply the algorithm to all patients and proceed with the analyses (**subtasks 3c-3i**).

4. IMPACT:

- a. **What was the impact on the development of the principal discipline(s) of the project?**

Although we are currently working on our first manuscript which will assist with dissemination, it will be very helpful for mental health providers as well as mental health leadership to know that the rates of EBT in our newly returning Veterans is quite low despite these psychotherapies being available throughout the VA system.

- b. **What was the impact on other disciplines?**

We created an NLP system to determine the type of psychotherapy described in clinical notes, and we also developed an NLP system to extract PCL scores, both of which potentially has a broader impact as it results in previously unavailable data for a range of other studies in a wide range of disciplines.

- c. **What was the impact on technology transfer?**

Nothing to report. Once the project is complete we will be able to share our algorithms to further research in this area.

- d. **What was the impact on society beyond science and technology?**

Nothing to report yet.

5. CHANGES/PROBLEMS:

Theoretically all PCL scores (outcome measure of primary aim) should be recorded in a structured database (Mental Health Assistant), but we discovered that the PCL scores were often recorded in the body of a clinical notes. So, we changed our approach and created an NLP system to extract PCL scores from clinical notes to get a more complete set of PCL measurements.

We are also continuing to experience delays in the VINCI computing infrastructure. For example, without notice, there will be OIC scans that will cause delays in access to VINCI. We are in communication with the managers of VINCI when this happens, yet they inform us that these delays are out of their control and associated with security measures.

PRODUCTS:

In this period, we have performed seven annotation projects and annotated over 11,935 documents, 1297 of which were annotated by four people (quadruple-annotated) and 7,226 were double annotated. We created an NLP system to analyze narrative text of psychotherapy notes to determine the type of psychotherapy described. We also developed an NLP system to extract PCL scores from psychotherapy notes.

Along with the NLP system, we have been building the PTS cohort database based on VA's Corporate Data Warehouse (CDW) and the Roster. We have built the following components of the database: demographics, geographic characters (distance and drive time to nearest VA facility), vital signs (weight, height, BMI, and blood pressure), comorbidity, healthcare utilization (outpatient and inpatient), military sexual trauma, smoking, and medication.

Finally, we have just submitted our first manuscript describing the algorithm development and some preliminary data related to that endeavor. The manuscript is currently under review and we hope to be able to submit our next manuscript in the next few months.

6. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

a. What individuals have worked on the project?

<i>Name:</i>	<i>Shira Maguen</i>
<i>Project Role:</i>	<i>Principle Investigator, San Francisco VAMC</i>
<i>Researcher Identifier (e.g. ORCID ID):</i>	<i>N/A</i>
<i>Nearest person month worked:</i>	<i>3.5</i>
<i>Contribution to Project:</i>	<i>Dr. Maguen has provided coordination, oversight, and management of all tasks outlined in the research plan, working closely with her co-investigators.</i>

<i>Name:</i>	<i>Brian Shiner</i>
<i>Project Role:</i>	<i>Co-investigator, White River Junction VAMC</i>
<i>Researcher Identifier (e.g. ORCID ID):</i>	<i>N/A</i>
<i>Nearest person month worked:</i>	<i>4</i>
<i>Contribution to Project:</i>	<i>Dr. Shiner has helped the team use his natural language processing algorithms to identify the use of evidence-based psychotherapy for PTS. He has also assisted with methods related to this project, given his prior experience with NLP.</i>

Name: Erin Madden
Project Role: Statistician
Researcher Identifier (e.g. ORCID ID): N/A
Nearest person month worked: 5
Contribution to Project: Ms. Madden has worked to acquire the data sources used for this project, built the initial cohort and derived administrative-based datasets for the cohort.

Name: Scott Duvall/Olga Patterson/Corinne Halls
Project Role: NLP Expert, Salt Lake City VAMC
Researcher Identifier (e.g. ORCID ID): N/A
Nearest person month worked: 4
Contribution to Project: Drs. Duvall and Patterson advised the study team on NLP methods and are starting to test and modify the algorithm. Ms. Halls is overseeing annotation and coding for NLP team.

Name: Kristine Burkman
Project Role: Clinical Psychologist Coder
Researcher Identifier (e.g. ORCID ID): N/A
Nearest person month worked: 2
Contribution to Project: Dr. Burkman is a clinical psychologist who has coded clinical notes during the performance evaluation phase of the study.

Name: Lisabeth Goldstein
Project Role: Clinical Therapist Coder
Researcher Identifier (e.g. ORCID ID): N/A
Nearest person month worked: 2
Contribution to Project: Dr. Goldstein is a postdoctoral fellow who has coded clinical notes during the performance evaluation phase of the study.

b. Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?

Nothing to report.

c. What other organizations were involved as partners?

As mentioned above, we are working with the Salt Lake City VAMC.

7. SPECIAL REPORTING REQUIREMENTS

a. **COLLABORATIVE AWARDS:** *N/A*

b. **QUAD CHARTS:**

8. APPENDICES: *N/A*

Does Evidence-Based PTS Treatment Reduce PTS Symptoms and Suicide in Iraq and Afghanistan Veterans Seeking VA Care?

JW140056

PI: Shira Maguen, Ph.D.

Org: Northern California Institute for Research and Education (NCIRE)

Award Amount: \$763,732 (directs) + \$407,070 (F&A)

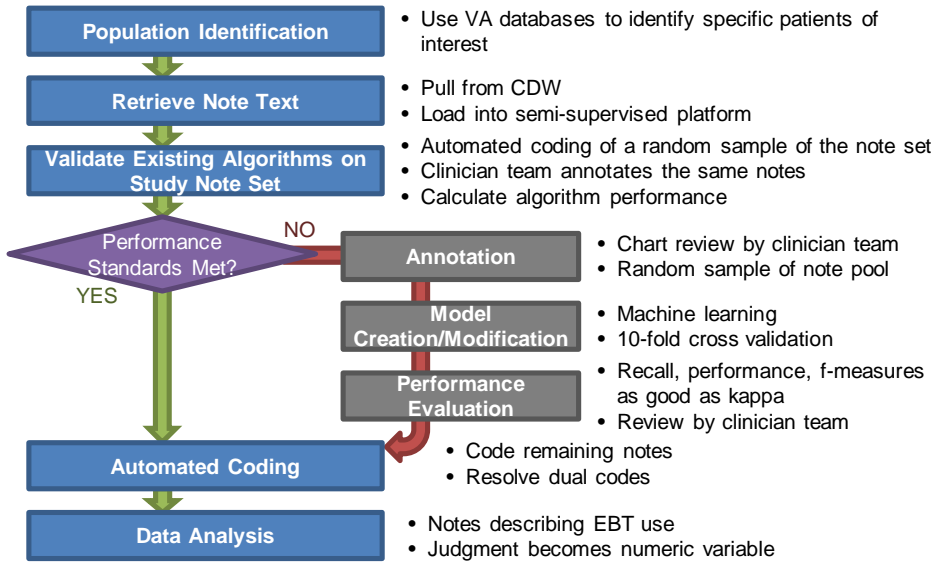
Study/Product Aim(s)

- Aim 1:** Determine whether Iraq and Afghanistan Veterans that receive EBT for PTS across the entire Veterans Administration (VA) demonstrate improvement in PTS and suicide symptoms.
- Aim 2:** Determine what percentage of Veterans with PTS complete a minimally-adequate dose of EBT for PTS, as well as factors associated with treatment completion.
- Aim 3:** Determine the association between treatment profiles (early, delayed, and no EBT) and symptom improvement in Veterans with PTS, including those with complex comorbidities (depression, TBI, substance use disorders, and/or pain disorders).

Approach

Retrospective cohort study using multiple sources of VA data from 2007 to 2014. Sample will include Iraq and Afghanistan Veterans with PTS who are new users enrolled in the VA health care system. Natural Language Processing (NLP) will be used to determine receipt of evidence-based psychotherapy for PTS.

Natural Language Processing Methods



Timeline and Cost

Activities CY	15	16	17	18
Update and Merge Existing Data and Datasets				
Use NLP to Evaluate Clinical Notes				
Data Analysis				
Finalize Study Requirements, Prepare for Future Funding, and Disseminate Findings				
Estimated Budget \$763,732 (directs)	\$57,177	\$193,098	\$256,729	\$256,728

Goals/Milestones

- CY15 Goals – Update and Merge Existing Data and Datasets**
 - ☑ Update and merge multiple VA datasets
 - ☑ Population identification
 - ☑ Retrieve note text
 - ☑ Begin developing standardized annotation guide
- CY16 Goals – Use NLP to Evaluate Clinical Notes**
 - ☑ Complete creation of standardized annotation guide
 - ☑ Quadruple annotation of 650 psychotherapy notes
- CY17 Goals –**
 - ☑ Build classifier to remove irrelevant notes
 - ☑ Annotation of enriched set of 650 notes (exceeded goal)
 - ☑ Build NLP model for types of EBT
 - ☑ Automated coding
 - ☑ Begin Data Analysis
- CY18 Goals – Complete Data Analysis and Disseminate Findings**
 - ☐ Complete data analysis
 - ☐ Finalize study requirements
 - ☐ Prepare for future funding
 - ☐ Disseminate findings