Predicting anxiety disorders and suicide tendency using machine learning: a review

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Abstract: Anxiety disorders constitute the largest group and the most common type of mental disorders. At the same time, machine learning techniques can be used for analyzing a patient's history and diagnose problems imitating the human reasoning or in making logical decisions. This work reviews the main concepts and applications of machine learning techniques in predicting anxiety disorder types. Seventeen (17) studies were considered, that applied machine learning techniques for predicting anxiety disorders and five (5) additional studies were examined for predicting suicide tendencies. The accuracy of the results varies according to the type of anxiety disorder and the type of methods utilized for predicting the disorder.

Keywords: Machine learning; generalized anxiety disorder; panic disorder; agoraphobia; social anxiety disorder; posttraumatic stress disorder; suicide tendency.

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1 Introduction

The prevalence of mental health disorders is constantly increasing especially in children and youth population (Olfson et al. 2014). At the same time, anxiety disorders constitute the largest group and the most common type of mental disorders (Lueken et al. 2016). According to Kessler et al. (2017) the types of anxiety disorders are separated in Generalized Anxiety Disorder (GAD), Posttraumatic Stress Disorder (PTSD), Social Anxiety Disorder (SAD), Panic Disorder (PD) and Agoraphobia. Machine learning techniques can be used for analyzing patient's history to diagnose the problem, imitating the human reasoning or in making logical decisions. The primary objective of this review article is to introduce researchers in the domains of medical informatics and healthcare to the main concepts and applications of machine learning techniques in predicting anxiety disorder types. We do not attempt to provide any technical details of algorithms and tools that are used to perform predictions. Instead, we provide a complete taxonomy based on the anxiety disorder which will allow us to identify and gain insights into the most commonly utilized methodologies and techniques. As the key role of machine learning prediction techniques in medicine is well established, positive effects might also be true for the prediction of anxiety disorders. Towards the validation of this assumption, we formulated two broad questions within the scope of this survey: i) which machine learning algorithms with verified accuracy are applied

in anxiety disorders prediction? and ii) which are the characteristics of the machine learning prediction techniques in the field of anxiety disorders?

The rest of the paper is organized as follows. Section 2 presents the research methodology adopted in this work. Section 3 reviews the studies included in the review and performs the analysis of the results. Finally, Section 4 concludes the paper discussing some issues for future research.

2 Research methodology

This systematic review was performed according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines (Moher et al. 2009) and the review methods were defined before conducting the review so as to ensure unbiased strategy. The following sections depict the applied methodology.

2.1 Eligibility criteria & Search strategy

In the context of this work, papers that did not meet the following set of strict inclusion criteria were excluded from this study: i) articles not assessing the accuracy of machine learning techniques in the field of anxiety disorders, ii) articles not involving participants' self-reports or claims & Electronic Health Record (EHR) data, iii) articles studying the prediction of anxiety disorders and not the outcome of relevant therapies, iv) publications other than journal or conference full articles, v) articles written in languages other than English, vi) articles published between January 2005 and December 2017.

A literature search was performed over the electronic databases of PubMed and ScienceDirect. We also performed additional searches in the conference proceedings and publication data-bases of the Institute of Electrical and Electronics Engineers, SpringerLink and SagePub. The following terms were used, being adapted to each of the databases, using standard terminology (i.e. Medical Subject Headings - MeSH) when available: ("Anxiety Disorders" OR "Generalized Anxiety Disorder" OR "Panic Disorder" OR "Agoraphobia" OR "Social Anxiety Disorder" OR "Posttraumatic stress disorder" OR "Suicide Tendency") AND "prediction" AND "machine learning".

2.2 Studies selection and data collection

The studies selection and data collection procedure was divided in three steps. Initially, studies related to mental disorders and machine learning were included. The inclusion criteria assessment was performed by two (2) of the authors over the titles and abstracts of the articles retrieved from the search strategy stage. Any discords were resolved by discussion with a third author. Subsequently, articles that focused on predicting anxiety disorders and suicide tendency using machine learning techniques were included by reviewing their full-text. The reference lists of these articles were checked manually for tracing extra related studies. Thus, we created a supplementary list of articles that was appended to the major one (i.e. the list resulted from steps 1 and 2). At the third step, the final list was examined thoroughly, in order to acquire essential information as for, the input data, the measurements and prediction methods, the tools used for the experiments, the accuracy achieved and the conclusions drawn.

3 Discussion

The database search yielded 959 studies (with duplicates removed). Articles were excluded based on information in the title and abstract. The full texts of potentially relevant articles were obtained for further assessment. Twenty-two (22) studies met the inclusion criteria. Seventeen (17) studies were examined for predicting anxiety disorders and five (5) studies were examined for predicting suicide tendencies. The major characteristics of the articles are aggregated in Tables 1-4, where *N* denotes the number of studies and *M* denotes the number that each method was applied for classification and prediction. Notice that some studies assess more than one methods. The majority of the articles considered in our review coped with PTSD (7 studies - 31.8%) while SAD and suicide tendency were studied in 5 articles each (22.7%). Moreover, Hybrid methods were the most frequently applied classification methods as it was included in 9 studies (33.3%). Most of the studies enrolled less than 100 participants, while overall the number of participants is spanning from 5 to 1728549.

The included studies use two different metrics for measuring the algorithms' prediction performance, namely Accuracy and Area Under Curve (AUC) score. Nevertheless, these two performance metrics are not directly comparable as AUC is a concrete optimization measure compared to accuracy and that there is no method of direct conversion among those metrics (Huang & Ling 2005). Furthermore, the studies were also classified according the data collection method, namely self/screening reports and claims/clinical data. The articles are equally employing both data collection methods. However no study was identified to use both methods that would potentially benefit the prediction process in terms of scope and detail.

3.1 GAD

Katsis et al. (2011) described a system based on physiological signals for the assessment of affective states in patients with anxiety disorders. This system predicts an individual's affective state based on 5 predefined classes (neutral, relaxed, startled, apprehensive and very apprehensive). Chatterjee et al. (2014) proposed a computational approach to automatically predict anxiety disorders based on visually inferred heart-rate measurements of 48 patients. They investigated the multiple heart-rate variability descriptors which can integrate affective information from the question context along with the discriminative information contained in the heart-rate variability. Husain et al. (2016) examined the potential of random forests to predict GAD among women in order to provide an effective screening process. The accuracy achieved was over 90% and the best reported one was 99.31% for a setup of 100 trees, 5 features and a balanced dataset. Hilbert et al. (2017) applied supervised machine learning algorithms on multimodal biobehavioral data from a sample of subjects suffering of GAD, major depression, both disorders, or no disorder. The authors utilized clinical questionnaire data, cortisol release, and structural MRI data in their study. Cortisol and MRI data were particularly able to provide incremental value to the disorder classification of GAD subjects beyond clinical questionnaire data alone. Classification based on combined data resulted in significant accuracy rates.

3.2 PTSD

A neural network model is proposed by Dabek & Caban (2015) which is able to predict the likelihood of developing multiple psychological conditions (including post-traumatic

stress disorder). Saxe et al. (2017) employed machine learning computational methods in order to predict development of PTSD in acutely traumatized children. In another study, Galatzer-Levy et al. (2014) assessed machine learning techniques for the identification of a set of predictive characteristics and the evaluation of their accuracy in predicting PTSD from information collected within 10 days of a traumatic event. Karstoft et al. (2015) collected data variables reflecting event characteristics, emergency department records and early symptoms from 957 trauma survivors within ten days of admission, and used them to predict PTSD symptom trajectories during the following fifteen months. A Target Information Equivalence algorithm identified all minimal sets of features that maximized the prediction of PTSD by using a support vector machine classifier. Kessler et al. (2014) examined the predictive factors of PTSD in a large sample based on the World Health Organization's world mental health surveys encompassing traumatic event exposures in surveys from 24 countries. Hybrid techniques were applied by Omurca & Ekinci (2015) in order to develop automatic classifiers for predicting PTSD patients. Also, 7 features were acknowledged as critical in diagnosing PTSD. Liu et al. (2015*b*) identified PTSD using multi-level measures derived from fMRI data. Three levels of measures are extracted as classification features: (1) regional amplitude of low-frequency fluctuations (univariate feature), (2) temporal functional connectivity (bivariate feature), and (3) spatial functional connectivity (multivariate feature).

3.3 SAD

Frick et al. (2014) utilized fMRI and sMRI data in order to discern SAD from healthy subjects based on patterns of (1) neural responses to fearful faces evaluated using Blood Oxygenation Level-Dependent (BOLD) fMRI and (2) regional gray matter volume evaluated with sMRI. Pantazatos et al. (2014) tried to identify pairwise feature correlations which discriminated patients with SAD from health subjects, utilizing BOLD fMRI during emotional face perceptual tasks, a new condition-dependent functional connectivity and a Support Vector Machine (SVM). Liu et al. (2015*a*) divided the brain into 116 regions based on automated anatomical labeling atlas and examined the potential of the functional connectivity to be used for SAD diagnosis. The functional connectivity between each pair of regions was computed using Pearson's correlation coefficient and used as classification feature. Patient's classification from healthy controls was performed with multivariate pattern analysis using linear SVM. In a work conducted by Zhang et al. (2015), forty patients were scanned by resting-state fMRI in order to examine the diagnostic potential of Regional Homogeneity (ReHo) underlying neural correlates of SAD using SVM. The ReHo was calculated as synchronization of fMRI signals of nearest neighboring 27 voxels. Subsequently, a linear SVM was applied for the classification of the two groups. Sharma et al. (2016) examined electrodermal activity features for the estimation of SAD via neural networks. 60 adolescent female participants were initially screened through Social Phobia Inventory questionnaire and randomly divided in two groups (i.e. anxious and control). Subsequently, Electrodermal activity was recorded and wavelet features were extracted to perform classification.

3.4 PD & Agoraphobia - Suicide tendency

A random undersampling tree ensemble in a leave-one-out cross-validation framework was utilized by Lueken et al. (2015) to predict the comorbidity status of 59 participating patients. Iliou et al. (2016) developed a machine learning mechanism for predicting whether a patient suffering from depression is suspect of committing suicide. Among the main findings of this

work is that depression symptoms in adolescents as early as 14-15 years old is a predictor of suicidal tendency. Walsh et al. (2017) made an effort to overcome limitations of traditional approaches to the prediction of suicide attempts by applying machine learning to electronic health records within a large medical database. The main objective of Barak-Corren et al. (2016) was to perform a feasibility study to identify whether longitudinal historical data from EHR systems, can be used to predict patients' future risk of suicide tendency. Oh et al. (2017) investigated the predictive power of the information from multiple self-report clinical scales for identifying actual suicide attempts. The purpose of this approach was to identify patients under high risk of suicidal attempts. A technique that automatically classifies subjects according their linguistic and acoustic patterns in three categories (i.e. suicidal, mentally ill but not suicidal and control) was proposed by Pestian et al. (2017).

Anxiety Disorder Type	*N*	%
GAD	4	18.2%
PD & Agoraphobia	1	4.5%
PTSD	7	31.8%
SAD	5	22.7%
Suicide tendency	5	22.7%

Table 1 Studies included in review per anxiety disorder type

Study type	*N*	%
Claims and/or Clinical data	13	59.1%
Self or screening report	9	40.9%

Table 2 Studies included in review classified per study type

Sample size	*N*	%
< 100	11	50.0%
$100 - 1000$	7	31.8%
> 1000	4	18.2%

Table 3 Studies included in review per sample size

Classification and prediction method	*M*	%
Bayesian networks	2	7.4%
Artificial neural networks	3	11.1%
Support vector machines	5	18.5%
Decision trees	2	7.4%
Logistic regression	2	7.4%
Fuzzy systems	1	3.7%
Ensemble methods	3	11.1%
Hybrid methods	9	33.3%

Table 4 Studies included in review per classification and prediction method

4 Conclusions

In summary, we deduce that significant work has been done on the prediction of anxiety using artificial intelligence and data mining. Several machine learning techniques have been utilized to develop accurate prediction models in order to assist in providing better medical services. We observed that Hybrid methods and SVM were the most highly used method especially for the prediction of PTSD and SAD respectively. Moreover, artificial neural networks and ensemble methods performed very well, managing to achieve the highest prediction scores while Neuro-Fuzzy systems had some good scores too. Furthermore, we saw that the combination of multi-level features using multi-kernel learning can lead to an improvement of the classification performance for predicting PTSD.

However, in all those cases where the dataset size is too small, not available (N/A), or not explicitly mentioned in the respective article, one cannot verify with any degree of certainty the classification accuracy reported as achieved by the authors of the article. A very analytic presentation of this work can be found in Kotsilieris et al. (2018).

Our future work is concentrated on identifying which method performs better depending on the type of anxiety. Another interesting aspect is experimenting with other methodologies and techniques in order to achieve even higher scores for the prediction of anxiety and that could enhance the treatment support for patients.

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