Discovering useful insights, and how they can be applied, from text-based digital media, in relation to mental health and suicide prevention, using data analysis and machine learning: A systematic review

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Abstract

Background: Digital media platforms have revolutionized communication and information sharing, providing valuable access to knowledge and understanding in the fields of mental health and suicide prevention.

Objective: This systematic review will determine how machine learning and data analysis can be applied to text-based digital media data, to understand mental health and to aid suicide prevention.

Methods: A systematic review of research papers from the following major electronic databases was conducted: Web of Science, MEDLINE, EMBASE (via MEDLINE), and PsycINFO (via MEDLINE). The database search was supplemented by hand-search using Google Scholar. The searches were carried out using the following categories: (mental health OR suicide) AND machine learning AND data analysis AND digital interventions.

Results: Overall, 19 studies were included, with five major themes as to how data analysis and machine learning techniques could be applied: 1) As predictors of personal mental health; 2) Understanding how personal mental health and suicidal behavior are communicated; 3) To detect mental disorders and suicidal risk; 4) To identify help seeking for mental health difficulties; and 5) To determine the efficacy of interventions to support mental wellbeing.

Conclusions: Our findings show that data analysis and machine learning can be utilized to gain valuable insights: where online conversations relating to depression have shown to vary among different ethnic groups; teenagers engage in an online conversation about suicide more often than adults; and people seeking support in online mental health communities feel better, after receiving online support. Digital tools and mental health apps are being used successfully to manage mental health, particularly through the Covid-19 epidemic, where analysis has revealed that there was increased anxiety and depression, and online communities played a part during the pandemic. Predictive analytics were also shown to have potential and virtual reality shows promising results in the delivery of preventive or curative care. Future research efforts could center on optimizing algorithms to enhance the potential of digital media analysis in mental health and suicide prevention. In addressing depression, a crucial step involves identifying the factors that contribute to happiness and employing machine learning to forecast these sources of 'happiness'. This could extend to understanding how various activities result in improved happiness across different socio-economic groups. Using insights gathered from such data analysis and machine learning, there is an opportunity to craft digital interventions, such as chatbots, designed to provide support and address mental health challenges.

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Keywords: Mental Health; Suicide Prevention; Machine Learning; Data Analysis; Digital Intervention.

Introduction

Text-based digital media platforms have revolutionized communication and information sharing, offering valuable opportunities to gain insights into various domains, including mental health and suicide prevention.

Social media platforms have become significant sources of data for studying mental health and suicide prevention, where researchers have explored the potential of using platforms such as Twitter and Facebook to gain insights into individuals' mental wellbeing, detect mental health concerns, and identify suicide risk factors. For example, Coppersmith et al. [CITATION Cop18 \l 6153] developed a machine learning model to detect signals related to depression in user posts on Twitter, achieving promising results. Additionally, De Choudhury et al. [CITATION DeC16 \l 6153] analysed Facebook posts to identify individuals at risk of depression, demonstrating the feasibility of using social media data for mental health monitoring. Research methods involve various techniques, including sentiment analysis, topic modelling, and Natural Language Processing, to analyse large volumes of data and identify patterns and trends. For instance, Park et al. [CITATION Par12 \l 6153] applied sentiment analysis to examine suicide-related tweets and identified specific linguistic features associated with suicidal ideation. Sik et al. [CITATION Sik21 \l 6153] used topic modelling to identify mental health-related topics in online forums, facilitating targeted interventions and support. Additionally, Burnap et al. [CITATION Bur17 \l 6153] employed Natural Language Processing techniques to analyse online content and identify individuals expressing suicidal ideation, which could enable timely interventions.

Data analysis and machine learning techniques have been utilized for detecting mental health issues and identifying individuals at risk of suicide, where these sophisticated techniques could enhance clinical decision-making in relation to suicide[CITATION Pig24 \l 6153]. Some researchers have explored the use of predictive models to assess suicide risk factors and facilitate early intervention. For example, O'Dea et al. [CITATION ODe15 \l 6153] developed a predictive model using machine learning algorithms to identify suicide attempt risk among social media users, highlighting the potential for targeted prevention strategies. Data analysis can also be used to provide valued understanding into factors associated with suicide and mental health, that are not easily identifiable. These insights can then be used to develop strategies for prevention and intervention. For example, data analysis can identify potential underlying causes and risk factors associated with suicide, which can then lead to the development of interventions for those vulnerable groups. Finally, data analysis can also be used to analyse the effectiveness of current prevention efforts to improve targeted interventions and strategies.

With the rise in the use of smart phones, digital interventions have been able to offer a solution to address the increased demand for mental health services[CITATION Kal05 \l 6153], and to relieve certain barriers in mental health provision, such as stigma around accessing psychological health services and geographical isolation[CITATION Swe213 \l 6153]. This paper presents a systematic review of the research on the use of machine learning and data analysis, to text-based digital media data, in relation to mental health and the prevention of suicide, to help answer the following research question:

How can machine learning and data analysis be applied to text-based digital media data to understand mental health and to aid suicide prevention?

Methods

Search Strategy – Electronic Database Search

A systematic literature search was performed for articles published from 1st January 2013 to 10th July 2023, and was conducted using 4 databases: Web of Science, MEDLINE, EMBASE (via MEDLINE), and PsycINFO (via MEDLINE)*, using the following search terms, which were adapted for each database: (mental health OR depression OR suicide) AND (machine learning OR deep learning OR artificial intelligence) AND (text analysis OR text mining OR data analysis) AND (digital intervention OR digital mental health). The full search strings are included in Appendix A – Electronic Database – Search criteria. Author CS performed the literature search. EE, MM and RB discussed and verified the inclusion/exclusion criteria. The Study Selection section identifies how articles were included in this review and also how articles have been included. These database searches were supplemented by hand-search techniques. An additional manual search was run using Google Scholar/Advanced Search (Date: 10/07/23. The first 5 pages of search results were screened on title (n=50 records), as per PRISMA guidelines [CITATION Ret21 \l 6153]).

*Note: Retrospective searches were conducted (using the same criteria) using both PubMed and Scopus databases, to extend the research to bigger databases. No new relevant articles were detected.

Study selection

A total of n = 27 records were identified according to the above search methods. An additional 50 records were identified through searching Google Scholar articles. Of n = 71 unique articles, a further n = 45 were excluded after abstract screening. A full text review was performed for n = 26 articles according to study inclusion criteria, and 19 were included after full text screening (see Figure 1). Seven reports failed to meet the stated inclusion criteria. This included failure due to: Analysing NLP methods in non-English language (n=1); Wrong study type - Qualitative analysis of the use of social media in mental health and teaching mental health intervention in schools/Feasibility Study/Review of previous studies (n=5); and did not relate to data analysis (n=1). See Figure 1 for all studies (n = 19).

Quality assessment

An assessment for bias risk was performed using the Transparent Reporting of a Multivariable Prediction Model for Individual Prognosis or Diagnosis (TRIPOD) guidelines [CITATION Col15 \l 6153]. See Supplementary Materials for more details relating to how the TRIPOD checklist was used and Tripod ratio calculated for the article relating to relate to prediction/classification (see Supplementary Table 2 for risk bias results).

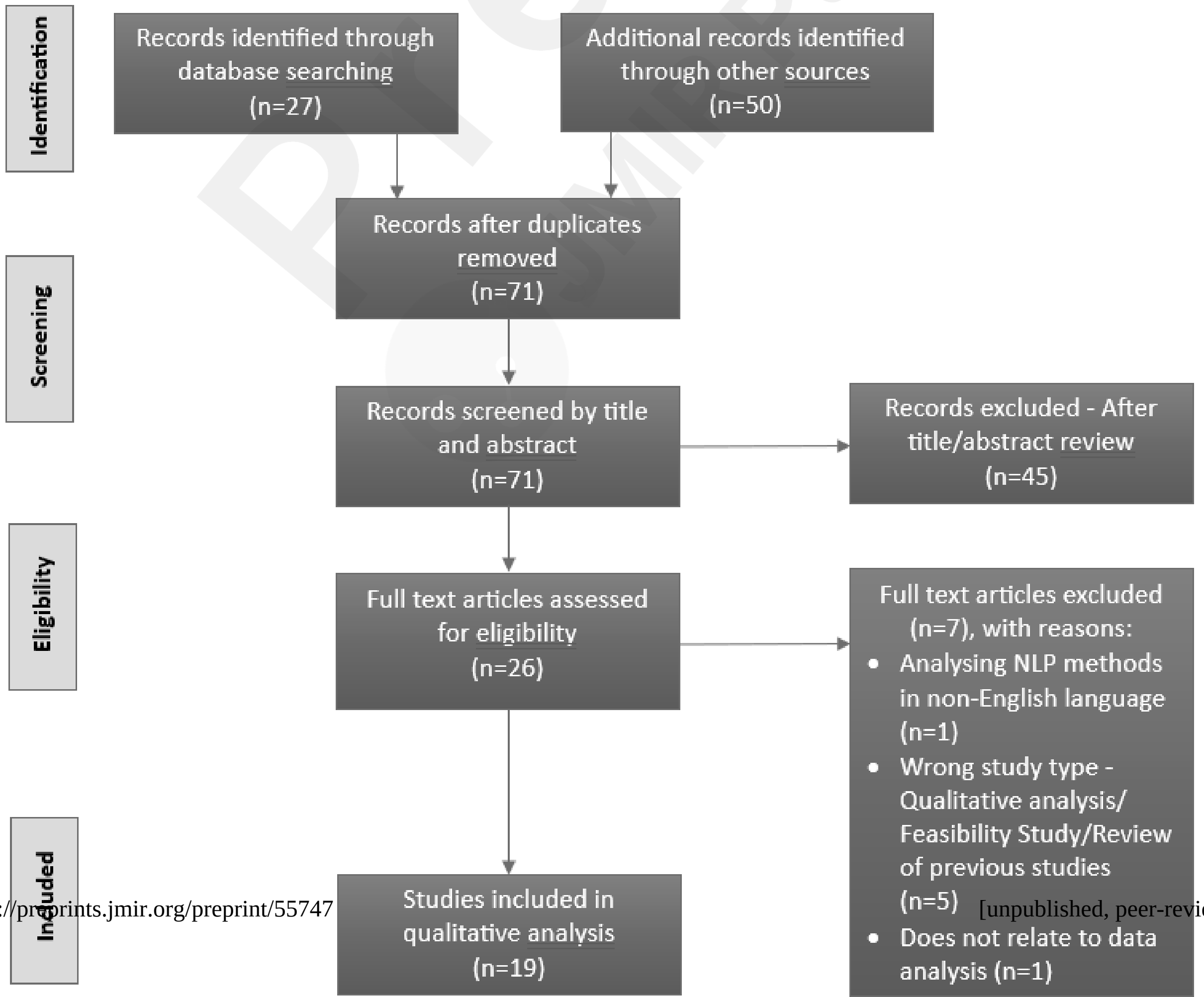

Figure 1. Preferred Reporting Items for Systematic Reviews (PRISMA) flow diagram.

Results

Types of analysis to assess text-based digital data and outcomes

This review is to determine how machine learning and data analysis can be used to assess text-based digital media data, in relation to mental health and the prevention of suicide. Regarding the type of analysis and outcome measures employed within these publications, machine learning and text-based data analysis was employed in four of the studies ([CITATION Sim17 \l 6153]; [CITATION Cas21 \l 6153]; [CITATION Fal20 \l 6153]; [CITATION Gol20 \l 6153]). Three of the studies performed some sort of analysis on survey or questionnaire data ([CITATION Ait21 \l 6153]; [CITATION Xia20 \l 6153]; [CITATION Wad23 \l 6153], [CITATION Kha20 \l 6153]) and three papers analysed the value of text-based digital media ([CITATION Liu211 \l 6153]; [CITATION Feu18 \l 6153]; [CITATION Chi20 \l 6153]). The analysis of digital interventions was the main type of analysis employed by ([CITATION Ony21 \l 6153]; [CITATION Ver20 \l 6153]; [CITATION Van141 \l 6153]). The remaining types of investigations include the analysis of forum or discussion data[CITATION Gol22 \l 6153], and longitudinal analysis [CITATION Val20 \l 6153]. Where machine learning for prediction were used within the studies, the outcome metrics were also listed in the table. These include Roy et al., who investigated how machine learning approaches could be used to predict suicidal ideation from social media data[CITATION Roy20 \l 6153]. They trained a random forest model using Neural Networks to predict suicide ideation status with a with an AUC of 0.88. Gu et al. use TextCNN (convolutional neural network for text) for classifier training and classification, which produced the following scores: Precision (0.84); Recall (0.84); and F1 (0.84) [CITATION GuD23 \l 6153]. Oyebode et al. used various different machine learning methods to evaluate mental health apps based on user reviews. Scorings for the 5 models was producing similar scores with the SGD (Stochastic Gradient Descent) showing the best performance of the five classifiers [CITATION Oye20 \l 6153] (see Table 2).

Another study [CITATION Sim17 \l 6153] used logistic regression, with a 73.0% accuracy of the logistic model at detecting cognitive distortions. Linear regression was another method used in predicting depressive symptoms and yielded a significant model as a significant predictor of depression [CITATION Van141 \l 6153]. Machine learning was also used in a psychotherapy research study, where the model that used therapist text and extracted features using tf-idf performed best overall, with MSE = 0.67 and Spearman's Rank Correlation Coefficient = 0.15 ($p < .001$) [CITATION Gol20 \l 6153]. Association rule mining was used in analysing survey data [CITATION Kha20 \l 6153], where the top rule identified an association between strong disappointment with missing events and missing friends in person (Support - 0.286, Confidence - 0.671 , Lift - 1.454), due to the pandemic.

Sentiment was measured for various studies, where it was measured as positive for a virtual community platform for mental health [CITATION Gol22 \l 6153], and text had a positive scoring which correlated with the number of likes [CITATION Liu211 \l 6153] of the posts. Another survey [CITATION Ony21 \l 6153] found that respondents with anxiety or depression were generally more likely to report that their smart device had helped them in their discussions with their healthcare providers (42.7% vs 35.3%; $p = 0.034$). Negative tone was also measured for Hispanics conversations compared to 39% among non-Hispanics [CITATION Cas21 \l 6153] and total causal effect of disability acquisition on mental health was estimated to be a 4.8-point decline in mental health [CITATION Ait21 \l 6153]. There was also a negative trajectory in sentiment scores from a longitudinal analysis of Twitter data during the COVID-19 pandemic [CITATION Val20 \l 6153]. Another study [CITATION Fal20 \l 6153] reported a higher percentage of adults show a defeatist attitude compared to teenagers (42% vs 4%) with epilepsy. In a family wellbeing study, 53% of respondents thought seeking help would negatively affect his/her career and 63% were afraid to ask for help [CITATION Wad23 \l 6153]. The results of a questionnaire to establish the mental health of Chinese online networkers, found that with an increase in socioeconomic status (SES), depression decreases by a margin of -0.52 ($p < 0.001$) [CITATION Xia20 \l 6153].

Having identified the 19 papers for further analysis, the authors attempted to identify any themes within the selected articles. This involved an initial in-depth review, to get familiarized with the text and by using simple coding to highlighting sections of the texts that best describe the content, we were able to identify shorthand labels or 'codes', for example, prediction and mental health detection of mental disorders and suicide risk. From the coding, we were then able to identify 5 themes, where machine learning and data analysis techniques could be applied. The are outlined, with the number of papers per theme in table 1 below.

Table 1: Table showing themes and number of papers per theme

Theme	**Name**	**Number of papers**
1	As predictors of personal mental health	n=4
2	To detect mental disorders and suicidal risk	n=2
3	Understanding how personal mental health and suicidal behaviour are communicated	n=5
4	To identify help seeking for mental health difficulties	n=1
5	To determine the efficacy of interventions to support mental wellbeing	n=7

Of the 19 papers that were reviewed, details including the author, year, title, population studied, data volume and main themes are shown in Table 2 below.

Table 2: Review of themes – showing author/year, title, population, data volume and theme

uthors ear)	Title	Population	Data	Volume	Type of analysis	Outcome metrics	Theme
tken et (2021) CITA ION it21 \ 153]	How much of the effect of disability acquisition on mental health is mediated through employment and income? A causal mediation analysis quantifying interventional indirect effects using data from four waves of an Australian cohort study	Australian households	Data from the Household, Income and Labour Dynamics in Australia (HILDA) Survey.	10,450 respondents to survey that completed data on disability.	Analysis of survey data – using causal mediation analysis.	Total causal effect of disability acquisition on mental health was estimated to be a 4.8-point decline in mental health.	Predictors of personal mental health.
nattar et (2020) [CIT ATIO N Kha2 0 \l 6153]	Effects of the disastrous pandemic COVID 19 on learning styles, activities and mental health of young Indian students-a machine learning approach	Young Indian students.	Online survey/ questionnaire results.	583 students' responses.	Analysis of survey/ questionnaire data - Using association rule mining.	Rule 1 produced scorings of: Support - 0.286, Confidence - 0.671 , Lift - 1.454.	Predictors of personal mental health.
ldez et (2020) CITA	Social media insights into US mental health during the COVID-19 pandemic: Longitudinal analysis of	Users of Twitter social	Publicly available Twitter data.	86,581 tweets.	Longitudinal analysis - Using	Negative trajectory in sentiment scores for the user-timeline	Predictors of personal mental health.

uthors ear)	Title	Population	Data	Volume	Type of analysis	Outcome metrics	Theme
ION al20 \ 153]	Twitter data	media platform.			(VADER) sentiment analysis tool.	data.	
ao et al. 020) CITA ION ia20 6153	Mental health of Chinese online networkers under COVID-19: A sociological analysis of survey data	Users of Chinese WeChat network platform.	Results of completed questionnaires.	Out of a total of 3,491 participants, 2,015 questionnaires were valid.	Analysis of Survey data - OLS regression.	With one-unit (standard deviation) increase in socioeconomic status (SES), depression decreases by a margin of -0.52 (p < 0.001).	Predictors of personal mental health.
oy et al. 020) CITAT ON oy20 \ 6153]	A machine learning approach predicts future risk to suicidal ideation from social media data	Users of Twitter social media platform.	Publicly available Twitter data.	512,526 tweets.	Machine Learning for prediction – Random Forest model using Neural Network outputs.	**RF/NN** AUC: 0.88 (95% CI 0.86–0.90).	Detection of mental disorders and suicidal risk.
mms et (2017) CITAT ON im17 \ 6153]	Detecting cognitive distortions through machine learning text analytics	Users of Tumblr microblogging and social networking site.	Personal blogs from Tumblr.	493 posts.	Machine learning and text-based data analysis - logistic regression.	Accuracy of the logistic model is 73.0%.	Detection of mental disorders and suicidal risk.
olz et al. 022) CITA ION ol22 6153	Mental health-related communication in a virtual community: text mining analysis of a digital exchange platform during the Covid-19 pandemic	Almost 700 users of virtual community platform for mental health - inCLOUsiv	Data from the forums and live discussions were stored in MySQL database.	Dataset consists of 31,764 words.	Analysis of forum/discussion data – Sentiment Analysis.	72% of the identified sentiments were positive.	Understanding how personal mental health and suicidal behaviour are communicated.
astilla- entes et (2021) CITA ION as21 6153	Digital conversations about depression among Hispanics and non-Hispanics in the US: a big-data, machine learning analysis identifies specific characteristics of depression narratives in Hispanics	Hispanics and non-Hispanics in the US.	Open-source sites, message boards, social networks and blogs.	441,000 unique open-source conversations about depression.	Machine learning and text-based data analysis – content analysis.	Content analysis shows that 66% of Hispanics conversations portray negative tone as compared to 39% among non-Hispanics.	Understanding how personal mental health and suicidal behaviour are communicated.
u et al. 021) CITA ION iu211 6153	Why do users of online mental health communities get likes and reposts: a combination of text mining and empirical analysis	Users on super topic community relating to depression.	Text was obtained from depression super-topic community.	Text data and user data for 49,047 posts in the depression.	Analysing the value of text-based digital media – using LDA topic model.	Social experience in posts (Coef. – 0.368), emotional expression (Coef. - 0.353), and the sentiment contained in the text (Coef. - 0.002) all had significant positive relationships with the number of likes and reposts.	Understanding how personal mental health and suicidal behaviour are communicated.
lcone et al. 020) CITA	Digital conversations about suicide among teenagers and adults with epilepsy: A big-data, machine learning analysis	Teenagers (13-to 19-year-olds) and adults	Open-source digital conversations - Across topical	222,000 unique conversations about epilepsy, including 9,000	Machine learning and text-based data analysis	Higher percentage of adults show a defeatist ("given up") attitude compared to	Understanding how personal mental health and suicidal

uthors ear)	Title	Population	Data	Volume	Type of analysis	Outcome metrics	Theme
		(≥20 years of age).	sites, blogs, social network, and message boards	(4%) related to suicide.	- thematic analysis.	teenagers (42% vs 4%).	behaviour are communicated.
euston al. (2018) CITA ION eu18 6153	Beyond the coded gaze: Analysing expression of mental health and illness on Instagram	Users of Instagram social media platform.	Posts relating to mental health from Instagram.	3,000+ posts.	Analysing the value of text-based digital media – using constructivist grounded theory approach.	Semi-structured interviews with 14 adults.	Understanding how personal mental health and suicidal behaviour are communicated.
addell et (2023) CITAT ON Vad23 \ 6153]	Families' experiences of supporting Australian veterans to seek help for a mental health problem: a linked data analysis of national surveys with families and veterans	Veterans and family members.	Family Wellbeing Study (FWS) with linked Mental Health Wellbeing Transition Study (MHWTS) data.	1,217 FWS respondents linked with 1,123 MHWTS respondents.	Analysis of survey data.	53% thought seeking help would negatively affect his/her career and 63% were afraid to ask for help.	Help seeking for mental health difficulties.
u et al. 023) CITAT ON uD23 153]	An analysis of cognitive change in online mental health communities: A textual data analysis based on post replies of support seekers	Users of online mental health communities.	Reply data from online mental health community.	31,935 replies to comments.	Machine Learning for prediction – using TextCNN.	**TextCNN** Precision: 0.84 Recall: 0.84 F1: 0.84	Efficacy of interventions to support mental wellbeing.
nyeaka et (2021) CITA ION Dny21 \ 6153]	Use of smartphones, mobile apps and wearables for health promotions by people with anxiety or depression: An analysis of a nationally representative survey data	Respondent to Health Information National Trends Survey (HINTS 5).	Data from Health Information National Trends Survey (HINTS 5).	5,438 respondents.	Analysis of digital Interventions – using chi-squared tests.	Those respondents with anxiety or depression were generally more likely to report that their smart device had helped them in their discussions with their healthcare providers (42.7% vs 35.3%; p = 0.034).	Efficacy of interventions to support mental wellbeing.
nikersal al. 020) CITAT ON hi20 \l 153]	Understanding client support strategies to improve clinical outcomes in an online mental health intervention	Supporters (of clients) on SilverCloud (iCBT) platform.	Supporter messages to clients.	234,735 supporter messages.	Analysing the value of text-based digital media – Using Association rule mining.	Lower word count is more salient in more successful messages.	Efficacy of interventions to support mental wellbeing.
oldberg al. 020) CITAT ON ol20 \l 153]	Machine learning and natural language processing in psychotherapy research: Alliance as example use case	Therapists and client attending counselling sessions.	Recordings from sessions with clients and therapists.	Recordings from 1,235 sessions.	Machine learning and text-based data analysis – using mean squared error (MSE) and Spearman's rank correlation.	The model that used therapist text and extracted features using tfidf performed best overall, with MSE = 0.67 and Spearman's Rank Correlation Coefficient = 0.15, p < .001.	Efficacy of interventions to support mental wellbeing.
yebode al. 020) CITAT ON	Using machine learning and thematic analysis methods to evaluate mental health apps based on user reviews	Users of mental health apps.	Reviews by user of mental health apps.	88,125 user reviews.	Machine Learning for prediction – Using SVM, LR, MNB, SGD and RF.	**SVM** Precision: 0.8940 Recall: 0.8939 F1: 0.8939 **LR** Precision: 0.8938	Efficacy of interventions to support mental wellbeing.

uthors ear)	Title	Population	Data	Volume	Type of analysis	Outcome metrics	Theme
						Recall: 0.8937 F1: 0.8937 **MNB** Precision: 0.8908 Recall: 0.8908 F1: 0.8907 **SGD** **Precision: 0.8945** **Recall: 0.8943** **F1: 0.8942** **RF** Precision: 0.8769 Recall: 0.8770 F1: 0.8769	
ermetten al. 020) CITA ION er20 \ 153]	Using VR-based interventions, wearable technology, and text mining to improve military and Veteran mental health	Military members and Veterans.	Self-narratives collected online.	300 self-narratives collected online.	Analysis of digital Interventions.	The variable of the word "family" was found to be the most significant predictor in Linguistic Inquiry and Word Count (LIWC).	Efficacy of interventions to support mental wellbeing.
an emert- jnen et (2014) CITA ION an14 \l 153]	Understanding the usage of content in a mental health intervention for depression: an analysis of log data	Users of Web-based intervention - 'Living to the Full'.	Log data from Web-based intervention system.	206 participants.	Analysis of digital Interventions – using linear regression.	Linear regression yielded a significant model with login quartile as a significant predictor (explained variance is 2.7%).	Efficacy of interventions to support mental wellbeing.

AUC - Area under the curve; LR - Logistic Regression; MNB - Multinomial Naïve Bayes; NN – Neural Network; SGD - Stochastic Gradient Descent; RF - Random Forest; SVM – Support Vector Machine; TextCNN - Convolutional Neural Network for text.

These themes are further expanded below.

Predictors of personal mental health

Personal mental health can be influenced by various factors, for example employment status and income and various analytical tools have been used to determine sentiment, or other predictors of personal mental health. Research by Aitken et al. [CITATION Ait21 \l 6153] sought to determine the extent to which alterations in employment and income impact mental health. Their methods employed logistic regression models specifically for employment and income, considering their conditional relationship with disability acquisition. The analysis technique focused on evaluating the significance of text-based digital media, where their findings indicated that 10.6% of the effect of disability acquisition on mental health was explained by changes in individuals' employment status, but with no similar effect observed through changes in income. This underscores the importance of addressing disability-related mental health disparities, specifically the equalization of employment rates between individuals with and without disabilities to reduce disability-related mental health inequalities.

Other research by Xiao et al. [CITATION Xia20 \l 6153] sought to examine survey data to measure the prevalence of depression symptoms and their correlation with an individual's socioeconomic status and lifestyle, during the COVID-19 pandemic, in China. The methodology involved statistical analyses using SPSS, to evaluate survey data. The findings revealed a noteworthy impact of the pandemic, indicating that respondents experienced more severe mental symptoms when their residential communities were more exposed to the virus. The implications drawn from these findings suggest that mental health conditions among survey respondents varied based on different levels of COVID-19 severity. Notably, residents in communities with a high severity of the epidemic exhibited more pronounced symptoms of depression and anxiety.

Khattar et al. [CITATION Kha20 \l 6153] conducted an online survey study with the goal of understanding the day-to-day experiences and mental well-being of young students in India, during the pandemic. They analysed survey responses using R and Python, to evaluate the mental health of diverse populations during the ongoing Covid-19 pandemic. Their findings revealed that approximately 19.2% expressed weariness with phone usage, while 42.9% reported feeling a mix of frustration, profound boredom, anxiety, overwork, and depression. Conversely, 37.9% indicated experiencing emotions such as relaxation, peace, optimism, calmness, hopefulness, and love. This suggests a crucial role for teachers and mentors in providing emotional support to students. They also used association rule mining to analyse the survey data, where the top rule identified an association between strong disappointment with missing events and missing friends in person (Support - 0.286, Confidence -0.671 , Lift - 1.454), due to the pandemic.

Valdez et al. [CITATION Val20 \l 6153] investigated the extent of social media usage at the onset of the pandemic, to uncover emerging themes from tweets related to COVID-19, and to examine whether sentiments changed in response to the COVID-19 crisis. They employed the Latent Dirichlet Allocation (LDA) method for topic modelling and Valence Aware Dictionary and sEntiment Reasoner (VADER) for sentiment analysis. Their findings indicated that sentiment scores were initially high and stable but exhibited a significant decrease over time, indicating reduced sentiment over the long-term.

Various data analysis techniques have been applied as predictors of personal mental health, where the effect of disability acquisition on mental health, for example, was explained by changes to people's employment but not through income[CITATION Ait21 \l 2057]. In relation to the Covid 19 pandemic, the overall emotional state of students during lockdown showed a mix of various moods with feelings ranging from frustration, boredom, anxiety, and depression[CITATION Xia20 \l 2057]. Additionally, themes emerged from tweets about COVID-19, to highlight the extent that social media use increased during the onset of the COVID-19 pandemic[CITATION Kha20 \l 2057], and how sentiment changed in response to the pandemic[CITATION Val20 \l 2057]. The pandemic has had a significant impact on mental health, where respondents had more serious mental symptoms when their residential communities exhibited a greater exposure to the spread of the virus[CITATION Xia20 \l 2057].

Detection of mental disorders and suicidal risk

Machine learning can be used in the detection of cognitive distortions, that may fuel anxiety and also for detecting those at risk to suicide. Roy et al. [CITATION Roy20 \l 6153] developed a model capable of predicting individuals at risk and assessing the likelihood of experiencing suicidal thoughts within a specific time frame. This involved employing a random forest model that utilized output from neural networks to predict binary suicidal ideation (SI) status, when matched with match at least one of the word patterns in the ordered word screening, for example 'feeling suicidal'. This study found that the neural network models successfully predicted suicidal ideation even before individuals articulated explicit thoughts of suicide. These findings suggest that there may be potential for predicting suicidal ideation before individuals explicitly express such thoughts, offering opportunities for early intervention and support.

Simms et al. [CITATION Sim17 \l 6153] demonstrated that machine learning could also be applied to detecting cognitive distortions (where the user would be thinking negatively and discounting the positive, for example), from personal blogs. Through the use of Linguistic Inquiry and Word Count software, this study found that it is feasible to automatically detect cognitive distortions from personal blogs with a relatively high accuracy of 73.0%. The implications drawn from these findings underscore the potential benefits of continued work in this area for mental health care and psychotherapy. This progress has the potential to lead to lower costs, earlier detection, and more efficient utilization of counselling time.

These findings show that it is possible to detect cognitive distortions automatically from personal blogs with an accuracy of 73.0%[CITATION Sim17 \l 2057], and this could lead to earlier detection of anxiety, and possible intervention at an earlier stage. Neural network models, which are powerful machine learning tools, have been shown that they can be successfully in the detection of mental disorders and suicidal risk, where certain models were shown to predict suicide ideation even before suicidal thoughts were articulated[CITATION Roy20 \l 2057].

Understanding how personal mental health and suicidal behaviour are communicated

When attempting to understand how we communicate personal mental health and suicidal behaviour, machine learning has been used to explore big data from open-source digital conversations with regard to suicidality. The aim of the research by Castilla-Puentes et al. [CITATION Cas21 \l 6153] was to delve into big data derived from open-source digital conversations among Hispanics, to determine attitudes toward depression, comparing Hispanics and non-Hispanics. The methodology involved the analysis of tone, topic, and attitude relating to depression using machine learning and Natural Language Processing (NLP). This study revealed a notable disparity in attitudes, beliefs, and treatment-seeking behaviour between the 2 groups, providing insights into the mindset and attitudes towards depression from a previously unexplored vantage point.

Falcone et al. [CITATION Fal20 \l 6153] investigated big data derived from open-source digital conversations among people with epilepsy (PWE) with regard to suicidality, within teenager and adult groups. They employed NLP and text analytics to reveal that a higher percentage of teenagers, compared to adults, expressed fear of ‘the unknown’ due to seizures (63% vs. 12%), concern about social consequences of seizures (30% vs. 21%), and a desire for emotional support (29% vs. 19%). In contrast, a significantly higher percentage of adults exhibited a defeatist (‘given up’) attitude compared to teenagers (42% vs. 4%). The implications of this study suggest that teenagers engage more frequently in online conversations about suicide than adults, and that there are notable differences in attitudes and concerns. These distinctions may have implications for the treatment of younger patients with epilepsy.

Liu et al. [CITATION Liu211 \l 6153] sought to identify the factors influencing the number of likes and reposts within an online community dedicated to depression. This involved using a combination of text mining and empirical analysis to delve into the factors affecting user engagement, specifically the number of likes and reposts. They found that users within online mental health communities exhibit a higher level of attention to topics related to social experiences and emotional expressions. These findings emphasize that understanding the factors influencing the number of likes and reposts in online mental health communities can be advantageous for users, facilitating greater support, and providing a sense of relief and comfort within the community.

Feuston et al. [CITATION Feu18 \l 6153] integrated manual data collection with digital ethnography (study of human interaction through the Internet technologies they use) and semi-structured interviews, to explore how various modes of expression (such as visual, textual, and oral) contribute to the overall understanding of mental health. By evaluating the value of text-based digital media, they found that individuals employ a diverse range of practices and utilize Instagram features to render their experiences with mental health and illness visible to others. This would have implications for the analysis of user interactions, suggesting an information flow from one person to the next.

Golz et al. [CITATION Gol22 \l 6153] used the inCLOUsiv platform to identify and interpret the communication patterns and verbal expression of its users during the initial lockdown in 2020. The methodology involved analysing discussions in forums and live chats using text mining, frequency analysis, correlation analysis, n-gram analysis, and sentiment analysis. Their analysis found that the communication behaviour of users on the inCLOUsiv platform was characterized by generosity and support, with 72% of the identified sentiments being positive. Users actively engaged with topics such as 'corona,' 'anxiety,' and 'crisis,' sharing coping strategies, which suggest that positive and supportive interactions align with other mental health-related communications in virtual communities, emphasizing the potential impact of such interactions on the well-being of community members.

When it comes to understanding how personal mental health and suicidal behaviour are communicated, it was found that teenagers engage more frequently in online conversations about suicide than adults[CITATION Fal20 \l 2057], and that the communication behaviour of users on a digital exchange platform was supportive and sentiments were mostly positive[CITATION Liu211 \l 2057]. Data analysis was also shown to reveal that individuals use a variety of practices and features of social media, to make experiences with mental health and illness visible to others[CITATION Feu18 \l 2057], and that users of online mental health communities were found to be more attentive to the topics of social experience and emotional expressions[CITATION Liu211 \l 2057]. Help seeking was also shown to vary between different populations where the attitudes, beliefs, and treatment-seeking behaviour towards depression showed great disparity between Hispanics and non-Hispanic populations[CITATION Cas21 \l 2057]. Finally, in relation to a specific illness - epilepsy, a higher percentage of teenagers are fearful of ‘the unknown’ due to seizures, concerned about social consequences of seizures, where a significantly higher percentage of adults show a defeatist (‘given up’) attitude compared to teenagers[CITATION Fal20 \l 2057].

Help seeking for mental health difficulties

Analysis of survey data has been shown to identify help seeking for mental health difficulties. Research by Waddell et al. [CITATION Wad23 \l 6153] sought to examine survey data in order to gain insights into the dynamics of help-seeking relationships within veteran families. The findings of the study brought to light that family members of veterans play a significant role in both the initial and ongoing processes of seeking help. However, the study also revealed substantial barriers to help-seeking, primarily linked to military culture. These barriers included the belief that mental health concerns could be self-managed (if recognized), highlighting concerns about potential impacts on careers, and fear of judgment by others. Educating families about identifying early signs of mental health problems is crucial, to inform families about the potential mental health risks associated with military careers. This knowledge can then contribute to fostering a supportive environment and breaking down barriers to help-seeking within veteran families. This study revealed that family members of veterans may have a significant role in the initial and ongoing help-seeking journey. However, substantial barriers to help-seeking were revealed, pre-dominantly related to the military culture, in the belief that mental health concerns can be self-managed, fear for career impacts and of being judged by others.

Efficacy of interventions to support mental wellbeing

The effectiveness of interventions to support mental wellbeing has also been analysed using machine learning. Gu et al. (2023) [CITATION GuD23 \l 6153] used NLP technology to identify psychological cognitive changes. Utilizing an emotion dictionary along with Word2vec semantic training, a model was trained to transform labelled text into a vector matrix, and TextCNN was employed for classifying the labelled text. The findings of the study indicated that posts signalling cognitive change tended to have longer word lengths. Additionally, support seekers who had not undergone cognitive change tended to express themselves more in online replies. This highlights the potential for supporting individuals with mental health problems, and for promoting the development of online mental health communities and constructing online psychological chatbots.

Research by Goldberg et al. [CITATION Gol20 \l 6153] used NLP and machine learning techniques to predict one of the most studied process variables in psychotherapy: the therapeutic alliance. The methodology involved employing Sent2vec to map sentences to vectors of real numbers, and Linear Regression was then utilized as the prediction model. The findings of the study revealed that, across the 1,235 alliance ratings, the mean rating was 5.47, indicating a negative slant often found in the assessment of the therapeutic alliance. The implications drawn from these findings suggest that machine learning holds promise for predicting observable linguistic behaviours, and these models could be trained using human coding as the gold standard, and thorough testing should be conducted using large datasets.

Oyebode et al. [CITATION Oye20 \l 6153] used sentiment analysis and other machine learning approaches to evaluate 104 mental health apps available on Google Play and the App Store. By integrating natural language processing and the Term Frequency-Inverse Document Frequency (TF-IDF) weighting technique to vectorize the reviews, supervised machine learning classifiers were then used to predict sentiment. The study revealed that the majority of the reviews were positive, indicating that most users found mental health apps to be useful and helpful, emphasizing the importance of ensuring that mental health apps are not only usable and of high quality but also supportive, secure, and non-invasive.

Research by Chikersal et al. [CITATION Chi20 \l 6153] used a deeper understanding of how supporter behaviours impact the utilization of online therapy programs. The methodology involved the application of unsupervised machine learning, along with statistical and data mining methods, to analyse complex, large-scale supporter-client interactions. They found that concrete, positive, and supportive feedback from supporters, particularly those referencing social behaviours, were strongly associated with better outcomes. This suggests the importance of identifying effective context-specific support strategies using data for personalized mental health support. This knowledge can contribute to improving the design and implementation of personalized human support in internet-based Cognitive Behavioural Therapy (iCBT) and enhance our understanding of (Big) Data in digital health interventions.

Onyeaka et al. [CITATION Ony21 \l 6153] investigated the usage and perceived benefits of digital health tools, identifying the association between the use of digital interventions and the adoption of healthy lifestyle behaviours, and the sociodemographic factors linked to the utilization of digital tools among individuals with anxiety or depression. Basic descriptive statistics and Chi-squared tests were used, identified a notable prevalence of digital interest among individuals with anxiety or depression, with up to 84.7% , 60.6%, and 57.7% reporting ownership of smartphones, tablets, and health apps, respectively. These results suggest that digital tools may offer promise for a subset of individuals with mental illness who prefer engaging in technology-based strategies for managing their health.

Vermetten et al. [CITATION Ver20 \l 6153] investigated the potential use of VR-based interventions, wearable technology, and text mining to enhance the mental health of military personnel and veterans. Using text mining and the statistical technique of Item Response Theory (IRT), they demonstrated that there was a high agreement of 82% with the diagnoses provided by psychiatrists and suggested that the combination of text mining and VR-based interventions holds promise as a valuable tool for psychological and psychiatric assessments in the future.

Van Gemert-Pijnen et al. [CITATION Van141 \l 6153] demonstrated how log data could be employed to comprehend the adoption of a web-based interventions and provide value in improving the incorporation of content in such interventions. By performing statistical analysis using SPSS, this study showed that pattern recognition could be utilized to customize the interventions based on usage patterns from earlier lessons, and act as an aid in supporting the adoption of content essential for therapy. By understanding how participants can derive greater benefits from the intervention, and identifying the most effective combination of features, this can lead to enhancing the effectiveness of web-based interventions.

There are many ways that data analysis can be used to support mental wellbeing, for example textual data analysis can be used to signal cognitive change, where it has been found that average word length within text is longer for posts that indicate a cognitive or emotional change[CITATION GuD23 \l 2057]. Other analysis results indicate a high prevalence of digital interest among people with anxiety or depression [CITATION Ony21 \l 2057] and when NLP and ML were employed to predict the therapeutic alliance, the mean rating showed a typical negative skew found in the assessment of the alliance[CITATION Gol20 \l 2057]. When trying to identify if VR-based interventions, wearable technology, and text mining can be used to improve mental health[CITATION Ver20 \l 2057], these are expected to be promising tools in psychiatric assessments in the future. When trying to illustrate how log data can be used to understand the uptake of a Web-based interventions, pattern recognition can be used to tailor the intervention based on usage patterns from the earlier lessons and to support the uptake of content essential for therapy[CITATION Van141 \l 2057]. For web-based and non-web-based mental health apps, the majority of reviews from a study of mental health apps available on Google Play and the App Store were positive, showing that most users found mental health apps useful and helpful[CITATION Oye20 \l 2057].

Discussion

When attempting to discover useful insights from text-based digital media, in relation to mental health and depression, machine learning and data analysis techniques can be applied in many different ways. They can be used as predictors of personal mental health to measure how an individual's socioeconomic status can relate to depression, for example. With the increasing prevalence of mental health issues since the Covid-19 pandemic [CITATION Win20 \l 6153] and the need for effective suicide prevention strategies, using data analysis and machine learning techniques on textual digital media data research has demonstrated that the Covid-19 pandemic and its associated restrictions have resulted in increased depression, anxiety, and feelings of loneliness[CITATION Kel20 \l 6153], but that sentiment improved following the news of vaccine rollout, to defend against the virus [CITATION Weg23 \l 6153]. The pandemic has made a big impact on research in this area, where findings show that students' overall emotional well-being reflected a combination of diverse moods, encompassing feelings of frustration, boredom, anxiety, being overworked, and experiencing depression during the pandemic. Further themes emerge from tweets related to COVID-19, showed that social media usage increased during the onset of the pandemic, and that participants of a survey exhibiting more pronounced mental health symptoms where their residential communities faced heightened exposure to the virus's spread.

Machine learning and data analysis techniques can also be used to detect mental ill health and suicidal risk, where neural network models can be used to predict suicide ideation before suicidal thoughts are articulated, and to generate models capable of predicting individuals who would be at risk to suicidal thoughts. These tools can also be used to identify help seeking for mental health difficulties, where survey data can be analysed to understand help-seeking in relation to mental health, and where the role of the family can be found to be important in encouraging help-seeking for war veterans and where substantial barriers to help-seeking were revealed, particularly in relation to military culture, in the belief that mental health concerns can be self-managed (if recognized), and there is a fear of being judged by others.

When attempting to understand how we communicate personal mental health and suicidal behaviour, machine learning techniques can be used in many diverse ways, to explore digital conversations with regard to suicidality, for example and to identify factors influencing the number of likes in an online community, for depression. Users were shown to exhibit both benevolent and supportive communication behaviour, with predominantly positive sentiments, on a digital exchange platform. When examining a specific illness, epilepsy, it was revealed that a higher percentage of teenagers express fear of the unknown associated with seizures and concern about the social consequences of seizures, and higher percentage of adults demonstrate a defeatist attitude compared to teenagers. When Instagram was used to better understand how we can communicate personal mental health, it was disclosed that individuals employ various different practices features on the platform, to make their experiences with mental health and illness visible to others. Finally, seeking assistance was found to differ across different populations, with significant differences in attitudes, beliefs, and the propensity to seek treatment for depression observed between Hispanics and non-Hispanic populations.

Insights from data analysis and machine learning can then be used to assist in the development of digital interventions, and the effectiveness of these interventions can be shown to provide support to people living with depression and improve mental wellbeing. Through textual data analysis, it was determined that posts signalling cognitive change exhibit longer word lengths, for example, and that support seekers who have not undergone cognitive change tend to express themselves more in online replies. Similarly, it was found that there was a heightened prevalence of digital interest among individuals with anxiety or depression. NLP and machine learning can also be used to predict therapeutic alliance between patient and therapist.

When exploring the potential of virtual reality-based interventions, integrating wearable technology and text mining, to enhance mental health, it emerged that text mining coupled with VR-based interventions, is anticipated as a promising tool for psychological and psychiatric assessments in the future. The use of mental health apps were analysed which showed that attitudes toward them were mainly positive, indicating that a majority of users find these apps useful and helpful. In the context of understanding the uptake of Web-based interventions, pattern recognition was also used to tailor individual interventions based on usage patterns from earlier lessons, thereby supporting the uptake of content essential for therapy.

Limitations

This study exhibits limitations in the selection of articles because it used only four journal databases (i.e., Web of Science, Medline, Embase, PsycINFO) as well as Google Scholar. Moreover, only articles published in English and related to mental health/suicide and machine learning/data analysis and digital interventions were included. The duration of the search for articles started in March 2023, and collected articles were published between 2013 and 2023. As some of the researched articles identified some sort of machine learning classification or prediction, the authors should have considered explainable AI to facilitate the understanding of any predictions made by the machine learning models, to better understand the models' behaviour. Another limitation involves how the inclusion and exclusion of papers were resolved. Even though CS, EE, MM and RB assessed the papers and decided what was to be included or excluded based on the applicability criteria, it was CS that made the final decision about what went into the paper.

Conclusions

In conclusion, this review illustrates that the utilization of data analysis and machine learning techniques to extract useful insights from text-based digital media related to mental health and suicide prevention holds significant promise. Data analysis and machine learning were utilized to gain valuable insights, for example, findings show that engagement in online conversations relating to depression may vary among different ethnic groups or that teenagers engage in online conversations about suicide more often than adults. Another finding was that disability acquisition (which is associated with a deterioration in mental health) was shown to be affected by changes to employment, but not income.

The efficacy of digital tools was also analysed, with machine learning approaches being used to understand users' opinion regarding mental health apps. Using positive and negative sentiments, it was shown that those with mental illness are digitally connected and are incorporating these tools to manage their health. Predictive analytics was also identified to be able to detect cognitive distortions, which are associated with depression and anxiety, from personal blogs with an accuracy of 73.0%, while other machine learning models were able to predict risk to suicidal ideation from social media. The use of modern technology has also been investigated, with the application of virtual reality-based interventions showing promising contributions to the field of military and veteran mental health, by developing new approaches to delivering preventive or curative care.

The recent pandemic has also had an influence in this area of research. Analysis work was undertaken to try to discover to what extent social media use increased during the onset of the COVID-19 pandemic and to assess how different populations communicate regarding their mental health. It was also discovered that virtual communities played an important role in mental health during the pandemic, and that social media may be used as a coping mechanism to combat feelings of isolation related to long-term social distancing. Online communities also offer great support for people with mental disorders, where the analysis of the number of likes and reposts for posts in online mental health communities allowed for these users to gain more support within the community.

Future research could focus on investigating further benefits of textual digital media analysis in mental health and suicide prevention, when dealing with depression, and importantly, what makes people happy. Machine learning can be used to predict what are the sources of ‘happiness’, or even how different activities make different socio-economic groups ‘happy’, and these insights can then be used to assist in the development of a wide range of digital interventions, for example chatbots.

Ultimately, this systematic review underscores the importance of harnessing advanced analytical methods to derive valuable insights that can lead to improved mental health interventions and enhanced strategies for suicide prevention.

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Appendix A

Electronic Database – Search criteria

mental health or mental health* or mental disorder or mental health symptoms or depress* or anxiety or mental health crisis or self-harm or suicid* or suicide prevention or mental health emergenc* or self-Injurious behavior or self-injurious behaviour or mental ill* or self-harm or self-injury or well being (Title)
and
prediction or machine learning or machine intelligence or data mining or data science or big data or algorithm* or predictive analy* or classifier* or cluster* or deep learning or artificial intelligence or AI or computational intelligence* or pattern recognition or pattern classification or text classification or classification or recommender system* or deep learning or or random forest or decision tree* or naive bayes or bayesian or support vector machine* or SVM or cluster* or neural network* (Title)
and
text analys* or text-base* or data analy* or text mining or natural language process* or text process* or sentiment analys* or information extraction (Title)
and
digital intervention* or mental health intervention* or digital mental intervention* or digital mental health intervention* or digit* mental health* or digital technolog* intervention* or digit* chat or digit* conversation or digital therapeutics* or virtual mental health* or mobile mental health* or online mental health* or computer-based mental health* or internet-based mental health* or e-mental health or help seek* or m-health or mobile health or digital health or e-health (Title)

Google Scholar – Search criteria

(mental health OR depression OR suicide) AND (machine learning OR deep learning OR artificial intelligence) AND (text analysis OR text mining OR data analysis) AND (digital intervention OR digital mental health)*

*Note: Google Scholar would not accept full text criteria, so the search criteria was reduced, to the above.