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COVID-19 Aşılaması için Twitter üzerinde Sentiment, Duruş ve Duygu Analizi: Bir Derleme[1]

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ÖZET

Sosyal medya analizi, trend analizinden öneri sistemlerine ve halk sağlığı takibine kadar çeşitli amaçlar için kullanılmaktadır. Bu çalışmada, insanların COVID-19 aşısına yönelik sentimentlerini, duruşlarını ve duygularını belirlemek için yapılan sosyal medya analizi çalışmaları derlenmiştir. COVID-19 devam eden bir salgındır ve Twitter'da COVID-19 aşıları hakkında tartışmalar devam etmektedir. Sağlıkla ilgili politikaların oluşturulmasında bu görüşlerin otomatik çıkarımı ve dikkate alınması pratik ve umut vericidir. Bu önemli konu hakkında yakın zamanda yapılmış birçok çalışma bulunmakta ve makalemiz bu çalışmaların bir derlemesini sunmayı amaçlamaktadır. Derlenen makalelerin ve bu derleme makalesinin bulguları, sağlıkla ilgili politika oluşturma süreçlerine önemli katkılarda bulunabilir.

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Sentiment, Stance, and Emotion Analysis on Twitter for COVID-19 Vaccination: A Survey

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ABSTRACT

Social media analysis is used for various purposes ranging from trend analysis to recommender systems and public health monitoring. In this paper, social media analysis studies conducted to determine people's sentiments, stances, and emotions towards COVID-19 vaccination are reviewed. COVID-19 is an ongoing pandemic, and there exist debates on Twitter about COVID-19 vaccines. It is practical and promising to automatically extract the opinions of Twitter users and consider them during health-related policy-making. There are several recent studies on this vital topic, and our paper aims to present a survey of the related significant studies. The findings of the reviewed papers and the current survey paper can make important contributions to health-related policy-making processes.

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A preliminary version of this paper was presented as an oral paper at 2021 International Conference on Informatics and Computer Science (ICI-CS2021) with title "*Sentiment, Stance, and Emotion Analysis on Twitter for COVID-19 Vaccination: A Brief Survey*". The current paper is the extended form of the conference paper.

1. INTRODUCTION *(GİRİŞ)*

COVID-19 is a global pandemic that is still effective all over the world since its starting in 2019. Due to the widespread use of social media in many countries, people also tend to share their opinions and feelings about the pandemic and its various aspects on social media. For instance, people like to publish social media posts about quarantines, vaccines, and face masks applied in several countries to prevent the spread of the disease. People also like to express their disease-specific symptoms and emotions on social media [1, 2].

COVID-19 vaccination is one of the controversial topics about which debates are observed on Internet forums, as news comments, and on social media sites. Both the proponents and opponents of vaccination are freely sharing their ideas and arguments. This textual data is a valuable source for public health professionals and decision-makers. The ideas and arguments of individuals can be observed and taken into consideration during related policy-making processes. Several related papers claim that these posts can be analyzed to understand vaccine hesitancy and vaccine confidence better. The vaccine hesitancy of the people can be decreased by considering people's concerns about the side effects of the vaccines. However, due to the large number of posts published instantly, automated social media analysis approaches must obtain useful information from these posts.

Three common social media analysis techniques are sentiment analysis, stance detection, and emotion recognition. The current survey paper aims to review those papers in which sentiment, stance, and emotion analysis are applied to tweets publishedabout COVID-19 vaccination. Since it is a very recent topic, all papers considered have been published in 2020, 2021, and 2022 and most of them are published in 2021. Yet, due to the topic's significance, the number of related papers is increasing, and there is a need for a survey of these related papers.

To the best of our knowledge, this is the first survey paper prepared on the topic of sentiment, stance, and emotion analysis on Twitter about COVID-19 vaccination.

The rest of the paper is organized as follows: the three social media techniques are described in Section 2. The actual papers reporting the results of social media analysis techniques performed on tweets about COVID-19 vaccination are surveyed in Section 3. Section 4 presents significant future research topics, and Section 5 concludes the paper with a summary.

2. SOCIAL MEDIA ANALYSIS TECHNIQUES *(SOSYAL MEDYA ÇÖZÜMLEMESİ TEKNİKLERİ)*

Sentiment analysis, stance detection, and emotion recognition are related and significant problems of automatic social media analysis and natural language processing (NLP). They can be considered text classification tasks. More recently, they are mainly applied to social media posts.

The rest of this section briefly describes these problems before reviewing the studies that use these techniques to analyze social media posts on COVID-19 vaccination.

2.1. Sentiment Analysis *(Sentiment Analizi)*

In the related literature, sentiment analysis is commonly defined as the determination of the polarity in a given text into one of these classes: positive, negative, and neutral [3]. Sometimes, only two sentiment classes (positive and negative) can be used, while in some other studies, a more significant number of sentiment classes (such as highly positive, positive, etc.) can be used. There is a large body of related studies on sentiment analysis, and there are subproblems of sentiment analysis such as aspect-based sentiment analysis. In aspect-based sentiment analysis, the sentiments towards an aspect or a set of aspects of an entity are usually explored. There are rule-based, lexicon-based, machine learning-based, and deep learning [4] based approaches to sentiment analysis in the related literature. Sentiment analysis is also known as opinion mining, and however, sentiment analysis and opinion mining are also used to mean emotion recognition (defined in Section 2.3 below) in some studies.

2.2. Stance Detection *(Duruş Tespiti)*

In stance detection (also known as stance prediction and stance analysis), there is a piece of text and a target as input and the position (stance) of the text author towards the given target is expected as output [5]. Most commonly, there are three stance classes (favor, against, and neither), however, in some studies, only two basic classes (favor and against) are utilized, and in some other studies, a neutral class label is added to the existing stance classes [5]. Instead of favor and against classes of stance detection, pro and anti may also be used in some related studies. There are subproblems of stance detection, such as multi-target stance detection and cross-target stance detection. In multi-target stance detection, the input does not include a single item as a target, but instead, it consists of a set

of targets. The training dataset is provided for a target in cross-target stance detection, but the test set is available for a related but different target [5]. Some studies jointly perform stance detection and sentiment analysis where annotated datasets are also made available [6]. The most common approaches to stance detection are either machine learning or deep learning-based.

2.3 Emotion Recognition *(Duygu Tanıma)*

Emotion recognition (or emotion extraction) in textual content aims to determine the emotion in the given text in various granularity levels [7]. That is, the number of emotion class labels changes in different studies. In some studies, less number of labels are used (joy, sadness, fear, disgust) while in other studies more labels are used (joy, sadness, fear, disgust, love, trust, surprise, anger, anxiety, anticipation). It should again be noted that some studies use the term sentiment (or opinion) analysis to mean emotion recognition. Emotion recognition is also commonly applied to other input genres like speech or videos. In the related literature, lexicon-based, machine learning-based, and deep learning-based methods are all used for emotion recognition.

The interrelationships and common classes of these three research problems are presented in Figure 1.

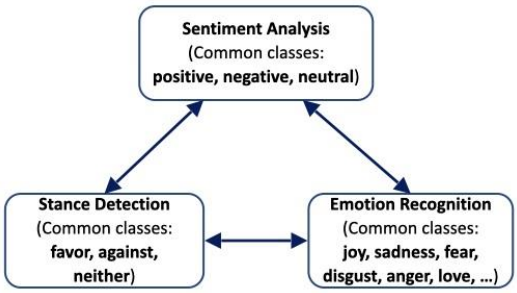

Figure 1. Interrelationships between sentiment analysis, stance detection, and emotion recognition *(Sentiment analizi, duruş tespiti ve duygu tanıma arasındaki karşılıklı ilişkiler)*

3. SURVEY OF PAPERS ON SOCIAL MEDIA ANALYSIS FOR COVID-19 VACCINATION *(COVID-19 AŞILAMASI İÇİN SOSYAL MEDYA ANALİZİ HAKKINDAKİ ÇALIŞMALARIN DERLEMESİ)*

As pointed out in Section 1, there are several recent works on using social media analysis to determine public attitudes and opinions about COVID-19 vaccines. In [8], it is emphasized that artificial intelligence, and particularly NLP techniques, can be used for social media analysis for COVID-19 vaccines. It is concluded that by analyzing the sentiments in social media and linked Web platforms, public concerns and barriers against the vaccines can be determined, and this will help develop strategies to increase the uptake of COVID-19 vaccines [8].

In [9], 300.000 social media posts about COVID-19 vaccines from the US and UK are extracted, and deep learning-based sentiment analysis (with three classes: positive, negative, and neutral) is applied to these posts. The study's findings show that positive sentiment is higher (over 55%) for posts from both countries [9].

A related study was performed between February and March of 2021 on social media posts of US citizens to determine their sentiments about COVID-19 vaccines [10]. They have performed a spatiotemporal analysis of public sentiment towards the vaccines using publicly available sentiment analysis tools for this purpose [10].

The study in [11] presents sentiment analysis results using deep learning methods on tweets from six countries: Pakistan, India, Norway, Sweden, Canada, and the US. Correlation percentages for sentiment classes among neighboring countries are also presented [11].

In [12], emotion analysis with emotion labels (anger, fear, joy, sadness) is performed on Reddit comments to determine the public emotions towards COVID-19 vaccines in Canada. Random forest regression is used for automatic emotion analysis. It is pointed out that local (city-level) comments should be analyzed to better grasp people's local concerns and opinions towards the vaccine [12].

In a recent study on Australian Twitter users, both sentiment analysis (with two classes: positive, negative) and emotion recognition (with eight classes: anger, fear, anticipation, trust, surprise, sadness, joy, disgust) are

performed using publicly available NLP tools [13]. It is concluded in the study that the level of positive sentiments across Twitter users may be insufficient for herd immunity, and such analysis results should be considered by the related governmental organizations [13].

In [14], both sentiment analysis and emotion recognition are performed on geotagged tweets from the US. The authors observe an increased positive and decreased negative trend in sentiments, and for emotion recognition; trust and anticipation along with fear, sadness, and anger are observed [9].

Another study [15] performs sentiment analysis on tweets related to COVID-19 vaccine types using the kNN machine learning algorithm. The sentiment classes are positive, negative, and neutral, and percentages of these classes are provided for each of the COVID-19 vaccine types [15].

In [16], tweets about COVID-19 vaccination posted from five countries are analyzed for emotions (hesitation, rage, sorrow, anticipation, faith, and contentment). The countries considered are India, the US, Brazil, the UK, and Australia, and it is reported that vaccine hesitancy varies in different geographies [16].

Emotion recognition is emphasized in [17] in order to address related issues like vaccine hesitancy and vaccine confidence. It is pointed out that suitable communication strategies should be used to identify the barriers and facilitators of COVID-19 vaccination [17].

Topic modeling and sentiment analysis are performed on tweets about COVID-19 vaccines using machine learning (logistic regression, random forest, SVM) and transfer learning methods in [18]. It is pointed out that these results can be used by education programs and other interventions to increase the acceptance of COVID-19 vaccines [18].In a subsequent study [19], the sentiment analysis results on the same tweet dataset of 2,678,372 tweets are presented as follows using a publicly available sentiment analyzer, called VADER [20]: 42.8% of the tweets about COVID-19 vaccines have positive sentiment while 30.3% of them have negative sentiment [19].

In [21]; topic modeling, sentiment analysis, and emotion recognition are performed on tweets about COVID-19 vaccination. Based on the reported results, the sentiments of Twitter users are increasingly positive, and the most frequent emotions are trust, anticipation, fear, and sadness [21]. In [22], Twitter conversations about COVID-19 vaccines are analyzed and mixed emotions about vaccine safety and its side effects are observed.

In [23], a total of 7,948,886 tweets about COVID-19 vaccines are analyzed for topic modeling and emotion recognition, using methods including deep learning-based ones like BERT [24]. Among the five emotions considered, it is found that fear is the most dominant emotion, and it is followed by joy [23].

A sentiment analysis study on tweets from India about COVID-19 vaccines is presented in [25]. It is concluded that 36% of the tweets have positive sentiment, 17% have negative sentiment, and 47% have a neutral sentiment. It is also presented that the tweets with positive sentiments increase as the number of COVID-19 cases increases [25].

Another topic modeling, sentiment analysis, and emotion recognition study on tweets about COVID-19 vaccines is performed in [26]. The overall sentiment is positive and while fear is the most frequent emotion in the earlier period, trust emotion has increased over time [26].

In [27]; TextBlob and VADER, sentiment analysis tools, are used on tweets about COVID-19 vaccines where three sentiment classes are considered: positive, negative, and neutral. It is found that the sentiments of the tweets are primarily positive [27].

A study performing emotion recognition on 4,765 popular tweets in English and Italian about COVID-19 vaccines is described in [28]. Knowledge graphs of semantic and syntactic associations are used in the study, and it is found that for English tweets, the emotions are polarized between trust/anticipation and anger/sadness [28].

Stance detection towards COVID-19 vaccination at the early days of vaccine announcements is performed in [29]. Based on stance analysis on collected tweets, it is found that most tweets have a neutral stance, while tweets with favor stance are higher than tweets with against stance [29].

Another stance detection study is reported in [30] regarding COVID-19 vaccines on Twitter, where the stance class labels are pro-vaccine, anti-vaccine, and neutral. About 1,000 tweets are examined, and it is recommended that the findings of this study can be used in national campaigns to increase vaccine application [30].

To determine sentiments of Iranian people about COVID-19 vaccines, 803,278 tweets were collected, where the tweets are related to COVIran Barekat, Pfizer/BioNtech, AstraZeneca/Oxford, Moderna, and Sinopharm from April 1, 2021 to September 30, 2021. A CNN-LSTM based model is suggested in the study. As the result of the study, there is a little difference between positive and negative classes [31].

In another study relevant to COVID-19 vaccines (Pfizer/BioNtech, AstraZeneca/Oxford, Moderna) on 701,891 tweets, sentiment analysis is performed on tweets day by day. Researchers observe that whereas sentiments about

Pfizer and Moderna are positive and at the same level for four months, there was a decrease on AstraZeneca/Oxford vaccine's sentiment point [32].

Another related study is conducted on Twitter data about COVID-19 vaccines for sentiment analysis purpose [33]. VADER sentiment analysis tool [20] is used on tweets. It is concluded that public sentiments about COVID-19 vaccines are affected by different factors such as the number of new COVID-19 cases [33].

Another sentiment analysis study is performed on Indonesian tweets about COVID-19 vaccine [34]. Naïve Bayes classification algorithm is used in this study for sentiment analysis. At the end of the analysis on 6,000 tweets, it is reported that the percentage of negative tweets is around 56%, the percentage of positive tweets is around 39% [34].

4,552,652 tweets about COVID-19 vaccines are analyzed for sentiment analysis in [35]. At the end of the sentiment analysis experiments using the VADER tool [20], it is observed that positive sentiment is more prevalent compared to negative sentiment [35].

Both sentiment analysis and emotion recognition are used to detect the opinions of Twitter users about COVID-19 vaccine in [36]. Sentiment classes used are positive and negative. Emotion classes include anger, trust, fear, sadness, joy, surprise, disgust, and anticipation. Lexicon-based approaches are used for sentiment analysis and emotion recognition [36].

In [37], sentiment analysis is performed on tweets about COVID-19 vaccination where the tweets are published from many different countries across the world, including Turkey. TextBlob sentiment analyzer is applied on the gathered tweets about COVID-19 vaccination. The results show that negative sentiment is more common when compared to positive sentiment [37].

In addition to the studies performed on Twitter, another sentiment analysis experiment about COVID-19 vaccines is performed on Reddit platform [38]. It is reported that positive sentiment is more common than the negative sentiment in discussions about COVID-19 vaccines [38].

In [39], sentiment analysis is performed on 857,128 tweets about COVID-19 vaccines using the VADER sentiment analyzer. The sentiment categories include highly positive, positive, neutral, negative, and highly negative, based on the scores calculated by the VADER tool. 46.51% of the tweets have a positive sentiment while 23.81% of the tweets have a negative sentiment [39].

Dictionary-based (VADER and TextBlob) and machine learning-based (random forest) approaches are used for sentiment analysis on vaccine-related tweets from India [40]. A total of 7,640 tweets are used during data analysis. It is reported that all three approaches output similar results [40].

Sentiment analysis and stance detection experiments on Turkish tweets about COVID-19 vaccination are presented in [41]. SVM and random forest algorithms are used for sentiment and stance analysis during the experiments. A total of 600 Turkish tweets are annotated with sentiment and stance within the course of this study [41].

A summary of the reviewed papers with respect to the research problems that are considered in each paper is presented in Table 1.

Table 1. A summary of the reviewed papers *(Derlenen makalelerin bir özeti)*

Reference	Sentiment Analysis	Stance Detection	Emotion Recognition
[9]	✓	✗	✗
[10]	✓	✗	✗
[11]	✓	✗	✗
[12]	✗	✗	✓
[13]	✓	✗	✓
[14]	✓	✗	✓
[15]	✓	✗	✗
[16]	✗	✗	✓

[17]	✗	✗	✓
[18]	✓	✗	✗
[19]	✓	✗	✗
[21]	✓	✗	✓
[22]	✗	✗	✓
[23]	✗	✗	✓
[25]	✓	✗	✗
[26]	✓	✗	✓
[27]	✓	✗	✗
[28]	✗	✗	✓
[29]	✗	✓	✗
[30]	✗	✓	✗
[31]	✓	✗	✗
[32]	✓	✗	✗
[33]	✓	✗	✗
[34]	✓	✗	✗
[35]	✓	✗	✗
[36]	✓	✗	✓
[37]	✓	✗	✗
[38]	✓	✗	✗
[39]	✓	✗	✗
[40]	✓	✗	✗
[41]	✓	✓	✗

4. FUTURE RESEARCH *(İLERİ ARAŞTIRMALAR)*

Most of the studies surveyed in the previous section point out that social media analysis for COVID-19 vaccination is essential for related policy-makers to better understand the public concerns and opinions about the vaccination and related process. Several studies are conducted to determine vaccine hesitancy in different communities of the population, such as [42].

Based on the findings of the reviewed papers, the future research directions are discussed in the following paragraphs.

The sizes of the related publicly available datasets (of social media posts) should be increased in order to improve the performance of the machine learning and deep learning systems. Additionally, the number of datasets in languages other than English should also be increased. For instance, a dataset of Turkish tweets annotated with sentiment and stance labels is presented in [41]. Creating annotated social media posts in various languages (multilingual datasets) is also very important.

The reviewed papers demonstrate that related studies are performed on related tweets from several countries, including India, US, UK, Canada, Turkey, Indonesia, and Australia. Similar studies can also be applied to tweets from other countries, and the results can be compared with previous work.

The number of studies that jointly use different social media analysis tasks (similar to the three tasks -sentiment analysis, stance detection, and emotion recognition- considered in the current paper) at the same time can be increased. Because each task produces a distinct and complementary output, the final output will be more beneficial for practical purposes.

A convenient graphical user interface (GUI) can be built in order to visualize the results of the social media analysis tasks for the related users such as public health professionals and policy-makers.

5. CONCLUSION *(SONUÇ)*

Social media analysis is essential for many application domains including health informatics. Because of the recent COVID-19 pandemic, social media posts have become crucial information sources of public opinions and ideas about the pandemic. This paper presents a brief review of sentiment, stance, and emotion extraction studies on social media posts about COVID-19 vaccination. Although the COVID-19 pandemic has started in 2019, there are several social media analysis studies about COVID-19 and its various aspects (like the lockdowns, masks, and vaccines). This survey paper is significant because the findings of the reviewed recent papers can be beneficial to the decision and policy-making procedures related to COVID-19 vaccination. Thereby, the applications of vaccination can be increased to better cope with this global pandemic.

Publication Ethics *(Yayın Etiği)*

A preliminary version of this paper was presented as an oral paper at 2021 International Conference on Informatics and Computer Science (ICI-CS2021) with title "Sentiment, Stance, and Emotion Analysis on Twitter for COVID-19 Vaccination: A Brief Survey". The current paper is the extended form of the conference paper.

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