

Multilingual Emoticon Prediction of Tweets about COVID-19 🤖

Stefanos Stoikos
Pomona College
st.stoikos@gmail.com

Mike Izbicki
Claremont Mckenna College
mike@izbicki.me

Abstract

Emojis are a widely used tool for encoding emotional content in informal messages such as tweets, and predicting which emoji corresponds to a piece of text can be used as a proxy for measuring the emotional content in the text. This paper presents the first model for predicting emojis in highly multilingual text. Our `BERTmoticon` model is a fine-tuned version of the multilingual BERT model (Devlin et al., 2018), and it can predict emojis for text written in 102 different languages. We trained our `BERTmoticon` model on 54.2 million geolocated tweets sent in the first 6 months of 2020, and we apply the model to a case study analyzing the emotional reaction of Twitter users to news about the coronavirus. Example findings include a spike in sadness when the World Health Organization (WHO) declared that coronavirus was a global pandemic, and a spike in anger and disgust when the number of COVID-19 related deaths in the United States surpassed one hundred thousand. We provide an easy-to-use and open source python library for predicting emojis with `BERTmoticon` so that the model can easily be applied to other data mining tasks.

1 Introduction

The COVID-19 pandemic has caused intense emotional reactions on social media. Some tweets are sad:

This Corona stuff is no joke. Watching people get laid off at work today really made me open my eyes. Wish it was all over. 🤔😞🙏

And other tweets are angry:

I saw that bottles of Purell were selling for \$149! Go away price gougers and go away coronavirus! 🤬🤬🤬🤬🤬🤬

What both of these tweets have in common is that their emotional content is captured by emojis present in the tweet’s text. Emojis are often used in informal tweets sent between friends (Danesi, 2016), but most tweets do not contain emojis. For example, the following tweet by the BBC (a major British newspaper) is clearly meant to help us find joy amidst the stress of COVID-19:

Father dresses as Transformers character Bumblebee to surprise his son on his first day back at school after lockdown.

But there are no emojis in the text to indicate that the tweet is joyful. One possible emoji for this tweet would be the “grinning face” (😊), but more subtle emojis like “grinning face with tongue” (😜) or “grinning face with smiling eyes” (😄) would also be appropriate and convey slightly different emotions. The goal of this paper is to automatically annotate these emoji-less tweets with appropriate emojis in order to better understand the emotional content in online discussions of COVID-19.

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language	tweet	emoji prediction (top 5)
English	Washington sick man Is 1st in US to Catch Newly Discovered Dangerous Pneumonia. Get out your face masks folks! #coronavirus #wuhan #mask	
French	Un homme malade de Washington est le premier aux États-Unis à attraper une pneumonie dangereuse nouvellement découverte. Sortez vos masques! #coronavirus #wuhan #mask	
German	Der kranke Mann aus Washington ist der erste in den USA, der an einer neu entdeckten gefährlichen Lungenentzündung erkrankt. Holen Sie sich Ihre Gesichtsmasken Leute! #coronavirus #wuhan #mask	
Hebrew	אחולה בווינגטון הוא הראשון בארה"ב כדי לתפוס דלקת ריאות מסוכנת שהתגלתה לאחרונה. תוציאו את המסכות בפנים שלכם, חבר'ה! גניף הקורונה וזהאן מסכה	
Indonesian	Orang sakit Washington adalah yang pertama di AS untuk Menangkap Pneumonia Berbahaya yang Baru Ditemukan. Keluarkan masker wajah kalian! #coronavirus #wuhan #mask	
Italian	Un malato di Washington è il primo negli Stati Uniti a contrarre una polmonite pericolosa scoperta di recente. Tira fuori le tue maschere per il viso, gente! #coronavirus #wuhan #mask	
Japanese	ワシントンの病人は新しく発見された危険な肺炎を捕まえるために米国で最初です。フェイスマスクの人を出してください！ #コロナウイルス #武漢 #マスク	
Portuguese	Homem doente em Washington é o primeiro nos Estados Unidos a pegar pneumonia perigosa recém-descoberta. Tirem suas máscaras, pessoal! #coronavirus #wuhan #mask	
Spanish	Un enfermo de Washington es el primero en los Estados Unidos en contraer una neumonía peligrosa recién descubierta. ¡Saquen sus mascarillas, amigos! #coronavirus #wuhan #mascara	
Tagalog	Ang taong may sakit sa Washington ay Ika-1 sa Estados Unidos upang Makuha ang Bagong Nakatuklas na Mapanganib na pneumonia. Lumabas ang iyong mga maskara sa mukha mga kamag-anak! #coronavirus #wuhan #mask	

Figure 1: BERT_{moticon} predicts good emojis in a wide variety of languages. All non-English text above was translated from the English using Google Translate.

Prior work on predicting emojis from the text of a tweet (Barbieri et al., 2017, Felbo et al., 2017, Zhang et al., 2019) has focused only on English language tweets. Models submitted for the SemEval 2018 Task 2 (Barbieri et al., 2018) are the most multilingual emoji prediction models currently published, but this task considered only English and Spanish tweets. Because COVID-19 is a worldwide phenomenon, however, to understand emotional responses to COVID-19, we must be able to predict emojis in all languages used on Twitter. We therefore introduce the first highly multilingual model for emoji prediction, which we call BERT_{moticon}. Our model is based on fine-tuning the multilingual BERT model (Devlin et al., 2018), which was trained on a dataset of 102 distinct languages. Figure 1 shows the output of our model on a tweet translated into ten different languages.

A large body of work has emerged analyzing tweets about COVID-19. One prominent line of research attempts to identify how misinformation about the disease spreads online (Elhadad et al., 2020, Kouzy et al., 2020, Prabhakar Kaila et al., 2020, Sharma et al., 2020, Yang et al., 2020). An important subcategory of this research investigates the spread of racist (Budhwani and Sun, 2020, Schild et al., 2020) and ageist (Jimenez-Sotomayor et al., 2020) misinformation. Other research more similar to our own investigates the sentiment of tweets about the coronavirus. Some of this research focuses on specific locations such as Belgium (Kurten and Beullens, 2020), Paris (Saire and Cruz, 2020), Poland (Jarynowski et al., 2020) or India (Das and Dutta, 2020). Other research studies English-language tweets (Rajput et al., 2020, Yin et al., 2020) over wider geographic areas. Our research stands out from this prior work in two important ways. First, we do not consider a subset of tweets about COVID-19, we consider all tweets, written in all languages, sent from anywhere in the world. This is a significantly more challenging technical problem than previous research addressed, but it is also much more useful. Second, we are the first paper to consider the more general emoji prediction problem rather than the sentiment prediction problem. In sentiment prediction, the goal is to assign a positive or negative sentiment to each tweet, and for the coronavirus topic it can be difficult to decidedly assign one sentiment. Tweets about COVID-19 can express negative sentiments because the disease has killed millions of people and forced us to make drastic changes to our lifestyles but also can contain funny, uplifting content exhibiting a positive sentiment such as:

Happy #NationalCatDay from my beautiful adopted pandemic pet!

In the emoji prediction task, we are able to get a more fine-tuned emotional understanding of tweets. For example, we can answer questions like: is the tweet sad? angry? joyful?

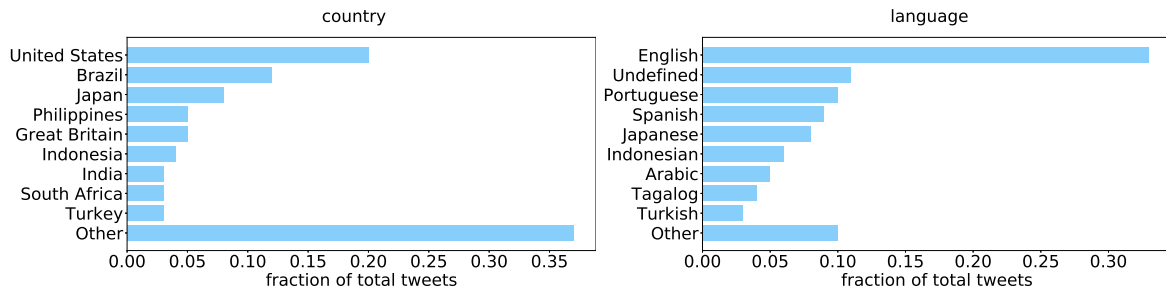


Figure 3: Stats on the most common countries of origin (*left*) and languages (*right*) for tweets in the `TwitterEmoticon` dataset. Languages are determined using Twitter’s API, which has official support for 66 languages. It is known, however, that more than 100 language are actively used on Twitter (Hong et al., 2011), and our `BERTmoticon` model supports all of these languages. All prior work on emoji prediction has focused on only 1 or 2 languages.

- $0 \times 1 \text{f} 650$). In common usage, the words *emoji* and *emoticon* are interchangeable, but in this paper we adopt the Unicode Standard’s definitions of these terms. By these definitions, an *emoji* is any one of 3304 pictographs that are not part of any written language, and an *emoticon* is one of the original 80 emoji defined in the code block specified above. We limit our analysis to emoticons for three reasons. First, they are the most commonly used emoji on twitter, so we can expect to achieve relatively high accuracy. Second, each emoticon represents an emotion (emoticon is a portmanteau of emotion and icon). Third, the emoticon block contains the “face with medical mask” emoji (🤒), which is important for our case study analyzing emotional responses to the coronavirus.

Figure 2 shows the 80 emoticons and a mapping from these emoticons to the Plutchik wheel of emotions (Plutchik, 1991). The Plutchik wheel is a standard psychological model for encoding emotions that has been highly influential in emotion prediction systems (e.g. Kant et al., 2018, Liu et al., 2019, Suttles and Ide, 2013). It has 8 primary emotional categories (anger, anticipation, disgust, fear, joy, sadness, surprise, and trust). These emotions are arranged spatially so that similar emotions (e.g. joy, trust) appear near each other, and dissimilar emotions (e.g. joy, sadness) appear opposite each other. Furthermore, each emotional category is broken down into sub-categories that encode the strength of the emotion (e.g. ecstasy is an extreme form of joy, and serenity is a mild form of joy).

There is currently no standard mapping from emoticons onto the Plutchik wheel, and in Figure 2 (*right*) we provide a suggested mapping. To generate this mapping, we manually assigned each emoticon to an emotion based on the description of the emoticon on the website emojipedia.org. The mapping is not perfect. The category joy has many emoticons representing different facets of joy, but the category anticipation has only a single emoticon. We emphasize that our `BERTmoticon` model will predict raw emoticons directly, but we present the mapping onto the Plutchnik wheel emotions to help make the wide array of emoticon emotions more easily understandable.

2.2 The `TwitterEmoticon` Dataset

The `TwitterEmoticon` dataset is designed for training a classifier that takes as input a tweet and outputs an emoticon that represents the emotion of the tweet. To generate the dataset, we collected all geolocated³ tweets sent over the six month period between January and June, 2020. Approximately 400 million tweets meet this criteria. Then we filtered these tweets so that only tweets containing one of our 80 target emoticons were included, and any retweets were removed. In total, the `TwitterEmoticon` dataset contains 64.2 million tweets sent by 4.2 million users. The tweets are written in 66 different languages and were sent from 246 different countries. Figure 3 shows the total number of tweets per

³Twitter users can adjust their privacy settings to include different amounts of geolocation metadata. In particular, they can include the exact GPS coordinate that a tweet was sent from, an approximate location (for example, the city that the tweet was sent from), or no location information at all. We say that a tweet is *geolocated* if any of this metadata is included about the tweet. Approximately 1% of all tweets are geolocated.



Figure 4: The 80 target emoticons we are trying to predict, and their fraction of all emoticons in the `TwitterEmoticon` dataset. The distribution follows a power law.

language, and Figure 4 shows the frequency of each emoticon in the dataset.

We preprocess each tweet by replacing all user mentions with a special token `<mention>` and all URLs with a special token `<url>` and deleting all emojis. We decided to keep all hashtags because hashtags can contain potentially valuable emotional content useful for emoticon prediction. Finally, we delete all emoticons from the tweet, and use the emoticons as the tweet’s classification label. Most tweets have only a single emoticon label, but some tweets have multiple emoticons. This is a problem because standard multi-class classification techniques require only a single label per data point. We address the issue by following the procedure established by (Felbo et al., 2017). If a tweet has multiple emoticons, then we duplicate it in the training data once for each emoticon, with each instance being labeled by a single one of the emoticons.

We carefully split the `TwitterEmoticon` dataset into training, validation, and test sets ensuring that no user is present in more than one set in order to prevent data leakage. In particular we assign 80% of users to the training set, 10% to the validation set, and 10% to the test set. The tweets contained in each set are then the tweets sent by each of the users in the set.

2.3 Training Protocol

Our `BERTmoticon` model is the multilingual BERT model (Devlin et al., 2018) fine-tuned on the `TwitterEmoticon` dataset. The multilingual BERT model is a popular model for fine-tuning because it achieves state-of-the-art performance on a wide variety of natural language tasks. It was trained on data from 102 distinct languages, and the language of each training sample need not be known for either training or inference. Followup research has shown that the multilingual BERT model has language-independent internal representations that allow it to encode information from languages it has not seen during training time (Pires et al., 2019, Wu et al., 2019). Feng et al. (2020) recently released a more advanced version of the multilingual BERT model that achieves better performance on standard NLP tasks and uses 109 training languages. We would expect better performance on our emoticon-prediction task using this more advanced multilingual BERT model, but we did not use this model because all of our experiments were completed before this model was publicly released.

We followed a two step fine-tuning procedure. First, we trained only the last layer of the model, generating a model we call `BERTmoticon-LL`. Then, we trained all parameters to generate the `BERTmoticon` model, warm starting from `BERTmoticon-LL`. We used the validation set to select optimal hyperparameters for both models. `BERTmoticon-LL` was trained using Adam (Kingma and Ba, 2014) with a learning rate of 10^{-4} , and `BERTmoticon` was trained using Adam with a learning rate of 10^{-5} . Both models used a batch size of 64. A single epoch on the `TwitterEmoticon` dataset took approximately 6 days to run on one NVidia GeForce RTX 2080 GPU. We trained both models on a single epoch, but found that the model converged before the epoch was finished.

2.4 Model Evaluation

The `BERTmoticon-LL` model achieves a Macro-F1 score of 0.159 on the test set and the `BERTmoticon` model achieves a Macro-F1 score of 0.210. Table 1 shows a performance breakdown by emoji and by language. Prediction performance on each language varies dramatically because each

	😭	🙏	😄	😓	😞	😁	😬	😏	😇	😬	😬	😬	Macro-F1
Model													
BERTmoticon-LL	0.440	0.226	0.190	0.111	0.111	0.185	0.018	0.111	0.049	0.008	0.011	0.007	0.159
BERTmoticon	0.479	0.361	0.309	0.256	0.249	0.244	0.215	0.211	0.106	0.078	0.073	0.035	0.210
Language													
Arabic	0.637	0.268	0.224	0.117	0.002	0.000	0.064	0.000	0.000	0.006	0.000	0.000	0.319
Dutch	0.371	0.201	0.141	0.149	0.364	0.225	0.068	0.027	0.055	0.004	0.006	0.000	0.168
English	0.506	0.367	0.295	0.235	0.241	0.230	0.160	0.201	0.128	0.034	0.031	0.006	0.221
French	0.418	0.196	0.227	0.356	0.414	0.109	0.083	0.056	0.180	0.010	0.008	0.004	0.208
Hindi	0.443	0.717	0.103	0.067	0.027	0.007	0.025	0.016	0.010	0.002	0.010	0.000	0.310
Indonesian	0.442	0.339	0.188	0.393	0.218	0.065	0.073	0.053	0.073	0.002	0.027	0.001	0.203
Italian	0.430	0.119	0.273	0.144	0.439	0.205	0.168	0.220	0.074	0.031	0.071	0.007	0.181
Japanese	0.115	0.142	0.199	0.223	0.003	0.336	0.268	0.323	0.137	0.000	0.055	0.004	0.133
Portuguese	0.380	0.340	0.426	0.249	0.128	0.004	0.294	0.310	0.092	0.155	0.183	0.110	0.177
Russian	0.375	0.044	0.267	0.248	0.249	0.028	0.000	0.000	0.000	0.000	0.000	0.000	0.122
Spanish	0.388	0.305	0.381	0.254	0.423	0.090	0.185	0.183	0.142	0.087	0.073	0.065	0.170
Tagalog	0.509	0.225	0.247	0.293	0.174	0.051	0.154	0.070	0.035	0.035	0.002	0.019	0.208
Thai	0.271	0.022	0.124	0.208	0.000	0.042	0.009	0.023	0.012	0.000	0.000	0.000	0.078
Turkish	0.469	0.392	0.132	0.118	0.085	0.121	0.023	0.055	0.036	0.059	0.003	0.002	0.174
(*) Undefined	0.485	0.103	0.127	0.042	0.003	0.010	0.083	0.030	0.041	0.008	0.042	0.000	0.171

Table 1: (*top*) F1 scores for the BERTmoticon-LL and BERTmoticon models on 12 selected emojis, and the Macro-F1 incorporating all 80 target emoticons. The full BERTmoticon model offers significantly better performance across all emoji categories. (*bottom*) Performance of the BERTmoticon model broken down by language on 15 selected languages. The Undefined language corresponds to tweets for which the Twitter API was not able to assign a language. Even for these tweets, which are either written in an unsupported language or do not a significant amount of text within them, the BERTmoticon model is able to get performance comparable to many officially supported languages.

bacteria, cdc, china, corona, coronavirus, cough, covid, covid-19, covid19, disease, doctor, epidemic, fever, flatten the curve, flu, lockdown, n95, ncov, nurse, outbreak, pandemic, sars-cov-2, sick, sinophobia, social distancing, trump, vaccine, virus, wuhan

Figure 5: The 29 English-language search terms we used to select tweets. These terms were translated using Bing Translate into 72 other languages as part of our multilingual tweet filtering process.

language uses emojis with different frequencies. Arabic language tweets, for example, use the “crying tears of joy” emoticon (😭) frequently, but rarely use the “smiling face with heart eyes” emoticon (😍). The model has therefore learned to favor predictions of this emoticon whenever these predictions are present in the tweet. As Figure 1 demonstrates, this causes the same text translated into different languages to receive different emoji labels. We believe that this is a strength of our model, as different cultures use emojis differently, and our model is able to capture this fact.

3 Coronavirus Case Study

We now apply the BERTmoticon model to understand the emotional response of Twitter users to news about the coronavirus. We first introduce our TwitterCOVID dataset, then we present an analysis of this dataset.

3.1 The TwitterCOVID Dataset

The goal of the TwitterCOVID dataset is to include any geolocated tweet that references COVID-19 in any language. There is currently no standard procedure for generating multilingual datasets of tweets about a topic, so we used the following four step procedure: (1) We generated a list of 29 English-language search terms related to the coronavirus, as shown in Figure 5. The choice of terms was inspired by the terms used in a dataset generated by Chen et al. (2020), but we also removed Twitterisms like “kungflu” which would not translate well into non-English languages. (We discuss in detail the full differences between our dataset and the dataset of Chen et al. (2020) below.) Our search terms include generic words like “china” and “trump” that are not necessarily about the coronavirus, but given the time period we searched over, many tweets including these terms will be about the coronavirus. (2) We then used Bing’s translation API to translate each of these terms into the 72 languages supported by Bing

Afrikaans, Arabic, Armenian, Bulgarian, Catalan, Chinese, Croatian, Czech, Danish, Dutch, English, Estonian, Finnish, French, German, Greek, Gujarati, Hebrew, Hindi, Hungarian, Icelandic, Indonesian, Irish, Italian, Japanese, Kannada, Korean, Latvian, Lithuanian, Malayalam, Marathi, Norwegian Bokmål, Persian, Polish, Portuguese, Romanian, Russian, Serbian, Sinhala, Slovak, Slovenian, Spanish, Swedish, Tagalog, Tamil, Tatar, Telugu, Thai, Turkish, Ukrainian, Urdu, Vietnamese

Figure 6: The full list of 54 languages supported by all 3 tools in our processing pipeline (Bing translate, Spacy, and the Twitter API). Tweets in other languages are also included in our `TwitterCOVID` dataset, but the filtering step is less accurate for these unsupported languages.

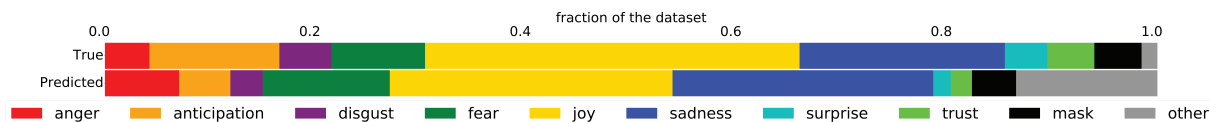


Figure 7: (*top*) The distribution of emotions in the subset of `TwitterCOVID` that contain emojis. (*bottom*) The distribution of emotions in the subset of `TwitterCOVID` that did not contain emojis, and that we used `BERTmoticon` to assign predictions for.

translate. (3) We used Python’s `spaCy` library (Honnibal and Montani, 2017) to tokenize and lemmatize each of the 400 million geolocated tweets sent between January and June 2020. This is the same time period that we examined for the `TwitterEmoticon` dataset, and so we hope that the `BERTmoticon` model trained on the `TwitterEmoticon` dataset will transfer well to this `TwitterCOVID` dataset. `spaCy` supports tokenization in 58 different languages, and for each tweet we used the appropriate `spaCy` module for the language specified in the tweet’s metadata. For languages not directly supported by `spaCy`, we tokenized on whitespace. (4) Finally, the `TwitterCOVID` dataset is constructed as the set of all tweets whose lemmatized text contains any of the search terms from the tweet’s language or English. We include both languages in this filtering step because it is common for non-English tweets to use English words like “coronavirus” when referencing the virus. Figure 6 shows the full list of 54 languages that are supported by all 3 services. The `TwitterCOVID` dataset contains tweets in an unknown number of other languages, and the filtering procedure for these unsupported languages used language-agnostic steps, which likely results in less recall. In total, 16.2 million tweets meet the criteria to be included in the `TwitterCOVID` dataset.

The other significant dataset of coronavirus related tweets was introduced by Chen et al. (2020). There are two main differences between our dataset and theirs. First, we only include geolocated tweets, whereas they include non-geolocated tweets as well. This results in their dataset being about fifteen times larger than ours, with about 250 million tweets over the same time period. Because their data is not geolocated, however, it is not suitable for understanding how different countries have reacted emotionally to COVID-19. The second difference is that our dataset uses a more advanced language-aware filtering method. They only search for tweets that contain English keywords. Most languages, however, have few words in common with English, and non-Latin based languages frequently do not even use the word “coronavirus” to describe the virus. Chinese tweets, for example, commonly refer to COVID-19 with the string 病毒, and Chinese-language tweets containing this string will get included in our dataset but not in their dataset. As a result of this more advanced processing, the fraction of non-English tweets is much larger in our dataset than theirs (48% versus 38%). Capturing as many non-English tweets as possible about COVID-19 is important for ensuring that our analysis is not unfairly skewed towards English-speaking countries.

3.2 Results

Only 15.11% percent of tweets in the `TwitterCOVID` dataset contain an emoticon. We used the `BERTmoticon` model to label the remaining tweets. Figure 7 shows the distribution of tweets present in the dataset vs those we predicted. The anticipation, disgust, joy, surprise, and trust emoticons appear less frequently in the predicted dataset, and the anger, sadness, and fear emotions appear more often in the predicted set. We hypothesize that this difference is due to the fact that more-formal Twitter accounts (such as for newspapers or government organizations) are less likely to use emoji in their tweets, and

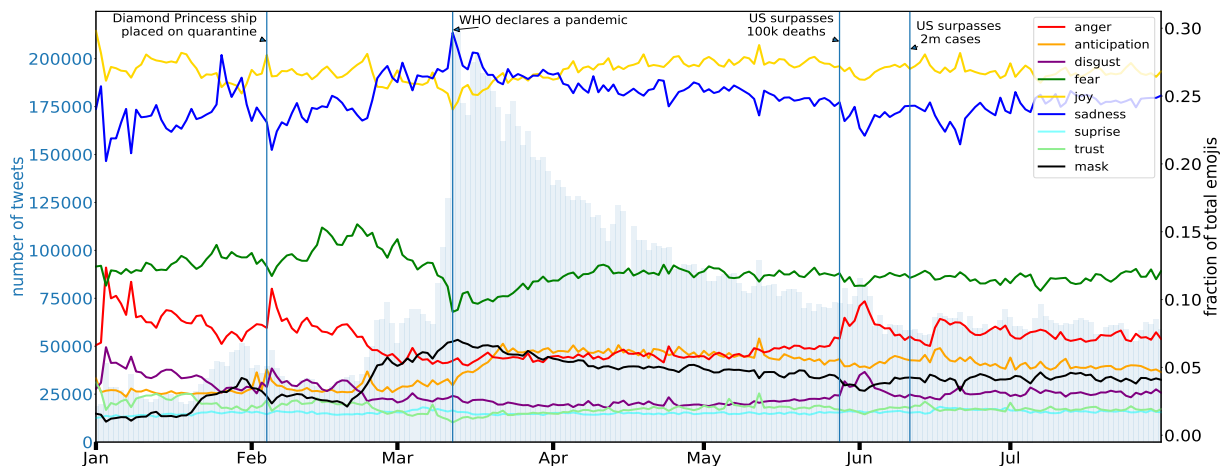


Figure 8: The emotional content of tweets in the TwitterCOVID dataset changes over time and reacts to major news events. The shaded bar plot in the background shows the total number of tweets in the TwitterCOVID dataset sent on a particular day (left y-axis scale), and the colored line charts show the fraction of tweets in a particular day that correspond to each emotion on the Plutchik wheel or the mask emoji (right y-axis scale). We can see clear emotional reactions to the news events labelled with vertical lines.

these formal accounts also tweet about different topics than more informal accounts of ordinary people.

Our main result is shown in Figure 8. For each day, we calculate the fraction of tweets that represent each emotion from the Plutchik wheel (see Figure 2), and we can observe a strong correlation between the emotional content of tweets and important COVID-19 news. For example, on March 11, the World Health Organization (WHO) declared COVID-19 a worldwide pandemic. At the same time, we can see a large spike in tweets about the coronavirus, and in particular we see an increase in sadness and a decrease in joy. Since sadness and joy are at opposite ends of the Plutchik wheel of emotions, it makes sense that a rise in one would cause a fall in the other. As another example, on May 28, the United States had its one hundred thousandth death to the coronavirus. At the same time, we see spikes in anger and disgust. The following tweet from this time period is a representative example:

How do we tolerate 3000 Americans dying everyday from #COVID19? THREE. THOUSAND. EVERY. DAY.

This tweet was not originally sent with any emoticons, but our BERTmoticon model was able to label it with 😞, 😟, 😠, 😡. As another example, notice that the mask emoji usage increases in mid-January. Interestingly, at that time little information was available about COVID-19 and protecting yourself against it. Finally, in early February some important news-events that circulated in Twitter were the Diamond Princess Ship being placed under quarantine and the death of Doctor Li Wenliang (a Chinese doctor who issued a warning about the coronavirus before the pandemic was officially recognized). At that point we notice a spike in anger and disgust.

4 Conclusion

We introduced the BERTmoticon model for multilingual emoji prediction, and used this model to better understand how Twitter users responded emotionally to news about the coronavirus. In follow up studies, we hope to analyze how different countries and language communities reacted differently to events, and have designed our TwitterCOVID dataset and BERTmoticon model to facilitate these cross-sectional analyses. We also hope that the BERTmoticon model will prove useful for analyzing the emotions of text in other contexts outside of COVID-19, and we make the model available in an easy to use Python package to facilitate this process.

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