

# NLP Analysis of CGM for Diabetes -

## Are customers satisfied with current available CGMs?

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### Executive Summary

Three products are important for diabetes patients to manage their disease status: Continuous Glucose Monitor, Insulin Pump, and Data-Recording/Reading APP. To increase user satisfaction, the CGM company should focus on product accuracy, compatibility with the insulin app, and the UI of the APP. Customers expect to see the CGM function in the apple watch. This function may be achieved<sup>1</sup>. CGM companies should consider how to compete with Apple or cooperate with them.

### 1. Introduction

Diabetes is a chronic disease that can lead to cardiovascular disease, kidney failure, renal complications, and even death. According to the Centers for Disease Control (CDC) research, 37.3 million people have diabetes (11.3% of the US population) and 96 million (38% of the US population) have prediabetes<sup>2</sup>. To manage the disease, it is important for patients to monitor their blood sugar level closely to prevent possible complications.

Patients can use self-monitoring of blood glucose (SMBG) or a continuous glucose monitor (CGM) to check their blood sugar. One of the disadvantages of SMBG is that it requires finger pricking. CGM, which analyzes blood sugar from sensors inserted under the skin, has become a popular alternative. The advantage of the CGM includes the real-time, dynamic information about the speed and direction of glucose levels. Therefore, users can easily identify what kind of food or habits that spike blood sugar and then they can manage their health better. Most CGM has a warning system to alert users of abnormal sugar levels. And may also interact with insulin pumps that enable automation of insulin dosing if the users are hyperglycemic. The features of CGMs improve people's comfort of life, reducing the anxiety associated with the changes in glucose concentration, and enable more effective control of their health.

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<sup>1</sup> "Apple Watch Creeps Closer to Adding Glucose Tracking: Bloomberg," accessed March 3, 2023, <https://www.fiercebiotech.com/medtech/apples-long-desired-glucose-tracking-reportedly-proof-concept-stage-bloomberg>.

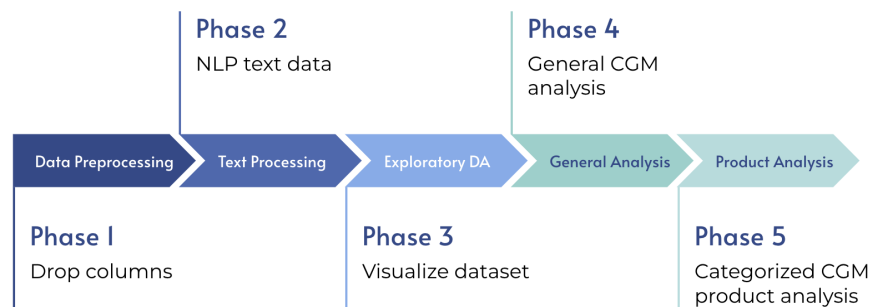
<sup>2</sup> "National Diabetes Statistics Report | Diabetes | CDC," June 29, 2022, <https://www.cdc.gov/diabetes/data/statistics-report/index.html>.

## 2. Problem Statement

Nevertheless, many people still remain skeptical of CGM's safety and accuracy. This project was conducted to assess if users are satisfied with current CGMs on the market.

## 3. Project Workflow

This project consists of 5 phases. The first phase is to tidy the dataset by eliminating columns that do not contribute to the project. The second phase is to use natural language processing modules to process text data. The third phase is the initial exploratory data analysis. The fourth and the final phases consist of general CGM and product-related CGM analysis. Following is a flowchart of the project workflow.



*Fig. 1 Project workflow*

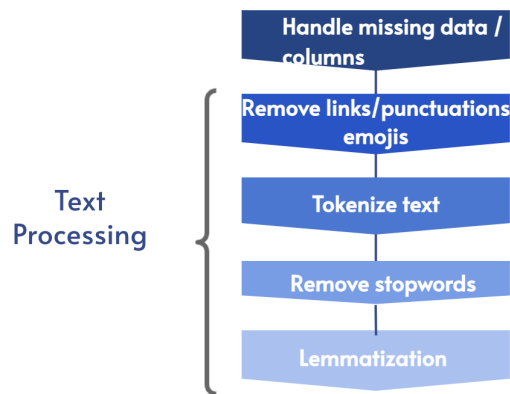
## 4. Data Source

The dataset, "Diabetes Continuous Glucose Monitoring - Data Export", is an excel file consists of 63 columns and 37844 rows. This dataset contains social media posts information such as post ID, text, title, author, source, sentiment, etc.

Upon the initial dataset reading, we discover that there are 42 columns that contain more than 90 percent of missing value. For example, dozens of columns' names beginning with "LexisNexis" are mostly empty. The text column is the column that the project should focus on, where it contains emojis, hashtags, and links.

## 5. Data pre-processing

The data pre-processing step is standard. Following is a chart that displays the flow of data preprocessing step.



*Fig. 2 Workflow of text data processing step*

After reading the excel file, we check the percentage of missing values in each column, if missing values exceed 90% of the entire column, then we drop the column. Later we find that column 'Positive Objects' and 'Negative Objects', although do not exceed 90%, have a sufficiently large portion of missing values, therefore we drop these two columns as well.

Then, we process text file. We find that the 'title' column also contains text information where we think there are values to consider them as text as well, although not every row contains title. In this case, we fill the empty cell from the 'title' column with string "empty title". Next, we concatenate the 'Sound Bite Text' column with the 'title' column and treat it as the text data we need to process during this step.

The text processing steps are, for each value of the text column, first, remove links that contains strings characters such as "www". Second, remove punctuations such as comma, period, exclamation point, etc. Third, remove emojis by encoding the text in ascii format and decoding them. Fourth, we tokenize the text using whitetokenizer from package nltk, during the process of tokenization, we also remove stopwords such as "is, am, very" in the function using the stopwords dictionary provided by package nltk as well. Last, we use workLemmatizer from package nltk to lematize the tokens.

We think that these 6 steps can let the text data contain most of the useful information and eliminate the meaningless information.

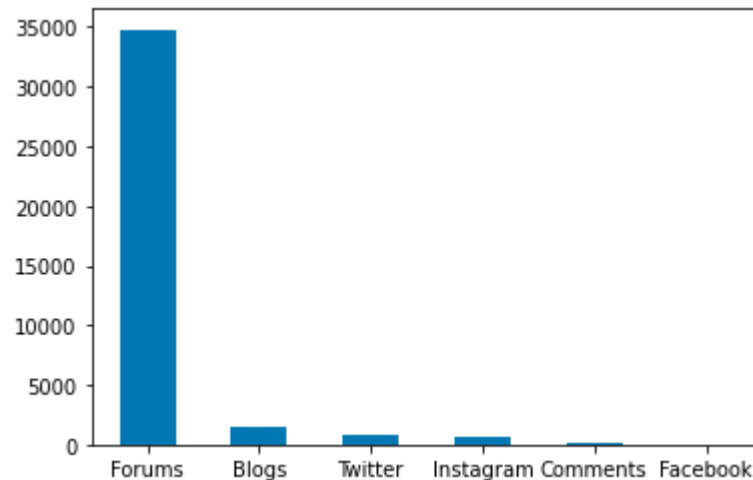
## 6. Result

### Exploratory Data Analysis

The dataset not only includes text columns, but also columns we find interesting and hoping to see if they can contribute to our analysis and result. In this

exploratory data analysis part, we examine two columns, 'source type' and 'sentiment'.

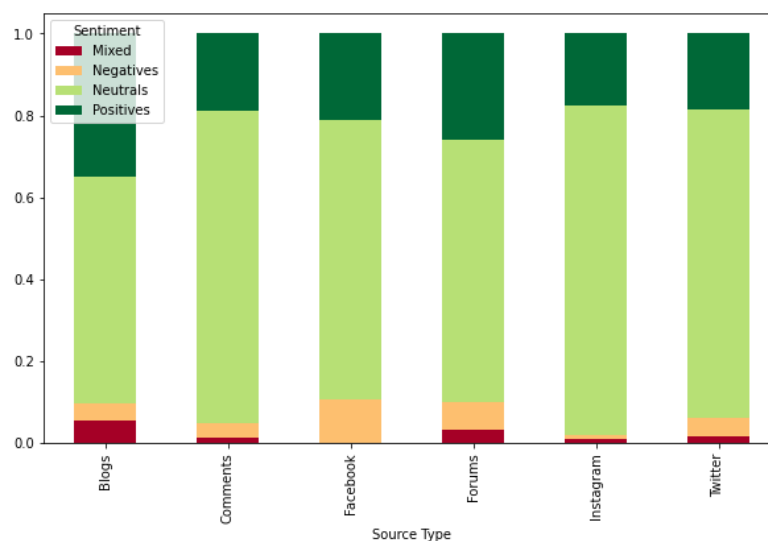
First, we make a bar plot for the 'source type' column.



*Fig. 3. Data distribution of source type*

From this plot, we can see that the count of forum posts dominates the total number of posts, which indicates that this dataset is imbalanced and heavily skewed with forum posts. Therefore, we decide not to further split and analyze each source type but instead treat all of the posts, regardless of the source type, as a whole.

Second, we create a stacked bar chart for the 'sentiment' column.



*Fig. 4 Sentiment distribution across source types*



As a result, we do not think the word cloud is a viable analysis to our project as it lacks interpretability. Instead, for the next steps, we use the CountVectorizer function from tfvectorizer to group words into grams. In this general CGM analysis, we use tri-grams as it is a perfect balance between interpretation and bias.

After generating the tri-gram from the count vectorizer, we also create a list of stop words that should not be in the analysis, from the output, we select the tri-grams that look interesting and refer back to the original post manually. The output is shown in below.

```
tf_vectorizer = CountVectorizer(max_df=0.95, min_df=2, stop_words=expectation_stop, ngram_range = (3, 3))
tf = tf_vectorizer.fit_transform(expectation_df['text_clean'])
word = list(tf_vectorizer.get_feature_names_out())
count = tf.sum(axis=0).A1
word_series = Counter(dict(zip(word, count)))
word_series.most_common(25)

[('close loop system', 203),
 ('durable medical equipment', 57),
 ('hybrid close loop', 55),
 ('14 day sensor', 51),
 ('low carb diet', 50),
 ('multiple daily injection', 50),
 ('insurance doesnt cover', 44),
 ('tandem control iq', 44),
 ('apple watch series', 42),
 ('insurance wont cover', 42),
 ('multiple time day', 35),
 ('check time day', 34),
 ('start new sensor', 34),
 ('test time day', 34),
 ('dont nondiabetics cgms', 30),
 ('finger prick test', 29),
 ('prick finger time', 29),
 ('wake middle night', 29),
 ('90 day supply', 28),
 ('flash monitor system', 28),
 ('go high low', 28),
 ('improve quality life', 28),
 ('last 10 day', 28),
 ('10 year old', 27),
 ('24 hour day', 27)]
```

*Fig. 6 Output result of the tri-grams words*

Upon evaluation, we find that people are most expecting several things:

1. Closed Loop System in lieu with CGM to better control patients' health condition.
2. Patients want the CGM to be listed as Durable Medical Equipment by the health supplier, where they can save more money in this way by letting health insurance to cover the cost.
3. Patients are hoping for future roll out of CGM app compatibility / blood sugar monitor on next generation Apple Watch.

## Knowledge Gap

To know what is the knowledge gap for the patients, as the previous procedure, we filter words that express confusion in the dataset, such as “confuse”, “unclear”, “misunderstand”, etc. After this step and filtering out the stopwords, we get the result very similar to the previous expectation tri-gram.

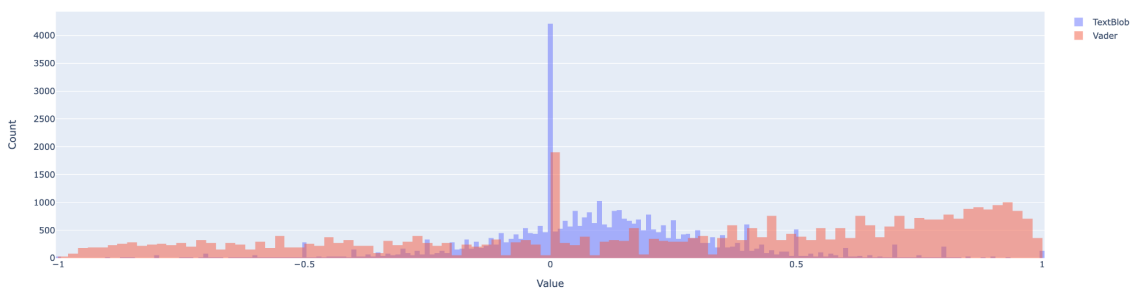
```
[('close loop system', 78),
 ('durable medical equipment', 30),
 ('14 day sensor', 24),
 ('multiple daily injection', 23),
 ('insurance doesnt cover', 20),
 ('start new sensor', 20),
```

*Fig. 7 Output result of knowledge gap analysis*

Upon evaluation, the “Close loop system” and “Durable Medical Equipment” remain on top of the frequencies as patients express knowledge gap on which brand and insulin pump support closed loop system. Patients also want to know which specific medical supplier cover CGM as Durable Medical Equipment.

### **Benefit and Unmet Needs**

For the benefit and unmet needs portion, we decide to perform sentiment analysis using sentiment modules Vader and Textblob. The reason behind this is we want to set thresholds based on sentiment analysis score. For the sentiment that are on the top 10 percent of the score distribution, we consider that patients must have praised the benefit of the CGM, vice versa, if the sentiment scores for post are at the bottom 10 percent, that means patients are complaining for unmet needs. The following graph shows the distribution of sentiment between 2 modules.



*Fig. 8 Distribution of sentiment analyzed by TextBlob and Vador modules*

After we filter the top 10 percent sentiment score data for both of the module, we perform a cross evaluation to look for commonalities between these two outputs. We find that the most important benefit of CGM for both of the output is continuous glucose monitor, which is exactly CGM, this seems very intuitive, but this is the reason why people use it and discuss about it. It stops people from spending years of time pricking finger to monitor blood sugar.

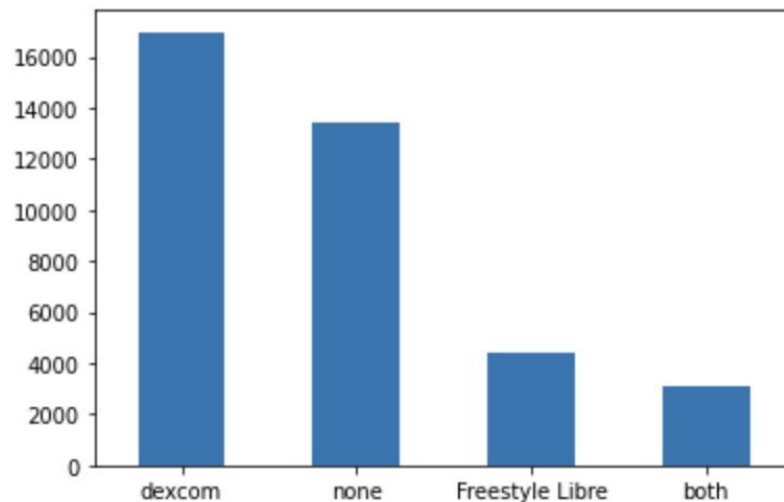
For unmet needs, we filter the bottom 10 percent of sentiment score data for both of the module. Combining both of the most negative results from textblob and

vader, we find these unmet needs from patients:

1. Closed loop system - although a lot of patients would want to use insulin pump for better health monitor, the FDA had not approved many close loop system to commercial use. This technology is still in the early stages which has potential of many improvements.
2. Accuracy - many patients complaints there are false low/high on monitoring blood sugar levels using cgm. An accurate equipment is the top need from all of the patients who use CGM.
3. Software update - CGM companies did not fulfill the software update demand for the CGM devices. People are actually developing their own softwares, these works should have done by CGMcompanies.

### **CGM product-related analysis**

We mainly focus on the Dexcom and Freestyle Libre companies so the dataset has been categorized into four groups. And from the following bar plot, we can see the data is quite imbalanced. Dexcom has about 4 times more posts than Freestyle Libre and nearly one thirds of data did not discuss either Dexcom or Freestyle Libre. Therefore, in the future, we may want to collect more balanced data and take more companies under consideration and analysis.



*Fig. 9 Data distribution for company categories*

#### **1. Dexcom**

##### **Dexcom Features**

We use the same methods that were used in the general product analysis to detect the main features. First, we start with one word cloud but realize it doesn't give us much information. So we next try the 3-gram analysis and the results are shown below. The most important feature is definitely the continuous glucose



monitoring itself. On top of that, Dexcom has integrated with Tandem Tslim x2 Insulin Pump which work together as closed loop systems. The Dexcom G6 can be wearable for up to 10 days and the insulin pump can hold up to 300 units of insulin. Dexcom also has its own app that can pair with sensors to see the glucose levels, and share the data with family and healthcare providers. And users can set up their own target values as thresholds for alerting functionality.

Fig. 10 word cloud for feature

Fig. 11 Top 5 most frequent 3-word phrase

```
('highly recommend get', 11),
('make life easy', 11),
('22 year battle finally feel free', 7),
('good continue monitor tire abuse finger', 5),
('dont people have hard time adjust', 5),
```

Fig. 12 Top 5 most frequent phrase from positive sentiments

## Complaints

the app connection has issues, particularly not working well with SAMSUNG galaxy note. Besides the app, sensors have bluetooth instability as well. Since Dexcom sensors can only last for 14 days, users have to pay more for those replacements. Not every insurance will cover the entire cost, so it becomes a concern for some consumers. Maybe Dexcom can try to make sensors last longer. The last but not least complaint is about inaccurate reading. Some people reflected that the CGMs usually give false low blood glucose value. It's actually a significant issue since it can directly affect how much insulin the users will get and it may harm their health.

```
('app update base', 9), ('sensor bluetooth issue', 4),
('app issue connect', 5), ('bad experience sensor', 5),
('cant find widget', 3), ('galaxy note issue', 4),
('insurance wont cover', 6), (('give false low', 8),
```

*Fig. 13 Top 8 most frequent negative phrases*

## 2. Freestyle Libre

Freestyle Libre features, praise, and complaints are identified using words frequency analysis and topic modeling method. Freestyle Libre-related and diabetes-related common words ('cgm', 'diabetes', 'blood', 'glucose', 'sugar', 'continuous', 'freestyle', 'libre', 'monitoring', 'pump', '1', '2', '14', 'insulin', 'tslim') were removed from the dataset. Before conducting the analysis, text labeled with category = "Freestyle Libre" are divided to 4 subsets by sentiment column values ("positive", "negative", "mixed", "neutral"). Below is an example of how we process top words and topic analysis result.

### a. Top words analysis

```
[('medical supply brooklyn', 22),
 ('flash monitor system', 18),
 ('credit natasha lomastechcrunch', 12),
 ('image credit natasha', 12),
 ('app compatible certain', 10),
 ('certain mobile device', 10),
 ('compatible certain mobile', 10),
 ('device operate system', 10),
 ('mobile device operate', 10),
 ('require registration libreview', 10),
 ('disease cardiovascular disease', 8),
 ('finger prick test', 8),
 ('inflammation oxidative stress', 8),
 ('measure interstitial fluid', 8),
 ('startup productizing technology', 8),
 ('app require registration', 7),
 ('compatibility app use', 7),
 ('data file abbott', 7),
 ('device compatibility app', 7),
 ('file abbott care', 7),
 ('information device compatibility', 7),
 ('interstitial fluid level', 7),
 ('operate system check', 7),
 ('read phone minute', 7),
 ('alarm level set', 6)]
```

*Fig. 14 top 25 common words result retrieved from Freestyle Libre sentiment = positive text.*

We tried different n\_gram parameters to obtain the Top 25 common words from

different sentiment subsets. We will read through the output and identify features, praises, and complaints. The above figure is an example of how we process the output result.

Table 1 result of identified Freestyle Libre features and prais

Identified Features Libre	Identified Praise
<ul style="list-style-type: none"> <li>- flash monitor system</li> <li>- app compatible</li> <li>- mobile device operate</li> <li>- app requires registration</li> <li>- read phone minute</li> <li>- alarm level set</li> </ul>	<ul style="list-style-type: none"> <li>- We can see the name Natasha in the output. Natasha is using Freestyle Libre to manage her diabetes and bring positive comment to the product<sup>3</sup>.</li> <li>- Disease management: some disease terms were mentioned in the text. It may link to disease Management (more supporting data are retrieved in the later analysis)</li> </ul>

## B. Topic modeling

We tried different `n_gram` and `num_topic` combinations to obtain different outputs and summarized the topic by human interpretation. In the following sample, we obtained the below conclusion:

Topic 0 - Freestyle sensor is easy to insert; it is a life-change product,

Topic 1 - The product is compatible with the app; the user can set the alarm level

```
[Topic 0]
medical supply brooklyn : 0.012005373554670302
diabetic test supply : 0.0033528523978439357
traditional diabetic test : 0.0033528523978439357
time stress money : 0.0033528467169672664
save time stress : 0.0033528467169672664
application guy action : 0.002812068941762995
experience case wonder : 0.002812068941762995
life change get : 0.002812068941762995
especially im comfortable : 0.002812068941762995
take quick video : 0.002812068941762995
quick video application : 0.002812068941762995
dont vuori romper : 0.002812068941762995
comfortable guy im : 0.002812068941762995
process nutrisense use : 0.002812068941762995
doctor work im : 0.002812068941762995
post dont vuori : 0.002812068941762995
wonder tip get : 0.002812068941762995
action especially im : 0.002812068941762995
work im share : 0.002812068941762995
amaze post dont : 0.002812068941762995
application process nutrisense : 0.002812068941762995
easy painless insert : 0.002812068941762995
phone easy painless : 0.002812068941762995
happy amaze post : 0.002812068941762995
guy action especially : 0.002812068941762995
```

```
[Topic 1]
flash monitor system : 0.004638041556497708
app compatible certain : 0.003877348954518913
certain mobile device : 0.0038773489545189128
device operate system : 0.0038773489545189106
compatible certain mobile : 0.0038773489545189097
mobile device operate : 0.0038773489545189097
require registration libreview : 0.0038773489545189093
measure interstitial fluid : 0.0031168003180969063
data file abbott : 0.002737135657117459
file abbott care : 0.002737135657117459
interstitial fluid level : 0.0027371227952086674
device compatibility app : 0.002736756505623331
app require registration : 0.0027367565056233304
compatibility app use : 0.002736756505623293
information device compatibility : 0.002736756505623286
operate system check : 0.0027367565056232814
base comparison list : 0.0023569779073654984
price portfolio versus : 0.0023569779073654984
```

Fig. 15 Topic modeling result retrieved from Freestyle Libre sentiment = positive text (`n_gram` = 3, `num_topic` = 5)

<sup>3</sup> Rachel Duffell, "Joanna and Natasha Hotung On How CGM Is Changing The Lives Of Diabetics," Tatler Asia, accessed March 3, 2023, <https://www.tatlerasia.com/the-scene/people-parties/joanna-and-natasha-hotung-youth-diabetes-action>.

## **Features**

Following the aforementioned data analysis methods, we analyzed the data from 4 different sentiment data subsets and identified the following features:

1. Flash monitor system - let patient check their sugar levels without finger pricking
2. Freestyle Libre App - read/record data in the user's phone
3. Alarm level set - alert the patient if the glucose level is too high or low
4. Wearable device
5. Continuous glucoses monitor
6. Compatible with an insulin pump (Medtronic)

## **Praise**

Praises were concluded from the positive sentiment data subset analysis result.

1. Fairly accurate
2. Compatible with an app, easy to read the data
2. Good for health management, including chronic disease monitoring
3. Painless when inserting the sensor, even the needle phobia can use the product
4. Affordable

To verify the result, we will return to raw data and use keywords to identify relevant texts. For information we cannot verify from the data, we will search online to confirm our findings.

It is estimated that patients need to pay \$200 per month for the Freestyle Libre products and \$300 for the Dexcom G6. This result confirms our finding that People appreciated Freestyle Libre for its affordable price.

## **Complaints**

Complaints were concluded from the negative sentiment data subset analysis result.

1. Inaccurate reading when a new sensor is replaced
2. app slow and unresponsive - some users also complained the app will not response suddenly
3. Non-recyclable material - the material is not recyclable. Users feel bad when changing the material
4. Backwards technology device - Medtronic 770G - we found people complaint about the compatible insulin pump and had negative feedback to the Freestyle Libre CGM

The non-recyclable material complaint is the comment we didn't expect.  
The raw text is as below:

wow and I thought the freestyle libre has a lot of waste So much trash for just one infusion and cgm change. Anyone else feel bad about the amount of non recyclable trash that comes with trying to stay alive?

### Overall sentiment Regarding Dexcom and Freestyle Libre CGM

The original sentiment classification has 4 distinct values, positive, negative, neutral, and mixed. The issue of categorical classification is it may simplify the information. For example, we are not able to distinguish very positive and less positive from the original sentiment column. Therefore, we decide to apply TextBlob and Vader for sentiment analysis.

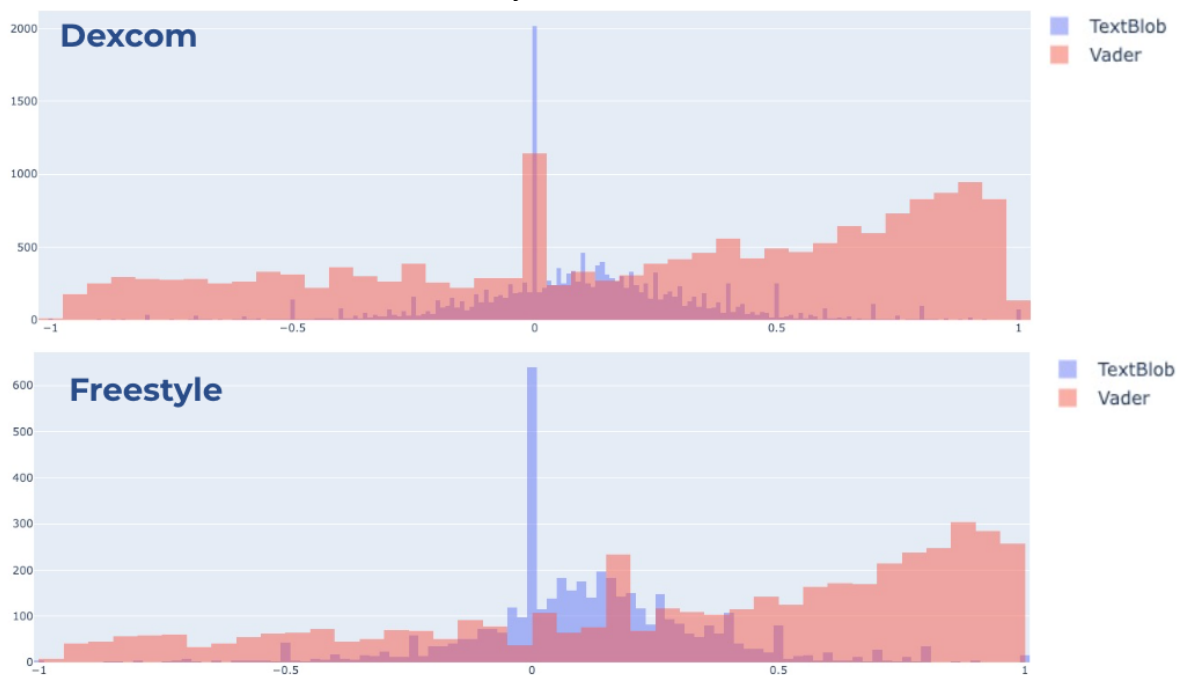


Fig. 15 overall sentiment of Dexcom and Freestyle Libre CGM products

The result shows that users had neutral to positive sentiments for Dexcom products. People using Freestyle Libre seem to have a higher positive sentiment. However, this result is analyzed from an imbalance dataset. There might be bias exist in this dataset.

## Comparison of Dexcom and Freestyle Libre CGM products

Table. 2 Comparison between Dexcom and Freestyle Libre CGMs

Company	Features	Complaints
<b>Dexcom &amp; Freestyle Libre</b>	<ul style="list-style-type: none"> <li>● Continues Glucose System</li> <li>● Close loop system (Compatible with insulin pump)</li> <li>● Blood sugar warning system</li> <li>● Compatible with App</li> </ul>	<ul style="list-style-type: none"> <li>● App issue <ul style="list-style-type: none"> <li>- unresponsive</li> <li>- unfriendly UI</li> </ul> </li> <li>● Inaccurate reading</li> </ul>
<b>Dexcom</b>	(Based on our analysis, Freestyle Libre and Dexcom hold common features)	<ul style="list-style-type: none"> <li>● Compatible issue with Galaxy Note</li> <li>● costly</li> </ul>
<b>Freestyle Libre</b>		<ul style="list-style-type: none"> <li>● Sensor issue</li> <li>● Non-recyclable material</li> <li>● Medtronic 770G <ul style="list-style-type: none"> <li>- backward technology</li> </ul> </li> </ul>

Our analysis didn't include a praises comparison since the praise conclusion was generated from the imbalance database. Although the complaint was also retrieved from the same dataset, this information is still meaningful for the company to improve its products.

Dexcom and Freestyle Libre have the similar product feature profile. They have the same complaint regarding app issues and inaccuracy reading. Dexcom and Freestyle Libre are leading companies in the CGM area. Their common complaints also reflect customers' expectations and unmet needs. Companies need to provide CGM with accurate reading and UI friendly APP to improve users' satisfaction.

Besides the common issue, Dexcom also needs to improve its compatibility with Galaxy Note phones. Price is a big market challenge for Dexcom CGM. As Dexcom and Freestyle Libre have similar product features, the price will be the key decision consideration for the customer.

The sensor is the most urgent issue for the Freestyle Libre product. Inaccurate data reading will not only decrease users' confidence in the product, but it will also danger user's life if they cannot be aware of the abnormal blood sugar level and take corresponding actions timely. Some of the Freestyle Libre complaints are related to the insulin pump - Medtronic 770G. Freestyle Libre company should consider finding new compatible insulin pumps, or they might lose the customer. Non-recycle material is also an issue that Freestyle Libre company can focus on. If the company is able to replace the original non-recyclable material with the environment-friendly one, it may also benefit the company's image.

## **7. Challenge**

Data imbalance is the biggest challenge in this analysis. This issues us difficulties in comparing Dexcom and Freestyle Libre CGM products fairly. Dexcom has almost 4 times more data in this dataset than Freestyle Libre. There are likely unrevealed Freestyle Libre praises and complaints. Freestyle Libre should conduct market research to collect more data to have a more comprehensive product analysis.

## **8. Summary**

Based on our analysis, we provide the following recommendation to the general CGM companies and specific recommendations to Dexcom and Freestyle Libre.

### **General recommendation**

1. CGM Accuracy is important for a diabetes patient to monitor their glucose value. The user raises a complaint if the reading value is inaccurate. Moreover, the inaccurate reading may lead to a lifethrenting event. CGM company should prioritize these features in the improvement plan.
2. APP design & operation smoothness affect users' product satisfaction levels. Although APP is a supporting system, it can make users annoyed if they are not able to read the value.
3. Users expect to have a closed loop system cooperate with the CGM system. CGM companies should carefully pick their business partner or consider to expand the business into the insulin pump market.
4. Users expect to see the CGM function on the Apple watch. CGM companies should focus on their APP design more or consider the opportunity to cooperate with Apple.

### **Specific recommendation to Dexcom**

1. Provide clear APP user instructions
2. Improve Bluetooth connectivity
3. Increase compatibility with Android phones

Compared with reducing the price to resolve the costly complaint, the above recommendations are easier to achieve and can positively affect customers' satisfaction.

### **Specific recommendation to Freestyle Libre**

1. Prioritize the sensor issue to resolve inaccurate reading
2. Cooperate with different insulin pump companies
3. Replace the consumable items with the recyclable material
4. Collect more user data to obtain a more comprehensive market research result

### **Work Distribution**

**Xi Yan** : Data pre-processing, general CGM analysis, presentation, report writing

**Wanying Zhang** : Data pre-processing, Dexcom CGM analysis, presentation, report writing

**Tiffany Huang** :Data pre-processing, Freestyle Libre CGM analysis, presentation, report writing