



# Boundary of Meaning

Natural Language Processing (NLP)

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## AI Usage Disclaimer

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Parts of this project have been developed with the help of OpenAI ChatGPT (GPT-4). AI was used to support the definition of a methodological procedure, the writing of code, the drafting of descriptive texts, and the identification of relevant datasets and references. All content produced with AI has been reviewed, edited, and validated by me.



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# Literal and Figurative Language

## 1 Introduction

- Literal language communicates meaning directly.
- Figurative language relies on indirect meaning.
- Transformer-based language models ability to differentiate them is still an open challenge.



# Research Questions

## 1 Introduction

- How do transformer-based language models internally represent literal and figurative expressions?
- Are contextualized embeddings linearly separable?
- Does fine-tuning enhance the separation?
- Can token embeddings capture the differences?
- Can multimodal models achieve better separation?



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# Methodology

## 2 Methodology

### Models

- BERT
- RoBERTa
- CLIP

### Contextualized Embeddings

- CLS Token Embedding
- Average Token Embedding
- Layer-Wise Embedding

### Dimensionality Reduction

- PCA
- t-SNE
- UMAP



# Methodology

## 2 Methodology

### Clustering and Classification

- K-Means
- Logistic Regression
- SVM

### Evaluation Metrics

- ARI
- Accuracy
- Precision
- Recall
- F1

### Datasets

- VUAMC
- V-FLUTE
- Flickr8k



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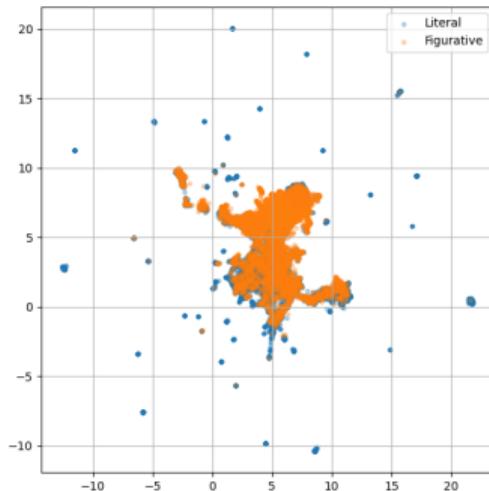
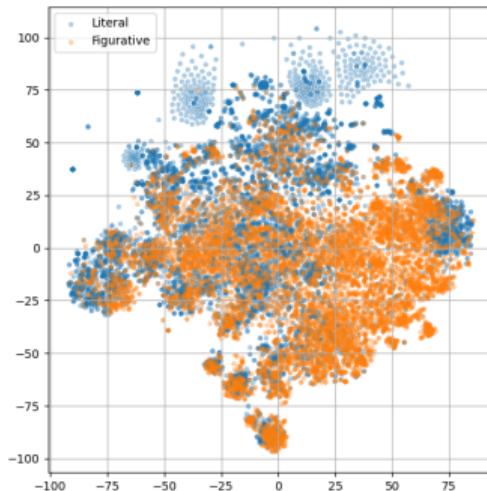
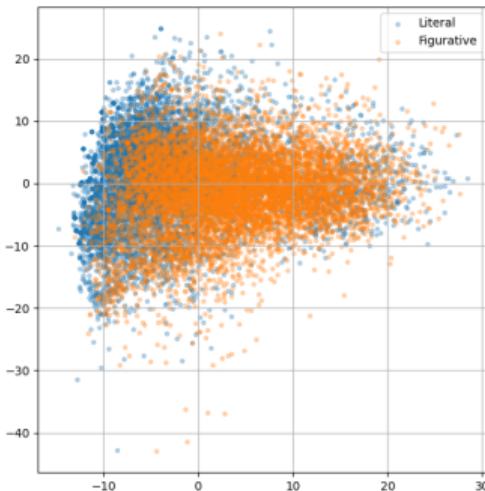
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# Dimensionality Reduction

## 3 Results

PCA, t-SNE and UMAP on BERT CLS embeddings.

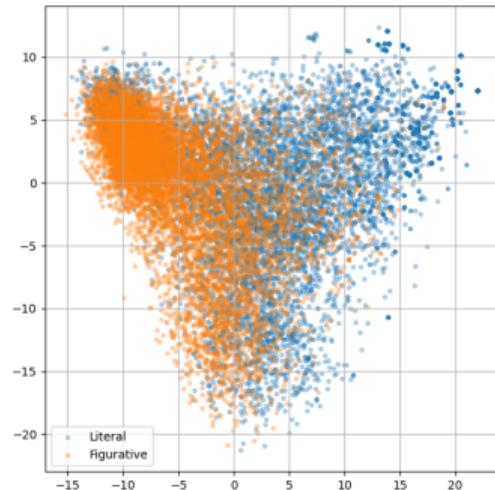
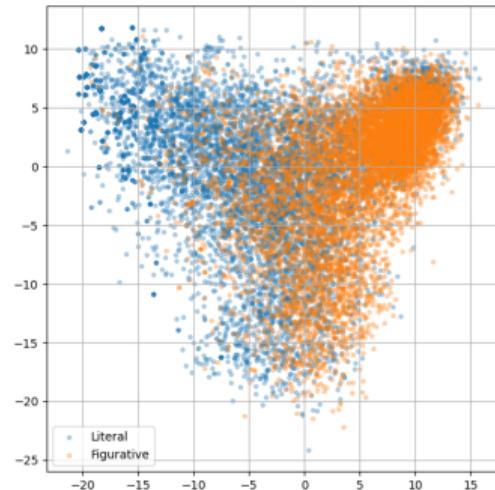
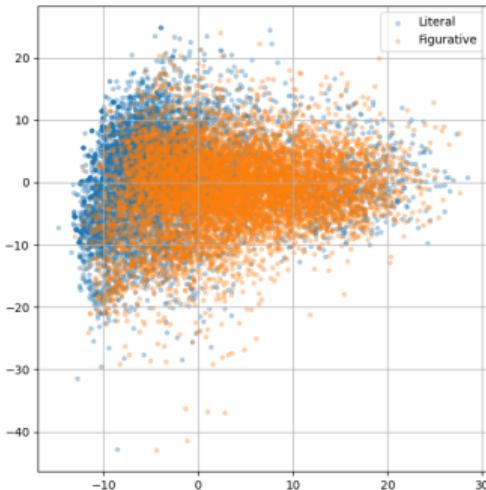




# Dimensionality Reduction

## 3 Results

PCA on BERT CLS, average and layer-wise embeddings.

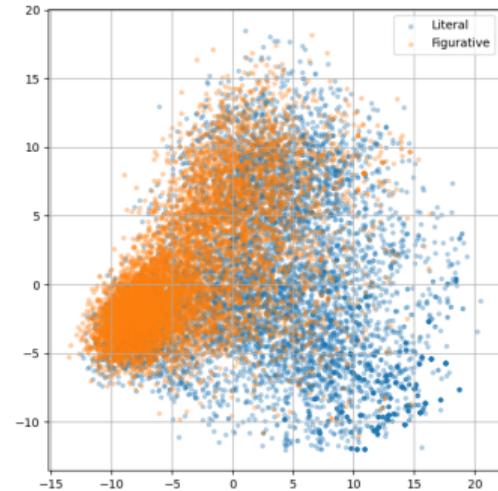
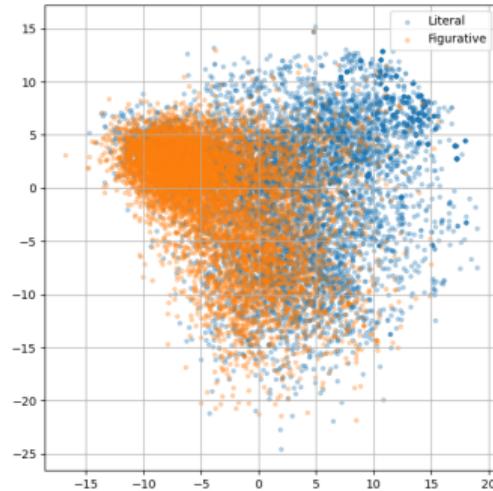
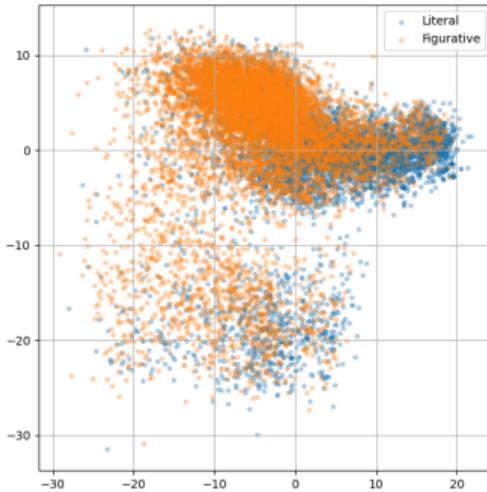




# Dimensionality Reduction

## 3 Results

PCA on RoBERTa CLS, average and layer-wise embeddings.

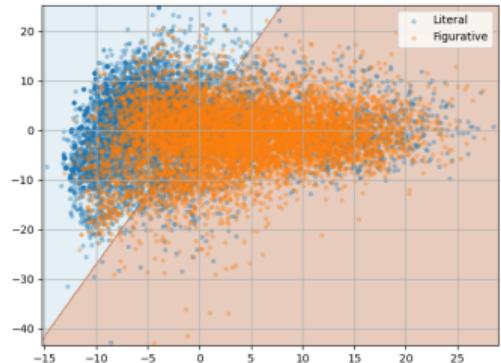
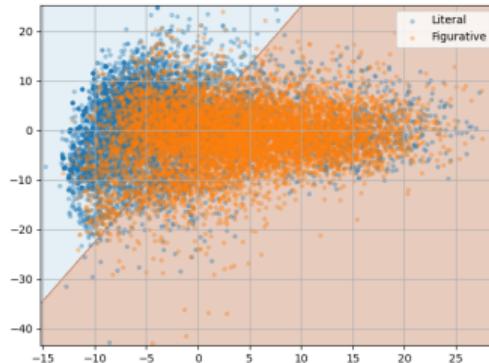
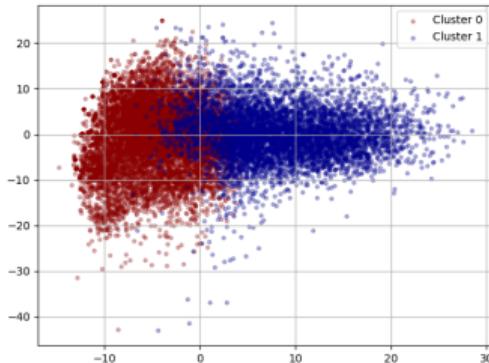




# Clustering and Classification

## 3 Results

K-Means, Logistic Regression and SVM results on BERT CLS embeddings.



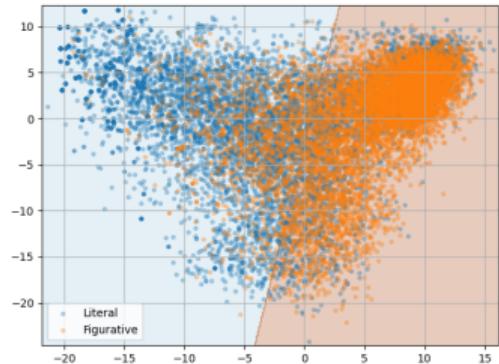
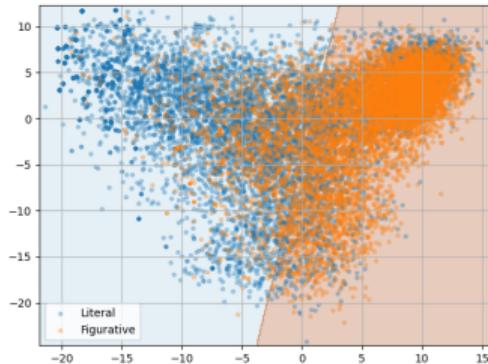
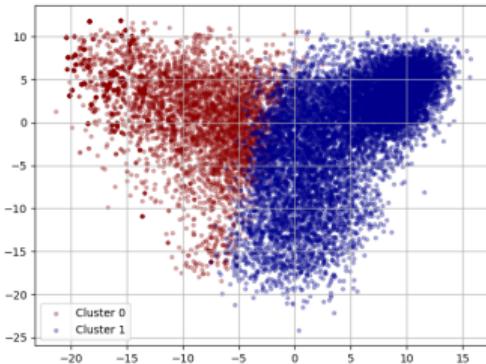
Method	ARI	Accuracy	Precision	Recall	F1
K-Means	0.156				
LogReg		0.803	0.813	0.794	0.803
SVM		0.803	0.814	0.791	0.802



# Clustering and Classification

## 3 Results

K-Means, Logistic Regression and SVM results on BERT average embeddings.



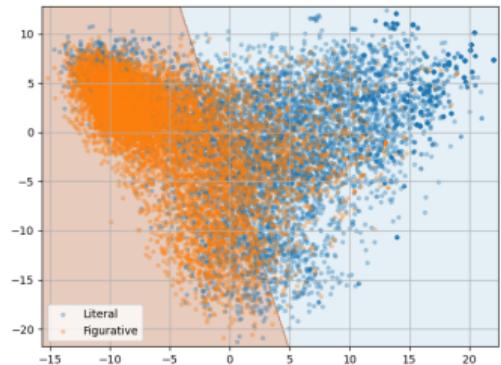
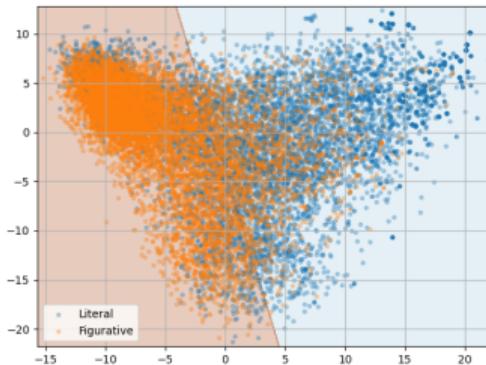
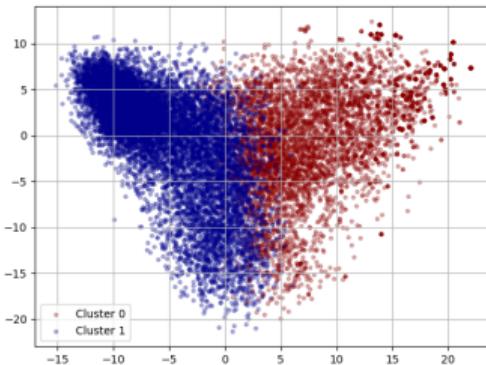
Method	ARI	Accuracy	Precision	Recall	F1
K-Means	0.213				
LogReg		0.825	0.829	0.823	0.826
SVM		0.819	0.82	0.821	0.821



# Clustering and Classification

## 3 Results

K-Means, LogReg and SVM results on BERT layer-wise embeddings.



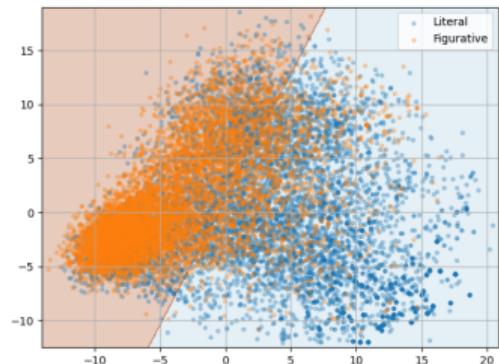
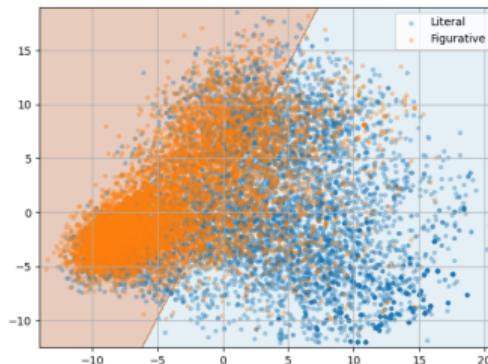
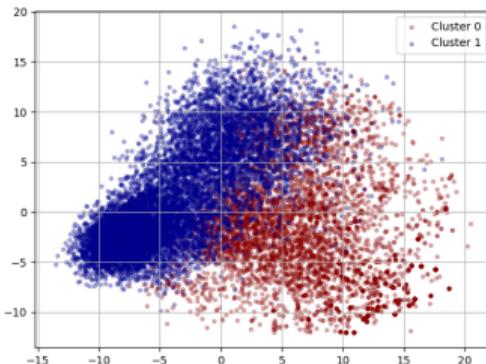
Method	ARI	Accuracy	Precision	Recall	F1
K-Means	0.257				
LogReg		0.833	0.835	0.836	0.835
SVM		0.831	0.829	0.839	0.834



# Clustering and Classification

## 3 Results

K-Means, LogReg and SVM results on RoBERTa layer-wise embeddings.



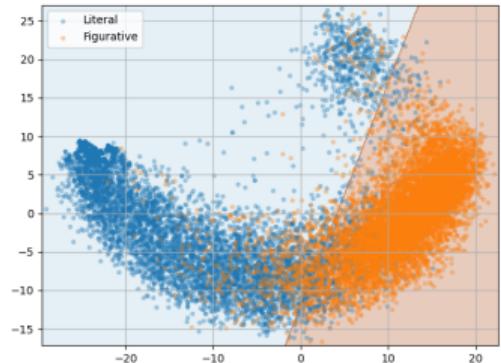
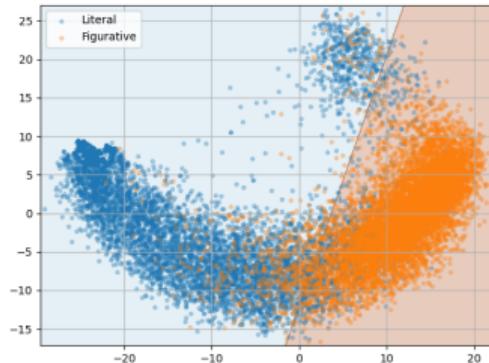
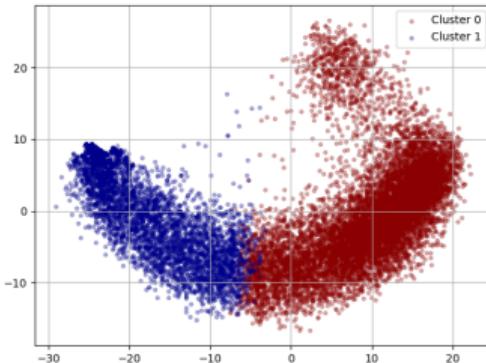
Method	ARI	Accuracy	Precision	Recall	F1
K-Means	0.245				
LogReg		0.833	0.833	0.838	0.835
SVM		0.829	0.825	0.841	0.833



# Clustering and Classification

## 3 Results

K-Means, LogReg and SVM results on fine-tuned BERT layer-wise.



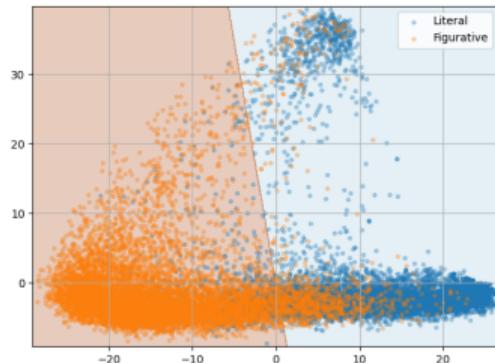
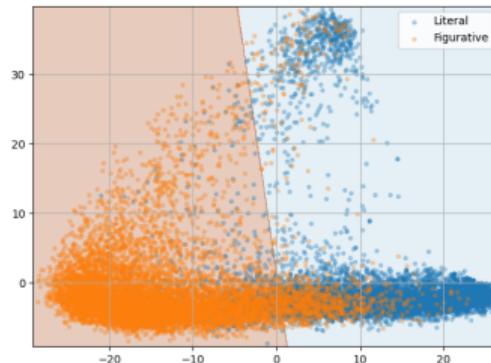
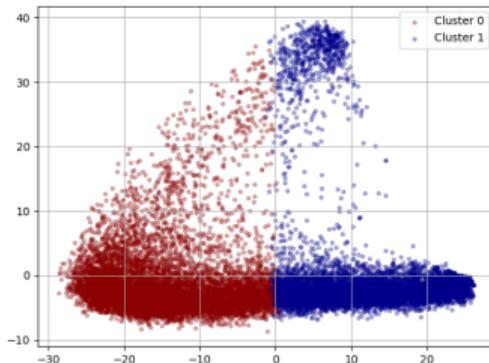
Method	ARI	Accuracy	Precision	Recall	F1
K-Means	0.428				
LogReg		0.863	0.861	0.87	0.865
SVM		0.863	0.865	0.863	0.864



# Clustering and Classification

## 3 Results

K-Means, LogReg and SVM results on fine-tuned RoBERTa layer-wise.



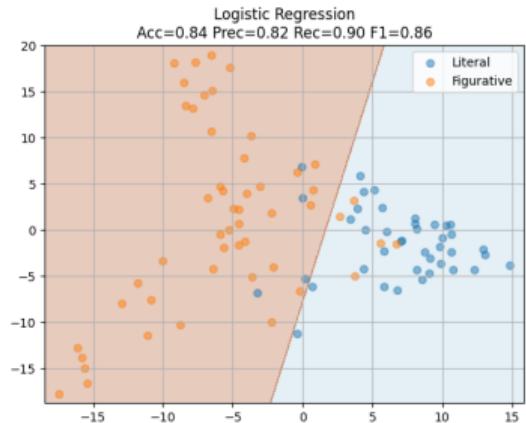
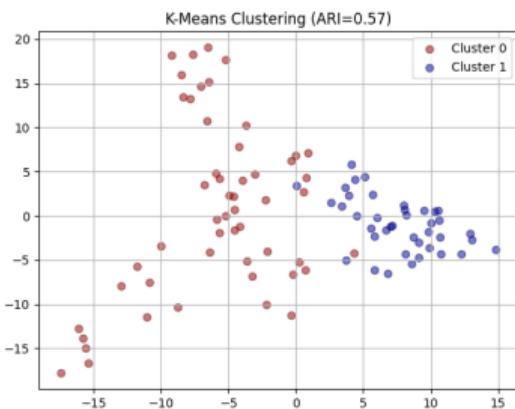
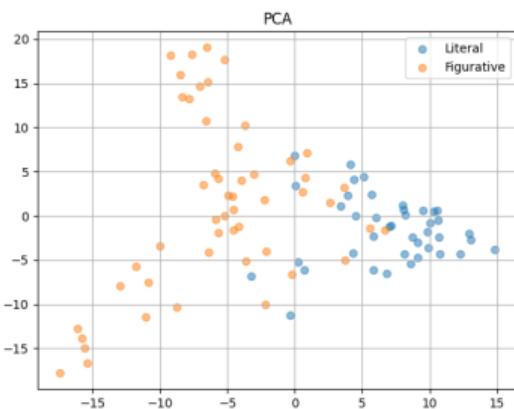
Method	ARI	Accuracy	Precision	Recall	F1
K-Means	0.607				
LogReg		0.873	0.88	0.867	0.873
SVM		0.869	0.877	0.863	0.87



# Token Embedding Analysis

## 3 Results

Token embeddings of “Found”.

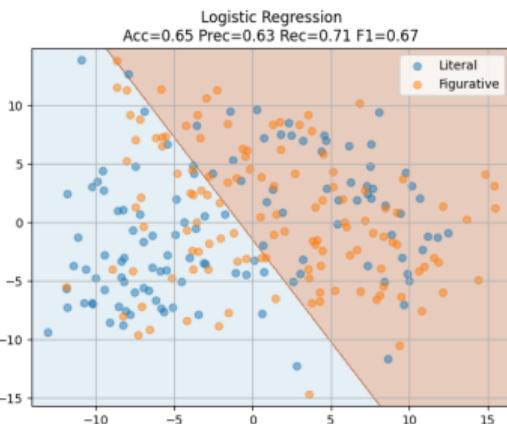
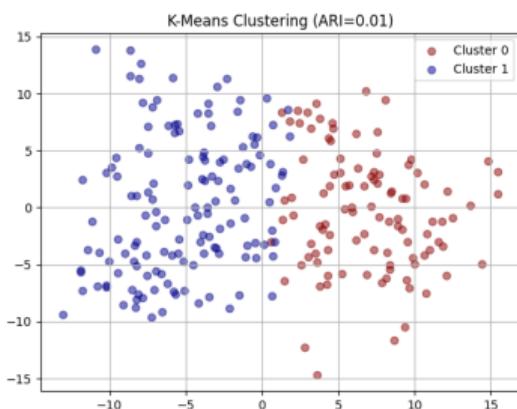




# Token Embedding Analysis

## 3 Results

Token embeddings of “Back”.

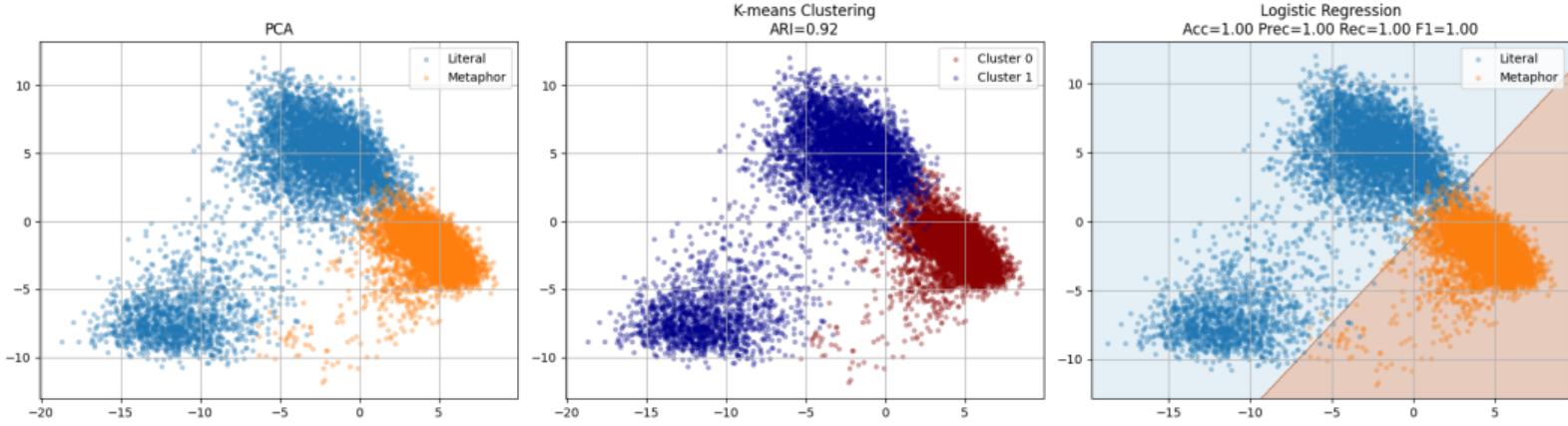




# Multimodal Analysis

## 3 Results

Clustering and classification results on CLIP embeddings.



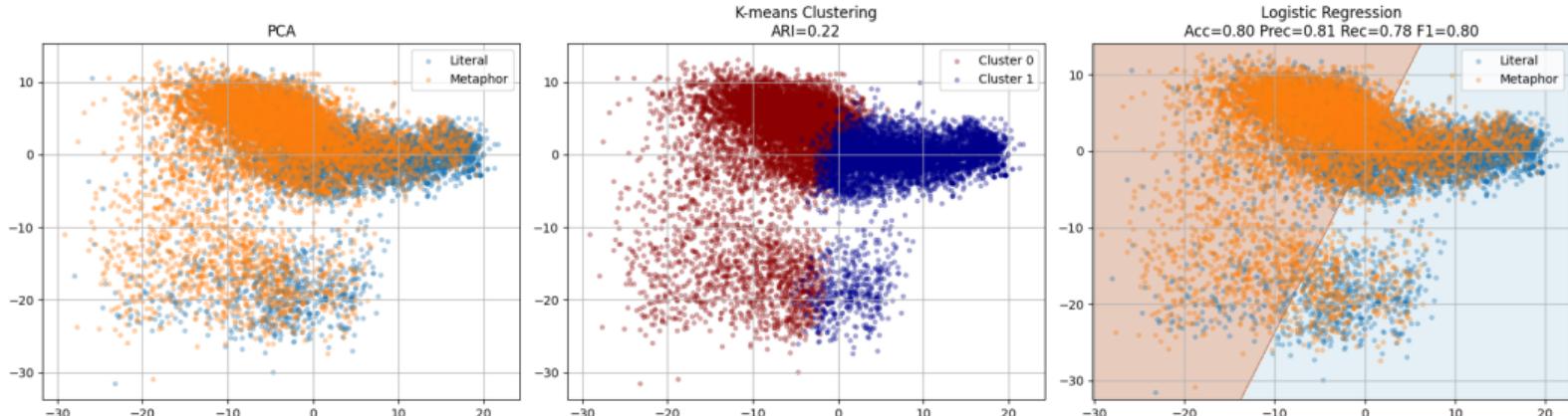
K-Means (ARI)	Accuracy	Precision	Recall	F1
0.92	1	1	1	1



# Multimodal Analysis

## 3 Results

Clustering and classification results on textual part.



K-Means (ARI)	Accuracy	Precision	Recall	F1
0.22	0.80	0.81	0.78	0.80



# Boundary of Meaning *Thank you for listening!*

*Any questions?*