Chapter 5

IDENTIFICATION OF EMOTIONS AND MOOD OF READER'S DURING STORY READING

5.1 INTRODUCTION

Story understanding is a very complex cognitive phenomenon. It involves word identification, syntactic relation estimation, finding semantic correlations between different story plots, and establishing relationships between other story characters. Words and sentence processing in story understanding have been a central aspect of study for a long time in different research fields like computer science, psychology, linguistics, and cognitive science. It has been found that the word and sentence processing in the brain during story reading is quietly different from the reading sentence and words in isolation. A complex network of activated voxels of the brain is obtained when an fMRI recording of the brain is done during story reading. It shows multiple regions of the brain communicating in the processing of running text and not confined to any specific area, as in the case of isolated words. It activates most of the brain regions simultaneously and becomes very difficult to identify the particular brain area involved in syntactic and semantic processing. Current research findings demonstrated different sets of information as to multiple brain regions, including Broca's and Wernicke's areas, involved in language processing. Other brain modules have been involved in language processing due to differences in experimental setup and hypotheses being tested, leading to disagreements in results. These results show that the brain areas involved in language processing are language-specific. In addition, processing areas for syntax and semantics are not the same for all experiments. [261] found that no region is specific for processing of syntax and semantics, whereas [262] found that syntax and semantics are processed differently in the brain. In processing text, the readers perform several basic operations, including decoding letters, assigning meaning to the words, parsing the syntactic structure, reading different words and sentences, constructing themes for the text, and finally, the reader's constructing a coherent mental picture of the text. In this process, readers use their linguistic knowledge, word knowledge, cultural knowledge, and the theme. Text comprehension is a mixture of top-down and bottom-up aspects of text and includes the interaction of the reader's background with the text's story. The mental representation built in this process is not static but changes during reading.

5.2 METHODS AND MODELS

5.2.1 DATASET DESCRIPTION

fMRI data [263] were collected from 9 healthy native English speakers (5 female and four male) aged 18 to 40 years. They were instructed to read chapter 9 of "Harry Potter and the Sorcerer's stone." Data from one participant was discarded as the artefacts could not be removed. Before taking part in the experiment, all the participants either read Harry Potter or watched the movie series to become familiar with the context and content of the story and its characters. Words were presented one by one on the screen for the 0.5-sec duration, and an fMRI image was taken every 2 sec. So, for four consecutive words, one fMRI image was captured. Images were captured using a Siemens Verio 3.0 T scanner using a T2* sensitive echo planar imaging pulse sequence with TR=2 s, echo time=29ms, flip angle=790, 36 slices, and 3*3*3 mm voxels.

5.2.2 EXTRACTING TOKEN LEVEL fMRI VECTORS

The fMRI images were recorded at every 2s interval while subjects were reading a chapter from Harry Potter. Words are shown one by one on the screen, each for 0.5 seconds, so from this setup, it is clear that a single fMRI image was recorded for four consecutive tokens. To analyse the fMRI signals at the word level, extracting an fMRI image for each word from a single fMRI image for four successive terms becomes essential. Also, the hemodynamic response latency is the fundamental problem in dealing with fMRI data, and due to this, the actual cognitive state is not represented by the fMRI data. This creates a dual challenge in token label signals generation, first extracting fMRI signals for each term and second calculating the time delay to compensate for hemodynamic latency. We have adopted the same procedure as described by Bingle et al. [264] First, fMRI recording is computed fourfold such that for each token, there must be one fMRI recording. The effect of stimulus shown on the screen takes a four to six-second delay in peak generation and lasts for 8 to 11 seconds; in some cases, up to 15 s. Bingel et al. [264] have taken the weighted average of all the (so calculated four-fold) fMRI recordings that lie within a time window by opting the Gaussian window [265] for their computation which considers the equal effect of fMRI from each window side having a peak at the middle. But the impact of the stimulus is not symmetrical in fMRI. It takes four

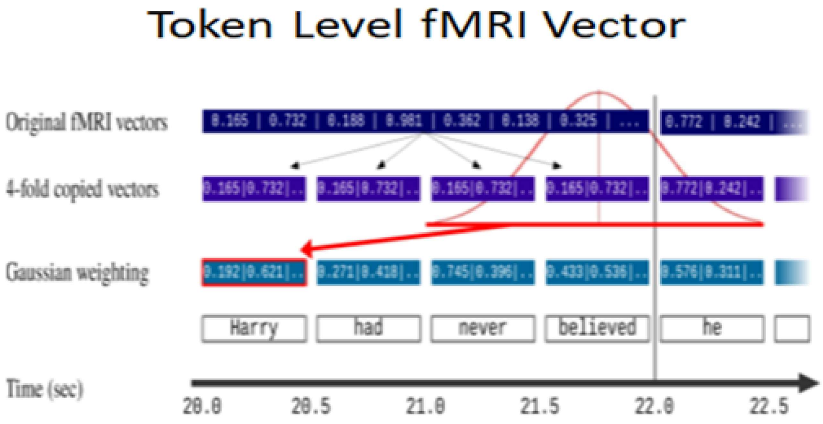

FIGURE 5.1: Token Level fMRI vector [289]

to six seconds to rise to an extreme and lasts for 8 to 11 seconds. We consider the Gumbel method for our token level fMRI signal extraction with a standard deviation of 1. The Gumbel curve is right-skewed, and for window size 2 to 12 sec, it takes 5-6 sec for peak activation. This way it considers almost all effects of stimulus shown on the screen to formulate fMRI signals for individual tokens. We used the Gumbel

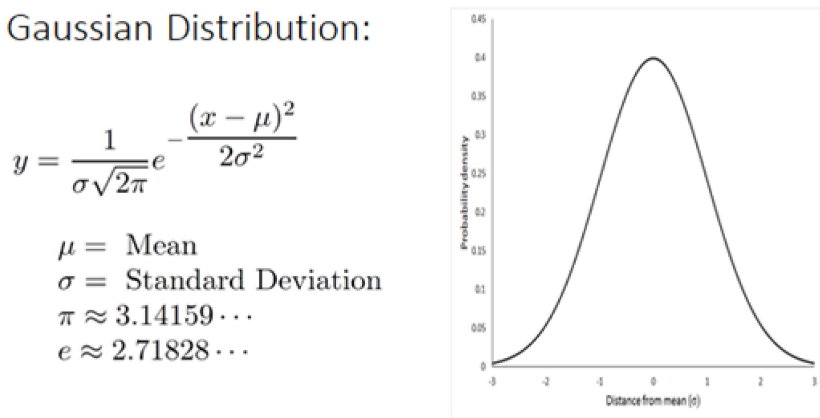

FIGURE 5.2: Gaussian Distribution

method [266]. To calculate the token level fMRI recording from the obtained token level fMRI vector, we classified the verbs and nouns using random forest and found accuracy of 36% in case of Gumbel whereas by Gaussian we obtained 34% accuracy in classification. This clearly proves the efficiency of Gumbel method over Gaussian in extracting token level fMRI vectors. We have used SPACY Tagging Tool [267]

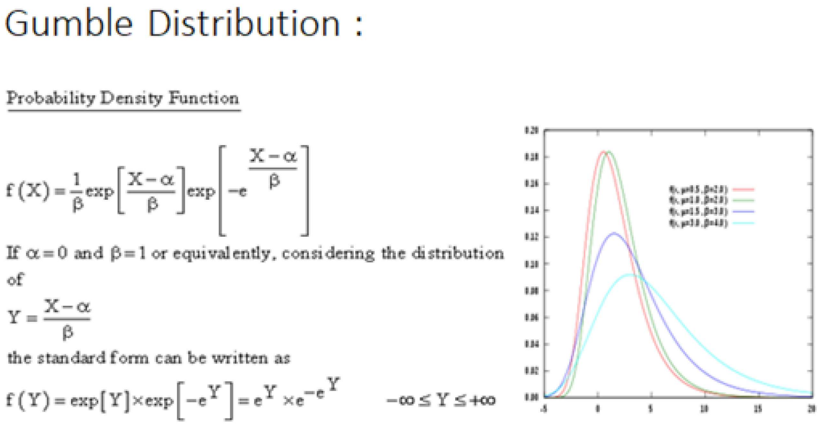

FIGURE 5.3: Gumbel Distribution

in Python to tag individual terms of the story. From the tagged corpora of the story, we separated the terms on the basis of their tags into different classes. We compared the activation pattern in fMRI data of individual POS tags to others and found that it is very hard to find the brain regions that are dedicated to processing of individual word types but all the word categories activate the entire brain in story reading paradigm. This contrasts the finding that different types of words activate different brain regions, that is processing of words in the brain depends on its semantics.

5.2.3 IDENTIFICATION OF EMOTIONS IN THE STORY

Emotions are inner statuses that are induced by assessment between the internal physical desires and the existing exterior resources, and are categorised by persuaded functional fluctuations, behavioural and cognitive variations. [268] In 1970 psychologist Paul Eckman acknowledged six fundamental emotions that he recommended were frequently experienced in all human philosophies. The emotions he recognized were happiness, sadness, disgust, fear, surprise, and anger. Later on, other scientists have included more emotions like pride, shame, embarrassment, and excitement in the list. In 2017, research was published in Proceedings of National Academy of Sciences; scientists recognized 27 different emotion classes. [269]

TABLE 5.1: **Emotion Classification**

Theorist	**Basic emotions**
Arnold	Anger, aversion, courage, dejection, desire, despair, fear, hate, hope, love, sadness
Plutchik	Fear, anger, joy, sadness, anticipation, disgust, surprise, acceptance
Ekman, Friesen, and Ellsworth	Fear, anger, joy, sadness, disgust, surprise,
Frijda	wonder, sorrow, interest, desire, surprise, happiness
McDougall	Fear, anger, disgust, wonder, elation, subjection, tender-emotion
Izard ,	Fear, anger, joy, contempt, disgust, distress shame, guilt, interest, surprise
Tomkins	Fear, anger, joy, interest, contempt, disgust, distress, shame, surprise
Oatley and Johnson-Laird Grey	Anger, happiness, sadness, anxiety, disgust

According to basic emotion theory, each type of emotion has its distinct neural circuitry. Some of the neuroimaging studies have found the localization of emotions like the amygdala for fear [270], disgust-insula [271], anterior cingulate cortex for sadness [272], and anger-orbitofrontal cortex [273], etc. But one to one correspondence between the location and the emotions is not found in some studies [274]. Recent neuroimaging research has revealed that some specific parts of the brain process emotions while other regions are involved in the perception, regularisation, or validation of feelings. [275],[276]. We have considered the six basic types of emotions as suggested by Paul Eckman for our analysis. All the four consecutive words shown on screen before recording fMRI were assigned a particular emotion category if there was any emotion in that. The groups of words containing no emotions were discarded. We have hired two professional linguists for this purpose, and all the groups of words that have been assigned the same emotion category by both the linguists were considered for the analysis. We have used Cohen's kappa coefficient for inter annotation agreement which emits a score of 0.87. Cohen's kappa statistic is the agreement between two raters where Po is the relative observed agreement among raters (identical to the accuracy), and Pe is the hypothetical probability of chance agreement.

$$kappa\,(k) = \frac{P_0 - P_e}{1 - P_e}$$

Out of the linguists, A and B, we have considered linguists A's annotation as the final decision whenever confusion was there between linguists since the qualification and academic record of A was much better than B. Chapter nine of Harry Potter and sorcerer's stone contains appx. 5200 words, out of these words, about 1300 tokens of four consecutive words were generated that were shown on screen before one fMRI image was captured. We have assigned emotion tag to these tokens based on context. The following table lists the token words and corresponding emotion categories.

The fMRI data for the emotion words group is extracted and it's activation is analysed. The difference between average and peak activation is considered as actual activation in the different brain regions. The top 15 highly activated areas of the brain so found in the case of all the six different types of emotions are following-

Analysing these areas, we observe that out of these areas the 10 highly activated regions of the brain found in emotion processing are almost same and are following- Temporal_Mid_R, Cerebelum_Crus1_L, Temporal_Pole_Mid_L, Temporal_Inf_R, Temporal_Pole_Sup_L, Postcentral_L, Postcentral_R, Rolandic_Oper_L, Fusiform_R, Temporal_Mid_L.

Table 5.2: **Emotion Classification**

Token index in chapter	**Tokens**	**Emotion**
8	>boy he hated more	Disgust
36	>put up with Malfoy	Disgust
60	>they all groan. Flying	Sadness
80	>"Typical," said Harry darkly.	Anger
92	>fool of myself on	Fear
104	>had been looking forward	Happiness
136	>about how good he	Disgust
156	>a lot. He complained	Sadness
344	>as nervous about flying	Fear
400	>word, desperate for anything	Fear
416	>else was very pleased	Happiness
464	>he opened gloatingly at	Happiness
484	>opened it excitedly and	Happiness
540	>red oh ..."	Surprise
544	>His face fell, because	Sadness
588	>jumped to their feet.	Anger
632	>Scowling, Malfoy quickly dropped	Anger
800	>for?" she barked. "Everyone	Anger
860	>hand at once, but	Surprise
896	>afraid, thought Harry; there	Fear
900	>was a quaver in	Fear
948	>and Ron were delighted	Happiness
1008	>Neville, nervous and jumpy	Fear
1012	>and frightened of being	Fear
1032	>"Come back, boy!" she	anger and fear
1060	>scared white face look	Fear
1072	>gasp, slip sideways off	Fear
1128	>face as white as	Fear
1196	>his face tear-streaked, clutching	Sadness
1224	>into laughter. + "Did	Happiness
1244	>Malfoy," snapped Parvati Patil.	Anger
1264	>like fat little crybabies,	Disgust
1268	>Parvati." + "Look!" said	Surprise
1340	>Harry yelled, but Malfoy	Anger
1404	>Blood was pounding in	Anger
1444	>joy he realised he'd	Surprise
1456	>– this was easy,	Surprise
1460	>this was @wonderful. He	Happiness
1476	>heard screams and gasps	fear, surprise

Token index in chapter	**Tokens**	**Emotion**
1488	>admiring whoop from Ron.	Happiness
1504	>Malfoy looked stunned. ”Give	Surprise
1528	>looking worried. + Harry	Fear
1580	>were clapping. + ”No	Happiness
1680	>with the screams of	Fear
1732	>then he’d just dived.	Fear
1744	>to his feet, trembling.	Fear
1756	>Hogwarts –” Professor McGonagall	Surprise
1768	>flashed furiously, ”—how	Anger
1812	>Crabbe, and Goyle’s triumphant	Happiness
1820	>walking numbly in Professor	Sadness
1856	>wrong with his voice.	Fear
1884	>lasted two weeks. He’d	Sadness
1896	>would the Dursleys say	Fear
1936	>Harry trotting miserably behind	sadness, fear
1968	>twisted as he imagined	Sadness
2020	>Harry, bewildered; was Wood	surprise, fear
2100	>”Out, Peeves!” she barked.	Anger
2116	>swooped out cursing. Professor	Anger
2120	>McGonagall slammed the door	Anger
2148	>expression changed from puzzlement	Happiness
2252	>had come true at	Happiness
2264	>Potter?” he asked excitedly.	Happiness
2344	>than last year. Flattened	Sadness
2396	>suddenly smiled. + ”Your	Happiness
2416	>”You’re @joking.” + It	Surprise
2492	>after the excitement of	Happiness
2504	>so amazed, so impressed,	Surprise
2512	>gaped at Harry. +	Surprise
2548	>over. + ”Well done,”	Happiness
2596	>going to be brilliant.	Happiness
2608	>skipping when he told	Happiness
2660	>when someone far less	Disgust
2744	>scowl. + ”I’d take	Anger
2968	>this place?” said Ron.	Disgust
3028	>of you.” + ”And	Disgust
3036	>your business,” said Harry.	Anger
3136	>another school rule today.	Fear
3144	>Malfoy’s sneering face kept	Disgust
3236	>them, ”I can’t believe	Surprise

Token index in chapter	Tokens	Emotion
3240	>you’re going to do	Disgust
3264	>said Ron furiously. ”Go	Anger
3276	>brother,” Hermione snapped, ”Percy	Anger
3296	>be so interfering. +	Disgust
3340	>an angry goose. ”Don’t	Anger
3364	>you’ll lose all the	Sadness
3380	>”Go away.” + ”All	Anger
3460	>she asked shrilly. +	Fear
3552	>Ron loudly. + ”Shut	Anger
3600	>jerked suddenly awake as	Surprise
3608	>”Thank goodness you found	Happiness
3708	>been past twice already.”	Fear
3720	>glared furiously at Hermione	Anger
3912	>then jump. Harry had	Surprise
3948	>to Mrs. Norris. Horror- struck,	Fear
4012	>petrified, they began to	Fear
4036	>out a frightened squeak	Fear
4316	>a squeal of delight.	Happiness
4328	>get us thrown out.”	Fear
4332	>+ Peeves cackled. +	Happiness
4388	>the way,” snapped Ron,	Anger
4424	>for their lives, right	Fear
4448	>it!” Ron moaned, as	Sadness
4484	>Hermione snarled. She grabbed	Anger
4536	>”Don’t mess with me,	Anger
4568	>haaa! Told you I	Happiness
4580	>Ha ha! Haaaaaa!” And	Happiness
4596	>rage. + ”He thinks	Anger
4648	>walked into a nightmare	surprise, fear
4780	>surprise, but it was	Surprise
4792	>what those thunderous growls	Anger
4868	>that monster. They didn’t	Fear
4932	>and collapsed, trembling, into	Fear
4956	>again. + ”What do	Fear
4992	>and her bad temper	Anger
5008	>you?” she snapped. ”Didn’t	Anger
5056	>glaring at them. +	Anger

Table 5.3: **Emotion Areas in Brain**

Emotion	**Brain Areas**
Happiness:	Temporal_Mid_R, Cerebelum_Crus1_L, Temporal_Pole_Mid_L, Temporal_Inf_R, Temporal_Pole_Sup_L, Postcentral_L, Postcentral_R, Occipital_Mid_R, Rolandic_Oper_L, Fusiform_R, Temporal_Mid_L, Tempora_Sup_R, Parietal_Sup_L, Frontal_Inf_Orb_R, 'Temporal_Pole_Sup_R.
Sadness:	Temporal_Mid_R, Cerebelum_Crus1_L, Temporal_Pole_Mid_L, Temporal_Inf_R, Temporal_Pole_Sup_L, Postcentral_L, Postcentral_R, Rolandic_Oper_L, Temporal_Mid_L, Occipital_Mid_R, Temporal_Pole_Sup_R, Fusiform_R, Parietal_Sup_L, Temporal_Sup_R, Frontal_Inf_Orb_R.
Fear:	Temporal_Mid_R, Cerebelum_Crus1_L, Temporal_Pole_Mid_L, Temporal_Inf_R, Temporal_Pole_Sup_L, Postcentral_L, Postcentral_R, Fusiform_R, Occipital_Mid_R, Rolandic_Oper_L, Temporal_Mid_L, Precuneus_R, Temporal_Sup_R, Frontal_Inf_Orb_R, Temporal_Pole_Sup_R.
Disgust:	Cerebelum_Crus1_L, Temporal_Mid_R, Temporal_Pole_Mid_L, Temporal_Inf_R, Temporal_Pole_Sup_L, Postcentral_L, Postcentral_R, Temporal_Pole_Sup_R, Rolandic_Oper_L, Occipital_Inf_L, Rectus_R, Temporal_Mid_L, Precuneus_R, Frontal_Inf_Orb_R, Fusiform_R.
Surprise:	Temporal_Mid_R, Cerebelum_Crus1_L, Temporal_Pole_Mid_L, Temporal_Inf_R, Temporal_Pole_Sup_L, Postcentral_L, Postcentral_R, Occipital_Mid_R, Fusiform_R, Rolandic_Oper_L, Temporal_Mid_L, Temporal_Sup_R, Parietal_Sup_L, Frontal_Inf_Orb_R, Precentral_R.
Anger:	Temporal_Mid_R, Cerebelum_Crus1_L, Temporal_Pole_Mid_L, Temporal_Inf_R, Temporal_Pole_Sup_L, Postcentral_L, Postcentral_R, Rolandic_Oper_L, Fusiform_R, Occipital_Mid_R, Temporal_Mid_L, Precuneus_R, Parietal_Sup_L, Temporal_Sup_R, Temporal_Pole_Sup_R.

In addition to this, in case of surprise, Precentral_R is more active; Occipital_Inf_L, Rectus_R are very active in disgust, whereas Precuneus_R is more active in case of anger, disgust, and fear. This result is per the previous finding in the literature that most of the emotional words activate the amygdala. This is also justified when the fMRI data is classified with random forest gives us only 39% of classification accuracy, showing that brain regions are not differently activated in emotional word processing. Still, emotional words activate similar regions of the brain.

5.3 RESULT ANALYSIS AND DISCUSSION

5.3.0.1 MOOD IDENTIFICATION

The reader of the story swung with the emotion contained in the story plot. It becomes sad with a sad story and happy with some pleasant feeling. Our motive is to find out the reader's mood by looking at its fMRI data. For this, we classified the basic emotion categories into two classes-Happiness, Surprise, as a positive mood and, Anger, Disgust, Fear, Sadness as a negative mood.

We employed variance threshold and PCA in a cascaded manner on the data set to extract prominent features. Finally, we implemented a Random Forest classifier to classify the fMRI data for mood identification. Our result shows that with this approach, we could identify the mood of the readers with more than 73% accuracy.

In table 5.4 the confusion matrix summarizes the performance of the Random Forest classifier. The subject wise results for different performance measure is displayed in Table 5.5. Figure 5.4 shows the avarage of the result obtained for each subject using Random forest. Whereas fig 5.5 show the avarage result of MLP.

Table 5.4: Confusion Matrix

Subject id	Predicted Class Negative Mood	Positive Mood	Actual Class
1	70	10	Negative
	21	16	Positive
2	74	6	Negative
	21	16	Positive
3	72	8	Negative
	24	13	Positive
4	73	7	Negative
	27	10	Positive
5	72	8	Negative
	25	12	Positive
6	69	11	Negative
	23	14	Positive
7	77	3	Negative
	32	5	Positive
8	80	0	Negative
	34	3	Positive

Table 5.5: Result Analysis

Subject	TP Rate	FP Rate	Precision	Recall	F-Measure	MCC	ROC Area	PRC Area	Accuracy
1	0.735	0.428	0.721	0.735	0.72	0.344	0.590	0.628	73.50
2	0.769	0.412	0.763	0.769	0.750	0.425	0.568	0.637	76.90
3	0.726	0.475	0.709	0.726	0.701	0.305	0.612	0.669	72.60
4	0.709	0.527	0.685	0.709	0.672	0.241	0.601	0.653	70.90
5	0.718	0.494	0.697	0.718	0.689	0.277	0.616	0.656	71.80
6	0.709	0.469	0.690	0.709	0.691	0.273	0.591	0.641	70.90
7	0.701	0.603	0.681	0.701	0.627	0.180	0.583	0.634	70.08
8	0.709	0.796	0.628	0.709	0.611	0.239	0.592	0.659	70.94

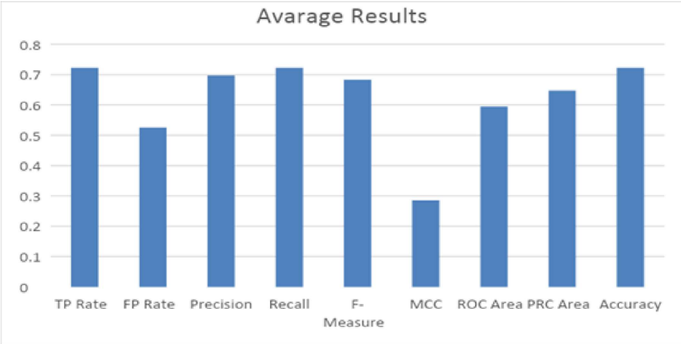

FIGURE 5.4: Result Random Forest

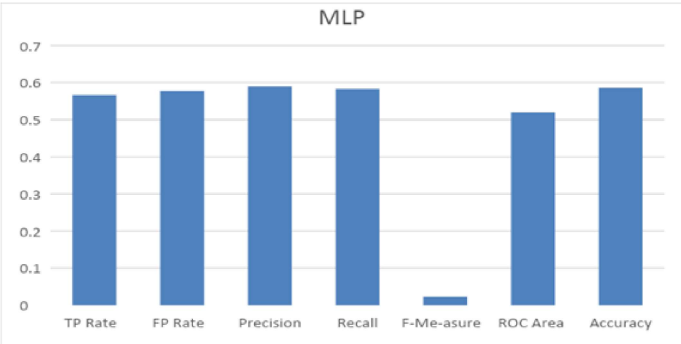

FIGURE 5.5: Result Random MLP

5.4 CONCLUSIONS

The activation in the brain during story reading is quietly different from the processing of individual words and sentences. The mood of the reader swung during the reading according to the context of the reading. The present work analysed the emotion processing during the reading and identified the reader's mood during reading by examining the brain's fMRI signals. Before that, token level signals are extracted from the composite signals of four consecutive words to analyse word-level fMRI activation