COMPUTATIONAL MODEL OF FALSE RECALL

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False recall has been one of the most studied field for understanding how our memory works. It refers to having false memory of an event that didn't happen in the past. Participants when presented a list of words comprising of strong semantic associates of the critical word, are found to recall the critical word with a high probability, while the recall of extralist or common words is infrequently observed. The model which we use is an associative model of memory which takes into account the associations formed during both the retrieval and the encoding process. This model also takes into account several core finding from the Deese-Roediger-McDermott experiment and the DRM paradigm. We have used semantic associations, episodic associations, association with the context and build two models. The first model is the add-add model which takes the addition of the strengths of the elements in the Short Term memory(STM) during both retrieval and encoding, the second model multiply-multiply uses multiplication.

Keywords: False recall, semantic distances, DRM paradigm, associative memory, episodic strength, probabilistic model, SAM(Search for Associative Memory), fSAM, WAS(Word Association Spaces), Short Term Memory(STM), Long Term Memory(LTM).

1 Introduction

False recall has been observed in the participants with the help of an experiment back in 1959 that formed the basis of the model. The experiment consisted of reciting words to the participants. The experiments contained 36 word-list of size 12 each of the list contained words that were closely related to the critical lure. The critical word is not presented in the list. For eg for the critical word `"needle"` the word list had the words [`"thread", "pin", "eye", "sewing", "sharp", "point", "pricked", "thimble", "haystack", "pain", "hurt", "injection"`]. It was observed that some list had the capability of inducing false recall while some haden't. The lists which had words which had a backward associative strength with the critical word were more successful in creating false recall.

2 Previous work in this field

There have been a lot of theories that have been formed to explain the effect observed in false recall. Firstly Deese came up with the DRM paradigm

2.1 DRM paradigm

This focused on gist and Back-word associative strength(BAS) as a measure of degree of false recall. When subjects were asked about the experience after the experiment, more than half of the participants reported that they were certain of hearing the not presented critical word, which indicates that these people had false memory. Backward Association is necessary to activate the critical word. For example the word `"short"` may elicit the word `"man"` but the word `"man"` won't elicit the word `"short"`. The results that Deese got said that critical word was recalled with a probability of 0.44 and that this probability varied for different lists.

2.2 Roediger and McDermott extensions to the Deese results - 1990's

They conducted to two experiments. In the first experiment they tried to duplicate Deese's work by selecting best lists of Deese, they also tested the participants on the recognition of the words. In the second experiment they tested the effect of word length on degree of free recall, effect of recall on subsequent recognition, false recall rates of critical word when the relevant list wasn't presented. The results on word length showed that with larger word list recall probability increased, demonstration an constructive superposition of the effects caused by each word. When relevant list were not presented the critical word wasn't recalled to good extent(value 0.14). The effect of recall on subsequent recognition test demonstrated that the associations are triggered both during the encoding and the retrieval step.

3 Computational Model

fSAM stands for framework for Search of Associative Memory. Our model tries to incorporate most of the features of the fSAM model.

3.1 Memory Stores

The model assumes the existence of two memory stores, STM and LTM. The STM denotes the limited capacity buffer known as the short term memory. In the short term memory the studied words get associated through the rehearsal process which will be discussed later. The LTM contains the association of the words with the context of the list and the episodic associations are stored in the episodic matrix.

3.2 Storage Process

In the SAM model as a list item is presented, it enter the short term memory buffer and is rehersed along with the other items in the STM. Rehearsal increases the strength of all the items in the buffer with the list context and also increases the episodic strength for each pair of items in the buffer at any time. For each unit of time for all the items occupying the buffer

- The association with the list context is increased by the value a, which is a parameter of the model.

- The episodic strength of all item i,j in the buffer at that time is increased by a value b1 for (i,j) and b2 for (j,i) depending on whether i or j entered the buffer first.

For this model we have set the value of b to be equal to 0.5*b1. This is in accordance to Sirotin et al(2005). SAM also uses the word association with itself, but it later models this has been ignored so we don't take this into account in the current model. The size of the buffer in the model has been fixed at 4. The episodic strength for two members who didn't occupied the buffer together at any point is set to μ with a standard deviation of σ.

3.3 Retrieval Process

The list items in the STM are always available for recall. The items at the end of list presentation, are present in the limited capacity buffer and thus are the one to be recalled in the start in immediate recall. However in this model we have only considered delayed recall i.e we assume the STM to have been emptied by the time recall starts.

The retrieval from the LTM relies on cues. The search process first tries to sample the list item and then it is recovered. As the buffer is initially empty the search only takes into account the association with the list context. The probability of a word being sampled is given by.

$$P_s(i|context) = \frac{S(i, context)}{\sum_k^{k \in N} S(k, contest)} \tag{1}$$

where S(i,context) denotes the association of the item i with the list contest, N is the set of items in the LTM.

After sampling the word the word may be recovered with a probability of

$$P_r(i|context) = 1 - e^{-S(i,context)} \tag{2}$$

If this item is successfully recalled it serves as a cue for retrieval of more items from the LTM.

3.3.1 Semantic retrieval mechanism

Here we will show two approaches taken when the retrieval uses items in STM as cues.

- Additive retrieval mechanism: In this model the sum of the episodic and the semantic strength(we will define these terms later) are used to calculate the sampling and recovery probabilities. Thus the probability of sampling an item i following the recovery of items j1, j2, j3, ... is given as

$$P_s(i|context, j \in M) = \frac{S(i, context)^{W_c} * (\sum_j^{j \in M} S_e(i,j))^{W_e} * (\sum_j^{j \in M} S_s(i,j))^{W_s}}{\sum_k^{k \in N} [S(k, context)^{W_c} * (\sum_j^{j \in M} S_e(k,j))^{W_e} * (\sum_j^{j \in M} S_s(k,j))^{W_s}]} \tag{3}$$

- Multiplicative retrieval mechanism: In this model the product of the episodic and the semantic strength(we will define these terms later) are used to calculate the sampling and recovery probabilities. Thus the probability of sampling an item i following the recovery of items j1, j2, j3, ... is given as

$$P_s(i|context, j \in M) = \frac{S(i, context)^{W_c} * (\prod_j^{j\in M} S_e(i,j))^{W_e} * (\prod_j^{j\in M} S_s(i,j))^{W_s}}{\prod_k^{k\in N}[S(k, context)^{W_c} * (\prod_j^{j\in M} S_e(k,j))^{W_e} * (\prod_j^{j\in M} S_s(k,j))^{W_s}]} \quad (4)$$

3.4 Semantic Encoding Mechanism

- **Context association strength**

The association with list context is incremented for each word by a value

- Additive Semantic Encoding

$$S(i, context)_t = S(i, context)_{t-1} + a_s \sum_j^{j\in M} S_s(i,j); \quad (5)$$

- Multiplicative Semantic Encoding

$$S(i, context)_t = S(i, context)_{t-1} + a_s \prod_j^{j\in M} S_s(i,j); \quad (6)$$

In both the above equation l is the counter which represents which word in the list is being presented, S_s(i,j) is the semantic distance between words i and j(The more the semantic distance $\Rightarrow$ the more closely the words are related, We have used Word Association Space for calculating Semantic distances), a_s is a model parameter.

3.5 Word Association Space

We decided to use WAS(word association space) over LSA(Latent semantic analysis) as it provided better estimates of false recall in the previous experiments conducted. WAS was constructed using free association norms.

3.6 Implementation details

The entire model was built in Matlab which took into consideration all the parameters mentioned above. Then we try to get results for the model using some of the word list of Roediger and McDermott. The parameters used in our model for the two case(additive and multiplicative are shown below).

For the additive case

Process	Parameter	Description	Value
Encoding	a	Item context strength for items in buffer	0.64
	a_s	Item context strength using semantic associations for items in buffer	0.06
	b1	Episodic association forward	0.14
Retrieval	W_c, W_e, W_s	Retrieval weigth for item-context, episodic, semantic strength	0.77,0.20,2.59
	K_{max}	Maximum failures allowed during recall	44

For the multiplicative case

Process	Parameter	Description	Value
Encoding	a	Item context strength for items in buffer	0.44
	a_s	Item context strength using semantic associations for items in buffer	0.21
	b1	episodic association forward	0.20
Retrieval	W_c, W_e, W_s	Retrieval weigth for item-context, episodic, semantic strength	0.67,0.29,2.09
	K_{max}	Maximum failures allowed during recall	39

4 Results

We used 4 word list of size 13 each picked from the 15 size word list from the Roediger McDermott lists. These lists were

- king − > queen, england, crown, prince, george, dictator, palace, throne, chess, rule, monarch, royal, leader
- cold − > hot, snow, warm, winter, ice, wet, frigid, heat, weather, freeze, air, shiver, frost
- bread − > butter, food, eat, sandwich, rye, jam, milk, flour, jelly, dough, crust, slice, wine
- girl − > boy, doll, female, young, dress, pretty, hair, niece, dance, beautiful, cute, date, daughter

We obtained better results for the additive case.

The average result of recall for the position 1, 13 is shown below
0.4887, 0.3613, 0.4706, 0.4259, 0.4341, 0.4624, 0.4001, 0.4481, 0.42542, 0.5384, 0.4208, 0.5390, 0.5413

The false recall probability found was **0.4314**. The raw result data can be obtained here.

One of the results is shown in the picture below.

```
>> recall

recall =

  Columns 1 through 9

    0.6603    0.2304    0.6281    0.5694    0.3970    0.4859    0.6601    0.6584    0.5929

  Columns 10 through 14

    0.5468    0.5185    0.6084    0.6124    0.5059

>> wordlist

wordlist =

  Columns 1 through 7

    'QUEEN'    'ENGLAND'    'CROWN'    'PRINCE'    'GEORGE'    'DICTATOR'    'PALACE'

  Columns 8 through 14

    'THRONE'    'CHESS'    'RULE'    'MONARCH'    'ROYAL'    'LEADER'    'KING'

fx >> 
```

5 Conclusion

This model incorporates the context association, the episodic association and the symantic association. The results obtained appear to correctly predict false recall as

- The curve obtained for the false recall has higher values towards the start and end of the list and low values in the middle. The recall value is found in between the higher values in the corners and the lower value in the middle. This is what has been observed in the experiments conducted in the past.
- The false recall for list 2(0.55) > list 1(0.51) > list 3(0.39) > list 4(0.27), this can also be seen as there is less semantic association in the words of list 4 as compared to other list.
- The value obtained for false recall is 0.4314 which is close to values found in experiment(0.44 by Deese and 0.55 by Roediger and McDermott)

6 References

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