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Storage Structure and Searching Process of Semantic Network

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ABSTRACT
The present study explored the spreading activation model of semantic networks in Chinese context to know how people research information from long-term memory and what influences the time of research mostly. Based on the three-level semantic networks of Collins and Qullian' s theory and the conclusion, "frequency will affect the reaction time", of Conrad's study, the present study put forward the hypothesis that the category and the frequency of semantic would interactively influence the retrieval time. The participants were 30 undergraduates aged from 19 to 21. The present study found that the level impacted the reaction time very little. On the contrary, the frequency impacted it most. In addition, the interaction between the category and the frequency of semantic was not significant. The present study supported the theories that frequency had great impact on the reaction time and further verified that the elements that would influence the retrieval time were complicated.

Keywords*: storage structure, semantic networks, activation-spreading model, information retrieval, Chinese context, frequency of the property*

1. INTRODUCTION

Long-term memory refers to the storage of information in mind. People utilize long-term memory to retrieve the concept and the property in semantic networks. The retrieval time can indicate how people store information into long-term memory, and how they trace the nodes and properties when they search the information in mind. By assuming the organization is a hierarchical network consisted of different levels, the present study conducts an experiment to test the retrieval time and find out that the properties are stored on the corresponding nodes in an economical way. Not only the distance between the levels can affect the retrieval time, the frequency of properties can also change the configuration of networks. Thus, the semantic network is more probable to be a three-dimension network.

There are many studies on the retrieval of semantic memory. The basic argument is how the knowledges are stored in the networks. Quillian [1] proposed a spreading-activation theory of semantic processing, which explained how information were retrieved in semantic memory. It also showed the model of semantic structure, where concepts could be stored in nodes and connected with each other. Collins and Quillian [2] proposed a model of economical storage organization like computer simulation. It assumed that the concepts and properties were ordered hierarchically in memory, and considered it as an economical way in terms of storage space. Afterwards, Conrad [3] argued about Collins and Quillian results that the increase of retrieval time by levels could attribute to a failure of control for the frequency with which properties were stored in memory. She rejected the theory of cognitive economy of storage model and concluded that the properties were stored in every exemplar word. With regard to the structure of memory storage, Landauer [4] gave a different idea of memory without organization. He refused the hierarchical model of economical storage organization, and interpreted that the retrieval process was indirect and random.

Some studies have provided support for the spreading activation theory. Collins and Quillian [2], Collins and Loftus [5], Freedman [6], and Meyer [7][8] all have found the effect of category size on reaction time. For example, Quillian found that in the three-layer semantic

structure, the higher the semantic category was, the slower the participants' response to their attributes became, such as "canary-bird-animal" [9]. However, existing research shows that although logically speaking, a three-layer semantic structure like dog-mammal-animal is established, in actual investigations, people may think of animals more quickly than mammals when they think about dog [10]. The reason for this may be that mammals do not appear frequently in daily life, but even 'canaries are canaries-canaries can fly-canaries can move' in a hierarchical structure with no obvious difference in the frequency of use, there are also many subjects who respond that the canary can move at a faster rate. This is inconsistent with the original theory, and the reasons for the inconsistency are more complicated.

The nodes are stored at different levels in the hierarchy, but the frequency of property can rebuild the link between the nodes and the properties in spatial neural network. There is a reasonable evidence to conclude that the frequency of properties can affect the retrieval time, and it has an interactive effect with the level of hierarchy in semantic networks. People will retrieve a familiar and frequently used semantic collocation faster than the retrieval of a general, infrequently used semantics, no matter which level the attribute is in the structure. The previous study using a true-false reaction time technique for the sentences and it is found that some frequently used vocabulary will make the subjects respond more quickly even at a higher level [3]. It seems that the frequency of properties is an obvious factor that affects the reaction time. It is added to the original experiment to explore how the hierarchy affects the reaction time under this influence, and which one of them affects the reaction time greater.

In present study, we examine the combined effect of frequency and level on the response time by setting the semantic network in the experiment to Chinese, not only for the convenience of Chinese subjects to conduct the experiment, but also hope to make a preliminary exploration for the comparative study of Chinese and English semantic retrieval. According to the background of the theory, we suggest a hypothesis: the higher the frequency of the property, the smaller the increases between levels. High-frequency properties are more likely to be stored at several levels in the hierarchy. Both the frequency and level will influence the reaction time, and there is an interaction effect between the two variables.

2. METHODS

2.1. Participants

Thirty undergraduate students aged from 19 to 21 (M=20.3, SD=0.702). Female 20 and male 10.

2.2. Design

The purpose of the experiment is to examine the influence of levels and frequency of properties in semantic networks, which are the independent variables. The dependent variable is reaction time, tested by using a true-false reaction time technique for sentences. For guaranteeing the accuracy of the experiment, irrelevant variables need to be eliminated. The number of words should be the same in every group.

The model is based on Collins and Quillian's [2] theory and selected a 3-level hierarchy from the common culture (sparrow → bird → animal). The frequency of properties was determined under the Chinese context. The experiment selected nine sentences of the sparrow's property, each level has three sentences for different frequencies, low-frequency, moderate-frequency, and high frequency. The subject of sentences is all sparrow, level 1 is the property of sparrow, level 2 is the property of bird, level 3 is the property of animal. Every sentence contains five Chinese characters. To determine the frequency of sentences, we set a questionnaire before the experiment for 10 subjects (undergraduate students aged from 19 to 21, Mean=20.11, SD=0.60) to mark the 12 sentences' usage frequency from 1-10, 1 is the lowest and 10 is the highest. We calculated out the mean and standard error score of every sentence and sort them in order. According to the mean score of sentences, we selected 9 sentences 3 for each level and 3 for each frequency. The mean score of different frequencies range from 3-5 (low-frequency), 5-7 (moderate-frequency), 6-9 (high-frequency). According to the analysis of variance, there was significant differences between different frequency groups. Table 1 shows the sentences in different levels and frequencies, and the mean scores of the sentences.

Table 1 True-false sentences in different level and frequency

	Level 1	Level 2	Level 3
High-frequency	Sparrow is small	Sparrow can fly	Sparrow is alive
Moderate-frequency	Sparrow eats cereal	Sparrow has feather	Sparrow can breathe
Low-frequency	Sparrow has mottled color	Sparrow has light bones	Sparrow can give birth

2.3. Experiment procedures

The experiment is done by Psychopy on computer. Firstly, we created an introduction trail in Psychopy. In the introduction trail, we obtained consent from all participating individuals before the experiment gets started. We promised this experiment has been conducted following a statement of ethical principles. Then we

made an instruction about the experiment. If the subjects think the sentence is right, they will press 'T' button, otherwise they press 'F' button. Because the subjects are not familiar with this experiment, the reaction time of the first sentence may be inaccurate. Thus, we made a fixed first sentence trail with invalid stimuli. The most important part is the stimuli. We made the stimuli trail by adding sentences in text, collecting the response on a keyboard of 'T' and 'F'. The stimuli consisted of 15 sentences, 9 of the sentences are valid stimuli from the control group or experimental group, which are all right sentences, and the rest 6 sentences are invalid stimuli, which are wrong sentences.

2.4. Statistical analysis

After the experiment was done, the experiment was uploaded online and sent to the subjects. The results data was downloaded in 'csv' format. The valid stimuli and the response time were collected into a new Excel file. The first step is to arrange the data into groups for calculating out the mean and standard error of each sentence. With the mean response time of different sentences, the line graph can be drawn out. Mean reaction time on the vertical Y-axis and level in the hierarchies on the horizontal X-axis. The four lines on the graph represent different frequencies. With the mean reaction time of different levels and different frequencies, we make a two-way ANOVA to show if there any differences between the groups and whether there is an interacting effect.

3. RESULTS

Data were collected from 30 participants, and response time was integrated into every valid sentence. The first step is data processing. We categorized the response time in different levels and frequencies. For every sentence, there were 30 lines of data, and for every level or frequency, there were 90 lines of data. We used z-scores to eliminate the outlier data, and there were six out of the high outlier. In the next step, we calculated out the mean and standard error of reaction time. Table 2 shows the outcomes.

Table 2 Mean and standard error of mean reaction time of sentences

level	frequency					
	High		Moderate		Low	
	M	SD	M	SD	M	SD
1	0.90	0.281	1.03	0.314	1.231	0.333
2	0.87	0.262	0.88	0.286	1.21	0.372
3	0.94	0.346	1.06	0.386	1.16	0.398

Mean reaction time of sentences showed increasing tendency in every level in the hierarchy as frequency decreased. As expected, the frequency of property was a crucial influence on reaction time in the true-false judgment technique. Especially the mean reaction time of low frequency, it has an obvious increase comparing to the high- and moderate- frequency. It may account for that the pretest score of the low-frequency group was apparently lower. However, the mean reaction time didn't show an increasing tendency as levels up. Figure 1 shows the mean reaction time plot. The high- and moderate-frequency group decreased from level 1 to level 2, and increased from level 2 to level 3. And the low-frequency group decreased from level 1 to level 3.

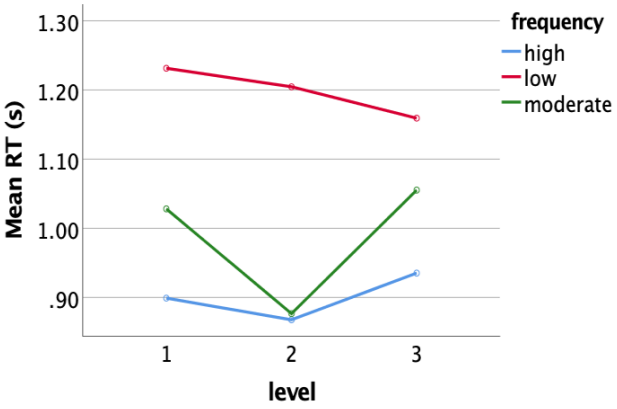

Figure 1 Mean reaction time plot

The two-way ANOVA was used to analyze the main effect and interactive effect by using SPSS. Table 3 shows the results of the analysis of variance for the two-factor. There was a significant main effect of frequency variable, $F(2,16) = 27.470$, $p < .05$. However, there was no significant effect of level variable nor the interaction of level and frequency.

Table 3 Tests of Between-Subjects Effects

Dependent Variable: reaction time					
Source	Sum of Squares	df	Mean Square	F	Sig.
frequency	4.146	2	2.073	18.519	.000
level	.275	2	.137	1.228	.295
frequency * level	.414	4	.104	.925	.450
Error	28.658	256	.112		
Total	313.778	265			
Corrected Total	33.452	264			

4. CONCLUSION

4.1. Consequences

To explore whether the properties in semantic networks are stored in a hierarchical structure or not, the experiment used a true-false sentence judging technique

to test the reaction time. The main question was how the frequency of property and level of the hierarchy will affect the retrieval time of searching the properties in semantic memory. The hypothesis was that both the frequency and level will have an influence on reaction time, and interaction between them, especially the levels that will influence the reaction time at low-frequency. Results found that there was no significant influence on the reaction time of which level the property belongs, and there was significant evidence to conclude the frequency of property had an effect on the reaction time [11]. The lower the frequency of the property, the longer the reaction time was. There was no interactive effect between level and frequency to retrieval time.

The levels had no significant effect on the reaction time. This result suggested that the properties are not stored in a hierarchical structure, which Collins and Quillian [2] thought to be economical for the storage space in semantic memory. The result in this experiment was conflicted with Collins's experiment and their theory of cognitive economy of semantic networks. However, it was the same with Conrad's results [3]. Conrad [3] also found the insignificance of levels after controlling the frequency variable. The inconsistency of the correlation between mean reaction time and levels may attribute to the failure to control the frequency of the sentences in Collins's experiment. The sentences chose in the experiment in the Chinese context for different frequencies didn't show the correlation between levels and retrieval time. Whether the property belonged to the higher level (animal) or the subject itself (sparrow), the retrieval time had no difference with levels. It provided evidence that the properties are stored in every node, instead of being stored only in the superset.

The present study founded that the frequency impacted the reaction time significantly. Although the hypothesis assumed level is the primary independent variable, the experiment didn't represent it. Actually, the level didn't affect reaction time at all, for the influence of frequency had a much greater influence than it. The higher frequency of properties, the smaller time of reaction. As the results of the present experiment showed, people don't search properties of things according to the three-level model but optionally remind of some related information. So frequency is the main independent variable that had the most significant impact on reaction time [12].

There was no significant interaction effect between the two variables, which was different from Conrad's results [3]. In Conrad's experiment [3], there was a significant interaction effect between level and frequency, and only the RT of high-frequency didn't increase as the level increased, which may suggest that it's more beneficial to search the properties from low level to high level for moderate- and low-frequency properties, but not for high-frequency properties. The different results of interaction effect in this experiment and Conrad's experiment [3] may attribute to the subject of stimuli. The subjects of sentences used in the experiment were all sparrow, and Conrad [3] used different subjects for every sentence. In this experiment, participants reacted to several sentences with the same subjects. They may tend to be familiar with the properties of a sparrow, and the reaction time will reduce more obviously in low- and moderate- frequency. This may explain why there was no significant interaction effect in the experiment.

4.2. Limitations

There are some limitations in the present study. Firstly, because the range and time of the experiment are restricted, the number of subjects is just 30. If the subject base is larger, the results of the experiment will be more logical and representative. Secondly, the using frequency of properties can't be ascertained easily. Although a survey about semantic frequency has been made before conducting the normal experiment, the frequency is still floating and isn't consistent with prediction completely. So we can't ensure the frequency of property that the study set is scientific enough or not. Thirdly, the sentences of the experiment could be designed more reasonably. The subjects of these sentences may be a key to make the experiment better. The subjects of sentences in Conrad's study [3] are all uniform that is different from subjects in the present study, and the results of Conrad's study [3] also represent the interactive effect that the present study didn't get. But we still can't find a way to decrease the uncertainty of the experiment by designing the properties.

4.3. Contributions

What's more, there are also some contributions in the present study. At the beginning of the experiment design, in order to facilitate the domestic subjects to understand the semantics, the study set the experimental vocabularies to Chinese. Then, the study found that our contribution is also related to this: it is to study the spreading activation model in the Chinese context, which may provide a reference for related research on the comparison of Chinese and English contexts in the future. In addition, there are so many disturbance terms which probably affect subjects' responses. By the present study, we draw a conclusion that the frequency of semantic has the greatest impact on the reaction time. It has supported previous studies that reached the same conclusion and provided a probability which a category of semantic won't affect the reaction time at all. In a word, the present study further explored the factors that will affect people when they search for semantic information stored as memory.

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