

THE REPRESENTATION OF RADICALS THAT CAN BE USED AS CHARACTERS*

Guosheng Ding

(Department of Psychology, Beijing Normal University, Beijing 100875)

Marcus Taft Xiaoping Zhu

(University New South Wales, Sydney)

Abstract Sometimes the radicals of a Chinese compound character happen to coincide with the characters of a two-character word (e.g., 好 and 女子). The latency and error rate to recognise this kind of characters and words were examined in the current research. It was found that recognition times to the compound characters were significantly facilitated by their relationship to the two-character word, whereas the reverse was not true. Such an asymmetric result was used to draw conclusions about the nature of the representation of radicals and characters in the Chinese mental lexicon. In particular, it was concluded that radicals are represented by units that are activated via the combined activity of a position-free "simple character" representation and the appropriate positional information.

Key words Chinese character, radical, representation

1 Introduction

Chinese words are composed of one or more characters, which in turn are composed of one or more radicals, which are themselves composed of one or more strokes. For example, the compound character “引 (guide)” is composed of the radical “弓” plus the stroke “丨”, while the radical “弓” is composed of the strokes “一”、“丨”、“丿”. The issue of how these units might be organized and represented in lexical memory has been addressed in a number of ways using a range of experimental paradigms^[1-5]. Arising from such research is the proposal that representations exist in a hierarchy of levels corresponding to the stroke, radical and character units and that activation passes up through those levels when a Chinese word is presented for recognition^[6,3,5]. This multilevel interactive model is presented in Fig. 1.

Such a framework is quite simplistic and ignores some of the relationships that exist between units at different levels. For example, the radicals that compose Chinese compound characters can sometimes be characters in their own right. As an instance, the left-hand radical of 引 can be used as a simple character (i.e., 弓 meaning a bow).

That is, there is both a radical and a character version of 弓 and the question then arises what the relationship is between the two. Is there an abstract representation underlying the two, which is used in the recognition of both a compound character containing the radical (e.g., 引) and a compound word containing the character (e.g., 弓箭, bow and arrow)? Or are they independently represented forms?

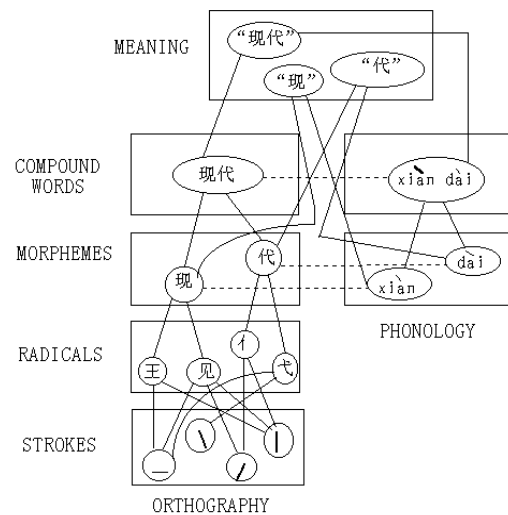


Fig1. Multilevel Interactive Activation Model, MIA

There appear to be four ways to conceptualise the possible relationship between the character and radical versions of a particular stroke-combination:

- Option 1, both radical and character share the same abstract representation (see Fig. 2). In this case, both the character “女 (female)” and radical “女” share the same unit, via which all the compound characters containing the radical “女” are activated, as well as the simple character “女”. The shared representation is abstract in the sense that it is neither specifically defined as a radical nor as a character, but merely as a combination of strokes. The main feature of this model is that there is no position-sensitive

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representation for any radical: A complex character is activated via the same stroke-combination unit regardless of whether that stroke-combination is found on the left or right of the character.

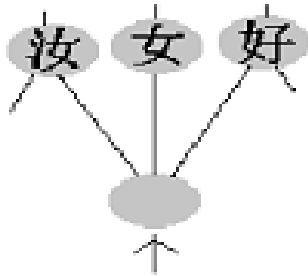


Fig.2 the relationship between radicals and characters: possibility one.

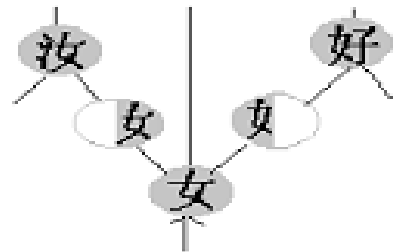


Fig.4 the relationship between radicals and characters: possibility three.

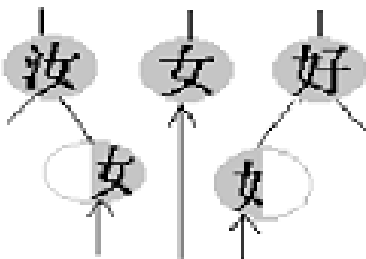


Fig.3 the relationship between radicals and characters: possibility two.

● Option 2, radical and character are independently represented in lexical memory (see Fig. 3). In this case, the representations for the character “女” and for the radical “女” are independently activated by the relevant strokes. This is equivalent to Fig 2A in Taft, Zhu, & Ding^[7] in the current issue. The relevant radical representation is activated when the positional features extracted from the stimulus are congruent with it (for example, either the features *+right-side* or *+left-side*, or the features *+left-hand character boundary* or *+right-hand character boundary*). In fact, the character representation is indistinguishable from a position-free radical representation activated by both the features *-left-side* and *-right-side* or by both the features *+left-hand character boundary* and *+right-hand character boundary*. For this reason, it would be redundant to incorporate both a character representation and a position-free radical representation into the model.

● Option 3, radical and character are separately represented, and the radical is activated via the representation of its simple character version (see Fig. 4). This is equivalent to Fig 2C in Taft et al (*current issue*). Here, there is only one unit that is receptive to the particular stroke-combination and that unit is the same one that directly links to the meaning of the simple character version. However, when activated in combination with positional

information extracted from the stimulus, the appropriate radical representation is also activated. In this way, a complex character containing a particular radical is activated via both a representation of that radical and a representation of the simple character version of that radical.

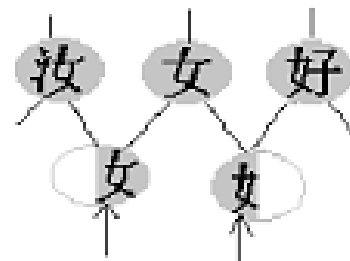


Fig.5 the relationship between radicals and characters: possibility four.

● Option 4, radical and character are separately represented, and the simple character is activated via the representation of its radical version (see Fig. 5). This is equivalent to Fig 2B in Taft et al (*current issue*). When a simple character is presented, both the *+left-hand character boundary* and *+right-hand character boundary* position-sensitive representations (i.e., radical representations) are activated because the simple character does have a boundary on both sides. Although such a model may seem unrealistic, it nevertheless exists as a logical possibility.

There is already strong evidence for the rejection of Option 1. It has been clearly shown by Taft et al (1999) that positional information of a radical is important in the recognition of Chinese compound characters. In addition, other research^[8] has revealed a radical priming effect if the radical in the prime appears in the same position as in the target (e.g. 如 *if* - 好 *good*), but not if it appears in a different position (e.g. 汝 *you* - 好 *good*). These findings do not support the idea in Option 1 that the radical and character share the same abstract representation. Instead, it suggests that radicals with the same form, but different positional information, are represented separately.

Option 2 can be rejected on the basis of other results that suggest that there is a relationship between the representation of the radical and character versions of a stroke-combination. For example, Taft et al (*current issue*) showed that recognition of a simple character is influenced by its frequency of use as a radical, and Ding et al (*current issue*) found that a simple character (e.g., “女”) can prime a compound character that contains the radical version of that simple character (e.g., “如”).

The findings mentioned above could be explained by both Options 3 and 4, since both of them hold that the radical is represented separately from its character version but that a relationship exists between them. Taft et al (*current issue*) come out in favor of Option 3 over Option 4 on the basis of experiments that manipulate the frequency characteristics of a radical within a compound character. The present study aims to provide converging evidence for this conclusion using a very different paradigm.

In the Chinese writing system, there are times when the two radicals of a character accidentally coincide with the two characters of a compound word. For example, the radicals of 好 (*good*) coincide with the characters of the word 女子 (*female person*). This specific orthographic and morphological phenomenon provides the opportunity to examine the relationship between the representation in lexical memory of the radical and of the character using a novel approach. Since both Options 1 and 2 have been rejected on the basis of previous findings, the focus here will be on the differentiation of Options 3 and 4. The experiments will determine whether there is confusion between these special characters and words. That is, does the existence of the word 女子 influence the recognition of the character 好, and vice versa? The two options appear to make different predictions.

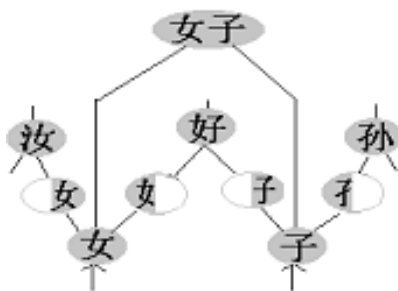


Fig.6 the extension to the possibility three above.

Figs 6 and 7 depict the relationship between the representational units for the radicals 女 and 子 in 好 and those for the characters 女 and 子 in 女子. These figures correspond to Options 3 and 4 respectively.

According to Option 3 (Fig. 6), when the character “好” is presented, the simple character units “女” and “子” will be firstly activated which, in combination with positional information, will activate the relevant radical units which, in turn, will activate the compound character “好”. Since the

character units “女” and “子” have a direct connection with the word unit “女子”, they should readily activate this word unit when it is actually the character “好” that is to be recognized. Thus, interference could well arise. When the word “女子” is presented, on the other hand, the character units “女” and “子” will again be the first units activated, followed by activation of the word unit “女子”. There may also be activation in the radical units for “女” and “子” (although the positional information extracted from the stimulus will not be exactly compatible with the radical unit) and this, in turn, will lead to activation of the compound character unit “好”. In other words, it is possible that the existence of the character “好” will interfere with recognition of the word “女子”. However, because the subunits of “好” are only indirectly activated in the recognition of “女子”, this interference should be weaker than the interference of the word “女子” on recognition of the character “好”.

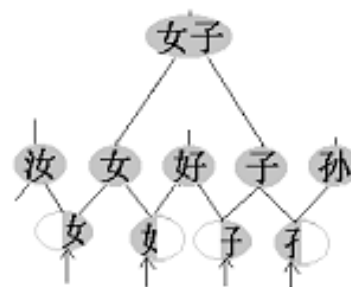


Fig.7 the extension to the possibility four above.

If Option 4 is adopted (Fig. 7), the opposite pattern is expected. That is, recognition of the word “女子” requires the activation of the very subunits that activate the character unit “好” (i.e., the radical units “女” and “子”); whereas in the recognition of the character “好”, the subunits that activate the word unit “女子” (i.e., the simple character units “女” and “子”) are only incidentally activated. So, the interference of the character “好” on recognition of the word “女子” should be stronger than the interference of the word “女子” on recognition of the character “好”.

In this research, two experiments were conducted to distinguish Option 3 from Option 4 based on the above logic. In the first experiment, character decisions were carried out on characters whose two constituent radicals could either form an existing two-character word (for example, 好) or could not (for example, 时). In the second experiment, word decisions were made to words whose two component characters could also be the constituent radicals of an existing compound character (e.g., 女子 *women*) and those that could not (e.g., 马上 *immediately*). If Option 3 is correct, it would be expected that the effect of word units on character targets in Experiment 1 will be stronger than the effect of character units on word targets in Experiment 2. If Option 4 is correct, however, the opposite pattern would

be expected.

2 Experiment 1

2.1 Method

2.1.1 Materials Sixteen compound characters were selected as the test items. Each of these characters contained two radicals that could also be used as characters, and those two characters could also compose an existing two-character word. For example, the two component radicals of 好 (*good*) can also compose the two-character word 女子 (*woman*). Each test item was matched with a control item on character frequency^[9], stroke number of component radicals. The radical position frequency of the items was roughly matched between test group and control group^[10] (see Table 1). The radicals of the control characters could also be characters in their own right, but did not compose a two-character word (e.g., 时, *time*, whose radicals “日” and “寸” are characters, but do not compose an existing word). Also included in the experiment were 32 non-characters used as distractor items. They were created by combining real radicals inappropriately, and half were those whose radicals created a real word when used as simple characters (i.e., constructed in the same way as the real characters).

Table 1 Item statistics for Experiment 1

| | Target(AB) | CF | Log CF | A | SN | B | SN | RF |
|------------|--|-------|--------|---|-----|---|-----|------|
| Test Group | 好 <i>good</i> (女子 <i>women</i>) | 338.1 | 1.5 | 女 | 3.4 | 子 | 5.3 | 18.4 |
| Control | 时 <i>time</i> (日寸) | 355.4 | 1.5 | 日 | 3.8 | 寸 | 5.8 | 17.6 |

CF = Character Frequency (per million) SN = Stroke Number

A = First radical RF = Radical Frequency (position sensitive)

B = Second radical

2.1.2 Participants Thirty Chinese postgraduate or visiting scholars at the University of New South Wales took part in Experiment 1. Their eyesight or adjusted eyesight was normal.

2.1.3 Procedure The experimental stimuli were presented on a monitor with the stimulus in white and the background black. When the experiment began, a fixation point of “+” was presented for 500ms at the center of the screen and was replaced by the target presented in the same location. The subjects were asked to judge as quickly as possible whether or not the target was an existing character. The order of presentation was randomized for each participant. Ten practice items were given prior to the formal experiment.

2.2 Result and discussion

In the analysis of the data (presented in Table 2), atypically long and short reaction times above 1500 ms or under 300 ms were eliminated.

Table 2 Reaction times (ms) and error rates (%) for Experiment 1

| | | RT | ER |
|------------|-------------|-----|------|
| Test Group | 好 (good) | 524 | 5.24 |
| Control | 时 (time) | 561 | 8.57 |

Response times to a compound character appear to be influenced by the fact that its radicals produce a real word when they are used as simple characters, with the difference between the test and control conditions being significant, $t_s(29) = -3.14$, $p < 0.01$, $t_i(15) = -2.50$, $p < 0.05$. There was no error rate difference, $t_s(29) = -0.21$, $p = 0.836$, $t_i(15) = 1.33$, $p = 0.203$.

Interestingly, the direction of influence of the “competing” word was the opposite to that predicted. That is, instead of interfering with the recognition of 好, the existence of the word 女子 actually facilitated recognition times. Before considering how to interpret this finding, it is necessary to determine whether the same effect was bigger or smaller when presenting the two-character word as the target. This will indicate whether Option 3 is more appropriate than Option 4.

3 Experiment 2

In this experiment, word decisions were made to words whose two component characters could also be the constituent radicals of an existing compound character (e.g., 月票 *monthly ticket*, cf. 膘 *fat*), and to words whose component characters could not (e.g., 白发 *white hair*).

3.1 Method

3.1.1 Materials Test items comprised 16 two-character words whose two component characters could also be the constituent radicals of an existing compound character. They were actually the same items (in reverse) that were used in Experiment 1. To each test item was matched a control word whose component characters did not compose an existing compound character. Matching was carried out on word frequency, as well as component character frequency (see Table 3). There were also 32 two-character non-words created as distractor items.

3.1.2 Participants Thirty Chinese postgraduate or visiting scholars at New South Wales University took part in Experiment 2. All had normal or normal-corrected vision. None of them had participated in the first experiment.

3.1.3 Procedure The procedure was the same as that of the first experiment except that the task was word/non-word decision.

Table 3 Item statistics for Experiment 2

| | Target (A+B) | WF (log) | WF (log) | A (log) | CF (log) | B (log) | CF (log) |
|------------|-----------------|-------------|-------------|------------|-------------|------------|-------------|
| Test group | 月票 | 20.6 | .787 | 月 | 2.9 | 票 | 2.7 |
| Control | 白发 | 21.4 | .783 | 白 | 2.8 | 发 | 2.5 |

Note: WF=Word Frequency, B=Second character, A=First character, CF=Character Frequency

Table 4 Reaction times (ms) and error rates (%) for Experiment 2.

| | | RT | ER |
|------------|------------------|-----|-------|
| Test group | 女子 (woman) | 604 | 8.44 |
| Control | 马上 (immediately) | 620 | 12.89 |

3.2 Results and discussion

The data is presented in Table 4. Upper and lower cut-offs of 1500 ms and 300 ms respectively were again applied to the reaction times.

Although there was a trend in the same direction as in Experiment 1, neither reaction time nor error rate revealed a significant difference between the test group and the control (RT: $t_s(29) = 1.64, p = 0.122, t_i(15) = 1.12, p = 0.281$; ER: $t_s(29) = 1.54, p = 0.146, t_i(15) = 1.27, p = 0.222$).

The result shows only a very weak difference, if any, between words whose component characters are the constituent radicals of an existing character and those whose component characters are not. That is, the character unit “好” has little if any influence on the recognition of the corresponding word unit “女子”. Combined with the finding in the first experiment that the word unit “女子” does influence the character target “好”, the results support Option 3 rather than Option 4 according to the logic outlined in the introduction. It was suggested that Option 4 would show a stronger effect of the manipulation on characters than words while Option 3 would show the reverse. Further analysis revealed that the interaction between the two experiments was significant in item analysis (RT: $F_1(1,58) = 1.89, p = 0.180, F_i(1,30) = 10.07, p < 0.005$; ER: $F_s(1,58) = 0.10, p = 0.752, F_i(1,30) = 21.38, p < 0.001$), it can at least be said that there is no sign of support for a greater effect for words than characters as predicted by Option 4.

Since the word targets here were those whose characters version were used as targets in Experiment 1, the relative frequency relationship may be a factor that influenced the experimental result. In particular, if the word versions are more frequent than the character versions, then the character judgments might be more affected than the word judgments because lower frequency items are more likely to be influenced by higher frequency items than the other way around. However, inspection of the frequencies for the items of the two

experiments (see Tables 1 and 3) revealed that this was not true. Instead, the former was much higher than the latter. So it seems the different results between Experiments 1 and 2 cannot be accounted for by the relative frequency relationship.

4 General discussion

There are Chinese characters, such as 好, whose two radicals coincidentally match with the two characters of a compound word, e.g., 女子. The two experiments reported here used these materials to try to provide new insight into the nature of the representation of radicals and characters in lexical memory. Experiment 1 showed that recognition of a compound character (like “好”) was strongly facilitated by the existence of the form-related word (e.g., “女子”), while Experiment 2 showed that the reverse was not true. The underlying mechanism that might account for the findings is probably to be found in the relationship between the radical representation and character representation. Either a radical representation is activated via its simple character version (Option 3: Figs 4 and 6) or the simple character representation is activated via its radical representations (Option 4: Figs 5 and 7). The former predicts a stronger influence of a two-character word on compound character recognition than the reverse, while the latter predicts a stronger influence of a compound character on word recognition and, therefore, Option 3 appears to be favored by the data.

A major question regarding the results, however, is why the influence of the related word or character was facilitatory. It was expected that activation of an inappropriate unit in lexical memory would compete with the appropriate unit and hence reveal an inhibitory effect. In order to explain why the recognition of 好 should be facilitated, rather than inhibited, by the existence of 女子, several assumptions need to be made. Firstly, the system appears to be sensitive to the distinction between units representing characters and units representing multi-character words and, importantly, activation in one of these types of unit does not compete with activation in the other type. Using the Option 3 framework, this means that activation developing in the 好 unit when 好 is presented is not adversely affected by the fact that the 女子 unit is also partly activated (via activation of the 女 and 子 units). Where the facilitation might come from, then, is the fact that there is additional activation in the system. That is, the bias toward saying that a presented stimulus is to be found in lexical memory (i.e., is a real character or word), is greater the more activity there is in the lexical processing system.

The reason for there being more activity in the processing system when the character is presented rather than the two-character word would be because, in the latter case, the unit representing the compound character is only indirectly activated by the word. Furthermore, the radical-level units that

mediate the activation of the compound character require positional information for their own activation. Because the position of a radical in a character is rather different to the position of a character within a word, the position-sensitive radical units will be only weakly activated when the two-character word is presented. In other words, when 女子 is presented, the simple character units for 女 and 子 will be activated, but these will only weakly activate their equivalent radical units because they are not associated with the relevant positional information (apart from the very broad categorization of being the "left-hand" and "right-hand" part of the stimulus). Therefore the unit for 好 will only be weakly activated. This is different to the situation where 好 is presented, because activation of the simple character units for 女 and 子 will be insensitive to whether those stroke-combinations occur as radicals in a character or as characters in a word. Therefore, activation in the unit for 女子 will be quite strong.

It can be seen, then, that the examination of characters whose radicals form the characters of a two-character word, and vice versa, is able to place constraints on one's model of lexical processing of Chinese. It allows conclusions to be drawn about the relationship between the mental representation of the radical version of a character and that of its character version. In particular, the results are taken as support for the idea that activation of the representation of the character version of a radical precedes that of the radical representation (Option 3), which is consistent with the conclusions drawn from other experimental paradigms reported in this issue (Ding et al, Taft et al). Moreover, the facilitatory nature of the effect demonstrated here allows conclusions to be drawn about the inhibitory links (or lack thereof) within the lexical processing system.

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汉语成字部件的心理表征

丁国盛

(北京师范大学心理系,北京 100875)

Marcus Taft 朱晓平

(University New South Wales, Sydney)

摘 要 汉语中有些复合字的两个部件恰好是一个双字词的两个成分字(如“好”和“女子”),该研究考察了这一特点是否会影响这类复合字或双字词的识别。实验一比较了这类复合字(例如,“好”)与相应的对照复合字(也是由两个成字部件构成,但这两个部件对应的汉字构不成一个双字词,例如,“时”)的识别,发现前者的反应时比后者要短。这说明该特点对复合字的识别有显著的促进作用。实验二比较了具有这类特点的双字词和相应的对照词的识别,发现两者在反应时和错误率上均没有区别。这说明这一特点对双字词的识别没有影响。这一不对称的结果提供了理解汉字及部件的心理表征方式的新依据。文章的结论是,部件表征由和它的形状相同的汉字表征及其相应的位置信息共同激活。

关键词 汉字,成字部件,心理表征。