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Phonology in Lexical Processing of Chinese: Priming Tone Neighbours*

Zhou Xiaolin

(Peking University and Cambridge University)

Abstract: Using both visual-visual and auditory-visual priming lexical decision tasks, this study investigated phonological processing in reading logographic Chinese. Compound words sharing segmental templates but differing in lexical tones were used as primes and targets while their relative frequency was manipulated. It was found that tone neighbours did not prime each other significantly and the SOA of 100 msec in visual-visual priming. When the SOA was increased to 357 msec, or when primes were presented auditorily, the processing of target words was significantly delayed by their tone neighbours. Larger inhibitory effects were observed for low frequency targets with high frequency primes. It was argued that although phonological information is automatically activated and this activation affects access to semantics in reading Chinese, phonological mediation is not the only or the main source of constraints on semantic activation.

Key Words: Chinese lexical processing, reading, phonological processing, visual-visual priming, cross modal priming.

Introduction

There are at least three crucial issues concerning the role of phonology in visual word recognition (e.g., Seidenberg & McClelland, 1989; Taft & Graan, 1998; Zhou, Shu, Bi, & Shi, 1999): a) whether phonological information is automatically activated in initial lexical processing; b) to what extent phonology plays a role in constraining access to lexical semantics; and c) how phonological information becomes available. Although these issues are closely related, they nevertheless need to be carefully distinguished. An answer to one question (e.g., a strong view of mandatory phonological activation) does not necessarily entail a similar answer to another question (e.g., phonological mediation in access to meaning).

In recent years, these issues have attracted many psycholinguists to the Chinese language, partly due to its unique logographic writing system. Does phonology function in the same way in reading Chinese as in reading alphabetic scripts? Many studies of Chinese provide converging evidence that phonological information in the mental lexicon is automatically activated, even in situations in which phonological activation is harmful to the completion of an experimental task in hand (Perfetti & Zhang, 1995; Zhou & Marslen-Wilson, in press -a; 1999). What is more contentious is whether phonology plays a strong role in constraining or mediating semantic activation. On the one hand, there are arguments that phonological information in reading Chinese, as in reading alphabetic languages, is activated earlier than semantic information and (therefore) access to semantic depends crucially on phonological activation (Perfetti, Tan, Zhang, Georgi, 1995; Perfetti & Zhang, 1995). On the other hand, there are propositions that access to lexical semantics in reading Chinese in constrained by both phonology and

* This research was supported by grants from UK Economic and Social Research Council and the Chinese University of Hong Kong. Correspondence concerning this paper should be addressed to Xiaolin Zhou, Department of Experimental Psychology, Cambridge University, Cambridge CB2 3EB, U.K. Electronic mail may be sent to xz 104 @cam.ac.uk.

orthography operation in interaction with each other, and that phonology has no inherently privileged role over orthography in constraining semantic activation (Zhou et al., 1999; Zhou & Marslen-Wilson, in press-a, in press-b, 1999).

While experimental evidence supporting the strong phonological view proves difficult to replicate (see Zhou & Marslen-Wilson, in press-a, in press-b), evidence supporting the interactive view has been collected from different paradigms, such as semantic categorisation (e.g., Chen, Cheung, & Flores d'Arcais, 1995; Leck, Weekes, & Chen, 1995; Sakuma, Sasanuma, Tatsumi, & Masaki, 1998), phonologically mediated semantic priming (e.g., Zhou et al., 1999; Zhou & Marslen-Wilson, in press-b), and pseudohomophone effects (Zhou & Marslen-wilson, 1999). Zhou and his colleagues (Zhou et al., 1999, Zhou & Marslen-Wilson, in press-a) compared priming effects between semantically related words (e.g., 卫生 wei(4)sheng(1), *hygienic*; 洁净 jie(2) jing(4), *clean*) and phonologically related words (e.g., 捷径 jie(2)jing(4), *shortcut*; 洁净 jie(2)jing(4), *clean*) for both compound words and single-character words. (Numbers in brackets represent the tones of the syllables). They observed strong semantic priming effects for both types of words at short (57 msec) and long (200 msec) SOAs in visual-visual priming lexical decision. However, phonologically related compound words did not show significant effects at either SOA, suggesting that phonological information activated by primes had no strong influence on semantic activation of targets, as measured by this task. For single-character words, phonological priming effects were obtained at the long SOA in character decision and at both the SOAs in naming. However, for neither compound words nor single-character words and in neither task, were phonological effects larger or earlier than semantic effects. These findings suggest that phonological information by itself has no strong influence on semantic activation in reading Chinese (see also Shen & Forster, in press).

The purpose of this study is to investigate further phonological activation and phonological constraints on semantic activation in reading Chinese compound words. Using the phonological priming lexical decision technique, Zhou and Marslen-Wilson (in press-a) observed non-significant facilitatory effects for true homophones (e.g., 捷径 jie(2)jing(4), *shortcut*; 洁净 jie(2)jing(4), *clean*) and non-significant inhibitory effects for semi-homophones differing on tones (e.g., 传统 chuan(2)tong(3), *tradition*; 串通 chuan(4)tong(1), *collude*) at the SOA of either 57 msec or 200 msec. In this study, we examine whether significant priming effects can be obtained for semi-homophones or tone neighbors when the SOA between primes and targets is sufficiently long to allow stronger phonological activation and competition, or when part of phonological information is given directly, i.e., through auditory presentation of primes.

The Experiments

This study included three experiments, with the same stimuli. Experiments 1 and 2 used a visual-visual priming task in which semi-homophone primes were presented for either 100 msec or 357 msec. Experiment 3 used an auditory-visual (cross-modal) priming task in which primes were presented auditorily and targets were presented immediately at the offset of primes. In all experiments participants were asked to decide as quickly and as accurately as possible whether the visual targets were real words. The rationales behind the experimental design are as follows.

After a critical prime (e.g., 传统 chuan(2)tong(3), *tradition*) is presented, its phonological representation is activated by the visual input and through its semantic activation (e.g., Zhou & Marslen-Wilson, 1997). When the target (e.g., 串通 chuan(4)tong(1), *collude*) is presented, its visual input

maps onto its own phonological representation, which shares the segmental template with the prime. Phonological activation of the target has to, at the suprasegmental(tonal)level, compete with phonological activation of the prime. The previous study by Zhou and Marslen-Wilson (in press-a)indicates that the facilitatory effect from sharing the segmental representation between the prime and target does not cancel the inhibitory effect from competition between suprasegmental representations. This competition could delay the processing of the target. There are potentially two ways for phonological competition to affect reaction times in lexical decision, depending on which domain of activation the decision task taps into. If the lexical decision task taps directly into phonological activation, the delayed phonological activation of the target, due to suprasegmental competition, should lead to a longer reaction time to the target. If the lexical decision task taps mainly into semantic activation, and if phonological activation of the target influences its semantic activation, a longer reaction time could also be observed for the target.

Thus, the level of phonological activation of the prime could affect directly the strength of competition with phonological activation of the target and hence the reaction time to the target. The higher the phonological activation of the prime, the stronger the phonological competition between the prime and the target, and the slower the reaction time to the target. There are several ways to increase phonological activation of the prime. One way is to increase to the duration of the prime, i.e., the SOA between the prime and target. This should allow the phonological information of the prime to have sufficient time to accumulate and to influence the processing of the target. The tendency of inhibition between tone neighbors observed by Zhou and Marslen-Wilson (in press-a)could become more evident when the SOA is sufficiently long. Similarly, presenting the prime auditorily should activate directly its phonological representation and increase phonological competition between the prime and the target. The third way to increase phonological activation of the prime and phonological competition between the prime and the target is to manipulate the relative frequency of the prime and the target. A high frequency prime should be able to activate more efficiently its phonological representation than a low frequency prime. Moreover, it may take longer time for a low frequency target than for a high frequency target to activate sufficiently and to overcome competition from the prime (e.g., Segui & Grainger, 1990).

Method

Design and Materials

Each experiment included two conditions: Low-High and High-Low. High and low frequency pairs of tone neighbours were selected and assigned as primes and targets in one condition and as targets and primes in another condition. Unrelated control primes were selected to match primes in frequency. High frequency words ranged from 68 to 542 per million while low frequency words ranged from 1 to 27 per million. Forty-four pairs of tone neighbours were selected. Primes and targets shared no semantic or orthographic similarities with their targets. Table 1 presents the sample stimuli and average frequencies of primes and targets.

The experiments also included 20 target words(e.g., 悲哀 bei(1)ai(1), *sorrowful*), preceded by morphological primes sharing the same initial morphemes(e.g., 悲惨 bei(1) can(3), *miserable*)and frequency-matched unrelated control primes(e.g., 谨慎 jin(3) shen(4), *prudent*). The purpose of including this design was to check whether the experiments were working if no significant priming effects were obtained for tone neighbours.

Table 1 Sample stimuli and average frequencies(per million)of primes and targets

Relative Frequency	Prime	Control	Target
Low-High	串通	雕刻	传统
	Chuan(4)tong(1)	dial(1)ke(4)	chuan(2)tong(3)
	Collude	carve	tradition
	6.5	6.6	156
High-Low	传统	历史	串通
	Chuang(2)tong(3)	li(4)shi(3)	Chuan(4)tong(1)
	Tradition	History	Collude
	156	155	6.5

Besides the critical stimuli, there were also 10 phonologically related word-nonword pairs differing on tones(e.g., 榜样 bang(3)yang(4), *example*; 帮扬 bang(1)yang(2))and 10 word-nonword pairs shared the initial morphemes(e.g., 规矩 gui(1)ju(0), *rule*; 规欢 gui(1)huan(1)). Another 36 word-word pairs and 80 word-nonword pairs were used as fillers. Primes and targets in these pairs had neither semantic, nor orthographic, nor phonological relations. Nonword targets were created by combining characters in a pseudo-random way. None of the nonwords were pseudohomophones that had the same phonological forms as real words. Characters that had been used in critical stimuli were not used again in filler items. The purpose of using related word-nonword pairs and unrelated fillers was to prevent participants from developing response strategies. There were also 34 pairs of practice items that had a similar composition to the test items.

Semi-homophones and the control primes were split, in a Latin Square design, into four counter-balanced test versions. In each version, there were 22 prime-target pairs from the Low-High condition, 11 being phonologically related and 11 unrelated. Similarly, there were also 22 prime-target pairs from the High-Low condition. No critical primes or targets appeared more than once in a test version. Words in morphological priming were also split in a counter-balanced way into two groups, each group having 10 targets preceded by morphologically related words and 10 targets preceded by unrelated primes. These two groups were added to Versions 1 and 2, and to Versions 3 and 4. Fillers were then added into each version. Thus in each version there were 100 word-word pairs and 100 word-nonword pairs. Among the word-word pairs, 22 were preceded by tone neighbours and 10 by words sharing the initial morphemes. A pseudo-random sequence was used to arrange the stimuli in each version in such a way that, across the four test versions, critical targets and filler prime-target pairs appeared at the same position. There were never more than 4 consecutive targets requiring the same responses. Prime-target pairs with the same relations were roughly evenly distributed across a test sequence.

Procedure

All visual stimuli were generated using a computer program and captured as pictures. Both prtimes and targets were created in 48-point *songti* font. A word was about 2.4 * 3.8cm in size and participants were seated about 60 cm from the screen. All primes were also recorded using a DAT tape recorder and digitised into a computer as speech files.

The presentation of stimuli to participants and recording of reaction times were controlled by the experimental software DMASTR and VMASTR, which were made available to us by Ken Forster. In each trial of visual-visual priming, an eye fixation signal("+")was first presented at the centre of the screen for 300 msec, followed by a blank screen for another 300 msec. A prime was then presented for either 100 msec or 357 msec depending on the SOA. The corresponding target was presented immediately after the prime at the same location for 400 msec. In each trial of cross modal priming, the prime was played out from a computer through the headphones to participants. The visual target appeared im-

mediately at the centre of the screen at the offset of the speech. There was an interval of about 3 seconds between the disappearance of the target and the next eye fixation signal or the onset of speech. Participants were tested in groups of three or less in a quiet room.

Because the notion of wordhood can be ambiguous for some Chinese compound words, participants were explicitly instructed that real words were those used in the language and have relatively fixed meanings while non-words were those not used in the language and had no fixed or commonly accepted meanings. This could bias participants to use semantic information in their lexical decision.

Participants

A total of 137 native speakers of Mandarin Chinese were tested, 44 at the SOA of 100 msec, 45 at the SOA of 357 msec, and 48 in cross-modal priming. They were all undergraduate students at the Beijing Normal university and were paid for their participation.

Results

One participant at the SOA of 100 msec was excluded from analyses because he made too many (over 30%)errors in responding to targets. At both the SOAs of 100 msec and 357 msec, one target in the High-Low condition was deleted because more than half of participants in one or more test versions gave incorrect responses. In cross-modal priming, three targets in the High-Low condition were deleted due to high response error rates. Mean reaction times for tone neighbours, based on the remaining items and correct responses, were computed separately for participants and items. Mean reaction times and error percentages in different experiments and different priming conditions are reported in Table 2.

Table 2 Mean reaction times(msec)and error percentages

	Frequency	Prime	Control	Effect
SOA 100 msec	Low-High	571	568	-3
		(1.7)	(3.0)	
	High-Low	639	628	-11
		(10.4)	(5.5)	
SOA357 msec	Low-High	547	542	−5
		(1.6)	(2.2)	
	High-Low	622	602	−20
		(10.6)	(6.3)	
Cross Modal	Low-High	544	529	−15
		(2.3)	(2.2)	
	High-Low	599	592	−7
		(10.7)	(6.9)	

The priming effects for morphologically(and semantically)related words , as assessed against the unrelated controls, were 58 msec at the SOA of 100 msec, 29 msec at the SOA of 357 msec, and 21 msec in cross-modal priming. They were all significant, indicating that the experiments were successful in revealing priming effects. We do not report the details of statistical analyses here to save space. For phonological priming, two-way analyses of variances(ANOVAs)were conducted separately for reaction times and error rates, with prime type(prime vs. control)and relative frequency(low-high vs. high-low) as two variables.

Experiment 1

In reaction times, the main effect of frequency was highly significant both by participants, $F1(1,42)=138.831$, $P<.001$, and by items, $F2(1,85)=47.300$, $P<.001$, indicating that responses to high frequency targets were much faster than responses to low frequency targets. However, the main effect of prime type(-7 msec)was not significant, $F1(1,42)=1.859$, $P>.1$, $F2(1,85)=1.716$, $P>.1$, nor the

interaction between prime type and frequency, $F1<1$, $F2<1$. These indicated that in both Low-High and High-Low conditions, the processing of target words was not significantly in fluenced by their semi-homophone primes. The analyses of error rates essentially mirrored the analyses of reaction times. There was a highly significant main effect of frequency, $F1(1,42)=27.268$, $P<.001$, $F2(1,85)=22.262$, $P>.001$, with more errors committed on low frequency targets(8.0%)than on high frequency targets (2.3%). However, the main effect of prime type and the interaction between prime type and frequency did not reach significance, although responses to low frequency targets tended to have more errors when they were preceded by semi-homophones than by control primes.

Experiment 2

The main effect of frequency was highly significant in the analyses of reaction times, $F1(1,44)=178.442$, $P<.001$, $F2(1,85)=59.558$, $P<.001$. More interestingly, the main effect of prime type(-13 msec)reached significance, $F1(1,44)=5.617$, $P<.05$, $F2(1,85)=5.241$, $P<.05$, suggesting that responses to targets were inhibited by their semi-homophone primes, as assessed against the control primes. The interaction between prime type and frequency was not significant, $F1(1,44)=1.262$, $P>.1$, $F2(1,85)=2.260$, $P>.1$, indicating that phonological inhibition was for both high and low frequency targets. The analyses of error rates found a significant main effect of frequency, $F1(1,44)=38.847$, $P<.001$, $F2(1,85)=18.323$, $P<.001$. Although the main effect of prime type was not significant, $F1(1,44)=3.434$, $.05<P>.1$, $F2(1,85)=2.174$, $P>.1$, the interaction between prime type and frequency reached significance, $F1(1,44)=5.197$, $P<.05$, $F2(1,85)=3.824$, $.05<P<.1$. This indicated that mor errors were made to targets when they were preceded by semi-homophones than by control primes, but this effect was restricted mainly to low frequency targets(see Table 2).

Experiment 3

Once again, the main effect of frequency was significant in reaction times, $F1(1,47)=108.190$, $P<.001$, $F2(1,83)=44.302$, $P<.001$. Moreover, the main effect of prime type(-11 msec)was significant, $F1(1,47)=5.707$, $P<.05$, $F2(1,83)=3.857$, $.05<P<.1$, indicating that the processing of targets was delayed by their auditorily presented semi-homophone primes. The interaction between prime type and frequency was not significant, $F1<1$, $F2<1$. In the analyses of error rates, the main effect of frequency was significant, $F1(1,47)=35.156$, $P<.001$, $F2(1,83)=21.309$, $P<.001$. The main effect of prime type was marginally significant, $F1(1,47)=3.228$, $.05<P<.1$, $F2(1,83)=3.419$, $.05<P<.1$, suggesting that slightly more errors were made to targets when they were preceded by semi-homophone primes than by control primes. The interaction between prime type and frequency was not significant, $F1(1,47)=2.751$, $P>.1$, $F2(1,83)=3.611$, $.05<P<.1$

Discussion

The main purpose of this study was to investigate phonological processing in visual recognition of Chinese compound words. Three experiments, using visual-visual and cross-modal priming lexical decision tasks, observed consistent inhibitory effects between tone neighbours. In Experiment 1, the inhibitory effects did not reach statistical significance, consistent with Zhou and Marslen-Wilson (in press-a). With a longer SOA in Experiment 2, the processing of targets was significantly delayed by semi-homophone primes. When phonological information of semi-homophone primes was given directly through auditory presentation in Experiment 3, its effect on lexical processing of targets was also augmented. Moreover, it is clear from Table 2 that, in both reaction times and error rates, there tended to be larger inhibitory effects for low frequency targets with high frequency primes in visual-visual priming, even

though the effect of relative frequency did not reach statistical significance.

Clearly, the data can be taken as evidence that phonological information is automatically activated in reading Chinese, even though this phonological activation can only lexical decision to target words. More argument is needed to relate the present results to the issue of the extent to which access to semantics is constrained by phonology. As we pointed out earlier, there are two potential ways for the lexical decision task to obtain inhibitory effects between tone neighbours. If the task taps mainly into phonological activation, the increase of inhibitory effects in visual-visual priming across the two SOAs may indicate that phonological activation of primes takes time to build up and inhibit significantly phonological activation of target words. The larger inhibitory effects for high frequency primes than for low frequency primes may also indicate the efficiency of phonological activation of primes has significant influences on phonological activation of targets and hence on the priming effects. High frequency primes are recognised more quickly, allowing phonological information of these primes more time to accumulate and inhibit phonological activation of targets. (The frequency and hence the efficiency of phonological activation of targets may also contribute to the pattern of priming effects). Indeed, when phonological information of primes were presented auditorily, there was not much difference between the efficiency of phonological activation of high and low frequency primes. The difference between inhibitory effects for high and low frequency primes consequently disappeared when both reaction times and error rates are taken into account (see Table 2).

If, on the other hand, lexical decision to compound words is assumed to tap mainly into semantic activation (Zhou & Marslen-Wilson, in press-a), the patterns of priming effects in this study suggest phonological constraints on semantic activation. The account discussed above can be readily modified by assuming that phonological competition between primes and targets affects the efficiency of phonological activation and hence semantic activation of targets. The question is whether these phonological constraints predominate over direct computation from orthography to semantics in reading the target words. Lack of manipulations in which orthographic effects on semantic activation is directly examined may not allow us to draw strong conclusions about the relative strength of phonological and orthographic influences on semantic activation (but see Shen & Forster, in press, who, in a masked priming study, found orthographic effects in both character decision and naming and phonological effects only in naming). However, the patterns of priming effects in this study do allow us to conclude that phonological effects on semantic activation is not as strong as some researcher assumed (e.g., Perfetti et al., 1995). If phonological information is activated very early and if phonological mediation is the only or the main source of constraints on semantic activation, we should have observed significant inhibitory effects between tone neighbours throughout the experiments. The strong phonological activation of the prime should inhibit the phonological and hence the semantic activation of the target. Instead, we observed that the inhibitory effects varied according to the SOAs between primes and targets, with no significant effects at the short SOA (see also Zhou & marslen-Wilson, in press-a). The relatively weak phonological effects, contrasting with the early and strong semantic priming effects (Zhou et al., 1999; Zhou & Marslen-Wilson, in press-a) and with strong phonological effects in reading alphabetic scripts (e.g., Grainger & Ferrand, 1994; Lukatela & Turvey, 1994), suggest that phonological mediation is just one route of accessing semantics in reading Chinese. The other route to semantics, i.e., direct computation from orthography to semantics, is probably more efficient than phonological mediation, even though the two routes are not independent from each other (Zhou et al., 1999; Zhou & Marslen-Wilson, in press, 1999a, 1999b; Zhou, Wu, & Shu, 1998).

To summarise, using visual-visual and cross modal priming lexical decision tasks, the present study found inhibitory priming effects between tone neighbours differing only in tones. These effects were most evident when phonological information of semi-homophone primes was activated more prominently, due to a longer SOA between the prime and target, due to direct auditory presentation, or due to higher word frequency. Taking together other evidence concerning lexical processing of Chinese, it is concluded that although phonological information is automatically activated in reading Chinese, phonological mediation is only one, and probably not the most important one, source of constraints on semantic activation in visual lexical processing.

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ENGLISH ABSTRACTS

TASK — INVOLVED INTERVENTION APPROACH: ITS EFFECT ON THE IMPROVEMENT OFTEACHERS' TEACHING — REGULATED ABILITY

Xin Tao, Lin Chongde, Shen Jiliang
(Institute of Developmental Psychology, Beijing Normal University)

Through the task — involved intervention approach, this study trained elementary teachers' teaching regulated ability The result showed that training not only improved the teachers' teaching — regulated ability, but also promoted their cognition on teaching process

Key words: training, task — involved intervention approach, teaching — regulated ability

PHONOLOGY IN THE LEXICAL PROCESSING OF CHINESE: PRIMING TONE NEIGHBOURS

Zhou Xiaolin
(Beijing University and Cambridge University)

By means of both visual — visual and auditory — visual priming lexical decision tasks, this study investigated the phonological processing in reading logographic Chinese Compound words sharing segmental templates but differing in lexical tones were used as primes and targets while their relative frequency was manipulated It was found that the tone neighbors did not prime each other significantly at the SOA of 100 msec in visual — visual priming When the SOA was increased to 357 msec, or when primes were presented auditorily, the processing of target words was significantly delayed by their tone neighbors Larger inhibitory effects were observed for low frequency targets with high frequency primes It is argued that although phonological information is automatically activated and this activation affects access to semantics in reading Chinese, phonological mediation is not the only or the main source of constraints on semantic activation

Key words: Chinese lexical processing, reading, phonological processing, visual — visual priming, cross modal priming

A CROSS — CULTRUAL STUDY OF THE METAPHORICAL REPRESENTATION OF TIME

Zhou Rong, Huang Xiting
(Psychology Department, Southwest — China Normal University)

Based on widely — collected metaphorical sentences of time, structures of Chinese and English metaphorical representation of time , we tried to find the conceptual by using content analysis and factor analysis Eleven dimensions were obtained and the two cultures shared more or less the same structural dimensions This similarity indicates that metaphorical representation of time and time thinking are the result of pan — human experience and general cognitive capacity

Key words: time, metaphorical representation, time metaphoricaldimensions, cross — cultural

IMPLICIT THEORIES OF ACADEMIC SUBJECTS: GENERALITY AND AGE — RELATED DIFFERENCES

Cheng Zijuan
(Psychology Department, Northeast Normal University)
Kit — Tai Hau
(Faculty of Education, The Chinese University of Hong Kong, Hong Kong)

Are the abilities of mathematics, Chinese and other subjects inborn and unchangeable? Or, are they cultivated by the environment and changeable? Students' subjective opinion on these issues will directly affect their learning behavior The extent of its influence relies on how common and general such belief is In this study, we examined whether there is a central and dominating thought influencing students' attitude towards different academic abilities We also analyzed the age — related difference of such belief The subjects were 1650 primary 6, junior secondary 2, and senior secondary 1 students from Changchun, China Questionnaires were administered Structural equation modeling was used to examine the hypotheses Results tended to support a general implicit theory dominating the students' attitude toward the malleability of mathematics, Chinese and other subject abilities As age increased, the students were more inclined to believe mathematics and music abilities to be fixed and unchangeable

Key words: motivation, implicit theory, high — order factor, academic subject ability, structural equation modeling

A DEMONSTRATIVE RESEARCH ON THE CLASSIFICATION OF THE SUB — SANE SOCIAL CHARACTER

Yu Wenzhao, Lu Jianqing, Song Jiwen