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TITLE:

Interaction between Phonological and Semantic Processes in Visual Word Recognition Using Electrophysiology

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SUMMARY:

We present a protocol to explore the relative activation sequence of phonology and semantics in visual word recognition. The results show that consistent with interactive accounts, semantic and phonological representations may be processed interactively, and higher-level linguistic representations may affect early processing.

ABSTRACT:

Controversies have always existed in research related to reading abilities; on whether printed words are perceived in a feedforward manner based on orthographic information after which, other representations, such as phonology and semantics are activated, or whether these are fully interactive and high-level semantic information affects early processing. An interference paradigm was implemented in the presented protocol of phonological and semantic judgment tasks that utilized the same precede-target pairs to explore the relative order of phonological and semantic activation. The high- and low-frequency target words were preceded with three conditions: semantically related, phonological-related (homophones), or unrelated. The results showed that the induced P200 component of low-frequency word pairs was significantly greater than high-frequency words in both the semantic and phonological tasks. In addition, both the homophones in the semantic task and the semantically related pairs in the phonological task caused reduction in N400 when compared to the the control condition, word frequency-independently. It is worth noting that for the low-frequency pairs in the phonological judgment task, the P200 released by the semantically related word pairs was significantly larger than that in the control condition. Overall, semantic processing in phonological tasks and phonological processing in semantic tasks were found in both high- and low-frequency words, suggesting that the interaction between semantics and phonology may operate in a task-independent manner. However, the specific time this interaction occurred may have been affected by the task and

frequency.

INTRODUCTION:

The critical issue in any word recognition model is understanding the role of phonology in the process of semantic access[1]. For alphabetic languages, many studies consistently view phonology as playing an important role in semantic access, including English[2-4], Hebrew[5], French[6], and Spanish[7]. In other words, written word recognition involves not only orthographic but also phonological and semantic processing. This observation in the interactive connectionist model is explained by extensions activated throughout the network, where orthography is associated with phonological and semantic representations through weighted connections[8]. This proliferation of activation provides the core mechanism for the visual word recognition model, which assumes that phonological and semantic representations are automatically activated in response to orthographic input[9].

However, current empirical evidence supporting the hypothesis of interactive automation remains controversial. Some studies claim that the activation of phonological and semantic representations can be adjusted or prevented by task demands or attention, which implies a certain top-down influence on the high-level processes involved in word perception[10,11]. However, the aforementioned description has been questioned by many findings that report phonological and semantic effects in visual word recognition even though these representations are completely irrelevant to the task or cannot be directly accessed[12], thereby supporting the view that semantics and phonology may be accessed automatically and forcibly during the reading process[13]. Therefore, there is uncertainty on whether the phonological and semantic activation in visual word recognition depends on the specific task or whether it occurs forcibly and automatically in a task-independent manner.

The answer to aforementioned question is difficult for Chinese readers. Compared to English, Chinese is a logographic script whose characters represent morphemes instead of phonemes[14]. At present, the role of phonology for semantic access to Chinese words remains controversial. Some studies have claimed that phonology plays an important role in semantic access to Chinese words[15-17]. Others, however, have held the opposite view[18,19]. After evaluating the aforementioned research for Chinese phonological processing, we found that the experimental paradigm and specific research methods differ. On the whole, it was mainly divided into two paradigms: word priming[15,18,19] and violation paradigm in the sentence[17,20,21]. The target word is usually embedded at the end of the sentence in the violation paradigm[22]. In terms of language mechanism, a short two-word phrase is a more manageable unit than a complete sentence that is difficult to process[23]. In addition, variables that are difficult to control in a sentence, such as syntax, context, or other factors, may lead to different conclusions[24]. The word priming paradigm is a method commonly used to explore word recognition models, whether in alphabetic languages or Chinese. The task of this paradigm is to judge whether the target word preceded by the primes is a real word or pseudoword; that is, this paradigm usually contains only one lexical task. However, a single lexical decision task may not be the best choice to solve the problem of whether the activation of phonology and semantics depends on the task. Therefore, two different tasks may be more suitable for exploring this question.

Therefore, this research aimed to explore the role of phonology in Chinese word recognition and simultaneously attempt to determine whether the activation of phonology and semantics is in task independent. Our research includes two tasks using the interference paradigm: semantic judgment and phonological judgment. To the best of our knowledge, this is the first event-related potential (ERP) study of Chinese two-character compound recognition using this interference paradigm, and this method rarely appears in studies of alphabetic languages. Specifically, in the semantic judgment task, participants must judge whether the target word and its precedent are semantically related, while in the phonological task, they must judge whether the paired words have the same pronunciation.

The former is a semantic matching task that does not require a priori phonological processing, and the latter is a phonological judgment task that does not require a priori semantic processing. Therefore, we compared homophone pairs and unrelated control groups in the semantic judgment task to reveal whether and how phonology affects semantic processing. Similarly, we compared semantically related word pairs with unrelated control conditions in the phonological judgment task to reveal whether and how semantics affect phonological processing. In addition, the aforementioned problem was verified in high- and low-frequency words. Thus, this complementary semantic and phonological judgment task can not only reveal the importance of phonological processing in Chinese word recognition but also reveal whether and how phonology and semantics interact.

If the phonology and semantic processes are early, automatic, and interactive, the effect of phonological and semantic activation should be observed in the response time of the two tasks. For ERP, phonological and semantic processes trigger two different electrophysiological markers[2,7]. In addition, their time courses and their spatial distributions should be different. An early positive component (P200) should reflect phonological processing, and the typical semantic processing marker N400 should also be identified[20,21]. We assumed that both the phonologically related pairs in the semantic task and the semantic-related pairs in the phonological task would cause a significant decrease in N400, which would have indicated that phonological processing may lead to some degree of activation at lexical-semantic levels. In addition, we monitored whether the P200, which characterizes phonological processing, appeared in the semantic judgment task or the phonological judgment task. In the phonological judgment task, semantic-related conditions trigger the P200, which can be seen as evidence of the early influence of semantics on phonological processing.

PROTOCOL:

The protocol used for this study was approved by the Institutional Review Board of Tsinghua University.

1. Stimuli construction and presentation

1.1. Stimuli construction

1.1.1. Stimuli preparation: Prepare target words containing approximately 140 Chinese two-character compounds, of which low- and high-frequency words account for half. Precede each target by three analogues: a phonologically identical word (homonymous word), a word with related meaning, and an irrelevant control word.

1.1.1.1. Ensure that high-frequency targets are always preceded by high-frequency antecedents and low-frequency targets are always preceded by low-frequency precedents, whether in related conditions or unrelated control groups. In addition, ensure the precede-target pairs are similar in the number of strokes and frequency.

NOTE: All the words for this study were selected from the Modern Chinese Frequency Dictionary (Xiandai Hanyu Pinlu Cidian). The frequency of low-frequency words was less than eight times per million, and the frequency of high-frequency words exceeded 800 times per million.

1.1.2. Stimuli assessment: Recruit a separate group of approximately 30 students to evaluate the degree of semantic relevance between word pairs on a seven-point scale, wherein 1 reflects the lowest correlation and 7 reflects the highest correlation.

1.1.2. Final stimulus determination: Delete inappropriate word pairs, such as word pairs with lower scores in semantically related conditions and word pairs with higher scores in homophone and irrelevant condition scores.

1.1.2.1. Calculate the respective average scores of high- and low-frequency semantic-related word pairs and ensure no significant difference is present between the two.

1.1.2.2. In addition, ensure that the scores of homophone pairs and unrelated pairs are not significantly different at both high and low frequency. Finally, determine the final experimental stimulus material (see **Table Materials**).

NOTE: For the semantic-related values of the semantic-related pairs in this experiment, the final average values were 5.62 and 5.73 for high-frequency and low-frequency pairs, respectively, and there was no significant difference between the two ($p > .1$). In addition, the semantic relatedness between the homophonic and unrelated pairs was not significantly different ($p > .1$).

1.2. Stimuli presentation

1.2.1. Build a program to show the task to the subjects and fill in the aforementioned materials (the program can be written in E-prime or other programming languages).

1.2.2. Ensure that each core structure of the program starts with a screen displaying a " + " sign that lasts for 300 ms, directly after which the preceding word must appear for 140 ms, with no interval between the two.

1.2.3. After that, set a blank screen lasting for 360 ms, and then set the target word, which will appear for 500 ms. Finally, set a question mark (?) that will continue to be displayed until the participant has decided on the word pair just shown and pressed the button as quickly and accurately as possible.

1.2.4. Tell the participants in advance that they need to judge whether the word pair is semantically related in the semantic judgment task and whether the phonology is the same in the phonological judgment task.

1.2.5. Practice session setup: Set up two practice groups to include semantic judgment and phonological judgment tasks, respectively, with no less than 10-word pairs for each task. Inform the participants that they can repeat the exercises to ensure that the accuracy in the practice session is more than 70%.

1.2.6. Formal experiment setup: Divide the whole experiment into 6 blocks, with the semantic judgment task and the phonological judgment task each accounting for half.

1.2.6.1. Make sure that there are no repeated target words in each block, and that the number of priming types in each block is the same. In addition, set up a few filler trials to reduce the response deviation caused by the unequal number of tests requiring positive or negative reactions.

1.2.6.2. Randomize the order of items in each block and counterbalance the block order among the subjects.

NOTE: The entire experiment can also be divided into eight or ten or more blocks according to the number of experimental materials to be prepared, which minimizes the repetition of target words in each block.

2. Experiment preparation and electrophysiological recording

2.1 Recruit right-handed native Chinese speakers with a normal vision that may have been previously corrected.

2.1.1. Exclude participants with any neurological or psychiatric diseases.

2.1.2. Ensure there is a balanced number of female and male participants in the desired age range (18-28 years old).

2.1.3. Ensure that the participants do not have any history of perming or dyeing their hair for the past two months.

2.1.4. Inform the participants that they will need to have sufficient sleep and rest time before the experiment[25].

2.1.5. When participating in the experiment, please make sure the participants are in a healthy state at the time of conducting the experiment.

2.2. When a participant arrives at the lab, introduce the experimental equipment, tasks, and time costs. Explain the requirements (such as not being sleepy, moving, and blinking) to help them understand the entire process and eliminate unnecessary worries.

2.3 If the participant has no other questions about the experiment, ask them to fill in the Edinburgh Handedness Query Form, which is used to confirm that all participants have the same right-handed habits.

2.4 Provide the informed consent form to the participants and ask them to read and sign carefully. If participants have questions about the content of the consent form, provide them with the necessary explanations.

2.5 Instruct the participant to properly clean their scalp and dry their hair in the laboratory. While waiting for participants, please prepare all experimental materials.

NOTE: The electroencephalogram (EEG) signal is amplified using an amplifier system with a bandpass of 0.01 to 100 Hz and continuously sample at 500 Hz.

2.6 Invite the participants to sit comfortably on a chair in the chamber where the experiment will be conducted. Instructed them not to move the chair.

2.7 Use cotton swabs and facial scrubs to clean the skin under the participant's left eye (for the vertical electro-oculographic electrode), near the outer canthus of the right eye (for the horizontal electro-oculographic), and around the right and left mastoid bones (for Tp9 and Tp10, which will be used as new offline references).

NOTE: The distribution of electrodes may vary depending on the caps used.

2.8 Place the elastic cap on the participant's head and make sure that the Cz electrode is at the center of the top of the head. Fix the electrode cap strap under the chin with care to ensure that it is not too tight or too loose.

2.9 Make sure that the cap and amplifier are connected to the recording system. Next, switch the recording software to the impedance monitoring interface.

2.10 Ensure that the impedance of all electrodes does not exceed 5 kΩ or 10 kΩ, starting with the reference (Ref) and ground (Gnd) electrodes.

2.11 Pass the syringe filled with conductive gel through the small hole of an electrode to the scalp and then push the plunger to inject a small amount of conductive gel into the scalp while being careful not to cause an overflow. At the same time, monitor the display system that displays the impedance in real-time until the impedance drops to the threshold.

2.12 After the Ref and Gnd electrodes are prepared, reduce the impedance of the other electrodes in the same way. Treat the impedance reduction of ocular electricity carefully.

2.12.1 Tape the small holes on one side of the two electro-oculographic electrodes to prevent the injected conductive gel from leaking. Fix them to the bottom of the left eye and the outer canthus of the right eye with tape.

2.13 After all the electrodes are prepared, instruct the participants to be ready for the experiment. Instruct the participants to relax and avoid excessive eye blinking and body movement during the experiment.

2.14 Present the stimulus via the stimulus demonstration program and let the participants practice in the practice section.

NOTE: After the practice session, participants can ask questions if they have any doubts or questions about how to proceed.

2.15 Start the formal experiment and record the EEG information. Monitor the recording system during recording. If an electrode is loose or the resistance exceeds the threshold, refill the electrode when the participant is resting.

NOTE: Participants can rest for 4-10 min after each block.

2.16 After the experiment is completed, save the EEG signal and turn off the equipment, such as the recording system and amplifier. Then take off the participant's cap and instruct the participant to wash off the conductive gel from the hair and skin. Finally, reward the participants and thank them for their cooperation.

3. EEG preprocessing

3.1 Utilize semi-automatic ocular correction with independent component analysis.

3.2. Compute the ERPs from 100 ms to 600 ms after the onset of the target word (100 ms pre-target baseline).

3.3. Set the EEG bandpass-filtered offline from 0.05 to 30 Hz (zero phase shift mode, 24 dB/oct).

3.4. Discard epochs exceeding ±80 μV by artifact rejection and eliminate the trials of erroneous responses.

REPRESENTATIVE RESULTS:

This protocol was used in a recent study to investigate the role of phonology in Chinese two-character compound recognition and to infer the word recognition model[26]. All stimuli used in this study were fully disclosed[26]. Three time windows were selected on the basis of global field power (GFP): at 100-150 ms, 160–280 ms, and 300– 500 ms for N1, P200, and N400 components, respectively[26]. The average amplitudes of the above two time windows were analyzed by repeated measures analysis of variance (ANOVA), and frequency (low and high), relationship type (phonologically or semantically related, or unrelated), and lateral areas (left and right hemispheres × front, middle, and posterior regions = six areas in total) or midline electrodes (Fz, Cz, Pz), which were the three within-participant factors involved. More detailed results and graphs can be found in Wang et al. (2021)[26].

ERP results for the semantic judgment task

The 100-150 ms Period (N1)

For the midline electrodes, ANOVA yielded a main effect of Frequency [$F(1, 23) = 9.451$, $P = .005$, $\eta^2_p = .291$], indicating that high-frequency pairs elicited a significantly more negative waveform than low-frequency condition.). A similar significant main effect of Frequency was also observed at the lateral sites. In addition, for high-frequency pairs, a significant main effect of Relation Type was also observed [$F(1, 23) = 8.826$, $P = .007$, $\eta^2_p = .277$], showing that unrelated pairs elicited a significantly more negative waveform than homophone condition. A similar significant main effect of Relation Type for high-frequency pairs was also observed at the left hemisphere.

The 160–280 ms Period (P200)

For the midline electrodes, ANOVA yielded a main effect of Frequency [$F(1, 23) = 5.546$, $P = .027$, $\eta^2_p = .194$], indicating that low-frequency pairs elicited a significantly more positive waveform than high-frequency condition. No other significant effects or interactions were observed in the midline electrodes. Moreover, the main effect of Frequency was also found at lateral sites.

The 300–500 ms Period (N400)

In the 300-500 ms time window, ANOVA yielded a significant main effect of Relation Type [$F(1, 23) = 27.783$, $P < .001$, $\eta^2_p = .547$] in the midline electrodes, showing that a target primed by homophones elicited significantly less negative amplitude than did the unrelated condition (see **Figure 1**). A similar significant main effect of Relation Type was observed at lateral sites.

[Insert **Figure 1** here]

ERP Results for the Homophone Judgment Task

The 100-150 ms Period (N1)

No significant effect or interaction was found in the midline electrodes or lateral sites.

The 160–280 ms Period (P200)

No significant main effect for Relation Type or Frequency (*ps* > .1) was observed at the anterior frontal electrodes. However, a significant interactive effect between Frequency and Relation Type was found [$F(1, 23) = 7.951$, $P = .010$, $\eta^2_p = .257$]. Further analysis found that the influence of Relationship type was only significant under low-frequency conditions at the anterior frontal electrodes (FPz: P =.055; FP1: P =.027; FP2: P =.004; AF3: P =.060; AF4: P =.021; AF8: P =.009), indicating that in the P200 time window, the ERP signal was significantly more positive under semantically related conditions than under unrelated conditions (see **Figure 2**).

In addition, the analyses showed that the effect of Frequency was significant in two regions (left central: $F(1, 23) = 4.506$, $P = .045$, $\eta^2_p = .164$and left posterior: $F(1, 23) = 10.470$, $P = .004$, $\eta^2_p = .313$).

[Insert **Figure 2** here]

The 300–500 ms Period (N400)

In the N400 time window, a significant main effect of Relation Type was found [$F(1, 23) = 9.082$, $P = .006$, $\eta^2_p = .283$] in the midline electrodes, indicating that the target primed by semantically-related words released a significantly less negative amplitude than unrelated primes (see **Figure 3**). In addition, a significant main effect of Relation Type was observed at the lateral sites.

[Insert **Figure 3** here]

FIGURE & TABLE LEGENDS:

Figure 1: Grand mean event-related potentials in response to target words, from representative electrodes (Fz, Cz, Pz), for homophonic and control pairs in the semantic task. This figure, taken from Wang et al. (2021)[26], shows that in the semantic judgment task, homophone pairs released a smaller N400 components than irrelevant conditions regardless of high and low frequencies.

Figure 2: Grand mean event-related potentials in response to target words from six anterior frontal electrodes (Fpz, Fp1, Fp2, AF3, AF4, AF8) for the semantically related and control pairs of low-frequency in the homophone task. This figure, taken from Wang et al. (2021)[26], shows that in the phonological judgment task, low-frequency semantic related words released a more positive P200 component than unrelated words.

Figure 3: Grand mean event-related potentials in response to target words, from representative electrodes (Fz, Cz, Pz), for the semantically related and control pairs in the homophone task. This figure, taken from Wang et al. (2021)[26], shows that in the phonological judgment task, semantically related pairs released a smaller N400 components than irrelevant conditions regardless of high and low frequencies.

DISCUSSION:

Experimental results and significance:

The purpose of this protocol was to infer the following: 1) whether the word recognition model is a feedforward model or an interactive model and 2) the interaction between the phonological and semantic patterns in Chinese two-character compound recognition of high and low frequency under different tasks. An interference paradigm of phonological and semantic matching task using the ERP technique was adopted. The ERP responses preceded by homophones and unrelated words to targets were compared in semantic judgment tasks that did not require a priori phonological processing to reveal when and whether phonology affects semantic processing. Similarly, for phonological judgment tasks that did not require a priori semantic processing, the ERP responses of target words triggered by semantic and unrelated words were compared to reveal whether and semantics interferes with phonological processing. Next, according to the latency of the relevant ERP components, the relative time course of semantic and phonological processing was compared, and the influence of word frequency on such processing patterns was checked.

Our results showed that the target primed by semantically related precedents in the phonological task and the targets primed by homophones in the semantic judgment task both triggered a significantly less negative N400 component than did the unrelated precedes, regardless of word frequency. Hence, for high-frequency words, the data suggested that semantic activation occurs earlier or at least no later than phonological processing during the recognition of Chinese two-character compounds in different tasks. In addition, the induced P200 component of low-frequency word pairs were significantly more positive than that of high-frequency word pairs in both semantic and phonological tasks. Other studies have also concluded that early ERP components may be sensitive to word frequency[27,28]. The earliest N1 and the P200 effects can also be, at least partly, due to the semantic processing of the previous word. However, for low-frequency words in the phonological judgment task, it was found that the semantically related pairs released a significantly larger P200 than the control condition. In contrast, it was found that P200 triggered by low-frequency semantically related word pairs was significantly more positive than low-frequency control conditions in phonological judgment tasks. This result does not seem to be difficult to explain for low-frequency words, as phonological activation is expected in phonological judgment tasks, but the obvious P200 component was triggered by semantic precedents, which again strengthened the hypothesis that semantic processing may not occur later than phonological processing.

The above interaction between semantics and phonology confirmed the interaction model of word recognition that proposed that the system may be fully interactive, with low-level information flowing from bottom to top to the entire lexical information and high-level information flowing from top to bottom to form early visual word processing[1]. In addition, the P200 caused by frequency effects in the two tasks also confirmed the speculation that higher-level linguistic information may already exert its influence during early processing. Note that the interactions found in the two tasks, regardless of the high- and low-frequency conditions, supported the automatic and possibly mandatory access to phonology and meaning during reading. However, the specific time at which this interaction occurred may have been affected by the task and frequency. For example, for low-frequency words, it was found that the interaction occurred in the P200 time window in the phonological task while in the N400 time window in the semantic judgment task. Nevertheless, for high-frequency words, the interaction was observed in the N400 time window for both semantic or phonological tasks. In conclusion, the current findings suggest the automatic interaction of semantics and phonology in a task-independent manner while considering that the interactive time and mode may be affected by tasks, frequency, etc.

Effectiveness of the method

In general, this interference paradigm can more comprehensively explore the interaction modes of phonological and semantic processing. Our experiments included phonological matching tasks that do not require priori semantic processing and semantic matching tasks that do not require priori phonological processing. In this way, the influence of semantics on phonological processing or the influence of phonology on semantic processing can be observed more clearly. Furthermore, as the phonology or semantics of the precedents and the target word need to be compared in both tasks, the phonology or semantics are forcibly activated in the two tasks. Therefore, if any interference effect occurs, it will be more obvious. The common method of exploring word recognition is a lexical decision task that includes priming conditions. Specifically, it only needs to judge whether the target word is a real word or a pseudoword. First, the semantic activation of lexical decision tasks may not be strong enough, and second, a single judgment task cannot explore the interaction mode under different tasks. Therefore, the interference paradigm of the two tasks may be more suitable for exploring the word recognition model. For the two distinct tasks of the interference paradigm, one needs to strongly activate semantic processing, and the other needs to strongly activate phonological processing, which is more conducive to exploring whether the interaction between phonology and semantics is task-independent and how to interact under different tasks.

Future applications of the technique

The present protocol was the first to use the interference paradigm to explore the semantic access to Chinese two character compound of high- and low-frequency. Currently, the two-task interference paradigm rarely appears in the studies of word recognition in alphabetic languages. Therefore, this method may provide a new opportunity for different languages characterizing by different relations between orthography, phonology, and semantics to explore word recognition models.

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DISCLOSURES:

There are no competing financial interests.

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27 Carreiras, M., Vergara, M., Barber, H. Early event-related potential effects of syllabic processing during visual word recognition. *Journal of Cognitive Neuroscience.* **17** (11), 1803-1817 (2005).

28 Hauk, O., Davis, M. H., Ford, M., Pulvermuller, F., Marslen-Wilson, W. D. The time course of visual word recognition as revealed by linear regression analysis of ERP data. *Neuroimage.* **30** (4), 1383-1400 (2006).

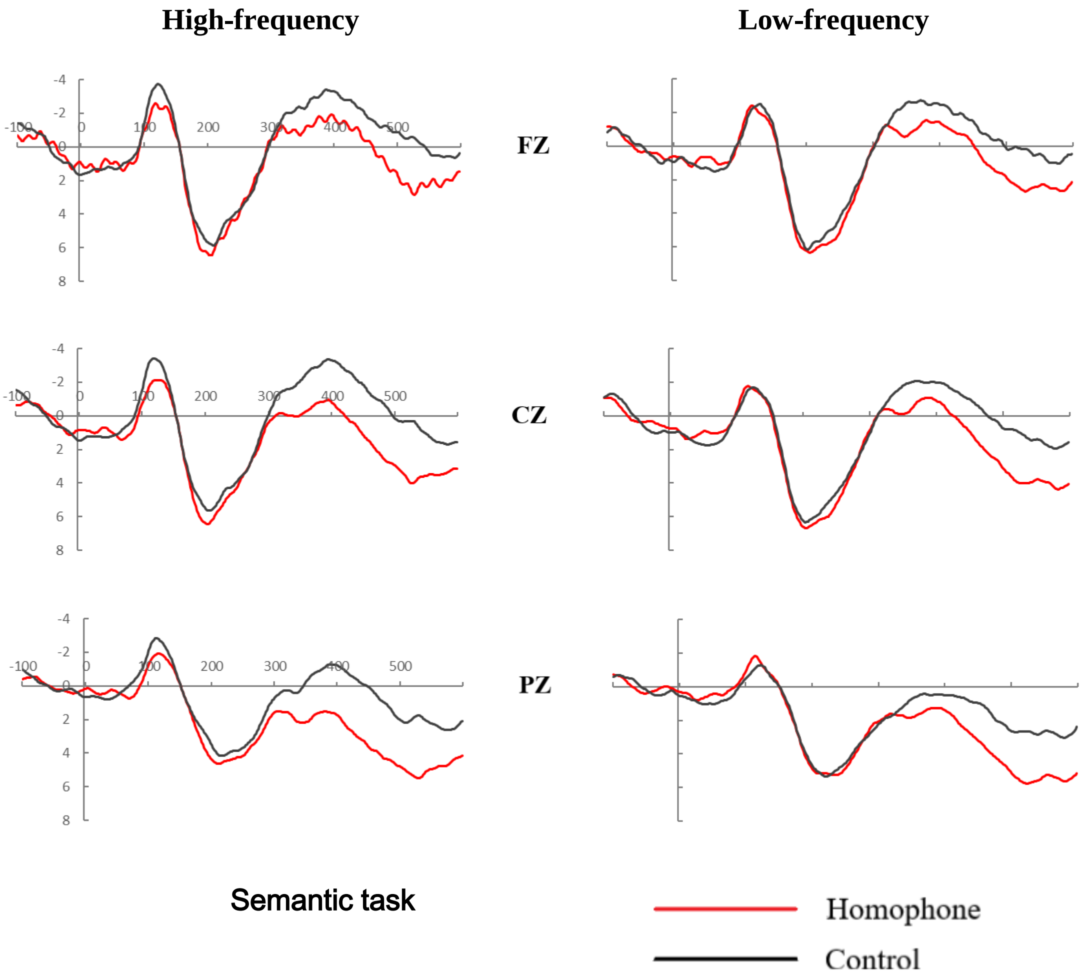
High-frequency
Low-frequency
FZ
CZ
PZ
-100
0
100
200
300
400
500
-4
-2
0
2
4
6
8
Semantic task
Homophone
Control

Figure 1.

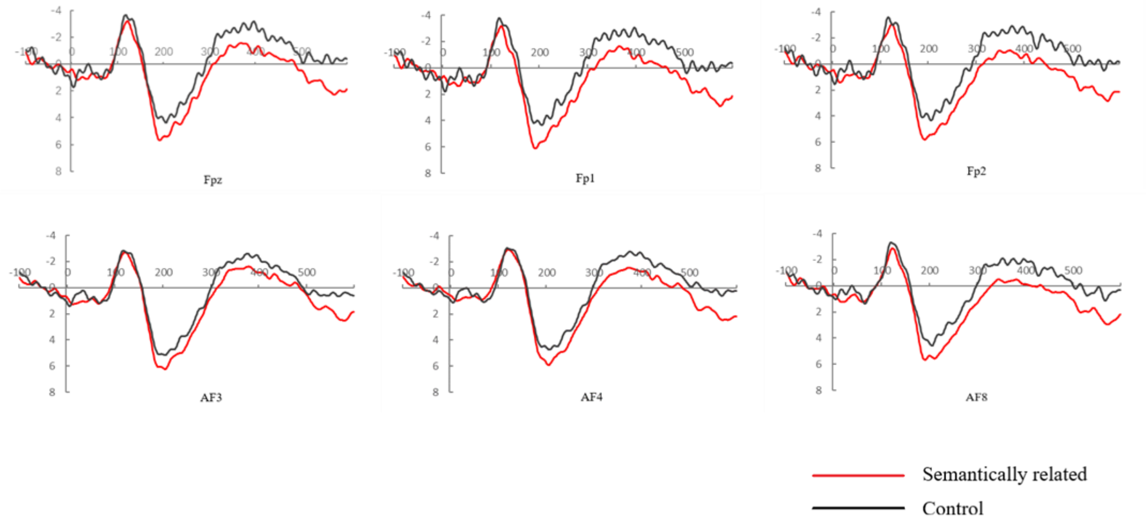

Figure 2.

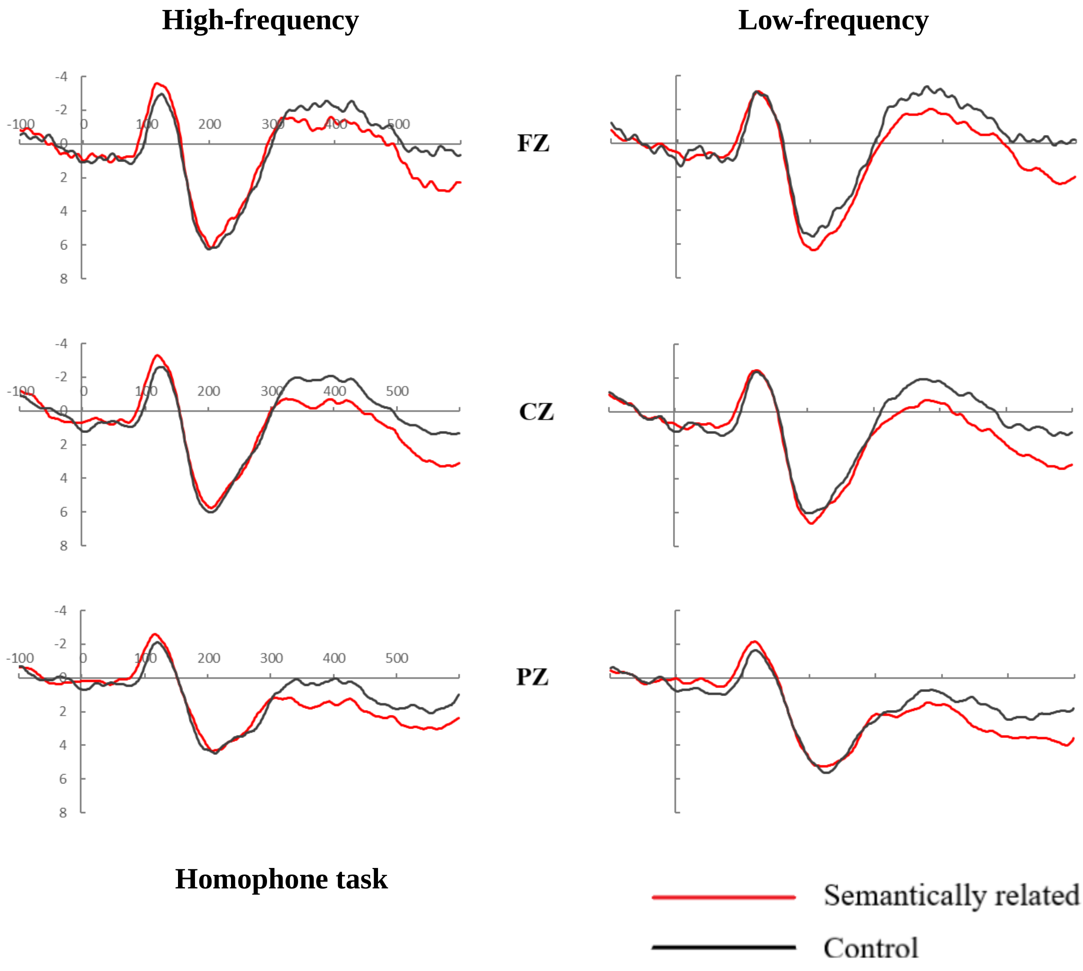
High-frequency
Low-frequency
FZ
CZ
PZ
-4
-2
0
2
4
6
8
-100
0
100
200
300
400
500
Homophone task
Semantically related
Control

Figure 3.

Click here to access/download
Table of Materials
Table of Materials.xlsx

Editorial comments:

Changes to be made by the Author(s):

1.Please take this opportunity to thoroughly proofread the manuscript to ensure that there are no spelling or grammar issues.

Reply: Thanks for the kind remind. The full manuscript has been proofread by our own and professional proofreading team "Taylor & Francis".

2. Please revise the following lines to avoid overlap with previously published work: 27-28, 31-34, 113, 286-291, 294-297, 321-324, 370-371, 382-385, 388-390

Reply: Thanks for the kind remind. All the repeated sentences above have been rewritten or quoted.

3. Please ensure that all text in the protocol section is written in the imperative tense as if telling someone how to do the technique (e.g., "Do this," "Ensure that," etc.). The actions should be described in the imperative tense in complete sentences wherever possible. Avoid usage of phrases such as "could be," "should be," and "would be" throughout the Protocol. Any text that cannot be written in the imperative tense may be added as a "Note."

Reply: Thanks for the kind remind. All text in the protocol section that were not imperatives have been corrected.

4. The Protocol should contain only numbered action items that direct the reader to do something.

Reply: Thanks for the kind remind. We reconfirmed that the protocol part only contains numbered action items.

5. We cannot have non numbered paragraph The Protocol should be made up almost entirely of discrete steps without large paragraphs of text between sections. Please simplify the Protocol so that individual steps contain only 2-3 actions per step.

Reply: Thanks for the kind remind. We have tried to simplify the Protocol.

6. Please include inclusion exclusion criteria for the recruitment for this study. Age specific bias?

Reply: Thanks for the kind remind. We have added the age requirement of participants, 18-28 years old.

7. Please add more details to your protocol steps. Please ensure you answer the "how" question, i.e., how is the step performed?

Reply: Thanks for the kind remind. At the request of the fourth reviewer, we have added equipment parameters for recording EEG and EEG pre-processing steps in the protocol section.

8. 1.2: How do you build the program? Please include all details. How long is each practice session?

Reply: Thanks for the kind remind. We added that the entire program can be written by E-Prime or other programming languages. In addition, we also detailed the core structure of the entire program.

9. 2.1: Reasons for only recruiting right-handed people?

Reply: Thanks for the kind remind. EEG experiments generally recruit right-handed subjects to prevent the results from being affected.

10. There is a 10-page limit for the Protocol, but there is a 3-page limit for filmable content. Please highlight 3 pages or less of the Protocol (including headings and spacing) that identifies the essential steps of the protocol for the video, i.e., the steps that should be visualized to tell the most cohesive story of the Protocol.

Reply: Thanks for the kind remind. We have highlight the filmable content.

11. Please ensure the results are described in the context of the presented technique e.g., how do these results show the technique, suggestions about how to analyze the outcome, etc. The paragraph text should refer to all of the figures. Data from both successful and sub-optimal experiments can be included.

Reply: Thanks for the kind remind. We have elaborated the analysis methods and interpretation of the results in as much detail as possible.

12. Please obtain explicit copyright permission to reuse any figures from a previous publication. Explicit permission can be expressed in the form of a letter from the editor or a link to the editorial policy that allows re-prints. Please upload this information as a .doc or .docx file to your Editorial Manager account. The Figure must be cited appropriately in the Figure Legend, i.e. "This figure has been modified from [citation]."

Reply: Thanks for the kind remind. We have obtained explicit permission to reprint the image, and the specific form is a reply letter from the editor. Please check the attachment for a detailed screenshot of the email.

13. As we are a methods journal, please ensure that the Discussion explicitly cover the following in detail in 3-6 paragraphs with citations:

a) Critical steps within the protocol

b) Any modifications and troubleshooting of the technique

c) Any limitations of the technique

d) The significance with respect to existing methods

e) Any future applications of the technique

Reply: Thanks for the kind remind. In the discussion section, we added subtitles to make the advantages and application value of this method more obvious.

14. Please upload the appendix as a supplementary file.

Reply: Thanks for the kind remind.

15. Please include a table of the essential supplies, reagents, and equipment. The table should include the name, company, and catalog number of all relevant materials in separate columns in an xls/xlsx file.

Reply: Thanks for the kind remind. We have added a table of the essential supplies, reagents, and equipment.

16. For the revision, please do not upload it as a new submission, please revise this submission and let us know if you are unable to do so.

Reply: Thanks for the kind remind.

Reviewers' comments:

Reviewer #1:

The article "Electrophysiology Reveals an Interaction between Phonological and Semantic Processes in Visual Word Recognition" details the method, data analysis, and interpretation of an experiment designed to measure ERPs to words in the phonological and semantic judgement tasks.

Major Concerns

My main concern with this work has to do with the control of the stimuli. The targets are divided into high-frequency and low-frequency, but there is no attempt that I can see to control these words on any of the myriad variables we know affect word recognition. This become a problem when the authors talk about differences in ERPs as a function of frequency as it is impossible to know if the differences are due to frequency or some other potential confound. It would be useful to evaluate the stimuli on other control variables to assure the reader that the effects are due to frequency.

Reply: Thanks for the kind remind. It is our fault that the variable control of the stimulus was not reported in detail in the submitted manuscript. However, it was described in the *frontiers in psychology*. The details are as follows:

"The target words consisted of 120 Chinese two-character compounds, and both high-and low-frequency words accounted for half the words. Each of the targets was paired with three analogues: a phonologically identical word (a homophone), a word of related meaning, and a control (unrelated) word. High-frequency target words were always paired with high-frequency preceding words, low-frequency targets were always paired with low-frequency precedes, and both tended to be consistent in terms of the number of strokes and frequency. In addition, the semantic association between semantically related pairs were strictly controlled. A separate group of 30 participants evaluated the degree of semantic relevance between the semantically related pairs used in this study on a 7-point scale, with 1 reflecting the lowest and 7 the highest relevance. The average score of the high-frequency semantically related word-pairs was 5.62, and the average score of the low-frequency pairs was 5.73, with no significant difference between these ($p > .1$). In addition, the semantic relatedness between the homophonic pairs and unrelated pairs was also no significant difference ($p > .1$). All stimuli used in this study are shown in Appendix.

All materials in this experiment are selected from the Xiandai Hanyu Pinlu Cidian [Modern Chinese Frequency Dictionary]. The low-frequency words are selected from a word list of less frequently used words in the dictionary which every word appears less than 8 times per million. The high-frequency words in this experiment are mainly selected from the high-frequency list in the dictionary which every word appears more than 800 times per million.

The whole experiment was divided into six blocks, three for semantic judgment tasks and three for phonological judgment tasks. The order of item presentation within each block was random and the block order was counter-balanced across-subjects. There were 144 trials per block, including 120 test trials and 24 filler trials. Half of the trials used high-frequency word-pairs and the other half used low-frequency word-pairs. For each frequency, 20 trials were performed on semantically related pairs, 20 trials were performed on homophone pairs, and 20 trials were performed on unrelated pairs. Consequently, a total of 864 trials were included in the present experiment. Each target word appears only once in each block. Filler trials were used to reduce reaction bias due to unequal number of trials requiring positive or negative reactions."

Wang, Y., Jiang, M., Huang, Y. & Qiu, P. An ERP Study on the Role of Phonological Processing in Reading Two-Character Compound Chinese Words of High and Low Frequency. *Frontiers in Psychology.* **12**, doi:10.3389/fpsyg.2021.637238, (2021).

As for other variables that affect word recognition: such as length, phonological similarity, were more obvious. Our experimental materials are all two-character compounds, so the length is 2. The pronunciation of homophones is exactly the same regardless of the spelling and tone, while the semantically related pairs are completely different to the pronunciation. In general, we have tried our best to control other variables that may influence the conclusion. In addition, in the stimuli construction part, we have briefly added the above frequency and semantic related value information.

Minor Concerns

There are numerous wording issues that need to be corrected.

Reply: Thanks for the kind remind. The full manuscript has been proofread by our own and professional proofreading team "Taylor & Francis".

How was the duration of 140ms chosen for the preceding word?

Reply: Thanks for the kind remind. Different from the common lexical decision task that only needs to judge the target word, the task of our experiment is to judge whether the preceding-target word matches in semantics or phonology, so the preceding word needs to be clearly seen by the participants. After comprehensive consideration, the masked priming time of about 50 ms cannot be selected, and about 200ms may be too long. Furthermore, considering that Chinese low-frequency two-character compounds are difficult to recognize in a short time, we finally chose 140ms to preceding time.

The choice of preceding time is very important, and it is the first time that we have verified the influence of semantics on early word recognition by setting up the Chinese lexical interference task above. Later, we verified the above conclusions again through two different experiments. Specifically, we continued to explore whether semantics had an impact on early morphological decomposition. We used traditional masked and non-masked lexical decision tasks. The specific priming times were set at 50 and 200ms respectively. Both of them once again found that semantics has an influence on early word processing. The above results undoubtedly strengthen the credibility of the interactive activation model for word recognition (This article has been submitted to the *Language Cognition and Neuroscience*).

Reviewer #2:

Manuscript Summary:

Using the interference paradigm, the authors examined the phonological and semantic processing in Chinese two-character word recognition by means of the ERP technique. The results suggested inevitable interactions between these two types of processing, which were likely to be influenced by word frequency.

Major Concerns:

The language seems to be too poor.

Reply: Thanks for the kind remind. The full manuscript has been proofread by our own and professional proofreading team “Taylor & Francis”.

Reviewer #3:

Manuscript Summary:

The previous studies on the present research topic are conducted mostly on alphabetic languages. These studies have suggested heavy phonological involvement on lexical conceptual access (i.e., lexical access). However, studies on lexical access in Chinese have provided two separate views: (1) lexical access via purely orthographic representations with no or little involvement of phonological representations and (2) lexical access via interactive (or concurrent) activations of both orthographical and phonological representations. Using electroencephalogram (EEG), the present study by Wang et al. provided evidence for interactive activations of orthography and phonology for lexical access. The methodology and analyses used in their study are sufficient with no ethical problems. The authors utilized two different experimental tasks, (1) the phonological judgement task and (2) the semantic judgement task. Although these two tasks were expected to require different activations for performance, similar components (P200 and N400) and the frequency effect were found in EEGs of both tasks. This result supports the interactive view of orthography and phonology for lexical access. The experimental approach of the present study is worth introducing in JoVE, especially focusing on (1) two different views of lexical access, (2) stimulus selection procedure, (3) EEG experimental technique, and (4) EEG result interpretation.

Major Concerns:

Line 158 - The interval of two stimulus presentations was set at 140ms. This seems to be a longer version of "priming condition". The interval duration may be long enough to activate orthographic and phonological representations of a primed-like lexical item. After the interval, the next target stimulus is presented to perform the task(s). This interval duration plus decision time may give participants enough time to activate a target phonological representation while accessing the lexical concept in both phonological and semantic judgements. Authors should explain the difference between the traditional priming task and the phonological/semantic judgement tasks used in the present study.

Reply: Thanks for the kind remind. We completely agree with your opinion. The goal of this research was to explore the role of phonology in Chinese word recognition and simultaneously attempt to determine whether the activation of phonology and semantics is in task-independent. Since we are the first study to verify the interaction model through the interference task of Chinese two-character compounds, and we were also not completely convinced of this result at first. Regarding the P200 frequency effect in this experiment, there may be two explanations. First, this early component may be a carry-over effect of the processing of the primes. Because our priming words were only presented for 140ms, the subjects may still process the primes when the target words were presented. Thus, the P200 effect may be the carry-over of the primes' N400 and late positive components. Second, it has been reported that early ERP components are sensitive to lexical frequency (Carreiras et al., 2005;Hauk et al., 2006). So the P200 frequency effect in our experiment may prove a top-down flow of information during visual word recognition.

However, in order to verify the above results, and also to further explore whether semantics have an influence on the early morphological decomposition, we conducted two common lexical decision experiments with masked (50ms) and unmasked (200ms) priming paradigms (This article has been submitted to the *Language Cognition and Neuroscience*). These two experiments once again obtained the effect of semantics on early word recognition, which echoes the results of this article. In addition, we highlight the advantages of the research method in this article in the discussion section, as follows:

Effectiveness of the method

"In general, this interference paradigm can more comprehensively explore the interaction modes of phonological and semantic processing. Our experiments included phonological matching tasks that do not require priori semantic processing and semantic matching tasks that do not require priori phonological processing. In this way, the influence of semantics on phonological processing or the influence of phonology on semantic processing can be observed more clearly. Furthermore, as the phonology or semantics of the precedents and the target word need to be compared in both tasks, the phonology or semantics are forcibly activated in the two tasks. Therefore, if any interference effect occurs, it will be more obvious. The common method of exploring word recognition is a lexical decision task that includes priming conditions. Specifically, it only needs to judge whether the target word is a real word or a pseudoword. First, the semantic activation of lexical decision tasks may not be strong enough, and second, a single judgement task cannot explore the interaction mode under different tasks. Therefore, the interference paradigm of the two tasks may be more suitable for exploring the word recognition model. For the two distinct tasks of the interference paradigm, one needs to strongly activate semantic processing, and the other needs to strongly activate phonological processing, which is more conducive to exploring whether the interaction between phonology and semantics is task-independent and how to interact under different tasks."

On the whole, the interference paradigm is not superior to the traditional priming paradigm, may be more suitable for discussing the issues that this article focuses on.

Minor Concerns:

Line 92 - The authors simply stated that the lexical decision task is not adequate. The detailed reason should be presented.

Reply: Thanks for the kind remind. In the introduction section, we briefly compared the traditional priming paradigm and the interference paradigm, but these two methods were compared in detail in the discussion section.

Line 143-165 - The present study seems to select well-controlled stimulus items (two-character Chinese words). However, no corpus resource and actual word frequencies were reported. Since the authors separated high and low frequency stimulus groups, detailed frequency information is needed. Readers (audience) would appreciate resource information of Chinese character/word frequencies.

Reply: Thanks for the kind remind. It is our fault that the variable control of the stimulus was not reported in detail in the submitted manuscript. However, it was described in the *frontiers in psychology*. The details are as follows:

"The target words consisted of 120 Chinese two-character compounds, and both high-and low-frequency words accounted for half the words. Each of the targets was paired with three analogues: a phonologically identical word (a homophone), a word of related meaning, and a control (unrelated) word. High-frequency target words were always paired with high-frequency preceding words, low-frequency targets were always paired with low-frequency precedes, and both tended to be consistent in terms of the number of strokes and frequency. In addition, the semantic association between semantically related pairs were strictly controlled. A separate group of 30 participants evaluated the degree of semantic relevance between the semantically related pairs used in this study on a 7-point scale, with 1 reflecting the lowest and 7 the highest relevance. The average score of the high-frequency semantically related word-pairs was 5.62, and the average score of the low-frequency pairs was 5.73, with no significant difference between these ($p > .1$). In addition, the semantic relatedness between the homophonic pairs and unrelated pairs was also no significant difference ($p > .1$). All stimuli used in this study are shown in Appendix.

All materials in this experiment are selected from the Modern Chinese Frequency Dictionary. The low-frequency words are selected from a word list of less frequently used words in the dictionary which every word appears less than 8 times per million. The high-frequency words in this experiment are mainly selected from the high-frequency list in the dictionary which every word appears more than 800 times per million.

The whole experiment was divided into six blocks, three for semantic judgment tasks and three for phonological judgment tasks. The order of item presentation within each block was random and the block order was counter-balanced across-subjects. There were 144 trials per block, including 120 test trials and 24 filler trials. Half of the trials used high-frequency word-pairs and the other half used low-frequency word-pairs. For each frequency, 20 trials were performed on semantically related pairs, 20 trials were performed on homophone pairs, and 20 trials were performed on unrelated pairs. Consequently, a total of 864 trials were included in the present experiment. Each target word appears only once in each block. Filler trials were used to reduce reaction bias due to unequal number of trials requiring positive or negative reactions."

Wang, Y., Jiang, M., Huang, Y. & Qiu, P. An ERP Study on the Role of Phonological Processing in Reading Two-Character Compound Chinese Words of High and Low Frequency. *Frontiers in Psychology.* **12**, doi:10.3389/fpsyg.2021.637238, (2021).

As for other variables that affect word recognition: such as length, phonological similarity, were more obvious. Our experimental materials are all two-character compounds, so the length is 2. The pronunciation of homophones is exactly the same regardless of the spelling and tone, while the semantically related pairs are completely different to the pronunciation. In general, we have tried our best to control other variables that may influence the conclusion. In addition, in the stimuli construction part, we have briefly added the above frequency and semantic related value information.

Reviewer #4:

Manuscript Summary:

The present study aims at investigating the influence of phonology on visual word recognition in a semantic task and the influence of semantics in a phonological judgment task. The authors combined these paradigms with EEG recording to provide further exploration of the time-course of phonological and semantic effects during word recognition. The results highlighted automatic activation of phonology and semantics in the N400 component. Moreover, the authors found that the P200 component was mainly modulated by word frequency.

Major Concerns:

1/ The authors should be more explicit regarding their argument based on the Stroop task. As a reader of the manuscript, it is unclear why a lexical decision task is not suitable to address the questions raised by the authors and what is the link with the Stroop task.

Reply: Thanks for the kind remind. The purpose of the study determines the experimental method. The goal of this research was to explore the role of phonology in Chinese word recognition and simultaneously attempt to determine whether the activation of phonology and semantics is in task-independent. An interference paradigm of phonological and semantic matching task using the ERP technique was adopted. This interference paradigm can more comprehensively explore the interaction modes of phonological and semantic processing. Our experiments included phonological matching tasks that do not require priori semantic processing and semantic matching tasks that do not require priori phonological processing. In this way, the influence of semantics on phonological processing or the influence of phonology on semantic processing can be observed more clearly. Furthermore, as the phonology or semantics of the precedents and the target word need to be compared in both tasks, the phonology or semantics are forcibly activated in the two tasks. Therefore, if any interference effect occurs, it will be more obvious. The common method of exploring word recognition is a lexical decision task that includes priming conditions. Specifically, it only needs to judge whether the target word is a real word or a pseudoword. First, the semantic activation of lexical decision tasks may not be strong enough, and second, a single judgement task cannot explore the interaction mode under different tasks. Therefore, the interference paradigm of the two tasks may be more suitable for exploring the word recognition model. For the two distinct tasks of the interference paradigm, one needs to strongly activate semantic processing, and the other needs to strongly activate phonological processing, which is more conducive to exploring whether the interaction between phonology and semantics is task-independent and how to interact under different tasks.

At first we thought that Stroop task is a special lexical decision task, so it is listed separately. However, this task usually only contains colour words and their related vocabulary, so the results may not be representative. We deleted the discussion about Stroop task.

2/ The authors should cite some related studies when presenting their hypotheses. Indeed, they hypothesized that phonological related pairs should produce a less negative N400 waveforms as compared to unrelated pairs. However, in the literature in this research field, the N400 has been hypothesized to reflect lexico-semantic processing. Therefore, one alternative hypothesis could be that phonological processing may lead to some degree of activation at lexical-

semantic levels - rather than phonological processing occurs in the N400 time-window.

Reply: Thanks for the kind remind. In the hypothesis part, we have cited relevant studies, and we have also revised the hypothesis to " phonological processing may lead to some degree of activation at lexical-semantic levels ".

3/ In the section "prepare all stimuli", some critical information is missing. For instance, it is very important to match the "irrelevant words" to those used in the experimental conditions in terms of frequency, length, neighborhood density and son on. Similarly, it is unclear whether the control words were the same in both paradigms, or whether two lists of control words were used. Finally, no information is given regarding the selection criteria for the manipulation of lexical frequency.

Reply: Thanks for the kind remind. It is our fault that the variable control of the stimulus was not reported in detail in the submitted manuscript. However, it was described in the *frontiers in psychology*. The details are as follows:

"The target words consisted of 120 Chinese two-character compounds, and both high-and low-frequency words accounted for half the words. Each of the targets was paired with three analogues: a phonologically identical word (a homophone), a word of related meaning, and a control (unrelated) word. High-frequency target words were always paired with high-frequency preceding words, low-frequency targets were always paired with low-frequency precedes, and both tended to be consistent in terms of the number of strokes and frequency. In addition, the semantic association between semantically related pairs were strictly controlled. A separate group of 30 participants evaluated the degree of semantic relevance between the semantically related pairs used in this study on a 7-point scale, with 1 reflecting the lowest and 7 the highest relevance. The average score of the high-frequency semantically related word-pairs was 5.62, and the average score of the low-frequency pairs was 5.73, with no significant difference between these ($p > .1$). In addition, the semantic relatedness between the homophonic pairs and unrelated pairs was also no significant difference ($p > .1$). All stimuli used in this study are shown in Appendix.

All materials in this experiment are selected from the Xiandai Hanyu Pinlu Cidian [Modern Chinese Frequency Dictionary]. The low-frequency words are selected from a word list of less frequently used words in the dictionary which every word appears less than 8 times per million. The high-frequency words in this experiment are mainly selected from the high-frequency list in the dictionary which every word appears more than 800 times per million.

The whole experiment was divided into six blocks, three for semantic judgment tasks and three for phonological judgment tasks. The order of item presentation within each block was random and the block order was counter-balanced across-subjects. There were 144 trials per block, including 120 test trials and 24 filler trials. Half of the trials used high-frequency word-pairs and the other half used low-frequency word-pairs. For each frequency, 20 trials were performed on semantically related pairs, 20 trials were performed on homophone pairs, and 20 trials were performed on unrelated pairs. Consequently, a total of 864 trials were included in the present experiment. Each target word appears only once in each block. Filler trials were used to reduce reaction bias due to unequal number of trials requiring positive or negative reactions."

Wang, Y., Jiang, M., Huang, Y. & Qiu, P. An ERP Study on the Role of Phonological

Processing in Reading Two-Character Compound Chinese Words of High and Low Frequency. *Frontiers in Psychology.* **12**, doi:10.3389/fpsyg.2021.637238, (2021).

As for other variables that affect word recognition: such as length, phonetic similarity, were more obvious. Our experimental materials are all two-character compounds, so the length is 2. The pronunciation of homophones is exactly the same regardless of the spelling and tone, while the semantically related pairs are completely different to the pronunciation. In general, we have tried our best to control other variables that may influence the conclusion. In addition, in the stimuli construction part, we have briefly added the above frequency and semantic related value information.

4/ The authors mentioned that high-frequency words were preceded by high-frequency words. However, nothing is said for low-frequency target words. In the case they were preceded by a high-frequency word, how did the authors take into consideration a possible effect of frequency in their data?

Reply: Thanks for the kind remind. We have added that “low-frequency targets were always paired with low-frequency precedents”. Our experiment was divided into high-frequency words and low-frequency groups as a whole. High-frequency priming words always match high-frequency targets, and low-frequency precedes always match low-frequency targets, regardless of whether they are in the related group or the unrelated condition.

If the low-frequency target word is preceded by the high-frequency word, we have not considered this situation.

5/ As for the final set of stimuli, the authors should provide all values (mean and SD) regarding length, frequency, scores of semantic relatedness and of phonological relatedness, and so on…

Reply: Thanks for the kind remind. The variable control of this experiment has been replied to question 3.

6/ In the paragraph "set up formal experiments in blocks", it is mentioned that some filler trials as been added in the investigation. However, the reader has no information regarding the kind of trials it is.

Reply: Thanks for the kind remind. The experimental materials are allocated as follows：

“The whole experiment was divided into six blocks, three for semantic judgment tasks and three for phonological judgment tasks. The order of item presentation within each block was random and the block order was counter-balanced across-subjects. There were 144 trials per block, including 120 test trials and 24 filler trials. Half of the trials used high-frequency word-pairs and the other half used low-frequency word-pairs. For each frequency, 20 trials were performed on semantically related pairs, 20 trials were performed on homophone pairs, and 20 trials were performed on unrelated pairs. Consequently, a total of 864 trials were included in the present experiment. Each target word appears only once in each block. Filler trials were used to reduce reaction bias due to unequal number of trials requiring positive or negative reactions."

Specifically, the filler trials in each block are also half high-frequency and half low-frequency. For the block of semantic judgment task, filler trials were all semantically related pairs. For the block of phonological judgment task, filler trials were all homophone pairs.

7/ I think that it is not useful to provide the full explanation on how to set up a cap. Indeed, the setup is mainly driven by the type of EEG system used by the researchers. In a similar vein, the choice of mastoids as reference is dependent on researchers' choice. I think that there is too much detail on the setup, whereas nothing is mentioned on parameters used for EEG recording (bandpass, online filtering, sample rate, ...).

Reply: Thanks for the kind remind. The parameters used for EEG recording have been added in protocol section and as follows:

"All electrode impedances were kept below 10 kΩ. The EEG signal was amplified by the BrainAmpDC amplifier system (Brain Products GmbH) with a bandpass of 0.01 to 100 Hz and was continuously sampled at 500 Hz."

8/ Similarly, there is no information at all regarding EEG preprocessing which is crucial to understand how the authors obtained their ERP waveforms.

Reply: Thanks for the kind remind. The EEG preprocessing has been added in protocol section and as follows:

"The ERPs were computed from the 100 ms before to 600 ms after the onset of the target word (100 ms pre-target baseline). Semi-automatic Ocular Correction with Independent Component Analysis was adopted. The EEGs were bandpass-filtered offline from 0.05 to 30 Hz (zero phase shift mode, 24 dB/oct). Epochs exceeding ±80μV were automatically discarded by artifact rejection and trials that responded incorrectly were also eliminated. Overall, 17.4% of the trials were discarded."

9/ The authors should be very careful when analyzing and interpreting their data, since the related pairs and unrelated pairs (that are compared) to do require the same behavioral response. Thus, how the authors did take that into consideration?

Reply: Thanks for the kind remind. Sorry, I don't understand your question. Since we are the first study to verify the interaction model through the interference task of Chinese two-character compounds, and we were also not completely convinced of this result at first. However, in order to verify the above results, and also to further explore whether semantics have an influence on the early morphological decomposition, we conducted two common lexical decision experiments with masked (50ms) and unmasked (200ms) priming paradigms (This article has been submitted to the *Language Cognition and Neuroscience*). These two experiments once again obtained the effect of semantics on early word recognition, which echoes the results of this article.

10/ Behavioral data should be described, and the statistical analyses reported in the manuscript.

Reply: Thanks for the kind remind. The target word presented for 500 ms. Then, a questioning cue "?" was presented until the participant were asked to press a button as quickly and accurately as possible once they made their decision for the word-pairs just presented. We found that although the ERPs were recorded from the onset of target word, the behavioural data was recorded from the onset of "?". This leads to our response time seems to be about 300-400ms less, so we did not reported behaviour data. However, it is worth noting that both the error rate and reaction time data are basically consistent with the ERP results. In the following article, the starting point of behavioural data recording was highlighted, and the data was also analysed in detail.

Wang, Y., Jiang, M., Huang, Y. & Qiu, P. An ERP Study on the Role of Phonological Processing in Reading Two-Character Compound Chinese Words of High and Low Frequency. *Frontiers in Psychology.* **12**, doi:10.3389/fpsyg.2021.637238, (2021).

11/ Regarding the interpretations, it is difficult to follow, since we cannot exclude that the phonological effect observed in the 300-500 ms in the semantic task could be sustained by other stimuli characteristics (or rather other types of differences between related and unrelated pairs), since the reader did not know how related pairs and unrelated pairs are matched. The same critic can be applied to the semantic effect obtained in the phonological task.

Reply: Thanks for the kind remind. We have tried our best to control other variables that may influence the conclusion. For a detailed answer, see question 3.

12/ Based on Figure 1, why the authors did not perform any statistical analyses in earlier time-window? It seems that control pairs are clearly associated with larger negativities compared with homophone pairs in the 100-150 ms over the left hemisphere.

Reply: Thanks for the kind remind. Because N1 was not analysed in the relevant literature we consulted, we did not consider this component originally. In the results section of this article, the data analysis results on N1 have been added.

ERP Results for the Semantic Judgment Task

THE 100-150-ms Period (N1)

For the midline electrodes, the ANOVA yielded a main effect of Frequency [$F(1, 23) = 9.451$, $P = .005$, $\eta^2_p = .291$], indicating that high-frequency pairs elicited a significantly more negative waveform than low-frequency condition. A similar significant main effect of Frequency was also observed at the lateral sites ($P = .008$). In addition, for high-frequency pairs, a significant main effect of Relation Type was also observed [$F(1, 23) = 8.826$, $P = .007$, $\eta^2_p = .277$], showing that unrelated pairs elicited a significantly more negative waveform than homophone condition. A similar significant main effect of Relation Type for high-frequency pairs was also observed at the left hemisphere.

ERP Results for the Homophone Judgment Task

THE 100-150-ms Period (N1)

No significant effect or interaction was found in the midline electrodes or lateral sites.

13/ It should be noted that the earliest "N1" and the P200 effects can also be, at least partly, due to the semantic processing of the previous word. Indeed, there is only 400 ms separating the presentation of the two words. It is then reasonable to think that processing of the preceding word is not fully done when the second word is displayed on screen. Therefore, there is still some influence of semantic processing in the ERP waveforms time-locked on the onset of the second word.

Reply: Thanks for the kind remind. In this article we did not explain the P200 in detail, but in the original paper in *Frontiers* we discussed the possibility you mentioned.

“Regarding the P200 frequency effect, there may be two explanations. First, this early component may be a carry-over effect of the processing of the primes. Because our priming words were only presented for 140ms, the subjects may still process the primes when the target words were presented. Thus, the P200 effect may be the carry-over of the primes’ N400 and late positive components. Second, it has been reported that early ERP components are sensitive to lexical frequency (Carreiras et al., 2005;Hauk et al., 2006). So the P200 frequency effect in our experiment may prove a top-down flow of information during visual word recognition.”

In addition, we have added this view in the discussion part of this article.

Minor Concerns:

1/ "fake word" (for instance, p3, l92) should be replaced with "pseudoword throughout the *manuscript.*

Reply: Thanks for the kind remind. All "fake word" have been replaced with "pseudoword throughout the manuscript.

2/ In the section "determine the final stimuli", the cutoff criteria for selecting lower and higher scores should be provided.

Reply: Thanks for the kind remind. We have added all the detailed information about the stimulus material.

3/ It is mentioned that participants could rest for 4 to 10 minutes after each block. This seems to be very long breaks. Is there any justification for this duration?

Reply: Thanks for the kind remind. Our task needs to determine whether the preceding and the target word are semantically or phonologically consistent, rather than just the target word. In addition, each block contains a large number of words (144 pairs), so the participants rested for an average of about 4 minutes after each block, and some participants would ask for a longer rest time.

4/ In the different sections in which the authors reported the statistical analyses, some values are missing. For instance, for the semantic task, no values are reported for the frequency effect in the P200 time-window as well as for the effect of relation type in the N400 time-window.

Reply: Thanks for the kind remind. The frequency effect in the semantic task was modified as follows:

ERP Results for the Semantic Judgment Task

The 160–280-ms Period (P200)

For the midline electrodes, the ANOVA yielded a main effect of Frequency [$F(1, 23) = 5.546$, $P = .027$, $\eta^2_p = .194$], indicating that low-frequency pairs elicited a significantly more positive waveform than high-frequency condition. No other significant effect or interaction was found in the midline electrodes. Moreover, the main effect of frequency was also found at the lateral sites.

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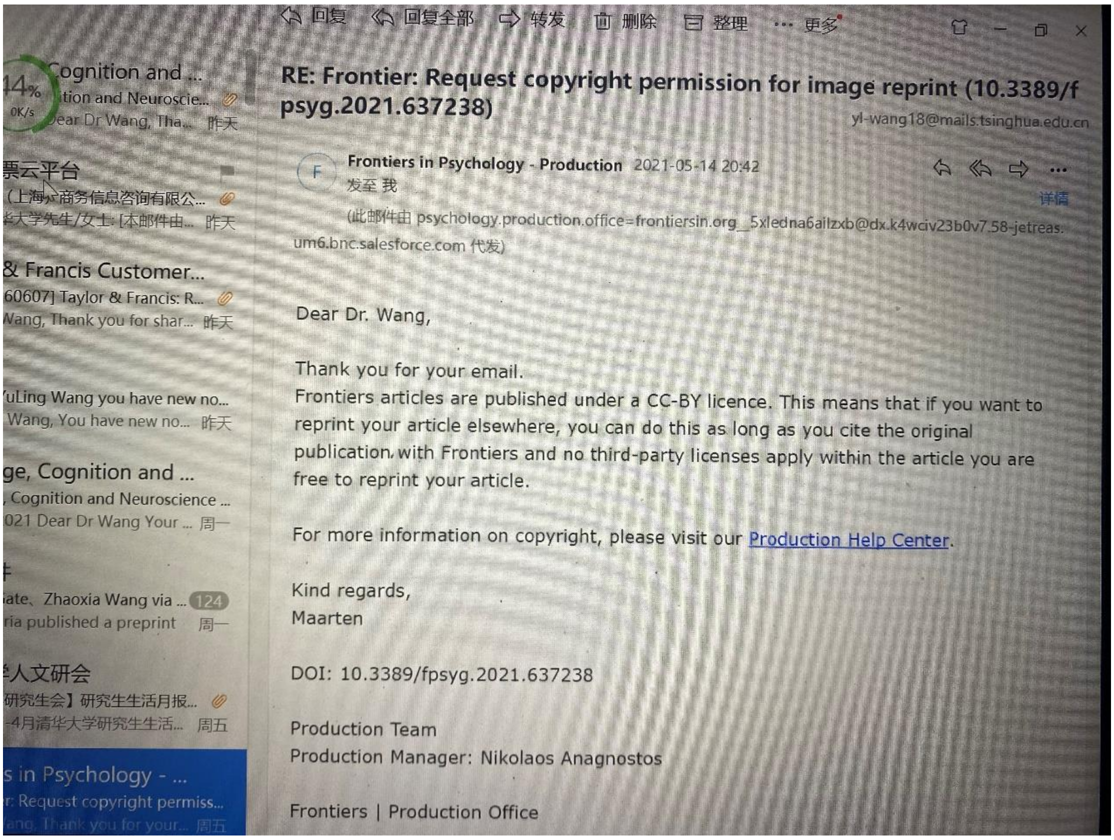

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APPENDIX

he first 60 rows of words form the high frequency group while the rest form the low frequency grou

	Phonological precede	Semantic precede	Control precede	Target
1	精力 jing(1)li(4)	体验 ti(3)yan(4)	政治 zheng(4)zhi(4)	经历 jing(1)li(4)
2	形成 xing(2)cheng(2)	路线 lu(4)xian(4)	要求 yao(1)qiu(2)	行程 xing(2)cheng(2)
3	店员 dian(4)yuan(2)	插座 cha(1)zuo(4)	非常 fei(1)chang(2)	电源 dian(4)yuan(2)
4	消瘦 xiao(1)shou(4)	市场 shi(4)chang(3)	母亲 mu(3)qin(1)	销售 xiao(1)shou(4)
5	进士 jin(4)shi(4)	眼镜 yan(3)jing(4)	活动 huo(2)dong(4)	近视 jin(4)shi(4)
6	失声 shi(1)sheng(1)	学校 xue(2)xiao(4)	汽车qi(4)che(1)	师生 shi(1)sheng(1)
7	报时 bao(4)shi(2)	肥胖 fei(2)pang(4)	中间 zhong(1)jian(1)	暴食 bao(4)shi(2)
8	闻名 wen(2)ming(2)	礼貌 li(3)mao(4)	计算 ji(4)suan(4)	文明 wen(2)ming(2)
9	骑士 qi(2)shi(4)	小看 xiao(3)kan(4)	立刻 li(4)ke(4)	歧视 qi(2)shi(4)
10	同化 tong(2)hua(4)	寓言 yu(4)yan(2)	批评 pi(1)ping(2)	童话 tong(2)hua(4)
11	密封 mi(4)feng(4)	昆虫 kun(1)chong(2)	身体 sheng(1)ti(3)	蜜蜂 mi(4)feng(4)
12	例证 li(4)zheng(4)	笔直 bi(3)zhi(2)	严重 yan(2)zhong(4)	立正 li(4)zheng(4)
13	冲击 chong(1)ji(1)	吃饱 chi(1)bao(3)	文学 wen(2)xue(2)	充饥 chong(1)ji(1)
14	遗弃 yi(2)qi(4)	设备 she(4)bei(4)	道理 dao(4)li(3)	仪器 yi(2)qi(4)
15	饱食 bao(3)shi(2)	钻戒 zuan(4)jie(4)	矛盾 mao(2)dun(4)	宝石 bao(3)shi(2)
16	升值 sheng(1)zhi(2)	怀孕 huai(2)yun(4)	旁边 pang(2)bian(1)	生殖 sheng(1)zhi(2)
17	经验 jing(1)yan(4)	漂亮 piao(4)liang(0)	明天 ming(2)tian(1)	惊艳 jing(1)yan(4
18	异议 yi(4)yi(4)	价值 jia(4)zhi(2)	服务 fu(2)wu(4)	意义 yi(4)yi(4)
19	只是 zhi(3)shi(4)	命令 ming(4)ling(4)	石油 shi(2)you(2)	指示 zhi(3)shi(4)
20	视线 shi(4)xian(4)	地区 di(4)qu(1)	热情 re(4)qing(2)	市县 shi(4)xian(4)
21	石狮 shi(2)shi(1)	执行 zhi(2)xing(2)	电影 dian(4)ying(3)	实施 shi(2)shi(1)
22	芝士 zhi(1)shi(4)	学问 xue(2)wen(4)	门口 men(2)kou(4)	知识 zhi(1)shi(4)
23	现成 xian(4)cheng(2)	乡村 xiang(1)cun(1)	首先 shou(3)xian(1)	县城 xian(4)cheng(2)
24	行事 xing(2)shi(4)	局面 ju(2)mian(4)	材料 cai(2)liao(4)	形势 xing(2)shi(4
25	立意 li(4)yi(4)	好处 hao(3)chu(4)	物质 wu(4)zhi(4)	利益 li(4)yi(4)
26	纪实 ji(4)shi(2)	秒表 miao(3)biao(3)	平原 ping(2)yuan(2)	计时 ji(4)shi(2)
27	起夜 qi(3)ye(4)	公司 gong(1)si(1)	内容 nei(4)rong(2)	企业 qi(3)ye(4
28	时务 shi(2)wu(4)	包子bao(1)zi(0)	成立 cheng(2)li(4)	食物 shi(2)wu(4)
29	旺季 wang(4)ji(4)	回忆 hui(2)yi(4)	道理 dao(4)li(3)	忘记 wang(4)ji(4)
30	升涨 sheng(1)zhang(3)	成熟 cheng(2)shu(2)	责任 ze(2)ren(4)	生长 sheng(1)zhang(3)
31	示例 shi(4)li(4)	眼睛 yan(3)jing(0)	小时 xiao(3)shi(2)	视力 shi(4)li(4)
32	事迹 shi(4)ji(4)	时代 shi(2)dai(4)	介绍 jie(4)shao(4)	世纪 shi(4)ji(4)
33	职务 zhi(2)wu(4)	树木 shu(4)mu(4)	互相 hu(4)xiang(1)	植物 zhi(2)wu(4)
34	河里 he(2)li(3)	过分 guo(4)fen(4)	到处 dao(4)chu(4)	合理 he(2)li(3)
35	紧紧 jin(3)jin(3)	只有 zhi(3)you(3)	自由 zi(4)you(2)	仅仅 jin(3)jin(3)
36	工艺 gong(1)yi(4)	爱心 ai(4)xin(1)	报告 bao(4)gao(4)	公益 gong(1)yi(4)
37	织布 zhi(1)bu(4)	党委 dang(3)wei(3)	简单 jian(3)dan(1)	支部 zhi(1)bu(4)
38	集齐 ji(2)qi(2)	特别 te(4)bie(2)	昨天 zuo(2)tian(1)	极其 ji(2)qi(2
39	一栋 yi(2)dong(4)	联通 lian(2)tong(1)	哲学 zhe(2)xue(2)	移动 yi(2)dong(4
40	画功 hua(4)gong(1)	石油 shi(2)you(2)	天气 tian(1)qi(4)	化工 hua(4)gong(1)
41	晶莹 jing(1)ying(2)	销售 xiao(1)shou(4)	耳朵 er(3)duo(0)	经营 jing(1)ying(2)
42	声誉 sheng(1)yu(4)	怀孕 huai(2)yun(4)	商品 shang(1)pin(3)	生育 sheng(1)yu(4)
43	先验 xian(1)yan(4)	暗淡 an(4)dan(4)	处理 chu(3)li(3)	鲜艳 xian(1)yan(4)
44	预示 yu(4)shi(4)	厕所 ce(4)suo(3)	具体 ju(4)ti(3)	浴室 yu(4)shi(4)
45	鸡冠 ji(1)guan(1)	单位 dan(1)wei(4)	最近 zui(4)jin(4)	机关 ji(1)guan(1)
46	奇异 qi(2)yi(4)	明确 ming(2)que(4)	宣传 xuan(1)chuan(2)	歧义 qi(2)yi(4)
47	减值 jian(3)zhi(2)	几乎 ji(1)hu(1)	资料 zi(1)liao(4)	简直 jian(3)zhi(2)
48	笔试 bi(3)shi(4)	小看 xiao(3)kan(4)	成绩 cheng(2)ji(4)	鄙视 bi(3)shi(4)

49	前程 qian(2)cheng(2)	真心 zhen(1)xin(1)	原因 yuan(2)yin(1)	虔诚 qian(2)cheng(2)
50	祝愿 zhu(4)yuan(4)	生病 sheng(1)bing(4)	同学 tong(2)xue(2)	住院 zhu(4)yuan(4)
51	加剧 jia(1)ju(4)	沙发 sha(1)fa(1)	目的 mu(4)di(3)	家具 jia(1)ju(4)
52	劣势 lie(4)shi(4)	牺牲 xi(1)sheng(4)	提供 ti(2)gong(1)	烈士 lie(4)shi(4)
53	夹心 jia(1)xin(1)	升职 sheng(1)zhi(2)	例如 li(4)ru(2)	加薪 jia(1)xin(1)
54	揭示 jie(1)shi(4)	繁华 fan(2)hua(2)	报纸 bao(4)zhi(3)	街市 jie(1)shi(4)
55	连结 lian(2)jie(2)	朴素 pu(3)su(4)	人口 ren(2)kou(3)	廉洁 lian(2)jie(2)
56	实证 shi(2)zheng(4)	热点 re(4)dian(3)	论文 lun(4)wen(2)	时政 shi(2)zheng(4)
57	现世 xian(4)shi(4)	地区 di(4)qu(1)	帽子 mao(4)zi(0)	县市 xian(4)shi(4)
58	实心 shi(2)xin(1)	兼职 jian(1)zhi(2)	似乎 si(4)hu(2)	时薪 shi(2)xin(1)
59	明丽 ming(2)li(4)	声望 sheng(1)wang(4)	实验 shi(2)yan(4)	名利 ming(2)li(4)
60	便意 bian(4)yi(4)	遗传 yi(2)chuan(2)	商品 shang(1)pin(3)	变异 bian(4)yi(4)
61	耗竭 hao(4)jie(2)	皎白 jiao(3)bai(2)	粗疏 cu(1)shu(1)	皓洁 hao(4)jie(2)
62	中数 zhong(1)shu(4)	孝悌 xiao(4)ti(4)	茶坊 cha(2)fang(1)	忠恕 zhong(1)shu(4)
63	颌骨 he(2)gu(3)	黍米 shu(3)mi(3)	权柄 quan(2)bing(3)	禾谷 he(2)gu(3)
64	肃立 su(4)li(4)	姣好 jiao(1)hao(3)	讳言 hui(4)yan(2)	素丽 su(4)li(4)
65	货量 huo(4)liang(4)	晦暗 hui(4)an(4)	酣梦 han(1)meng(4)	豁亮 huo(4)liang(4
66	参试 can(1)shi(4)	饭厅 fan(4)ting(1)	怅然 chang(4)ran(2)	餐室 can(1)shi(4)
67	风蚀 feng(1)shi(2)	充盈 chong(1)ying(2)	芦蒿 lu(2)hao(1)	丰实 feng(1)shi(2)
68	附议 fu(4)yi(4)	田税 tian(2)shui(4)	镂空 lou(2)kong(1)	赋役 fu(4)yi(4)
69	丰益 feng(1)yi(4)	倜傥 ti(4)tang(3)	莴苣 wo(1)ju(4)	风逸 feng(1)yi(4)
70	古稀 gu(3)xi(1)	红利 hong(2)li(4)	辞章 ci(2)zhang(1)	股息 gu(3)xi(1)
71	榆钱 yu(2)qian(2)	湘鄂 xiang(1)e(4)	筹措 chou(2)cuo(4)	渝黔 yu(2)qian(2)
72	书立 shu(1)li(4)	婉约 wan(3)yue(1)	营私 ying(2)si(1)	淑丽 shu(1)li(4)
73	败叶 bai(4)ye(4)	探访 tan(4)fang(3)	媲美 pi(4)mei(3)	拜谒 bai(4)ye(4)
74	霉雨 mei(2)yu(3)	笑靥 xiao(4)ye(4)	凌驾 ling(2)jia(4)	眉宇 mei(2)yu(3)
75	凌宇 ling(2)yu(3)	监牢 jian(1)lao(2)	倒戈 dao(3)ge(1)	囹圄 ling(2)yu(3)
76	岂是 qi(3)shi(4)	赌咒 du(3)zhou(4)	缔约 di(4)yue(1)	起誓 qi(3)shi(4)
77	轻拂 qing(1)fu(2)	安闲 an(1)xian(2)	盐碱 yan(2)jian(3)	清福 qing(1)fu(2)
78	示警 shi(4)jing(3)	流俗 liu(2)su(2)	斟酌 zhen(1)zhuo(2)	市井 shi(4)jing(3)
79	鲫鱼 ji(4)yu(2)	妄图 wang(4)tu(2)	猖獗 chang(1)jue(2)	觊觎 ji(4)yu(2)
80	夹击 jia(1)ji(1)	野雉 ye(3)zhi(4)	宽宥 kuan(1)you(4)	家鸡 jia(1)ji(1)
81	球市 qiu(2)shi(4)	监禁 jian(1)jin(4)	甘霖 gan(1)lin(2)	囚室 qiu(2)shi(4)
82	倾心 qing(1)xin(1)	怡然 yi(2)ran(2)	遁去 dun(4)qu(4)	清馨 qing(1)xin(1)
83	幼鱼 you(4)yu(2)	拘泥 ju(1)ni(2)	盘踞 pan(2)ju(4)	囿于 you(4)yu(2)
84	电势 dian(4)shi(4)	遴选 lin(2)xuan(3)	船舷 chuan(2)xian(2)	殿试 dian(4)shi(4)
85	带劲 dai(4)jin(4)	泯灭 min(3)mie(4)	接洽 jia(1)qiao(4)	殆尽 dai(4)jin(4)
86	覆合 fu(4)he(2)	稽查 ji(1)cha(2)	胡琴 hu(2)qin(2)	复核 fu(4)he(2)
87	飞鸿 fei(1)hong(2)	黛绿 dai(4)lv(4)	督率 du(1)shuai(4)	绯红 fei(1)hong(2)
88	俯仰 fu(2)yang(3)	监护 jian(1)hu(4)	革履 ge(2)lv(3)	扶养 fu(2)yang(3)
89	归一 gui(1)yi(1)	加持 jia(1)chi(2)	湮没 yan(1)mo(4)	皈依 gui(1)yi(1)
90	倾卸 qing(1)xie(4)	对虾 dui(4)xia(1)	官宦 guan(1)huan(4)	青蟹 qing(1)xie(4)
91	绯夜 fei(1)ye(4)	内封 fei(4)feng(1)	俸禄 feng(4)lu(4)	扉页 fei(1)ye(4)
92	溶汇 rong(2)hui(4)	通透 tong(1)tou(4)	洗濯 xi(3)di(2)	融会 rong(2)hui(4)
93	倾销 qing(1)xiao(1)	碧空 bi(4)kong(1)	狐疑 hu(2)yi(2)	青霄 qing(1)xiao(1)
94	逆市 ni(4)shi(4)	冷观 leng(3)guan(1)	伏案 fu(2)an(4)	睨视 ni(4)shi(4)
95	目眶 mu(4)kuang(4)	铅锌 qian(1)xin(1)	沟壕 gou(1)hao(2)	钼矿 mu(4)kuang(4）
96	明慧 ming(2)hui(4)	避忌 bi(4)ji(4)	孤孀 gu(1)shuang(1)	名讳 ming(2)hui(4)
97	开市 kai(1)shi(4)	擦抹 ca(1)mo(3)	歉收 qian(4)shou(1)	揩拭 kai(1)shj(4)
98	经纪 jing(1)ji(4)	惶恐 huang(2)kong(3)	攀越 pan(1)yue(4)	惊悸 jing(1)ji(4)
99	后裔 hou(4)yi(4)	盛情 sheng(4)qing(2)	桅杆 wei(2)gan(1)	厚意 hou(4)yi(4)
100	丙烯 bing(3)xi(1)	发怵 fa(1)chu(4)	凝脂 ning(2)zhi(1)	屏息 bing(3)xi(1)
101	结利 jie(2)li(4)	零丁 ling(2)ding(1)	抹煞 mo(3)sha(4)	孑立 jie(2)li(4)
102	休市 xiu(1)shi(4)	神职 shen(2)zhi(2)	暮春 mu(4)chun(1)	修士 xiu(1)shi(4)

103	监查 jian(1)cha(2)	冲泡 chong(1)pao(4)	脉冲 mai(4)chong(1)	煎茶 jian(1)cha(2)
104	进制 jin(4)zhi(4)	酣畅 han(1)chang(4)	茅亭 mao(2)ting(2)	尽致 jin(4)zhi(4)
105	顾及 gu(4)ji(2)	顽症 wan(2)zheng(4)	蛮劲 man(2)jin(4)	痼疾 gu(4)ji(2)
106	休憩 xiu(1)qi(4)	拆卸 chai(1)xie(4)	寥落 liao(2)luo(4)	修葺 xiu(1)qi(4)
107	经售 jing(1)shou(4)	肥硕 fei(2)shuo(4)	劳顿 lao(2)dun(4)	精瘦 jing(1)shou(4)
108	胶质 jiao(1)zhi(4)	泰然 tai(4)ran(2)	知悉 zhi(1)xi(1)	焦炙 jiao(1)zhi(4)
109	宪制 xian(4)zhi(4)	考据 kao(3)ju(4)	淫威 yin(2)wei(1)	县志 xian(4)zhi(4)
110	浮世 fu(2)shi(4)	擦除 ca(1)chu(2)	鼓噪 gu(3)zao(4)	拂拭 fu(2)shi(4)
111	自缢 zi(4)yi(4)	大肆 da(4)si(4)	皂荚 zao(4)jia(2)	恣意 zi(4)yi(4)
112	甄姬 zhen(1)ji(1)	搜捕 sou(1)bu(3)	扪心 men(2)xin(1)	侦缉 zen(1)ji(1)
113	直译 zhi(1)yi(4)	迟疑 chi(2)yi(2)	冗杂 rong(3)za(2)	执意 zhi(2)yi(4)
114	时移 shi(2)yi(2)	拣获 jian(3)huo(4)	疏浚 shu(1)jun(4)	拾遗 shi(2)yi(2)
115	语意 yu(3)yi(4)	爪牙 zhao(3)ya(2)	拂晓 fu(2)xiao(3)	羽翼 yu(3)yi(4)
116	微贷 wei(1)dai(4)	告急 gao(4)ji(2)	田埂 tian(2)geng(3)	危殆 wei(1)dai(4)
117	研习 yan(2)xi(2)	秉承 bing(3)cheng(2)	梦呓 meng(4)yi(4)	沿袭 yan(2)xi(2)
118	雾面 wu(4)mian(4)	接见 jie(1)jian(4)	羸弱 lei(2)ruo(4)	晤面 wu(4)mian(4)
119	集聚 ji(2)ju(4)	紧迫 jin(3)po(4)	顺遂 shui(4)sui(4)	急遽 ji(2)ju(4)
120	池浴 chi(2)yu(4)	名扬 ming(2)yang(2)	赫然 he(4)ran(2)	驰誉 chi(2)yu(4)