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Understanding phonological processing in Chinese reading: A multidimensional literature review

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Abstract: This paper aims to provide a review of research on phonological processing in Chinese reading, addressing theoretical debates, experimental evidence, influencing factors, and the development of models. It discusses the core perspectives and focal points of contention surrounding the direct access viewpoint, the phonological mediation hypothesis, and the dual-route theory. Furthermore, it analyzes findings from behavioral experiments, Event-related Potential (ERP) studies, and cross-language comparisons while exploring how Chinese characters, tasks, and individual differences influence phonological processing. The paper summarizes existing models and highlights their challenges and future development directions. The findings suggest that phonological processing in Chinese reading is interactively influenced by multiple factors. Future research should delve deeper into the interplay between phonology, semantics, and graphic forms; broaden research methodologies; and consider individual differences and developmental aspects. This approach will enhance our understanding of the phonological processing mechanisms in Chinese reading, advance reading theory, and inform educational practices.

Keywords: Chinese reading; phonological processing; behavioral experiments; ERP experiments

1. Introduction

“Processing”, a core concept in cognitive science, was first proposed by George Miller [1] (a pioneer in cognitive psychology) in the 1950s to describe human mental operations on information, such as memory and language comprehension. However, the explicit theorization of “language processing” is attributed to Noam Chomsky’s [2] generative grammar theory (in “Syntactic Structures” in 1957) and David Marr’s [3] computational levels theory. And “phonological processing” means that the ability to process phonological information includes phoneme recognition (such as differentiating between /b/ and /p/), phonological working memory (retaining phonological sequences), and orthography-phonology conversion (extracting pronunciation during reading). The field of psycholinguistics has systematized it, studying the dynamic process of language from perception to comprehension. In the field of reading research, phonological processing has always been one of the core issues and is crucial for understanding the cognitive process of language. As a unique logographic writing system, the phonological processing mechanism in Chinese reading not only shows commonalities with alphabetic languages but also has its distinct characteristics. Chinese characters usually correspond to monosyllabic morphemes, and this correspondence makes the phonological processing process in Chinese reading more complex than that in alphabetic languages [4,5]. In-depth

exploration of the mechanism of phonological processing in Chinese reading not only helps us understand the universality and particularity of human language cognition more comprehensively but also provides an important basis for the development of reading theories and has significant guiding value for Chinese teaching practice. Therefore, this article aims to systematically review the relevant research on phonological processing in Chinese reading, analyze its theoretical disputes, experimental evidence, influencing factors, and model development in order to provide a clear context and new ideas for subsequent research in this field.

2. Theories and disputes on phonological processing in Chinese

2.1. Theories on the role of phonology in Chinese reading

2.1.1. Direct access viewpoint

The direct access viewpoint [6] holds that in the process of Chinese reading, readers can obtain semantics directly from the graphic information, and phonology does not participate in this process. The theoretical basis of this viewpoint lies in the characteristics of the Chinese logographic writing system, where there is a relatively direct connection between the graphic form of Chinese characters and semantics. For example, some studies have found through experiments that in specific reading tasks, the speed and accuracy of semantic judgment of Chinese characters by subjects are not significantly interfered with by phonological factors, indicating the existence of a direct visual semantic activation path independent of phonology [7]. This means that in some cases, readers can bypass the phonological link and understand semantics directly from graphic recognition, reflecting the non-necessity of phonological processing in Chinese reading.

2.1.2. Phonological mediation hypothesis

The phonological mediation hypothesis contends that during Chinese reading, the graphic form first activates the phonological representation and then activates semantics through phonology. This hypothesis has received support from some studies. For instance, in the experiment by Tan and Perfetti [8], they used the phonological mediation semantic priming paradigm and found that when the prime word was a homophone of the target word's synonym, it would have a significant priming effect on the naming of the target word. This indicates that phonological information can play an important mediating role in the semantic activation process in Chinese reading, supporting the viewpoint of the phonological mediation hypothesis.

2.1.3. Dual-route theory

The dual-route theory was proposed by Max Coltheart in 1980. It emphasizes the separate mechanisms of the lexical and non-lexical routes in reading, providing a classic framework for understanding normal reading and reading disorders. Despite the challenges from connectionist models, its explanatory power remains significant in cognitive neuroscience and clinical linguistics. The dual-route theory integrates the viewpoints of direct access [6] and phonological mediation, arguing that there are two routes in Chinese reading: one is the direct route from the graphic form to semantics, and the other is the route via phonological mediation to semantics. Under different reading conditions, these two routes play different roles. Generally speaking, for high-

frequency Chinese characters, readers are more inclined to use the direct route because the connection between the graphic form and semantics of high-frequency Chinese characters is close, allowing for quick and direct acquisition of semantics; while for low-frequency Chinese characters, the phonological mediation route may be more important because the connection between the graphic form and semantics of low-frequency Chinese characters is relatively weak, requiring the assistance of phonological information for semantic extraction. This theory provides a relatively comprehensive framework for explaining the diversity of phonological processing in Chinese reading.

2.2. Focus and problems of disputes

The direct access view posits that high-frequency characters can rapidly retrieve semantics through a direct orthography-semantics pathway [7]. However, it fails to account for the necessity of phonological mediation in the processing of low-frequency characters [8]. Although the dual-route theory integrates these two aspects, the ‘route–selection’ mechanism remains questionable: Is it determined solely by character frequency, or is it regulated by task demands (such as naming vs. semantic judgment)? Zhou and Marslen-Wilson [9] found that phonological activation had no significant effect in semantic tasks, suggesting that the collaboration of the two routes may be highly context-dependent. In the future, it is necessary to systematically examine the boundary conditions of route selection by manipulating character frequency, task types, and context richness (such as sentences vs. single characters).

3. Experimental research evidence on phonological processing in Chinese

3.1. Behavioral experimental studies

3.1.1. Semantic category judgment task

The semantic category judgment task by Van Orden has been widely used in Chinese reading research. In this type of experiment, a category name (such as “fruit”) and a target word (such as “梨” or “离”, which is homophonic to “梨”) are presented, and subjects are required to judge whether the target word belongs to the category. For Chinese subjects, when the target word is a stimulus that is homophonic to the category example (such as “离”), their reaction time and error rate will be affected. Some studies have found that when Chinese subjects judge such homophonic stimuli, their reaction time will be prolonged, and the error rate will also increase, indicating that phonological information plays an interfering role in the semantic category judgment task, suggesting that Chinese readers will automatically activate phonological information when processing semantics [10]. However, compared with subjects of alphabetic languages, this interference effect of Chinese subjects may be relatively weak, which may be related to the characteristics of the Chinese writing system.

3.1.2. Homophone judgment task

The homophone judgment task aims to investigate the phonological processing process of Chinese readers for homophones. In the experiment, pairs of homophones

or non-homophones are presented, and subjects are required to judge whether they are homophones. The research results show that when subjects judge homophones, the reaction time and error rate will be affected by multiple factors. For example, homophones with similar graphic forms may be easier to judge than those with large differences in graphic forms, indicating that graphic form information interacts with phonological information in the homophone judgment task. However, the homophone judgment task (such as “杨” and “扬”) requires participants to explicitly focus on phonological information, which may induce strategic phonological processing, and it is essentially different from the automatic phonological activation in natural reading [11]. Additionally, the phonological interference effect in semantic tasks (such as “鸭” and “压”) may fluctuate due to task instructions (such as emphasizing speed or accuracy), so it is necessary to control the task demand variables in the experimental design. In addition, factors such as the difficulty of the task and the reading experience of the subjects also have an impact on the judgment of homophones [11].

3.1.3. Priming paradigm experiment

The priming paradigm experiment studies the influence of the priming stimulus on the processing of the target stimulus by presenting the priming stimulus and the target stimulus. In Chinese reading research, semantic-related words, homophones, etc., are often used as priming stimuli. For example, when the priming word is “河” and the target word is “江”, a semantic priming effect will occur; when the priming word is “河” and the target word is “和” (homophone), a phonological priming effect will occur. It has been found that the magnitude and occurrence time of the phonological priming effect will be affected by multiple factors, such as the frequency of the priming word and the target word, semantic relatedness, and presentation time interval. These results indicate that phonological priming can facilitate the processing of the target word in Chinese reading, but its mechanism of action is complex and regulated by multiple factors [12].

3.2. Event-related Potential (ERP) experimental studies

3.2.1. P200 component and phonological processing

In the study of phonological processing in Chinese, the P200 component (a positive peak that occurs approximately 150–250 ms after the stimulus, commonly found in the fronto-central region) has drawn much attention. They discovered that compared with the control group with no phonological relation, homophonic or rhyming Chinese characters would induce a larger P200 amplitude, and the scalp distribution was concentrated in the central parietal area. This indicates that P200 can be modulated by phonological similarity at the lexical level, reflecting the early stage of phonological processing and its sensitivity to both syllable and sub-syllable levels of phonology [13]. However, Ziegler et al. [14] questioned the relationship between P200 and phonological processing, arguing that its functional significance remains to be clarified. Gao and Zhang [15] studied the electrophysiological activities of different types of sign recognition. In the experiment, participants identified real, pseudo, and false signs. The results showed that the recognition performance for pseudo signs was poorer, and the P200 component induced by pseudo signs was more positive than that

of real or false signs, indicating that more attention resources were allocated to pseudo signs. Although Kong et al. [13] found that homophones elicited a larger P200, Ziegler et al. [14] questioned its specificity, suggesting that P200 might reflect early attentional allocation (such as devoting more resources to pseudowords) rather than phonological processing itself [15]. The differences in P200 between Chinese and alphabetic writing systems (e.g., P200 in Chinese is more dependent on orthographic consistency) imply that its function may be modulated by the orthographic system, which requires cross-linguistic comparative experiments for verification.

The role of phonology in word recognition in Chinese reading is unclear and differs from that in English. Wang et al [16]. conducted an event-related potential experiment, asking participants to perform semantic and homophone judgment tasks for high-frequency or low-frequency word pairs. They found that the P200 component induced by low-frequency word pairs was larger than that of high-frequency word pairs in both tasks, suggesting that the semantic activation of both high- and low-frequency words might not be later than the phonological activation. Zhou [17] explored the interaction between P200, phonology, and graphic form. Therefore, the author proposed the concept of mapping consistency to describe the orthographic and phonological mapping relationship.

Bermúdez-Margaretto et al. [18] explored the changes in brain activity during silent reading training of new written word forms. The results showed that training led to rapid and stable facilitation in the processing of new words, reflected in the modulation of P200 and N400 components (a negative peak occurs approximately 300–500 ms after the stimulus, with the maximum amplitude in the centro-parietal region). Zhang et al. [19] used ERP (Event-Related Potential) technology to conduct a picture-character matching task to study the temporal dynamics of graphic form and semantic activation in Chinese character recognition. The results showed that the influence of graphic form occurred early and lasted for a long time, while the semantic effect appeared relatively late. Characters that shared graphic form with the picture had a smaller frontal P200.

These studies provide information for understanding language cognition from multiple dimensions, but there are still issues to be explored, such as the exact function of P200 under different conditions and the interaction patterns of phonology and graphic form processing in different languages.

3.2.2. N400 component and phonological processing

The N400 component is of great significance in semantic processing studies and has also attracted much attention in the study of phonological processing in Chinese. Ziegler et al. [14] did not observe a similar effect in English. This difference may stem from the weak regularity of the orthography-phonology-semantics mapping in Chinese. In Chinese, phonology takes a longer time to interact with semantics, resulting in a delay or weakening of the N400 effect. In the future, it is necessary to manipulate semantic transparency (such as transparent characters vs. opaque characters) to test this hypothesis. The sensitive manifestations of N400 to phonological information in different studies are not completely consistent, which may be related to factors such as experimental tasks, stimulus materials, and individual differences among subjects [9,14,20].

In addition to the P200 and N400 components, there are other studies focusing on the relationship between ERP components and the phonological processing of Chinese characters. Yu et al. [21] revealed the parallel phonological processing process of Chinese characters through the flanker task, providing a new perspective for the research on the phonological processing of Chinese characters.

3.2.3. Other components and phonological processing

In addition to the P200 and N400 components, there are other components in ERP studies related to phonological processing. For example, the N100 component (a negative peak occurring approximately 80–120 ms after the stimulus is commonly found in the primary auditory or visual perception areas) is usually considered related to early sensory processing, but in Chinese reading studies, it may also be affected by phonological information. Some studies have found that in phonological judgment tasks, the amplitude of N100 would change due to different phonological stimuli, indicating that N100 may participate in the early stage of phonological processing in Chinese [22]. In addition, some studies have focused on the role of components such as P300 in phonological processing in Chinese [23,24]. These components show changes related to phonological processing under different experimental conditions, further enriching our understanding of ERP components in phonological processing in Chinese, but their exact functions and mechanisms of action still need in-depth research.

3.3. Cross-language research evidence

3.3.1. Comparative studies between Chinese and alphabetic languages

There are significant differences in phonological processing between Chinese and alphabetic languages. Alphabetic languages have a more regular letter-phoneme correspondence relationship, and readers can quickly perform phonological decoding through this correspondence. However, Chinese lacks this regular correspondence, and the connection between the graphic form of Chinese characters and phonology is relatively weak. Comparative studies have found that during the reading process, readers of alphabetic languages rely more on phonological information for lexical recognition and semantic understanding, while Chinese readers pay more attention to graphic form information [25]. For example, in semantic category judgment tasks, the interference effect of homophones is more obvious for readers of alphabetic languages, while Chinese readers are more sensitive to stimuli with similar graphic forms. These differences reflect the characteristics of the phonological processing mechanism under different writing systems and provide an important reference for studying the uniqueness of phonological processing in Chinese reading.

3.3.2. Cross-language phonological processing

(1) Cross-language phonological processing of Chinese learners of English as a second language (Chinese ESL learners)

Chinese ESL learners' acquisition of alphabetic scripts has revealed the transfer effect of native-language phonological processing habits on second-language acquisition and its unique cognitive-neural mechanisms. This cross-linguistic influence extends beyond speech to written language processing. For example, Zhang and Kang [26] found that ESL writing exhibits high syntactic flexibility (e.g., more

adverbial clauses) and information density, reflecting how immersion environments shape learners' orthography-phonology-semantic mapping strategies. Studies have shown that when Chinese ESL learners learn alphabetic scripts (such as English), due to the weak association of orthography-phonology correspondence rules in their native language, their phonological processing patterns differ significantly from those of native speakers of alphabetic scripts. Neuroimaging evidence further clarifies these differences. Li et al. [27] revealed that Chinese ESL learners' spoken word segmentation relies on both TPJ (bottom-up processing) and PFC (top-down control), with higher proficiency linked to reduced TPJ activation (efficient encoding) and increased PFC engagement (strategic parsing), reflecting neural adaptation to immersive English phonology. Short-term training studies further support this plasticity: Bermúdez-Margaretto et al. [28,29] found that even without semantic reference, neural memory traces of new word forms can be formed through only a small amount of exposure, but the deep binding of phonology and semantics still requires long-term learning.

(2) Cross-language phonological processing of Chinese as a second language learners (CSL learners)

With the accumulation of second-language learning experience, learners gradually develop adaptive mechanisms. Yum and Law [30] found through electroencephalogram (EEG) research that in the processing of second-language words, the N170 component of CSL learners reflects both visual familiarity and automatic access to sub-lexical phonology, indicating that their neural processing system can dynamically integrate native-language orthographic experience with second-language phonological rules. For advanced learners, Han et al. [31] pointed out that they can partially compensate for the inefficiency of phonological decoding by strengthening parallel phonology-semantics processing (such as quickly activating phonological information and integrating it with the context), but the synchrony of this integration still lags behind that of native speakers. Neuroimaging evidence shows that proficient learners reduce their dependence on native-language-related brain regions (such as the left middle frontal gyrus) and instead recruit the temporo-parietal network required for alphabetic script processing [32,33].

Future research needs to combine multimodal technologies (such as fMRI and NIRS) with behavioral experiments to deeply explore the interaction patterns of phonology, semantics, and grapheme processing in different contexts, as well as the long-term impact of the depth of native-language orthography on second-language neural representation, so as to provide a scientific basis for optimizing second-language teaching strategies.

4. Factors affecting phonological processing in Chinese

4.1. Chinese character factors

4.1.1. Frequency of Chinese characters

The frequency of Chinese characters has an important influence on phonological processing. High-frequency Chinese characters, due to their frequent appearance in daily life, readers are more familiar with the connection between their graphic forms,

phonology, and semantics. Therefore, in reading, they can activate phonological information more quickly, and the accuracy of phonological activation is higher. On the contrary, the speed of phonological activation for low-frequency Chinese characters is relatively slow, and errors are more likely to occur. For example, in naming tasks, the naming reaction time of subjects for high-frequency Chinese characters is significantly shorter than that for low-frequency Chinese characters [21]. In addition, the frequency of Chinese characters also affects the relationship between phonological processing and semantic access. For high-frequency Chinese characters, phonological information may play an auxiliary and reinforcing role in the semantic access process, while for low-frequency Chinese characters, phonological information may be more critical and may even become the main way of semantic access.

4.1.2. Structure of Chinese characters

The structure of Chinese characters can be divided into single-component characters and compound characters. Compound characters contain phonetic radicals and semantic radicals. Phonetic radicals are usually related to the pronunciation of Chinese characters, and semantic radicals are related to semantics. Studies have shown that the phonological information of phonetic radicals in compound characters plays an important role in phonological processing. When the phonetic radical is consistent with the pronunciation of the whole character, it will facilitate the activation and recognition of phonology; when the phonetic radical is inconsistent with the pronunciation of the whole character, it may cause interference [34]. In addition, semantic radicals also have an impact on phonological processing because the semantic information provided by semantic radicals may affect the utilization of phonological information of phonetic radicals. For example, when the semantic radical has a high degree of correlation with semantics, readers may be more inclined to use semantic radical information to assist semantic understanding, thereby reducing the degree of dependence on phonological information of phonetic radicals [35]. The structure of Chinese characters can be divided into single-component characters and compound characters, and compound characters include phonetic radicals and semantic radicals. Studies have shown that the phonological information of the phonetic radicals of compound characters plays an important role in phonological processing. When the pronunciation of the phonetic radical is consistent with that of the entire character, it is conducive to the activation and recognition of the phonology; otherwise, it may cause interference [35]. Hsieh et al. [36] reviewed the concept of neighborhood behind the phonological consistency effect in Chinese character recognition over the past four decades and deeply explored the development of related research. Li et al. [37] went beyond the phonological perspective and explained the potential mechanisms of the neighborhood effect in Chinese character recognition, providing more theoretical support for understanding the relationship between the structure of Chinese characters and phonological processing. In addition, semantic radicals also have an impact on phonological processing because the semantic information provided by semantic radicals may affect the utilization of the phonological information of phonetic radicals.

4.2. Task factors

4.2.1. Task type

Different reading tasks have different requirements and influences on phonological processing. In semantic judgment tasks, readers need to pay attention to the semantic information of Chinese characters, but phonological information may also be automatically activated and interfere with semantic judgment. For example, when judging whether “鸭” and “压” belong to the category of “animal”, the phonological information of “压” may interfere with the judgment of the subjects. In pronunciation judgment tasks, readers need to focus on the phonological information of Chinese characters. At this time, graphic form and semantic information may have an impact on phonological judgment. For example, when judging whether “杨” and “扬” are homophones, their similar graphic forms may speed up the judgment speed of the subjects [10]. In addition, other task types, such as lexical judgment tasks, also have differences in the way readers pay attention to and utilize phonological information due to different task requirements.

4.2.2. Task difficulty

Task difficulty affects the process of phonological processing. When the task difficulty increases, such as using low-frequency words or complex sentence structures, readers may rely more on phonological information to assist understanding. When reading texts containing low-frequency Chinese characters, readers may work harder to recognize and understand these Chinese characters through phonology, and the participation of phonological processing will be higher. On the contrary, in simple tasks, readers may rely more on graphic form or semantic information, and the role of phonological processing is relatively small. In addition, the increase in task difficulty may also lead to changes in the allocation of readers' attention, thereby affecting the coordination of phonological processing and other information processes [38].

4.3. Individual factors

4.3.1. Reading proficiency

Individuals with different levels of reading proficiency show significant differences in phonological processing in Chinese. During reading, the utilization of phonological information by skilled readers is more automated, and they can more effectively use phonological cues to understand the text. Novice readers, due to insufficient reading experience, have a slower activation speed of phonology and have difficulties in integrating phonology and semantics. For example, when reading an article, skilled readers can quickly recognize the phonology of Chinese characters and understand their semantics, while novice readers may spend more time on phonological recognition and are prone to comprehension errors [10].

4.3.2. Language experience

Individuals' language experience has a profound impact on phonological processing in Chinese. Readers who have learned pinyin may have certain advantages in phonological processing because the pinyin system provides them with a tool to link graphic forms and phonology [39]. Studies have found that Chinese readers who have

learned pinyin perform better in phonological judgment tasks and phonological priming tasks and can activate phonological information more quickly [35].

5. Models and theoretical developments of phonological processing in Chinese

5.1. Overview of existing models

5.1.1. Lexical component model

The lexical component model was proposed by Perfetti et al [7,37]. This model emphasizes the rapid and mandatory nature of phonological activation in Chinese character recognition and its strong constraining effect on semantic activation. During the process of Chinese character recognition, phonological information is activated rapidly, and this activation precedes semantic activation and has a significant impact on the extraction and understanding of semantics. For example, in a lexical judgment task, when a Chinese character is presented, even if the task of the subjects is to judge whether the character is a real word, phonological information is automatically activated and plays a role in semantic judgment [40]. This hypothesis is supported by ERP research. For example, Kong et al. [13] found that homophones elicited a larger P200 amplitude, indicating that phonological information is activated in the early stage (150–250 ms) of lexical recognition, which is consistent with the prediction of ‘phonological pre-activation’ in the model. However, this model also faces some challenges. Van Orden [38] found that the homophone interference effect was significant in semantic tasks. However, Zhou and Marslen-Wilson [9] did not observe the influence of phonology on semantic judgment in similar experiments. This contradiction may stem from differences in stimulus materials: the former used low-frequency characters (which rely on phonological mediation), while the latter used high-frequency characters (where the orthography-meaning direct pathway dominates). This contradiction suggests that the Lexical Component Model needs to further clarify the boundary conditions of phonological activation (such as character frequency and semantic transparency) [9,41].

5.1.2. Parallel distributed processing model

The parallel distributed processing model emphasizes the parallel activation and interaction of orthographic, phonological, and semantic information [42]. It can account for cross-linguistic differences: Chinese readers rely more on orthographic information because the weak regularity of orthography-phonology correspondence in Chinese requires multi-dimensional information integration [43]. Reading depends on writing in Chinese. *Proceedings of the National Academy of Sciences*, 102(24), 8781–8785. In contrast, alphabetic script readers rely on phonological decoding. Neural evidence further supports this model: fMRI studies show that the processing of low-frequency characters activates the left inferior frontal gyrus (a brain region related to phonology), while high-frequency characters activate the occipito-temporal orthography-semantics pathway [37,44], indicating the neural bases of different routes. Additionally, Bermúdez-Margaretto et al. [45–48] found that new orthography learning rapidly modulates P200 and N400, suggesting the dynamic plasticity of the distributed network.

5.1.3. Development of the dual-route model

The early dual-route model advocated that there are direct routes (from graphic form directly to semantics) and indirect routes (reaching semantics via phonological mediation) in reading. With the advancement of research, it has been continuously improved and incorporates influencing factors such as the frequency of Chinese characters and task types. The dual-route model posits that high-frequency characters extract semantics through the orthography-semantics direct route, while low-frequency characters rely on the orthography-phonology-semantics indirect route [44]. This framework can effectively explain the frequency effect in behavioral experiments: the naming reaction time of high-frequency characters is significantly shorter than that of low-frequency characters [21], as the direct route is more efficient, and semantic judgment of low-frequency characters is more susceptible to homophone interference [38], which requires phonological mediation. In addition, in ERP research, low-frequency characters elicit a larger P200 amplitude [16], which may reflect the additional demand for phonological resources by the indirect route. However, Zhou [17] found the moderating effect of orthographic consistency on P200, suggesting that the dynamic collaboration of the dual routes may be constrained by the orthography-phonology mapping rules, and it is necessary to incorporate the mapping consistency variable into the model.

5.2. Challenges and development directions of the models

Existing models face many challenges when explaining the phenomenon of phonological processing in Chinese reading. The lexical component model has difficulty explaining the situation where phonological activation does not significantly affect semantic judgment in some experiments; the parameter setting of the parallel distributed processing model is complex, and the explanation of special reading phenomena is not precise enough; the dual-route model is deficient in dealing with the dynamic interaction between phonology and other information. The future development of models needs to integrate multi-dimensional information, such as context and individual differences. Incorporating context information can better explain the real-time changes of phonological processing in reading; considering individual differences (reading proficiency, language experience, etc.) can enhance the explanatory and predictive power of the model for the reading process of different readers. At the same time, combining the research results of neuroscience to improve the model from the neural mechanism level and make it more in line with the actual processing process of the brain is also an important development direction in the future. For example, using techniques such as fMRI and MEG to reveal the neural activity characteristics of phonological processing provides a more solid biological basis for model construction.

6. Conclusion

Phonological processing in Chinese reading is influenced by multiple interacting factors and is not the result of single-factor control. Various theories and experiments reveal both consensus and differences regarding the mechanisms and influencing factors of phonological processing. Behavioral experiments infer the automaticity of

phonological processing through differences in reaction times [10]. However, such indicators make it difficult to distinguish whether phonological activation is an early automatic process or a late strategic compensation. For example, in semantic category judgment tasks, participants may actively suppress phonological interference to improve accuracy. As a result, the prolonged reaction time does not simply reflect the automatic activation of phonology [7]. In the future, eye-tracking techniques (such as first-fixation duration and number of regressions) can be combined to capture the real-time dynamics of processing. ERP studies highlight the timing and brain activity associated with phonological processing through components such as P200 and N400. Cross-language research emphasizes the differences between phonological processing in Chinese and alphabetic languages, as well as the influence of native language on second language acquisition. Despite the insights gained through these multi-dimensional approaches, unresolved issues remain, necessitating further investigation. Additionally, there is a need for more studies on individual differences in phonological processing, particularly developmental trajectories across ages and reading abilities, to inform targeted interventions in Chinese reading education.

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