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Rethinking of the Regularity and Consistency Effects in Reading

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Various models of visual word recognition have been proposed to explain the underlying processes of orthography-to-phonology transformation. There is still a debate concerning whether regularity or consistency is more appropriate for representing the knowledge of orthography-to-phonology correspondences and characterizing the difficulty of word naming. This article reviews findings of related studies and suggests that neighborhood characteristics, such as the relative frequency of friends and enemies, play a central role across different languages. Studies that aim to integrate behavioral and electrophysiologyical approaches might help to reveal the temporal dynamics of reading processes.

Key words: consistency, regularity, reading

1. Introduction

Various models of visual word recognition have been proposed to explain how various properties of a written word (such as frequency, word length, and spelling-to-sound consistency/regularity) affect the speed and accuracy of reading words. These models can be broadly classified into two main types. One is the dual-route cascade (DRC) model (Coltheart et al. 1993, Coltheart et al. 2001). The other is the parallel distributed processing (PDP) model (Plaut 1996, Seidenberg & McClelland 1989). According to the DRC model, spelling-to-sound knowledge can be represented by the grapheme-to-phoneme corresponding (GPC) rules. The words can be defined as regular or irregular depending on whether their pronunciations follow the GPC rules. There are two distinctive routes from print to sound. One is the direct or lexical route, which allows high-frequency or irregularly spelled words to be "sounded out" by directly mapping the whole word form to its phonological representation. The other is the indirect or assembled route for regularly spelled words and pseudowords, in which the individual letter units (graphemes) are translated into corresponding sound units (phonemes) via the GPC rules. On the other hand, the PDP models emphasize the role of learning and claim that spelling-to-sound knowledge is represented in a distributed approach. Word recognition is an instantiation of a continuous and dynamic learning process that depends on the interaction among the new input, the current state of the system, and its previous history. The information provided by previous encounters with any given linguistic information is crucial in shaping the system's response. Therefore, the statistical consistency of a language and its use are important determinants of the system's behavior. To be more specific, spelling-to-sound knowledge is represented as weights on connections between units that represent spelling and those that represent sound. Since there is no representation for individual words and the same set of units and connections is used for all words, the naming of a given word is influenced by the knowledge of the pronunciations of other similarly spelled words.

In general, studies have found that spelling-to-sound regularity/consistency has little impact on the naming time or accuracy for high-frequency words. However, for low-frequency words, the irregular/inconsistent words are typically named significantly more slowly and less accurately than regular/consistent words (Jared 1997, Seidenberg et al. 1984, Seidenberg 1985, Taraban & McClelland 1987, Waters & Seidenberg 1985). The DRC model explains the frequency-by-regularity interaction based on the relative time course of processing along the two routes. For high-frequency words, the whole-word pronunciations can be directly retrieved from the lexicon before the assembled pronunciation derived from the indirect route. Thus, the regularity effect is not expected for reading high-frequency words. In contrast, for low-frequency words, the output of assembled and direct routes is available at the same time. Irregular words will be named more slowly and less accurately than regular words. This is because the output of the assembly route for irregular words is incorrect, and it takes more time to resolve the conflict with the correct output from the direct route. On the other hand, the PDP model predicts that the ease of pronouncing a word depends on the relative consistency of the pronunciation of the letter patterns in the word. Words with letter patterns that are always pronounced in the same manner when they appear in a word (e.g., -ADE in MADE, JADE, LADE, etc.) will be named more quickly and faster than words with letter patterns that are pronounced differently in different words (e.g., -AVE in WAVE and HAVE). This is the so-called consistency effect. This model further predicts that the consistency effect is only expected in reading low-frequency words. This is because the model's performance on naming words is also affected by the number of exposures to the word itself (the word frequency), and additionally, by whether the pronunciations for similarly spelled words are consistent or not. Thus, a larger number of exposures to high-frequency inconsistent words is sufficient to eliminate the effects of exposures to their orthographic neighbors with a variety of inconsistent pronunciations.

2. Consistency effect in high-frequency words

These two models differ in terms of their underlying philosophies for implementation (local versus distributed representations) and the ways of representing the knowledge on spelling-to-sound correspondences. However, both models predict an interaction between word frequency and spelling-to-sound regularity/consistency in word naming. However, a series of studies conducted by Jared suggested that the observed interaction between frequency and consistency/regularity might be due to the fact that word frequency was confounded with neighborhood characteristics (Jared & Seidenberg 1990, Jared 1997, 2002). More specifically, in order to consider the degree of consistency, both the number (type frequency) and the frequencies (token frequency) of a word's orthographic neighbors should be taken into account. For example, words that share a word body are pronounced in the same manner can be classified as friends. In contrast, they can be classified as enemies if they are pronounced differently. Typically, high-frequency words were less likely than low-frequency words to have a much lower summed frequency of friends than enemies. It is possible that the interaction of frequency and consistency/regularity that was observed in some of these studies is actually due to the differences in the neighborhood characteristics of high- and low-frequency words.

Jared (1997) demonstrated that high-frequency words do produce the consistency effect when they are sufficiently inconsistent (i.e., when they have a low summed frequency of friends and a high summed frequency of enemies). Furthermore, when both high- and low-frequency words were closely matched for the same set of word bodies, the interaction between frequency and consistency was not significant in the latency data but was significant in the error data. Further, Jared (2002) orthogonally manipulated regularity and consistency, and demonstrated that when high- and low-frequency words are closely matched for neighborhood characteristics, a weak interaction of frequency and regularity/consistency is found in the latency and error rate. Jared concluded that the effects of atypical spelling-to-sound correspondences do decrease with increasing exposure to a word. However, the effects are primarily observed in the error data when frequency and neighborhood characteristics are unconfounded. More importantly, a robust regularity effect was mainly observed when exception words had a low summed frequency of friends and a high summed frequency of enemies. On the other hand, a much weaker regularity effect was observed when exception words had a high summed frequency of friends and a low summed frequency of enemies. Although both types of exception words had an unusual spelling-to-sound correspondence, in the word body context, the correspondence was unusual for the first group but not for the second group. It seems that the magnitude of the regularity effect depended on the neighborhood characteristics of the exception words. Jared's studies have two important implications.

First, neither qualitative spelling-to-sound regularity nor quantitative spelling-to-sound consistency accounted for all of the data; however, word-body consistency performed better than GPC regularity. Second, readers not only learn more than individual letter-sound correspondences but also learn how letters are pronounced in their surrounding context (i.e., word body). Moreover, the frequency-by-consistency interaction was overestimated in previous studies, and neighborhood characteristics, particularly for the relative frequencies of friends and enemies, should be considered.

3. Consistency and regularity effect in reading Chinese

Unlike the alphabetic script in which words comprise letters that represent phonemes, Chinese characters are thought to be composed of radicals, which cannot be assembled or combined to produce a larger phonological unit that would represent the character's sound. The orthography-to-phonology correspondence in Chinese is considered to be more arbitrary or opaque than in writing systems with shallow orthographies, such as Serbo-Croatian, Italian, and English. Although more than 85% of all Chinese characters are phonograms, the composed phonetic radicals might be used to specify the pronunciation of the whole character. Only 39% of these characters have the same pronunciations as their phonetic radicals, leading some researchers to believe that the sublexical generation of phonological representations is impossible in Chinese (Liu et al. 1996, Paap & Noel 1991, Valdes-Sosa et al. 1993). However, several studies have probed the issue of sublexical phonological processing in naming Chinese phonograms using either the indexes of regularity or indexes of consistency to describe the mappings between Chinese orthography and phonology (Fang et al. 1986, Hue 1992, Lien 1985, Seidenberg 1985). Regularity refers to whether the sound of a character is identical with that of its phonetic radical. Behaviorally, the naming speed for irregular characters is much slower than that for regular characters, particularly for low-frequency characters. This is the so-called frequency-by-regularity interaction, which suggests that Chinese phonograms are not read via a direct association between orthography and phonology but through the process of sublexical phonology. However, many phonetic radicals of phonograms are not legitimate characters and are thus unpronounceable. Hence, the concept of regularity cannot be applied to this type of phonogram, since the definition of regularity is based on whether the phonograms and their phonetic radicals sound the same. Alternatively, the issue of the phonological relationship between a phonogram and a phonetic radical can be addressed by consistency. Consistency refers to whether a character's pronunciation agrees with those of its orthographic neighbors which, by definition, contain the same phonetic radical. Many studies have demonstrated the frequency-by-consistency interaction in naming Chinese phonograms, and suggest that the phonological information provided by the sublexical unit plays a role in reading Chinese phonograms (Hue 1992, Lee et al. 2004, Lee et al. 2005). It is important to note that there is no GPC rule in Chinese. The indices of regularity for English and Chinese are similar at the conceptual level, namely, with regard to whether a word's pronunciation follows a particular rule but differs in terms of the type of orthography-to-phonology rule that can be applied in two writing systems (e.g., the GPC rule in English versus to sound out it phonetic radicals in Chinese). On the other hand, the indices of consistency for English and Chinese are parallel in nature with respect to the representation of the statistical relationship between orthographic forms and their pronunciations.

Two questions regarding the role of regularity/consistency in naming Chinese phonograms have been addressed in several studies. One is the relationship between regularity and consistency, and the other is whether the effects of regularity/consistency decreased with increasing word frequency. With regard to the first question, studies have shown that the interaction between frequency and regularity/consistency (Fang et al. 1986, Hue 1992, Lien 1985, Seidenberg 1985). Lee et al. (2005) orthogonally manipulated regularity and consistency and found a significant interaction between these two indices for naming low-frequency characters. This suggests that neither consistency nor regularity alone can represent the knowledge of orthography-to-phonology correspondences in Chinese. Lee's third experiment aimed to examine whether the regularity/consistency effects for naming Chinese phonograms could only be found when the constituent phonetic radicals are independent legal characters. The word frequency and consistency were manipulated for a set of independent phonograms whose phonetic radicals are not independent legal characters. In addition, in keeping with Jared's suggestions that neighborhood characteristics should be considered, the consistency effect was found in high-frequency words when both high- and low-frequency inconsistent words atypically represent the largest pronunciation (inconsistent words with low summed frequency of friends and high summed frequency of enemies). Thus, in Lee's third experiment, all inconsistent characters were selected when they have a low summed frequency of friends and a high summed frequency of enemies. This study demonstrated the consistency effects in naming independent phonograms irrespective of whether they are high- or low-frequency words, although the consistency-by-frequency interaction was still significant in the latency and error rate, which is partly congruent with Jared's findings. The main conclusions of this study support the contention that (1) the manner in which Chinese readers learn the statistical mapping between orthography and phonology is the same as that for English readers and (2) the knowledge for the statistical mapping is not restricted to phonograms whose phonetic radical must be a legal character. As suggested by Jared (2002), consistency, also the quantitative index of orthography-to-phonology correspondence performed better than regularity in representing the knowledge of orthography-to-phonology correspondence. The findings support the connectionist approach for Chinese word recognition. The performance in naming Chinese phonograms does not depend on whether or not the phonology of its phonetic radical would be activated; rather, it depends on the impact of its orthographic neighbors, with or without consistent pronunciations. Furthermore, when the connectionist model is adopted, there is no need to argue whether the sublexical phonology is processed pre- or post-lexically.

It is noteworthy that when the degree of consistency is measured by the relative frequency of friends and enemies, it is more difficult to find high-frequency characters with a low summed frequency of friends and a high summed frequency of enemies than for low-frequency characters. This is because the character frequency itself is included in the sum frequency of friends. Therefore, it is extremely difficult to match high- and low-frequency inconsistent characters with regard to both the number and summed frequency of friends and enemies. In Jared's study, a higher priority was placed on matching the summed frequency of friends and enemies. However, the relative number of friends and enemies was not controlled. In Lee's study (2005), the first priority was to ensure that every low-consistency character has an atypical pronunciation in terms of its relative frequency of friends and enemies. In other words, every inconsistent character has a low summed frequency of friends and a high summed frequency of enemies, although the summed frequency of friends was not matched for high- and low-frequency inconsistent characters. Chen (2008) comments on this and has conducted a new experiment by matching the summed frequency of friends. However, in Chen's experiment, the summed frequency of enemies was not matched and was higher than the summed frequency of friends. Therefore, the inconsistent characters used by Chen did not have the largest atypical pronunciations in terms of their relative frequency of friend and enemies. This might explain the missing interaction between frequency and consistency in his experiment. Due to this, it is extremely difficult to match the high- and low-frequency inconsistent characters with regard to both the number and summed frequency of friends and enemies. Further, such a stimulus list is likely to have included very few words. Other approaches such as regression analysis might be more suitable for examining the contributions of type and token frequency in determining the strength of the orthography-to-phonology consistency.

Various models have been successful in simulating and predicting various aspects of human reading performance. However, learning to read is accompanied by the evolution of other cognitive functions in the human brain. A more complete understanding of reading processes requires an understanding of how written words activate mental representations in the brain as a result of the orchestration of various processes and their temporal courses. A critical variable that will ultimately need to be an intrinsic part of visual word recognition models is the time course with which different information becomes available and is used until a set of writing units (such as letters or radicals) is recognized as a word. Electrophysiological data (such as event-related potentials (ERP)) that has great temporal resolution can offer unique contributions in delineating the various subprocesses involved in visual word recognition. The main reason is that ERPs provide data that reflects processing on a millisecond basis from the onset of language stimuli. Different ERP components can be used to index the different stages of lexical processes. Our recent study on ERPs attempts to trace the time course taken for the extraction of phonology while reading Chinese pseudocharacters. Participants were asked to passively attend to a set of pseudocharacters, each of which was paired with a spoken syllable. This syllable was either a predicable or an unpredictable pronunciation that was determined by the constituent phonetic radical of the pseudocharacter. The data revealed that pseudocharacters paired with unpredictable pronunciations elicited greater P200 and N400. The P200 component could indicate the early extraction of phonology in reading Chinese pseudocharacters, while the N400 is very likely to associated with post-lexical processing (Lee et al. 2006). A subsequent ERP study showed that low-consistency characters elicited greater N170 amplitude in the temporal-occipital region and greater P200 amplitude in the frontal region than high-consistency characters, while high-consistency characters showed greater negativity of N400 amplitude than low-consistency characters (Lee et al. 2007). These findings revealed the temporal dynamics of Chinese orthography-to-phonology transformation and were interpreted as indicating that low-consistency characters produce a greater activation in the initial analysis of the orthographical and phonological representations. On the other hand, high-consistency characters involve a greater lexical competition in the later stage. The integration of behavioral, neuropsychological, and neurophysiological data is critical for both the development and refinement of reading models with plausible neurological architectures and greater predictive power.

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閱讀歷程中的一致性與規則性效果

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關於閱讀之形音轉換歷程，至今已有各種不同的詞彙辨識模型提出解釋，然而有關究竟應該使用一致性或是規則性的來表徵字形字音的對應方式的爭議，則尚未有定論。這篇文章旨在回顧相關的文獻，並認爲形音對應一致性概念衍生出來的鄰項特性（諸如敵人與朋友鄰項的相對字頻），在中文或英文的文字辨識的歷程中都確有其影響力。本文最後建議，藉由整合傳統行爲研究與現代的電生理研究，可更進一步瞭解閱讀歷程的時序問題。

關鍵詞：一致性，規則性，閱讀