

The Neurophysiological Mechanism of Ambiguous Word Inhibition

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Abstract

Inhibition, as a cognitive processing mechanism in the process of language comprehension, plays a crucial role in different levels of language comprehension, such as vocabulary, sentence, paragraph, or text. This paper summarizes the recent studies on the important physiological and electrical index and brain mechanisms of the inhibition mechanism of ambiguous words, aiming to understand more systematically and deeply the influence of different foreign language proficiency, different frequency, and correlation degree of ambiguous words on language processing differences.

Keywords: ambiguous words, inhibition mechanism, N400, P600, meaning correlation, second language proficiency

1. Introduction

Ambiguous words are words with two or more meanings. Ambiguous words can be divided into two categories: contrastive ambiguous words (homographs) and polysemous. Contrastive ambiguous words are ambiguous semantics that is not related. While polysemous words are ambiguous and semantically similar (Wang, Y., 2019).

As an important cognitive function of the brain, Inhibition plays an important role in semantic comprehension. Scholars have divided inhibition into different definitions according to its different functions in information processing: Bjorklund & Harnishfeger defined it as cognitive repression, which excludes irrelevant information before it is processed or after it enters working memory to avoid interfering with the processing of target information (Bjorklund, D. F., & Harnishfeger, K. K., 1995); Gernsbacher believed that the inhibition mechanism reduced the activation level of irrelevant information (Gernsbacher, M. A., & Faust, M., 1995). Zacks proposed to restrain the editing of information entered into working memory to ensure that irrelevant information did not affect the processing of relevant information (Hasher, L., & Zacks, R. T., 1988). At present, researchers generally believe that inhibition mechanism is a process in which individuals can make target information more fully processed and suppress information irrelevant to their target information in the process of understanding language.

2. The Neurophysiological Mechanism of Ambiguous Word Suppression

The neurophysiological basis is important for linguistic analysis and model building. The latest research on the theoretical models of the resolution of different ambiguous words starts from the neurophysiological basis of language, discusses the inhibition and resolution of ambiguous words by physiological mechanisms of language, and points out the limitations of linguistic neural networks on language. Therefore, primitive EEG signals and important ERP parameters are the objective basis and important physiological index to further explore the brain's language processing mechanism.

2.1 N400

N400 is a brainwave pattern related to the difficulty of semantic integration, which represents the difficulty of semantic integration and is an important index to measure the ambiguity inhibition mechanism (Kutas, M., Hillyard, S. A., Kutas, M., & Hillyard, S. A., 1980; Kutas, M., & Federmeier, K. D., 2011). And LPC component may reflect the encoding strength of memory (Paller, K. A., Kutas, M., & Mayes, A. R., 1987; Ken A., Paller, K. A., & Wagner, A. D., 2002). An ERP experiment was conducted to investigate the effect of new meanings of unrelated ambiguous words and related ambiguous words on old meanings. The results show that for on matter

N400 or LPC, the difference wave of unrelated new meaning acquisition is larger than that of related new meaning acquisition. At the same time, the subsequent meanings change the establishment of the representation of the original meanings through integration into the original semantic network (Bjorklund, D. F., & Harnishfeger, K. K., 1995; Gernsbacher, M. A., & Faust, M., 1995; Hasher, L., & Zacks, R. T., 1988). This indicates that in the process of acquisition, there is a mechanism of facilitation or interference between the meanings. The higher the degree of correlation between the meanings, the easier it is to acquire them, and the more difficult it is to acquire them otherwise (McClelland, J. L., 1987; Zhang, Y.-Y., & Chen, B.-G., 2019).

2.2 P600

P600 is a positive wave with an incubation period of 600ms in the central parietal region after stimulus presentation (Wang, R.-L., Li, N., & Chen, B.-G., 2010). The monitoring theory suggests that P600 is caused by cognitive conflict during language processing (Wang, R.-L., Li, N., & Chen, B.-G., 2010; Kolk, H., Chwilla, D. J., Herten, M. V., et al., 2003). It reflects the process of syntactic processing, sentence integration and semantic interpretation (Wang, R.-L., Li, N., & Chen, B.-G., 2010; Jin, H.-G., Gao, F., & Chen, Z., 2019; Valentina, B., Chiara, B., Walter, S., et al., 2016). An ERP study used the priming paradigm to explore the different processing processes of metonymy and metaphor in ambiguous words. The results show that metaphorical ambiguous words have a delayed and higher amplitude P600 than metonymic ambiguous words (Yurchenko, A., Lopukhina, A., & Dragoy, O., 2020). This suggests that metaphorical and metonymic ambiguous words have different representations, and the inconsistent priming will result in the competition of the original meanings, which will lead to the reanalysis, activation and integration of the target meanings. However, the resolution of metaphorical words in reality often depends on the context. A study of metaphorical words in real context shows that P600 appears in the meaning of accessible metaphorical words (Valentina, B., Chiara, B., Walter, S., et al., 2016). It reflects that metaphorical ambiguous words reach meaning through contextual clues.

2.3 Research on Brain Functional Localization of Ambiguous Word Inhibition Mechanism

2.3.1 Influence of Brain Lateralization on Ambiguity Resolution

Fu-Rong Huang (2012) used the visual field separation velocity indicator experiment in the study of half field and found that under the condition of a stimulus time interval (SOA) of 35ms, both the primary and secondary meanings of ambiguous words were activated in the left hemisphere, but only the primary meaning of ambiguous words was activated in the right hemisphere. When SOA is 750ms, the main meaning of ambiguous words remains active in the left hemisphere, while the secondary meaning is inhibited, but both the primary and secondary meaning detecting words are active in the right hemisphere (Huang, F.-R., & Zhou, Z.-J., 2012). This suggests that the left hemisphere of the brain can activate multiple meanings of ambiguous words rapidly and suppress secondary meanings with lower relative frequency, while the right hemisphere of the brain can activate all relevant meanings of ambiguous words. However, in his research on brain injury, he found that neither the left hemisphere nor the right hemisphere of the brain could independently complete lexical ambiguity resolution, and both the left and right hemispheres of the brain could lead to semantic selection obstacles in lexical ambiguity resolution, and lexical ambiguity resolution required the joint action of the two hemispheres of the brain.

Some researchers (Grindrod et al., 2003) used the cross-channel semantic primes paradigm to study the non-fluency aphasia with left hemisphere injury, right hemisphere injury and healthy control subjects, and formed two experimental conditions of neutral and biased context by manipulating sentence local information. The results showed that both left and right brain injuries resulted in a deficiency in the use of contextual information in local sentences in the process of lexical ambiguity resolution, that is, the ability to integrate context and meaning. The difference is that the damage to the left hemisphere leads to the rapid decline of word meaning activation, while the damage to the right hemisphere leads to the over-dependence of word frequency in the activation of ambiguous words. This study shows that both hemispheres are involved in extracting contextual information (Bilenko, N., Grindrod, C., Myers, E., et al., 2009).

Zhang Wenpeng studied the cognitive processing brain mechanism of Chinese-English bilinguals in sentence context resolution of ambiguity of English nouns and found that the mean amplitude of N400 in the left hemisphere of the brain was significantly higher than that in the right hemisphere under semantically related conditions. Therefore, the right and left hemispheres of the brain have different functional divisions in language processing, and the left hemisphere has more advantages in word selection and processing. However, word ambiguity resolution requires the combined functions of the two hemispheres.

Some studies have found activation of the right inferior frontal gyrus by manipulating experimental conditions to improve the requirements of controlling semantic processing (Bilenko, N., Grindrod, C., Myers, E., et al., 2009;

Hoenig, K., & Scheef, L., 2009; Mason, R. A., & Just, M. A., 2007; Zemleni, M. Z., Renken, R., Hoeks, J., et al., 2007), which may mean that the right hemisphere plays an auxiliary role in lexical ambiguity resolution to the left hemisphere, and only when the left hemisphere is overloaded with semantic selection will the right hemisphere activate the semantic selection mechanism.

Therefore, in the process of lexical ambiguity resolution, both hemispheres can selectively activate the appropriate meaning of ambiguous words and suppress the inappropriate meaning according to the contextual information, and the left hemisphere has a stronger semantic selection function than the right hemisphere. However, the right brain not only activates a large number of secondary meanings of words but also helps to correct incorrect interpretations, so it plays an important role in lexical ambiguity processing.

2.3.2 Influence of Frontal Lobe on Semantic Choice

The neuroimaging study of Fu-Rong Huang (2012) further found that the frontal and temporal lobes jointly support lexical ambiguity resolution, and the selection of appropriate meaning of ambiguous words is performed by the frontal lobe (Huang, F.-R., & Zhou, Z.-J., 2012). Hargreaves, Pexman, Pittman, and Goodyear (2011), after strictly controlling the number of meanings and the frequency of relative meanings of ambiguous words, found that compared with unambiguous words, the classification processing of ambiguous words significantly increased the activation level of the left frontal lobe (Hargreaves, I. S., Pexman, P. M., Pittman, D. J., et al., 2011). Gennaria, MacDonald, Postle, and Seidenberg (2007) used prime words to guide the activation of ambiguous words in fMRI research. By comparing the activation levels of brain regions during the processing of ambiguous and unambiguous words, they found that the left frontal lobe was significantly activated (Gennari, S. P., Macdonald, M. C., Postle, B. R., et al., 2007). It is suggested that the left frontal lobe is related to the activation and selection of multiple meanings of ambiguous words. Compared with word context, sentence context has a stronger constraint on the activation and selection of multiple meanings of ambiguous words. Therefore, the left frontal lobe, which is responsible for the extraction and selection of multiple meanings of ambiguous words, is significantly activated in the process of understanding ambiguous sentences than in the process of understanding unambiguous sentences. These results indicate that the left frontal lobe is responsible for the activation and selection of multiple meanings of ambiguous words.

Some neuroimaging studies have shown that the prefrontal lobe, especially the left-hemisphere prefrontal lobe, contributes to word meaning processing and context-sensitive discourse processing. Frattali et al. (2007) studied the ability of patients with unilateral or bilateral prefrontal lobe injury to suppress contextually inconsistent information in the process of lexical ambiguity resolution by using the sentence-primed word judgment task (Frattali, C., Hanna, R., McGinty, A. S., et al., 2007). The results showed that the interference of inconsistent information decreased with time in the patients with prefrontal lobe injury, while the interference increased with time in the normal subjects, indicating that the function of prefrontal lobe injury patients was impaired and the inhibitory processing was weaker. The above studies indicate that the frontal lobe plays an important role in ambiguity resolution, especially the left frontal lobe is responsible for the selection and activation of multiple meanings of ambiguous words, which is of great significance for semantic and contextual processing.

2.3.3 Influence of Temporal Lobe on Semantic Integration

In addition to activating the temporal lobe during lexical ambiguity resolution, the temporal lobe is also activated, such as the left/right superior temporal gyrus, the left/right middle inferior temporal gyrus, and the left middle temporal gyrus, etc. These brain regions are often considered to be related to semantic integration in lexical ambiguity resolution. The neuroimaging study of Furong Huang (2012) further found that the frontal and temporal lobes jointly support lexical ambiguity resolution, and the temporal lobes are responsible for semantic integration processing of ambiguous words (Huang, F.-R., & Zhou, Z.-J., 2012). Existing research results on lexical ambiguity resolution are more conducive to the selection of the hypothesis model. The superior temporal gyrus or middle temporal gyrus of the temporal lobe is responsible for integrating the appropriate meaning of ambiguous words into context to form a complete semantic representation (Hoenig, K., & Scheef, L., 2009; Zemleni, M. Z., Renken, R., Hoeks, J., et al., 2007; Rodd, J. M., Longe, O. A., Randall, B., et al., 2010; Ihara, A., Hayakawa, T., Qiang, W., et al., 2007).

3. Factors Influencing the Inhibition Mechanism of Ambiguous Words

When ambiguity occurs in reading comprehension, it is necessary to use the inhibition and activation mechanisms of the language system to effectively understand the information. Therefore, appropriate mental representation is achieved through the language system's suppression of inappropriate meanings of ambiguous words to achieve ambiguity resolution and activation of their appropriate meanings. At present, a series of

studies have been conducted on the effects of L2 proficiency, lexical meaning frequency, relevance, and contextual intensity on lexical resolution.

3.1 Influence of Different Foreign Language Levels on the Inhibition of Ambiguous Words

Second language proficiency has an influence on the inhibition mechanism of ambiguous word acquisition. The difference of proficiency is reflected in the different mental representations of the storage of ambiguous words, namely, the representation of the core meaning and the representation of the independent meaning. The different representation systems affect the inhibition efficiency of ambiguous words.

Gernsbacher first used the task of meaning suitability judgment in 1966 to test the difference in response of people with high English proficiency under different ISI conditions, and the experimental results showed that people with high English proficiency presented lower effect size under high ISI (Gernsbacher, M. A., & Faust, M. E., 1991). This suggests that ambiguous words are more difficult to suppress by people with low foreign language proficiency.

Chinese English learners with different L2 proficiency have significant influence on the semantic processing of homophones and homographs, but there is no significant difference in the semantic processing of different categories of homophones and homographs. With the improvement of L2 proficiency, the meanings of polysemous words tend to be stored independently. However, it will not reach the completely independent representation state of the meanings of homographs, and the connections between the meanings will be maintained with different intensities (Xiang, C., 2015). Zhao Chen (2010) at different levels to eliminate ambiguity in the context of the sentence for Chinese learners of English word meaning of cognitive model, the study found a word, same spelling words metaphor and metonymy words semantic ambiguity word is on a continuum, with a high level of second language learners with spelling words and characterization of metonymy words divided both sides of the continuum, Metaphorical polysemous words lie in between (Wang, Y., 2019; Zhao, C., 2010). Wang Yu (2018) found that with the improvement of the level of second language, the meaning correlation of polysemous words gradually strengthened (Wang, Y., & Sui, M.-C., 2018).

A study on the listening comprehension of ambiguous words shows that the efficiency of foreign language listening inhibition mechanism in the Chinese population is related to the listening level under sentence processing conditions. The inhibition efficiency of both homophones and homophones was higher in the high-level English listening group than in the low-level English listening group. The intrinsic interference of the suppression semantics of Chinese people's foreign language listening is easily affected by Chinese words. In the low-level listening people, more "substructures" appear due to the "transfer" mechanism, which is inconsistent with the English sentence semantics. In the case of English sentence processing, it is found that the mechanism of second language listening inhibition is different from that of mother language reading comprehension. Thus it can be seen that there are different representations between polysemous words and homographs, and there are also relationships between the meanings of polysemous words. A recent study reveals that the second language levels associated with ambiguous words and meanings in order condition such as the inhibition mechanism of interaction between, compared with the second meanings are not commonly used in ambiguous words, due to the high level of second language learners in practice is more ambiguous terms related to the use of primary meanings, its semantic can be faster to the increase of second language level of mastery^[30]. However, the current research has not revealed the neurophysiological mechanism of different second language proficiency in ambiguous word inhibition.

3.2 Relative Meaning Frequency and Correlation Degree of Ambiguous Lexical Terms

In terms of the mapping relation between the meanings of ambiguous words, the homomorphic ambiguous words are one-to-many mapping relation between meaning and concept, while the polysemous words are one-to-one mapping relation. With the development of psycholinguistics, the meaning correlation of ambiguous words can be quantified to be studied: from homomorphic ambiguous words (least relevant) to polysemous words (most relevant), meaning correlation can be represented on the same continuum (Wang, Y., 2019; Zhao, C., 2010; Wang, Y., & Sui, M.-C., 2018).

Some studies using translation recognition tasks indicate that the source language of ambiguous words will correspond to two or more translations of the target language. However, the multiple meaning representations of the target language differ on the continuum of meaning relevance representations. According to the view of the distributed conceptual feature model (Groot, D., & Annette, M., 1992; Groot, A. M. B. D., 1998), one meaning is used more frequently than the other in multiple meanings generated in the output from the second language to the first language (L2-to-L1). This means that primary meanings have more shared nodes than secondary meanings, and this model has been supported by many studies. In these studies, participants had a longer

response time and a higher error rate on the task of translating ambiguous words with secondary meanings than with main meanings, which confirmed the existence of the semantic correlation effect (Zhou, G., Chen, Y., Feng, Y., et al., 2019; Boada, R., Sanchez-Casas, et al., 2013; Eddington, C. M., & Tokowicz, N., 2015).

The relative meaning frequency of ambiguous words has different effects at different stages of mental representation establishment. A recent study demonstrated for the first time that the second meaning of ambiguous words is weaker and less stable than the first meaning in early acquisition (Lu, Y., Wu, J., Susan, D., et al., 2017). This indicates that it is difficult to integrate meaning and concept from one-to-one mapping to one-to-many mapping due to the interference of primary meaning representation. However, this study only selected unrelated ambiguous words as the research object, and could not rigorously derive the general rules of the inhibition mechanism of ambiguous words. A follow-up study using a translation recognition task showed that related meanings had faster response times and higher accuracy than unrelated meanings, and the semantic association effect lasted for a week (Zhang, Y., Chen, B., Tang, Y., et al., 2018). This confirms the connectivist model that when new meanings enter the semantic web, there is competition between different meanings. The more relevant the new meaning is, the more semantic features the old meaning and the new meaning share. The entry of the unrelated meaning into the semantic network often requires greater interference, and thus requires the participation of inhibition mechanism in vocabulary learning. However, the dependent variables used in the above behavioral experiments can only indirectly support the hypothesis, and the use of ERP and fMRI technology is needed to further explore the mechanism of inhibition and the establishment of the morphology-meaning mapping relationship of ambiguous meanings.

As important electrical index, both N400 and LPC can be used in ERP research of psycholinguistics, and are accurate indicators to investigate the inhibition mechanism of ambiguous words. Zhang Y (2020) used ERP technology to explore the learning of ambiguous words and found that the second meaning of homonyms would induce a larger N400, while the polysemous would induce a larger LPC (Zhang, Y., Lu, Y., Liang, L., et al., 2020). Another related study divided ambiguous words into homonyms and polysemous words and found that homonyms had higher N400 than polysemous words under high ISI (750ms) conditions in the priming-delay lexical decision task, suggesting that homonyms' competing meanings hindered access, while polysemous meanings promoted each other and coordinated access. This research shows that the semantic relevance facilitates or interferes with the acquisition of ambiguous words and it confirms the existence of the semantic correlation effect from the neurophysiological mechanism.

3.3 Context Strength and Contextual Constraints

Early studies on the mechanism of ambiguous word inhibition focused on exposure frequency and second language level. However, second language learning largely depends on context, and there are few kinds of researches on it. In previous studies on ambiguous words, non-target words also affect the resolution of ambiguity, and related ambiguous words often activate their subordinate meanings in context (Zhou, G., Chen, Y., Feng, Y., et al., 2019). Zhou G conducted a study on the influence of highly restrictive sentences on the translation of ambiguous words, confirming that multiple competing meanings can be generated in the production of related ambiguous words L2-to-L1, while unrelated ambiguous words can quickly access the correct meanings and resolve ambiguities according to the context. In an ERP study of native-speaking subjects, highly restrictive sentences can quickly enable subjects to acquire contextual vocabulary. Baoguo C, Tengfei M et al. (2017) used ERP technology to test that when L2 subjects read highly restrictive statements, the amplitude of N400 was less, indicating that highly restrictive statements are conducive to the correct meaning of ambiguous words and can resolve ambiguity more quickly in highly restrictive statements.

4. Summary

The research on the inhibition mechanism of ambiguous words has undergone a transformation from theoretical model to behavioral experiment and then to brain mechanism. In recent years, the research in this field has shown a trend of differentiation, and scholars at home and abroad have carried out a series of studies on the specific types of different types of ambiguous words. However, these studies have not properly revealed the interaction among the vocabulary types, context, L2 proficiency, and other factors in the process of second language acquisition, and thus lack a certain degree of external validity. In addition, few existing studies have involved the neural mechanism of learners with different second language proficiency in the process of ambiguous word learning, and further studies need to be improved.

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