Advances in Educational Technology and Psychology (2022)
Clausius Scientific Press, Canada

DOI: 10.23977/aetp.2022.060513
ISSN 2371-9400 Vol. 6 Num. 5

Review on the Neural Mechanism of Focus Processing

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Keywords: Focus, Processing, ERP, Differentiated Processing, Neural Mechanism.

Abstract: In recent years, as more and more researchers pay attention to the linguistic phenomenon that different components in sentences are differentially processed, the processing mechanism of focal components has also been extensively focused. This paper reviews the researches on the neural mechanism of focus processing from the perspective of native speakers and second language speakers, combs several ERP components closely related to focus processing, and summarizes the mechanism of focus processing.

1. Introduction

Psycholinguistic researchers have been trying to explain how the process of language understanding develops gradually with the order of words, and how the information from various sources (vocabulary, syntax, semantics and pragmatics) can be integrated online quickly. Traditional sentence processing models, such as garden-path model and constraint-satisfaction model, basically assume that in the process of real-time understanding of sentences, each component in the sentence is processed equally and adequately. However, in recent years, according to some language phenomena, scholars have questioned the view that all components in sentences are processed equally, and attempt to put forward new theories and models to explain this language phenomenon and the mechanism behind it.

Ferreira and his colleagues challenged the view that all components in the process of language understanding were processed equally (Ferreira, 2003; Ferreira, Bailey, & Ferraro, 2002; Ferreira & Patson, 2007; Ferreira & Lowder, 2016), because many linguistic phenomena show that different components in the same sentence are processed differently. From this, they propose that in the process of language understanding, the representation established by the language understanding system for language input is not always detailed and sufficient, but adopts a schema (a general framework for organizing details based on past experience), according to the current communication purpose and task needs to form a good-enough representation. At the same time, Ferreira & Lowder (2016) clearly affirmed the impact of information structure on good-enough representation: since the important goal of communication is to obtain information, the information structure determines that new information and focus information will be processed and characterized more fully and carefully.

Focus is the sentence component that the speaker thinks it is relatively important based on his own judgment and decides to emphasize by grammatical means (Jeff, 2018: 123-124). As an important concept of information structure, how people process it is an important starting point to explore the differential processing. Throughout the research on the neural mechanism of focus processing, most of the studies have used ERP methods. On the one hand, the high time sensitivity of ERP allows researchers to study the process of online processing of focus and related sentence information. On the other hand, classical ERP components reflecting language processing and even different general cognitive processes can provide a more in-depth and detailed explanation for focus processing mechanism. This review will also mainly focus on the ERP components related to focal component processing, and supplement the neural mechanism research of focus processing by other means (such as fMRI) in relevant sections. Besides, in addition to focusing on the neural mechanism of focus processing of native speakers, we will also briefly summarize how second language speakers process focus.

2. Neural mechanism of focus processing in native speakers

2.1 P600: Mapping focus structure representation to syntactic and semantic representation.

Johnson, Clifton, Breen, & Morri (2003) studied focus processing under auditory conditions using different specific interrogative English sentences to set different focus on the same answer, and comparing the ERP patterns of the same information in the focus state and the non-focus state , found that the target word under the context-controlled focus condition elicited a broad and bilaterally distributed late positive wave (500-700 ms) regardless of whether prosodic stress matched the focus. Although Hruska, Alter, & Steinhauer (2000) and Hruska (2004) using German materials and similar designs found similar top late positive waves only when the rhythm matched the focus, these studies jointly inspired other researchers: although the cognitive process of this component is not clear, the focus information may cause greater late positive waves than the non-focus one.

Stoltfoht et al. (2007) found a similar ERP pattern reflecting focus processing, and at the same time, they explained and identified this component more clearly. They use the focus sensitive operator "*nur* (only)" to mark the focus, and set the conditions for focus correction processing through stress. The results show that this focus correction process will induce a widely distributed bilateral sustained positive wave (350-1300 ms). They believe that focus markers are part of the surface syntactic structure, and combined with studies such as Friederici (1999, 2002), they identified this positive wave as early-onset P600, reflecting the later language comprehension processing during which different types of language information are mapped to syntax and then re-analysed. And the condition requiring focal correction elicited a larger P600, reflecting the difficulty in mapping focal structural representations to syntactic and semantic representations.

In fact, in earlier studies, Stolterfoht & Bader (2004) marked the focus with a typical word order in German, and also set the conditions for focus correction processing with stress. As a result, the late positive wave at the top of the center (500-900 ms) and the right central negative wave (500-600 ms) were found at the same time. However, when explaining the results, they tended to think that the positive wave reflected the process of syntactic reanalysis, while the negative wave reflected the process of structural correction of focus. However, in Stoltenfurt et al. (2007), this view has been revised: the negative wave reflects the process of implicit prosodic processing, while the positive wave reflects the process of focus correction processing.

Drenhaus, Zimmermann, & Vasishth (2011) set a focus exhaustive violation with the German focus-sensitive operator "nur (only)", also found a P600 effect (600-800 ms) in the posterior central part, supporting Stolterfoht et al. (2007) and other previous studies. However, under the condition that cleft sentences mark the focus, only the N400 effect (400-600 ms) of whole brain distribution is found. Therefore, they believe that the processing modes related to exhaustive violation in different focus may be different. This also suggests that when studying the processing of focus, we should not only pay attention to its commonness as a focus, but also pay attention to its characteristics, and different types of focus may also have processing specificity.

2.2 N400: Focus semantics are easier to process and integrate

In addition to Drenhaus, Zimmermann, & Vasishth (2011) finding N400 under the condition of focus marked by cleft sentence, Wang et al. (2009) used specific questions in Chinese to control the focus of the answer, and set the semantic normal and violation conditions between the question and answer sentences. The results showed that: when the question and answer sentences were semantically consistent, and the target word in the answer sentence was the focus set by the question sentence, it elicited a significantly smaller N400 (300-500 ms) in the middle and posterior parts. They believe that this is because the focus gets more processing resources, so people can immediately connect the information in the answer with the expectation after reading the question, and it is easier to integrate the processing.

2.3 P3b/P300: Focus information is better integrated

Bornkessel, Schlesewsky, & Friederici (2003) found that the sentence processing mode under focus condition and non-focus condition is different during reading through ERP. Using German materials, they set the focus in the answer sentence by the specific question. They found that in the sentences of SO word order or OS word order, compared with the neutral context, under the condition of focus, the target phrase NP_1, the position of NP_2, and verb could induce larger top positive waves (280-480 ms). Because not only the focus information induced by the context will cause this positive wave, but also the verbs in the expected context sentences that are repeated under the focus condition will cause the same electrophysiological pattern. They tend to identify this component as P3b that can reflect the characteristics of language processing, and think that this focus positivity reflects the comparison between the language component predicted at the phrase or sentence level and the expectation generated according to the context, and the process of integrating this component into the context.

Cowles et al. (2007) used a combination of specific questions and It-cleft sentences to construct the conditions of focus agreement and focus violation, in order to gain a deeper understanding of focus processing. The results showed that: comparing the consistent conditions, when the focus preset by the context is inconsistent with the focus of the cleft sentence marker in the answer sentence, it will trigger an N400-like effect (200-500 ms) distributed in the middle right (in the original text, it is identified as “kind of N400/N400-like effect”, and the reason is that there is no sharp peak in this effect found in the study), indicating that focus violation does bring about difficulties in semantic processing. At the same time, no matter the focus in the target sentence is consistent with the focus set by the context or not, the focus word and the end word in the target sentence will cause P3b (200-800 ms) effect. The P3b amplitude of the focus word is greater than that of the end word, and under inconsistent conditions, the P3b amplitude will be significantly greater than that of the consistent condition at 700-900 ms. In the interpretation of P3b, they continued the "integration view" of Bornkessel et al. (2003), and combined with previous studies (see review Nieuwenhuis, Aston Jones, & Cohen, 2005), they believed that P3b also reflected the transmission of key information and the resolution of uncertainty, and that this component reflected the process of integrating focus words and sentence ending words into context as important new information while under inconsistent conditions, the larger P3b at the end of the sentence may reflect the subjects' awareness of the mismatch of the target sentence as the answer of the contextual sentence. It is worth noting that the P3b effect at the end of the sentence in the study is the embodiment of the ending focus in English, and this effect still exists even if the cleft sentence moves the focus forward.

Chen (2018) used Chinese materials and found that when words were emphasized by Chinese cleft sentences, they also caused larger positive waves at 265-495 ms. Although she defines it as P300 rather than P3b in the article, she still believes that her research reinforces the findings of Bornkessel et al. (2003) and Cowles et al. (2007) that focus can promote the textual integration of information. For this integration process, she puts forward a new explanation from the perspective of linguistics: the pragmatic function of emphasis is to establish a contrast between the emphasis component and other components (Halliday, 1967; Umbach, 2004), and in order to establish this contrast, readers must integrate text information.

2.4 P2: Focus gets more attention

The essence of focus is to highlight and emphasize, that is, to attract people's attention. Many behavioral experimental studies use focus regulating the allocation of attentional resources to explain the results that focus is processed differently from non-focus (Sturt et al., 2004; Sanford et al., 2009). Some EEG studies also use violation paradigms to discoverinformation structural violations or semantic violations at the focus elicited a larger N400 (Cowles et al., 2007; Wang et al., 2009), syntactic violations elicited a larger P600 (Wang et al., 2012) and used the moderating effect of focus on attention to explain the results of these studies. However, the first study that found that focus induced attention-related EEG components was Chen Lijing’s (2012) doctoral dissertation, which was published as Chen et al. (2014).

Chen et al. (2014) used the Chinese "Shi" cleft sentence to mark the focus and discussed the influence of information state (known information or new information) on the processing of focus components. The results showed that compared with non-focus conditions, the focus triggered a widely distributed and particularly obvious enhanced P2 (150-250 ms) in the left center and a widely distributed and particularly obvious P3b (250-700 ms) in the center. This P3b (250-700 ms) may also be a combination of weakened N400 (250-500 ms) and enhanced LPC (500-700 ms). P2 is related to attention distribution (Carretie, Mercado, Tapia, & Hinojosa, 2001; Hillyard & Münte, 1984; Luck & Hillyard, 1994), so this result proves that more attention has been paid to the focus of cleft sentences in Chinese. At the same time, they argue that the P3b (200-800 ms) effect under the focus condition discovered by Cowles et al. (2007) using Cleft sentence may not only be a simple P3b effect, but a combination of P2 effect with a latency of 200 ms and a relatively later P3b effect. Regarding the component of 250-700 ms, Chen et al. (2014) gave two explanations: it can be defined as a complete wave of P3b, reflecting the process of integrating focus into the context as key information (same as Bornkessel et al., 2003; Cowles et al., 2007); it can also be seen as weakened N400 (250-500 ms) and enhanced LPC (500-700 ms). The weakened N400 reflects that it is easier to process and integrate semantically with more attention (same as Wang et al., 2009). The enhanced LPC reflects that the cleft structure may break the sentence, and there is a pause in the sentence during silent reading, causing a "Closure Positive Shift" effect (Steinhauer et al., 1999; Li & Yang, 2009).

The fMRI study of Kristensen et al. (2013) also provides support for focus regulating attention allocation. They first used the auditory localization task to locate the subjects' attention network, and then asked the subjects to do the language understanding task using the materials marking the focus through stress, and compared the subjects' brain network activation patterns under the conditions of focus and non-focus. It was found that the subjects did activate the general attention network to a greater extent under the focus condition, including the superior and inferior parietal gyrus (extending to the internal parietal sulcus and the posterior central gyrus) and the left anterior central gyrus.

Wu et al. (2018) used Chinese specific sentences, and Chen (2018) used Chinese cleft sentences again, and they both found that focus words induced larger P2. Yang et al. (2019) used context and questions to set the focus in the answer to contextual focus, contrast focus, and neutral conditions as baselines. They found that no matter the contextual focus answering the specific question directly or the contrastive focus implicit in context, both elicited larger P200 (150-250 ms) than neutral conditions. Zheng et al. (2019) used Chinese specific interrogative sentence context and italics to mark focus at the same time. They was also found that both contextual focus and contrastive focus caused greater P2 (150-300 ms). These studies support the regulatory effect of focus on attention.

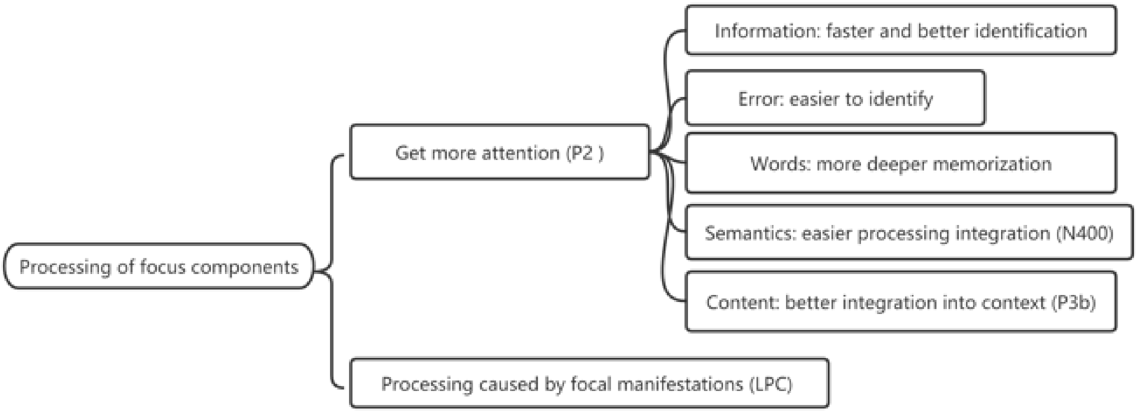

Figure 1: Diagram of the focus processing mechanism

Based on the above-mentioned cognitive neural researches and previous behavioral experiments, we can confirm the important role of focus in sentence processing, and further summarize the mechanism of focus processing (as shown above in Figure 1). First of all, when the focus component is processed, the essential feature that is different from the non-focus component is that the focus gets more attention, that is, the basic function of the focus in sentence processing is to adjust the distribution of attention resources, and this processing is reflected as P2 in EEG and greater activation of general attention network in neural mechanism. Semantic components that are focal information in single-sentence comprehension are identified faster and better because focal components receive more attention (Culter & Foder, 1979; Sturt et al., 2004; Sanford et al., 2009; Price & Sanford, 2012), content is better integrated into the context (reflected as P3b), semantics are easier to process and integrate (reflected as N400), and errors are easier to identify (Bredart & Modolo, 1988 ; Bredart & Doquier, 1989; Wang et al., 2009; Wang et al., 2012), words are remembered better (Mckoon, Ratcliff et al., 1993; Birch & Garnsey, 1995; Fraundorf et al., 2010 ; Price & Sanford, 2012), because on the basis of regulating the allocation of people's attention resources to each component in the sentence, the focus also regulates the processing depth of each component in the sentence, that is, the focal component gets more attention and is processed more deeply. In addition, different types of focus may also play an additional role in single sentence processing based on the characteristics of focus expression forms. For example, the cleft sentence focus marked with "shi" in Chinese may cause the Closure Positive Shift effect due to breaking the sentence and causing pause during silent reading, which is reflected as LPC in the EEG.

3. A Study on the Neural Mechanism of L2 Focus Processing

There is little research on the neural mechanism of focus processing in second language. Lee et al. (2019) marked focus with accents to explore the similarities and differences of focus processing and focus cues utilization mode between native English speakers and native Chinese speakers, which is only found.

Without contrastive stress, the target word is different from the previously mentioned words (appropriate):

(1) We ate Angela's ice cream but saved Benjamin's cake in the fridge.

With contrastive stress (capitalized in the example), the target word is different from the previously mentioned words (stress mismatch):

(2) We ate Angela's ice cream but saved BENjamin's cake in the fridge.

Without contrastive stress, the target word is the same as the previously mentioned word (lack of stress):

(3) We ate Angela's cake but saved Benjamin's cake in the fridge.

With contrastive stress (capitalized in the example), the target word is the same as the previously mentioned word (with appropriate stress):

(4) We ate Angela's cake but saved BENjamin's cake in the fridge.

The results show that, like native speakers, second language learners have different responses to target words with or without stress, which means that they can both perceive the mark of stress to focus. Compared with native English speakers and some high-proficiency second language speakers, less proficient second language speakers induce larger positive waves in 200-500 ms after stressed words, which means that less proficient second language speakers may pay more attention to the changes of sound signals. However, under the condition of stress mismatch, only native English speakers have N400(300-500 ms) which is widely distributed in other areas except forehead, which shows that native English speakers can use stress to predict whether the information status of the next noun is known or unknown, and adjust their attention accordingly, but second English speakers cannot do this. For second-language speakers, the condition with the largest negative wave and the most difficult processing is the proper condition without stress, and the more proficient second-language speakers are, the smaller this negative wave is, which means that second-language speakers will use stress to promote vocabulary access, and it is more difficult to process new words without stress. That is to say, although both native speakers and second-language speakers can perceive the marking of stress focus, their processing of focus and the use of focus cues are actually different: second-language speakers can only use focus cues to promote vocabulary access, while native speakers can use focal cues to predict information status and regulate attention to facilitate the processing and integration of entire sentences and even discourses.

It can be found that L2 learners, like native speakers, have different processing of focus and non-focus.

4. Conclusions

By combing the previous studies on the neural mechanism of focus processing by native speakers and second language speakers, this paper finds that people do perform differentiated processing on focus components and non-focus components. This processing mainly manifests as P2, N400 and P3b in EEG, which reflects that focus components will get more attention in the comprehension process, easier to integrate semantics and into context at the same time. However, what are the similarities and characteristics of focus processing mechanisms of different languages and different focus forms, and what are the essential differences between the processing of second language speakers and native speakers, still need to be explored further. A more deeper and detailed study of the neural mechanism of focus processing will help to solve the puzzle of how human brain can achieve the most economical and efficient language processing.

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