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A Review of Structural Priming

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Abstract

With the development of second language acquisition research involving more and more disciplines, structural priming, as an experimental paradigm, can study the syntactic representation, language comprehension and production from the perspective of psychology. And then how all these processes in the language mechanism, a "black box" in the human brain is represented and processed can be attained. Therefore, the research of structural priming is of great significance to the study of both native language and second language, and even contributes to patients with aphasia. This review will examine how structural priming has been used to investigate the representation, comprehension and production of syntactic structures.

Keywords: structural priming, syntactic priming, language production, language comprehension, second language acquisition

1. Introduction

Language development includes four processes: acquisition, comprehension, production, and attrition, so it is not a simple combination of lexical and semantic meanings, but involves the processing of syntactic structures. Whereas structure priming is increasingly becoming one of the most important experimental paradigms for studying sentence processing, the classic experiment began with Bock (1986). Structure priming refers to the tendency of learners to produce a sentence with the syntactic structure that they have just processed (read, listened to, or produced) (Yang, J. & Zhang, Y., 2007). In psycholinguistics, repetition is a central process which can help researchers with the investigation of language comprehension or production. More importantly, it may reflect the processing of learning (Chang, Dell, & Bock, 2006) or some critical communicative, imitative, and social functions (Pickering & Garrod, 2004). Up to now, more than one hundred experiments have been conducted using structural priming or related research methods. Most researchers have focused on the output process of language, and in recent years researchers have also studied priming in the comprehension process or studied this process from comprehension to output. In fact, some researchers use the term "syntactic priming" as well as "structural priming", but the latter has a broader meaning because it includes some abstract linguistic processes and is not limited to the syntactic level, and therefore does not presuppose the specific existence of a particular syntactic representation. The term priming is not only an interpretation of cognitive processing, but can also refer to an

experimental procedure.

2. Syntactic Priming in Language Comprehension and Production

Early studies of structural priming were limited to the process of language production, arguing that priming effects existed only for specific syntactic procedures in the language production (Bock & Loebell, 1990). However, later studies found that priming occurs from the comprehension stage and continues through the language production stage, so priming affects the mechanisms that control language comprehension and production. Further research revealed that in theory, there is a generalized abstraction mechanism between language use and language knowledge; in practice, this provides new ideas for studying language comprehension, i.e., assessing the effects of understanding sentences with different types of production. In most structure-initiated research experiments, subjects are asked to produce both the prime and target sentences. However, some studies have also found that merely comprehending the prime sentence also affects the production of the target sentences. In addition, the comprehension and production processes in a dialogue task can produce a strong priming effect. (Cleland & Pickering, 2003).

In dialogue, both speakers and listeners are engaged in repetitive processes of conversational comprehension and production, so their language production tend to be influenced by the linguistic structures they have just comprehended. Therefore, the conversational process is actually highly repetitive, and this repetition can occur at different linguistic levels, such as specific words, accents, speed of speech, expressions, etc. Studying the priming effects at different linguistic aspects can guide the actual language teaching activities. The number of repetitions can be increased at levels with stronger priming effects, while unnecessary repetitions can be reduced at levels with weaker priming effects in order to save time and use other teaching methods to compensate for the deficiencies. Research on the language convention predicts that in the dialogue, the speaker adjusts his expression. Similarly, there is good evidence of cooperation on many occasions through dialogues. In explaining abstract mazes, people tend to converge on certain types of descriptions and use the same expressions as each other. From the perspective of mental model adopted by speakers and listener, this is a type of semantic coordination. Studies on the coordination of referential expressions by participants have shown that participants make conceptual or temporary agreement on how to refer to an object. With the proceeding of the dialogue, the conceptual agreement may get a further development. For example, Branigan et al. found that the priming effect was greater when the same verb was used in the prime and target sentences than when different verbs were used, i.e., the lexical stimuli in the conversation could enhance the priming effect, which provides an idea for our vocabulary instruction.

To date, fewer studies have provided direct evidence for the priming effect of language comprehension processes. Apart from that, theories related to language comprehension have paid less attention to different dimensions of language representation, focusing more on semantic disambiguation, etc. Theories related to language comprehension often assume that syntax is automatically represented, yet this presupposition is not justified by structure-starting experimental data. The focus of attention in the past was on the selection of key syntactic structures and the choice of words in the language output process, so the main role of the priming effect was used to make choices in this regard, so that having comprehension processes was neglected. This also suggests that the priming effect is weaker during language comprehension than during language production, and that certain stimuli, such as semantic relevance or repetition of the same verb, may be needed if the priming effect is to be found during language comprehension. Second, the application of priming effects in the process of language comprehension is limited to when there is ambiguity in sentence meaning that needs to be reanalyzed. Finally, studies involving language comprehension usually measure reaction time, whereas structural priming during language output has a relatively small effect on reaction time (Corley & Scheepers, 2002; Wheeldon & Smith, 2003). Thus, for these reasons, research on structural priming aspects of language comprehension processes has been less available in the past. Whether priming effects in language comprehension processes need to be produced under certain stimuli remains to be further investigated, as language comprehension processes are more

cognitively grounded than process of language production (Pickering & Ferreira, 2008).

Besides the native monolingual adults, young children also show sensitivity to stimuli during language comprehension, i.e., priming effects (e.g., Arai & Mazuka, 2014). Evidence has revealed that there is structural priming effect for L2 learners in language comprehension (Wei et al., 2019). Further, Wei et al. (2019) found that structural priming effects can be independent from lexical facilitation for Chinese learners of English. In the study, an online reading task was conducted with the help of self-paced reading task. Even when the test materials were difficult for comprehension, there were still priming effects facilitating comprehension. Thus, we can safely arrive that regardless of sentence and language types, there is abstract structural priming. That is, the form of prime and target, identical or different, would not affect priming.

3. Structure in Sentence Comprehension

Structural priming attracts attention because it provides for abstract mental representation which can be dissociated with meaning- or sound-based representations. The earlier inferences predicted that prime and target sentences only share structure, thus the structure of prime sentences influence the choice of structure for target sentences, not content. Furthermore, target sentences during comprehension could be affected only when the prime and target sentences share similar structure and lexical items. Indeed, during comprehension structural processing is not the only stage. Though a large number of studies found abstract structural priming effects (e.g., Thothathiri & Snedeker, 2008a, 2008b), these studies differ from previous studies which argued the only influence of lexical items on structural priming effects in terms of experimental tasks. More recently, more and more studies observed significantly obvious structural priming effects even that prime and target sentences do not share the identical lexical item (e.g., Giavazzi et al., 2018).

Beyond monolingual adult groups and young children, abstract structural priming effects during comprehension have also been seen in bilingual speakers (Wei et al., 2019). Besides the trial-to-trial priming effects which take place when the target sentence follows a structurally identical to a manipulated prime sentence, many studies started changing from the abstract structural accessibility to cumulative priming effects (e.g., Tooley & Traxler, 2018). In cumulative priming studies, self-paced reading task is adopted with a focus on reading times for ambiguity between a main clause and the less preferred structure. Though longer reading times for the less-preferred structure, it can be reduced by more frequent exposure to structure. This finding argues that priming for relative clause structure can accumulates with repeating exposure. In a following study, the finding showed that more-preferred structure could also take longer reading time by manipulating participant's exposure first only to relative clause sentences. Cumulative structural priming effects have been observed in both single comprehension session or combined with other sessions. In short, these studies bring out the structural representations and stress the critical role of implicit learning in forming mental representations across time spans.

4. The Mechanisms Underlying Sentence Production

Bock held that the generation of statements requires activation of procedures related to the generation of a particular syntactic form. That is, there may be specific procedures related to the generation of sentences, like that *Dad gave a football to his son* (prepositional object form) and *Dad gave his son a football* (dual object form). The particular procedure of activation will not disappear directly. Therefore, then it becomes easier to use that procedure for sequent sentences production. As an alternative explanation for priming, they argued that priming is due to the episodic traces of a particular sentence or phonological memory. In fact, the prime and target sentences may differ significantly. However, if priming takes place from comprehension to production, the procedural explanation will be problematic. This is because the comprehension procedure is different from the one that generates it. For syntax priming, there is another explanation. The related information about syntax is the same. Therefore, it is best to express and compare this based on this same information.

Levelt and colleagues suggested a lexical representation which can be adopted during language production. According to this model, the first stage for language production is 'conceptualization', a message for expressing, and then 'formulation' which refers to encode the message with language, finally the

'articulation', using sounds to realize communicative goals. For this account, there are three levels for lexical entries: encoding semantic information, encoding syntactic information and encoding morphological and phonological information. Pickering and Branigan held that organization of lexical entries can be evidenced by structural priming. In their study, written sentence completion varied to investigate whether the verb in prime and target has the identical form. The results showed that the form of the verb, same or different, in prime and target did not affect structural priming.

It is argued that structural priming is associated with lexical entries which is generalized to both language comprehension and production during which priming takes place by activating knowledge stored in each level. Evidence from Chomsky supports the use of grammaticality judgements which are the product of language processing. Therefore, some argue that structural priming is more effected by grammaticality judgements. In experiment, subjects are not informed the purpose of the experiment and their mental representation is a natural reaction without taking explicit intentions. However, grammaticality judgements cannot provide for showing which sentences are syntactically related.

5. Syntactic Priming in Language Acquisition

Repetition-based priming effects may be relevant to memory because only the priming effect is stored long enough, the processing of the target sentence can be achieved. Some experiments suggest that structural priming needs to be stored in long-term memory. Structural priming may be an invisible language learning mechanism (Chang et al., 2000), and repetition of syntactic structure helps to establish a mapping between form and function (Ferreira & Bock, 2006) by reducing the error signal generated when the input information and the expected information do not match. Thus, the priming effect may be particularly strong in the process of learning. A related hypothesis is the inverse preference effect: syntactic structures with low frequency elicit a stronger priming effect, which results from the repetition of the structure (Ferreira & Bock, 2006), because an unexpected structure leads to a larger error signal (Chang, Janciauskas, & Fitz, 2012), and the learner then repeats it over and over again, producing a priming effect that also facilitates learning.

Do adults and children activate the same syntactic knowledge representations at structure initiation? Do priming effects differ depending on the stage of learning? Recent research has focused on the extent to which children use individual structures (e.g., specific lexical components) and abstract knowledge separately. As age increases, the two components are not used to the same extent when it comes to producing syntactic structures. Further refinement of age stages is yet to be investigated, and if it can be determined that learning relies on different mechanisms at different ages, then appropriate teaching methods can be used more accurately in the actual teaching activities.

Are the processing mechanisms for the acquisition of first and second languages the same? Studies have shown that first and second languages take place in the same brain areas (Indefrey, 2006; Weber & Indefery, 2009), and that the neural networks that process first languages are equally suited to second language processing, i.e., they have the same material basis, so are the abstract mechanisms of syntactic processing the same? Psycholinguistic studies of bilingualism have focused on lexical representation and processing (e.g., Gollan & Kroll, 2001). Structural priming provides a method for studying syntactic representation and processing in bilingual learners and suggests that there is a significant degree of similarity in representation and processing between first and second languages, at least in terms of factors related to structural priming. This allows further study of the degree of similarity across languages, for example, in syntax. For Chinese learners of English, cross-language syntactic priming is the use of native Chinese to prime syntactic structures in the second language by observing whether there is a syntactic priming effect in the Chinese-English direction. The relevant study was conducted to see whether native Chinese learners could achieve cross-linguistic priming using he structure priming experimental paradigm.

6. Factors Influencing the Structural Priming Effect

The presence of structure priming effects in both monolingual and cross-lingual syntactic method has been confirmed by a large number of studies, and some researchers have also turned their attention to the factors that affect the structural priming effect, which has aroused a great

number of researches in this area. The results show that the priming effect is influenced by various factors.

The first is language proficiency, and the question of whether language proficiency affects structure priming effects are well studied. Wang Min (2009) explored the effects of language proficiency and task type on second language structure priming and found that learners with high-proficiency level were significantly more sensitive to structure priming than low-proficiency level learners, and that the priming effect was stronger in oral picture description tasks than in written sentences completion task. There was no interaction effect between language proficiency and task type. This result is also confirmed in the experimental study of Zhao Chen (2014). For learners with low-proficiency level, no matter whether the prime sentence is transitive or intransitive, they are more inclined to produce intransitive sentences; while for learners of high-proficiency level, the prime sentence is exactly the same as the target sentence. It is concluded that the syntactic representation of Chinese English learners is a dynamic representation development process from abstract to concrete. For task type, the priming effect of children is significantly better than that of adults, which is related to task difficulty. Children need more time to do arithmetic and sentence processing than adults, resulting in a stronger priming effect, and adults have developed their own arithmetic habits, which can affect priming effects.

In order to study whether working memory affect structural priming, Xu Hao (2014) selected different methods. The results show that when the second language proficiency is high enough, the bigger the second language working memory is, the more easily the motivation of the syntactic representation of the first language is inhibited, and the less the priming amount is. In contrast, when the second language proficiency is low enough, the bigger the working memory of the first language is, the easier it is to promote the motivation of the syntactic representation of the first language, and the greater the amount of priming. Liu Zhaomin and Guo Chunyan (2013) broke the traditional experimental paradigm of structural priming and used event-related potential technology to record the relationship between long-term memory information and working memory and semantic structure priming. The results show that long-term memory can have a long-term semantic priming effect on working memory, and the content processed in working memory can also activate relevant long-term memory information.

7. Conclusions and Future Directions

A large number of studies on structural priming have provided a new perspective for the study of human language specifically about structural priming during comprehension and production and a direction for the future study of human language. Firstly, we explore syntactic representation through the experimental paradigm of structural priming, and further understand language comprehension, production and the relationship between them. In particular, theories related to the process of language understanding may be influenced by experimental studies related to structural priming, and the syntactic or other features of the brain representation constructed in the process of language understanding may be redefined. A large amount of experimental evidence shows that any level of representation can be primed. However, there are few researches on the meaning level. If the representations generated by learners in the process of information planning can be determined, then the initiated researches will be very meaningful. For example, in vocabulary teaching, which priming effect is greater, semantically relevant or semantically irrelevant? Are priming effects affected by age? There are still debate questions which deserve further exploration.

Currently, participants in domestic studies about structural prime are mainly undergraduate students and above. The application of the structural priming effect needs to be further studied. According to Piaget's theory of cognitive development, children and adults have unique cognitive structures. According to Piaget's cognitive development theory, both children and adults have unique cognitive structures. The results from studies of Zeng Tao, Liu Rongfeng, Fang Wen, and Zhang Min (2015) showed that children and adults have different structural initiation effects, and the priming effects of children are stronger than those of adults. Therefore, more research is needed in the future to investigate whether the structural priming effect can be applied to different age groups and learners with different language proficiency levels. It is also important to

investigate whether children and adults have different levels of structure priming effects when they use structure priming to acquire new syntactic structures.

At present, the research on structure priming is mainly conducted in the way of experiment, and there are few researches on structure priming based on classroom teaching. By analyzing the non-standard translation in corpus and the test results, Chen Yaping (2013) found that the generation of non-standard translation in the process of language understanding and production is caused by the structural priming, so teachers should use the structural priming to strengthen the normative structure in translation teaching. In addition, Peng Hongying (2017) explored the influence of promoting writing after reading on the coherence of writing by setting up different experiments. The results show that the continuous writing after reading has a positive effect on the coherence of writing and has a guiding effect on writing teaching. It can be seen that structural priming promotes comprehension and production of syntactic structures in English teaching and the language mechanism. Therefore, in the future, relevant studies can further combine structural priming with English teaching, so that teachers can better carry out teaching and provide methodological guidance for teachers' teaching from the perspective of second language acquisition.

The ultimate goal of linguistics is to describe human mental representation (e.g., Chomsky, 1986), that is, the purpose of studying language is to study human thinking. Psycholinguists are committed to using certain methods to study the mental representation of syntax. Is it possible that the structural priming cabinet can become a new and complete method to study linguistics? Structural priming effect is universal, it exists in children, second language learners, aphasia patients. In addition, the cross-language priming effect provides a reference to the extent to which different language structures can be analyzed in the same way, and more specifically, it can confirm the existence and characteristics of a universal grammar. In conclusion, a large number of studies in recent years have used structural priming to explore a range of issues in the field of psycholinguistics. Structural priming is a powerful tool, which can reflect the potential language mechanism of different people and promote language learning and communication. It will be an important method in psycholinguistics.

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