



Review Article

Structural Priming: A New Perspective of Language Learning

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Abstract: Repetition, as a common phenomenon of behavior, has been made extensive use of to illustrate mental representations. In the world of language, such repetition can be massively observed as well, which is called structural priming, people's preference to reuse or better process the present structure due to its syntactic similarity to the previously processed or produced structures. Research around structural priming has been explosively conducted in within-language and cross-language contexts since Bock firstly introduced structural priming into language field in 1986. Research on structural priming centralizes on the underlying driven mechanisms of structural priming and its occurrence and function in language production and comprehension. As researchers investigate structural priming deeper, it is necessary to assess the current status of the research on structural priming and make directions for future research. This review is to offer an overview of the recent research on structural priming and recommendations for future investigations. For deeper and more thorough investigation of structural priming, the author points out that researchers can dive into investigations of structural priming in different range of subject, especially in second language learners and probe into social influencing factors of the occurrence and magnitude of structural priming in a more natural experimental paradigm.

Keywords: Structural Priming, Syntactic Priming, Implicit Learning, Residual Activation, Second Language Acquisition

1. Introduction

In the last couple of decades, researchers have revealed a new form of repetition in language world which is called structural priming. In people's oral or written production, they prefer to choose the structures that they have produced or processed before. People firstly recognized this linguistic repetition in dialogues. For example,

At what time does your shop close?

At five o'clock.

What time does your shop close?

Five o'clock [1]

Previous occurrence of "at" impacts the speaker's answer. This phenomenon of repetition which can be easily noticed in everyday conversation motivates researchers to probe its existence in experimental settings. Bock conducted a pioneering experiment to observe structural priming in subjects' production [2]. In her experiment, subjects were

firstly offered a priming sentence embedding double object or prepositional object and read the priming sentence. And then, subjects were asked to describe an irrelevant picture that can be described with both pairs of structures. The results showed that the subjects tended to depict the picture with a double object structure after a priming sentence with double object, and the same with prepositional object structure. A strength of these results is that it reveals that structural priming occurs automatically and independently, free from the restrictions of specific communicative intentions, prime-target relations, or other discursual factors.

After this initial experiment, more and more experimental studies centering on structural priming have been conducted. Structural priming appears pervasive in language production and in language comprehension. And the interest in structural priming is mainly driven by several motivations. Firstly, the existence of structural priming between the prime and target constructions can reveal the nature of the mental representation underlying language use. Secondly, structural

priming can be used to explore if the brain has mental representations of abstract linguistic construction. Last but not least, it has been proposed and verified that structuring priming effect plays an important role in language acquisition, both in first language (L1) and second language (L2). Therefore, investigations of structural priming have the potential to illuminate the mechanism behind language use.

Besides, the techniques used to examine structural priming effect have been extensively explored. So far, there are four major techniques used to conduct structural priming research. The first developed one is memory tasks in which participants are asked to read out a prime sentence and then describe a picture which can trigger the same structure and the alternative one [2, 3]. The second is written or oral sentence completion tasks, in which the participants are presented with a test containing some sentence fragments and then complete each sentence with choices between the target structure and the alternative one [4]. The third one is sentence recall task, in which participants read a sentence from the computer screen where words in the sentence are showed one by one at a fast rate and they successively finish an intervening task and repeat the previously presented sentence orally [5]. The fourth is confederate scripting which requires a pair of participants, one of which is a confederate of the researcher. The participant and the confederate depict a serial of pictures to each other in turn and pick the pictures according to the description. This task is under condition that the confederate describes pictures with the verbs or structures written behind each picture, while the other participant create his or her descriptions freely and is unaware of the difference [6]. With these techniques, structural priming has been pervasively examined in language comprehension and production, offering convincing evidences to the existence of structural priming in language use.

Structural priming is not just a simple psychological phenomenon. Through years of investigations, researchers confirmed that structural priming has more general function in the field of language and conversational communication. Though we have spent much time trying to understand how and why structural priming happened, it is more necessary for us to understand how language is represented and processed in our brain through structural priming. So, in what follows, the author presents a critical review of experimental research on the structural priming and tries to offer some future directions.

2. Mechanism of Structural Priming

2.1. The Essence of Structural Priming

A central topic around the essence of structural priming is whether it is a semantic priming or a syntactic priming. Structural priming was firstly observed in language production, so semantic meaning conveyed by structural priming was the primary focus in the field of language production [2]. Some studies revealed that the thematic roles greatly affected sentence production. Chang et al. found that

the participants are more likely to produce sentences whose thematic roles are the same with those of the priming sentences [7]. For example, after encountering sentence like "The waitress rubbed polish onto the bar counter." people are more likely to produce a sentence whose thematic order is "agent-theme-position" instead of "agent-position-theme" as in "The waitress rubbed the bar counter with polish." The same conclusion is drawn in the study conducted by Vernice et al. that a passive construction is produced after a complex sentence in which patient, instead of the agent, is emphasized [8]. Zhao and Jiang employed two priming sentences which had the same syntactic structure but different numbers of thematic roles in the experiment, in order to explore interactive relationship between syntactic structures and conceptual structures in the production of Chinese English learners [9]. The results showed that the number of thematic roles did impact the intensity of the priming effect in the production of high proficiency learners but failed to influence lower proficiency learners.

But there were also some investigations gave support to the proposition that a particular construction of a prime sentence could trigger target sentence in the same construction even if their thematic roles did not match [10-12]. For example, the positional preposition phrase in "The wealthy woman drove her BMW to the supermarket." can trigger a sentence with propositional object, as in "A street boy sold some drugs to undercover police." The orders of thematic roles in these two sentences are different, in other words, the seemingly identical "to construction" convey totally different semantic meaning, but they can be primed by each other due to the similarity in structure. Gamez & Vasilyeva attributed the different results to the greater difference in syntactic structures than in thematic roles. In other words, the features of the thematic roles were less noted, so the priming effect of thematic roles did not occur [13].

Evidence of priming effect from language comprehension also suggested that structural priming was driven by syntactic overlap. Some researchers compared the different numbers of primed structures activated by a syntactic structure embedding a verb and its synonym [14, 15]. They found that the verbs in the prime sentence that were identical with those in target sentence enhanced the comprehension, while no sign of better comprehension of the target was observed even if the prime and the target had very close meaning and embedded in the same structure. If it had been the semantic overlap that facilitates the comprehension process of target sentences, the priming effect would have been triggered by the synonym carrying the same semantic meaning, which showed that structural priming is syntactic priming instead of semantic priming.

Yet Jiang proposed that the priming effect was a form-meaning correspondence constructional priming that resulted from semantic priming together with syntactic priming [16]. To be specific, Bock and her colleagues took DO and PO as two alternatives without difference in meaning so they ascribed priming to pure syntactic priming that occurred regardless of semantic difference. But according to

Construction Grammar [17], language is learned through constructions, a form and meaning pairing, which means change of form leads to change of meaning, so there must be a difference between DO and PO construction to some degree, thus, it is a constructional priming (semantic priming and syntactic priming jointing together) that make structural priming possible.

2.2. *The Driven Mechanism of Structural Priming*

Whether structural priming is lexical-independent or lexical driven is another topic around the studies of structural priming. Early researches conducted by Bock and her colleagues showed that after repeating the prime sentence embedding a passive construction, participants tended to describe a picture with passive structure and using another verb that fit the new contexts [2, 10]. This revealed that the process of structural priming did not depend on lexical repetition, in other words, priming occurred as long as the syntactic structures matched. Some researches in language comprehension also observed structural priming effects under condition of no lexical overlap [18-22].

But there also existed some evidence that support lexical priming. Pickering and Branigan reported that priming effect still occurred even if the prime and target contain different verbs, but that priming effect intensified if the verb was repeated [4]. Later, Melinger & Dobel provided further evidence [23]. They only had participants read ditransitive verbs that are constrained either to the prepositional or double object construction, and then let them describe pictures which can be described with either structure. The results showed that the participant used the same structure to describe, which revealed that a single verb in isolation could bias participants' preference even if it is not linked with its argument, and this enhancement by lexical repetition is called "lexical boost" [24]. What's more, studies using fMRI technique in language comprehension demonstrates that compared with nouns, verbs inserted greater influence on sentence comprehension. Specifically, priming effect can be observed in both active and passive structures when the verb repeated in the target, while only passive structure was primed when the verb changed [25, 26]. The results from an eye-tracking experiment and a self-paced reading experiment added to the "lexical boost" account of syntactic priming effects in comprehension [27, 28].

2.3. *The Mechanistic Accounts of the Time Course of Structural Priming*

As for the time course of structural priming, there are mainly three explanations accounting for it, including residual activation account, implicit account and dual-mechanism accounts.

Residual activation account ascribes the occurrence of structural priming to the residual activation for a certain syntactic structure in short-term memory [4]. According to this account, lemmas contain combinatorial nodes which carry the lemmas' subcategorization frames and lemmas are

connected to certain combinatorial nodes. when people comprehend and process a sentence, there is a temporary residual activation for that structure's combinatorial node. Thus, when subsequently encountering the same or similar structure, this residual activation helps accelerate the process by enabling people to choose recently processed structures over their alternatives, which leads to structural priming. More importantly, the link between the lemmas and its combinatorial nodes makes lexical boost possible. To be specific, priming effect occurs as the activations of the shared combinatorial node reserves no matter which verb is comprehended, and priming effect is strengthened when the prime and the target share the same lexical item. The repeated verbs act as a retrieval cue that enables speakers to use the explicit memory to recall and then reuse structure in the prime sentence [3, 29]. Residual activation account implies that structural priming is transient because the residual activation decays by the interference [30].

However, some researchers reported structural priming did not undergo a degradation after several intervening events [3, 29, 31-34], which posed challenges to the residual activation account of structural priming. So, an implicit learning account was proposed by Bock & Griffin to account for the persistence of structural priming [3]. They contended that most of structural priming effects in language production were the consequence of an implicit learning process, rather than short-lived activation. This account holds that structural priming is an unconscious learning process of abstract linguistic messages over a period of time course, offering a sound explanation for the endurance of structural priming over interfering sentences. Chang et al. used a connectionist model to account for structural priming, in which error-based learning mechanism is employed to acquire and adjust sequencing mechanisms and meaning-form mappings to generate syntactic representations [29]. Through error-based learning, learners predict about the upcoming words or structures from what they just heard, and if those predictions did not match, say, a double object followed instead of the assumed propositional object, this model would adjust the connection weights which is in charge of the prediction, so that the predictions adapt according to what was actually uttered, arousing preference for the priming structure (double object) instead of the alternative one (propositional object). All these results implied that structural priming occurs in the process of the derivation of abstract representations of linguistic messages, in which change of connection weights leads to the mapping of meaning to a particular form. So, the strength of the representation of a potential structure rises as the exposure to the structure rises. More importantly, this process occurs unconsciously and implicitly, which explains how syntactic structures are primed through an implicit learning process. Later, a series of experiments implemented by Kaschak and his colleagues also added to the data that support longitudinal effect of structural priming, which can't but be ascribed to implicit learning [31, 32]. The study of Bernolet et al. also replicated the findings that structural priming reserves over several distractors, supporting the

implicit learning account [34].

Dual mechanism account holds that structural priming can be activated by both implicit learning process and lexical overlap. Lexically independent structural priming is aroused by a long-lived implicit learning mechanism, while lexically dependent priming results from a more short-lived residual activation mechanism [35]. Hartsuiker et al. conducted four sets of experiments in both oral and written production tasks to account for the discrepancy of the above two accounts of structural priming [36]. The results showed that the priming effect is long-lasting, whereas the extra priming effect driven by lexical boost failed to exhibit persistence after several intervening filler tasks. The persistence of priming showed that structural priming is an implicit learning process, but implicit learning account cannot justify the decay of the lexical enhancement of the priming. So, the dual mechanism model is proposed, in which the lexically dependent, short-term activation mechanism that are related to the explicit memory of a prior structure works in tandem with the abstract, long-term learning mechanism that cause speakers to repeat abstract syntax.

3. The Influencing Factors of Structural Priming

As investigations on structural priming goes deeper, research focus gradually switched to influencing factors of structural priming. In this section, mainly four influencing factors will be discussed, namely, frequency interaction, cumulation, lexical overlap, language proficiency.

It is natural that people tend to use structures that they are familiar with and use unfamiliar structures less frequently. But many studies showed that less frequent structures can be better primed than frequent ones, exhibiting an inverse frequency effect [35, 37-39]. Hartsuiker & Westenberg reported that the structures which were observed as less frequently used in the pre-experimental baselines were significantly preferred in production and this preference stayed in the post-experimental baselines. The results revealed that there was a relatively longer-lasting, cumulative priming effect in the priming of less used structures [38]. what's more, studies of Chinese structural priming added to the current evidence of inverse preference effect. Yu & Zhang investigated how speakers' syntactic choice ratio influenced structural priming in Chinese and the results showed that speakers increasingly used the prime structures in the production, among which low frequency prime structures triggered the most priming [40]. Yang et al. explored structural priming under cross-linguistic context and also observed inverse frequency effect [41]. Implicit learning mechanism can account for this feature of structural priming. As is mentioned above, implicit learning account holds that syntax acquisition is achieved by an error-based learning and meaning-form mappings. Speakers make incorrect predictions when processing unfamiliar structures, so the speakers will make full use of all information available (existing knowledge or recent experience) to clear

the trouble, consequently strengthening the connection between meaning and form and that is how abstract syntax is learned implicitly [29]. This suggests that the deeper the discrepancy between the prediction and what is successively uttered is, the stronger the priming effect is.

Researchers also found that cumulative effect in structural priming, which refers to the phenomenon that the presence of multiple primes enhances subsequent priming. Some progress has been made by Kaschak and his colleagues with regard to cumulative effect of structural priming [42, 43]. In their experiments, participants were required to go through two phases: in the training phase, they produce or comprehend primes and in the priming phase, they complete subsequent production tasks. Results showed that the frequency of different structures in priming was consistent with that in training. Later studies showed that this influence maintained as long as one week [31, 32]. Investigating "complementizer-omission (that-omission)" in complement clauses and in relative clauses, Jaeger and Snider's data revealed significant cumulative persistence effect in the "Complementizer omission" and demonstrated that the more full complementizer clauses the speakers produced, the more likely the target was to be a full complementizer clause [44]. Segaert et al. discovered that priming effect of passive structure is significantly enhanced after participants were exposed to the prime three times compared with exposure to the prime once [45]. Wang & Wei examined cumulative effect in L2 written production [46]. They confirmed the presence of cumulative effect in L2 writings and claimed that cumulative effect was relatively stable as it was not influenced by temporal distribution and different subsequent tasks. Again, the presence of cumulative effect of structural priming manifested that structural is an implicit learning. According to Chang et al.'s model, meaning-form mappings are strengthened after every structure being processed, and that how previous cumulation of primes promotes subsequent production [29].

As was mentioned in last section, some studies showed that only when verbs in prime and target sentence were the same, did structural priming occur, although the results of some studies held that no matter whether the verbs were the same, structural priming occurred. Arai et al. used ditransitive structures which could take either a double object or propositional object construction [47]. And the verbs chosen in the ditransive structures were identical with those used in production tasks. Results showed that structural priming occurred only when the verbs in target sentences repeat the verbs in the prime. Thothathiri and Snedecker found significant priming effects that depend on lexical repetition in comprehension [18, 19]. That is to say, priming occurred even when the verbs in the target structure were different from the prime. Since both lexically dependent priming and lexically independent priming have solid supporting evidence, some researchers proposed that lexical repetition was not entailed in the occurrence of priming, but the reoccurrence of the verbs in the target sentences did enhance priming effect in production and this phenomenon of structural priming is called lexical

boost [24]. Studies of L2 learning also give support to lexical boost. Cao & Mou' study also provided evidence from Chinese L2 learners that both Chinese "ba" and "bei" constructions were primed, and this prime was strengthened by the repetition of verbs in prime and target structures [48]. Some studies of structural priming in L2 English also confirmed lexical boost effect in structural priming [49-52].

Studies also suggested that language proficiency played an important role in structural priming. Bernolet et al. argued that language proficiency was an important predictor of priming from L1 to L2 [53]. It was assumed that the more proficient the learners were, the stronger the priming. Besides, language proficiency was also used to predict priming from L2 to L2. It predicted stronger priming in more proficient L2 learners, which was akin to the development of abstraction of representations [29, 54]. Lower learners' abstract syntactic representations are underdeveloped, so they could only form relatively specific syntactic representations, not abstract enough to trigger priming. Wang's study also drew the same conclusion that high proficiency learners produce stronger priming effect and she used activation model to account for this result [55]. According to activation model, the more proficient the speakers are, the closer combinatorial nodes are linked, and thus, the stronger the priming is. More recently, Jackson & Ruf conducted two priming experiments in intermediate English-German L2 learners [56]. Though the participants showed equivalent short-term priming effect of adverb-first word order in both experiments, at the lower proficiency level, long-term priming in lower proficiency learners is found to hinge on the stability of specific semantically restricted structures instead of more generalized syntactic structure representations. In other words, structural priming in lower proficiency learners are more semantically driven than syntactically driven as their abstract syntactic representations have not been well developed.

4. Conclusion and Future Directions

Structural priming has witnessed explosive investigations in recent couple of decades and has now become a heated research concern in psychology and linguistics. Current investigations mainly use structural priming as an experimental tool to scrutinize the property of structural priming and interconnections of the representations in language production and comprehension. And more recently, the learning effect and communicative functions of structural priming have aroused researchers' interest and its function in learning and communication have manifested the application value. Although the research into structural priming has been deeply and extensively developing and the research methodology has been improving, many problems are still understudied. So here follows some directions and suggestions for future investigations.

Firstly, future research should be conducted in wider range of subjects and language contexts. Most of current research studied structural priming in English native speakers or

children. There are only a few recent studies on L2 or bilingual learners [54, 57, 58], which help us better understand the cognitive mechanism of L2 learning. However, the function of structural priming in L2 learning and structural priming in L2 classrooms are understudied. So, it is recommended that structural priming should be further studied in natural and diverse context and targeted at L2 learners of multiple languages.

Secondly, impact of socio-cognitive factors on structural priming also deserves further scrutiny. A major function of structural priming is to facilitate language learning and successful communication, which is closely connected to alignment [24]. Alignment is crucial in social interaction in that the psychological mapping usually occurs at linguistic level and linguistic alignment (structural priming) is key to successful communication [59]. In other words, alignment in nature is a process where interlocutors dynamically and reciprocally adapt and converge to each other in linguistic level to achieve convergence in other levels. And alignment occurs in context, which is a complex system, including linguistic context, situational context, the interlocutors and the social or cultural background etc. Therefore, structural priming or linguistic alignment is bound to be restrained by socio-cultural factors. But currently, researchers investigate structural priming as an independent cognitive process and ignore the social factors that impact structural priming, so future research should be deeply and thoroughly probe into the relationship between structural priming and socio-cultural factors, especially the factors that are socially and culturally interwoven, such as work memory, notice etc..

Thirdly, more experimental paradigms should be employed to examine structural priming in different environment of language use. The major experimental paradigms employed in current research are highly controlled laboratory experiment, such as, oral description, sentence recall, sentence completion, confederate scripting etc. These paradigms guarantee the reliability of the research, while at the same time, impede researchers to observe structural priming in natural and authentic context. To examine the occurrence of structural priming in natural settings, researchers began to investigate within-language and cross-language structural priming based on the data from corpus [60]. Some Chinese researchers found significant priming effect in continuation task and began to use continuation task to investigate structural priming in L2 context [61-63]. In continuation task, learners firstly read a story with its end removed, and then write to continue the story in a logical and coherent way based on full understanding of the story [64, 65]. In the process of continuation, learners need to not only fully understand the given text, but create new content, imitate and use the words and structures that appeared in the given text. With continuation task, researchers can previously manipulate the reading material for a specific syntactic structure. In other words, the syntactic structures in the reading material are regarded as priming sentences and learners' production serves as targeted structures. In this way, both experimental control and validity of the experiments of structural priming can be

achieved. Through these new paradigms, researchers can not only observe structural priming in natural language but also reveal complex influencing factors of structural priming in natural language.

As the author has shown, a great deal of research has been made to illuminate the driven mechanisms of structural priming, which helped people better understand how structural priming occurs. More importantly, in the process of investigation, structural priming manifested itself as a useful tool for researchers to probe into mental representation of language and also suggested more applications in language learning, especially in L2 learning. However, there are still many other problems remaining to be solved, providing many avenues for further investigation.

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