The Effects of Syntactic Priming on Language Processing and Learning

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Abstract: Priming can facilitate the language processing and learning by affecting speaker's response to the subsequent stimulus after introducing the new language form, for both comprehension and production. Syntactic priming, as a new branch of priming, is the main focus of this research as it is more practically applicable under psycholinguistic background. In this review, the effects of syntactic priming on language learning and the effects of syntactic priming on the link between language comprehension and production were both explored. It is assumed that there is a common lexical-boost effect as a mediator during the syntactic priming process through the implicit language learning. However, such effect can be somehow independent to the language comprehension based on the current research. Moreover, some neurological measures are applicable when investigating the neuronal correlates of the syntactic priming and lexical boost effect during sentence comprehension and production. In general, this study discussed the non-linear relationship between implicit language learning and syntactic priming highlighted with the lexical mediator effect, the independent effect between lexical and structural content on language comprehension, as well as the similar mechanism shared by language comprehension and production. The previous experiments still lacked the reliability and validity as the variables are difficult, and the tools or strategies used may not be appropriate to accurately measure the result. Hence, causations cannot be formed in a solid state even if some correlations are well evolved with research findings. The future direction, naturally, should keep track of how syntactic priming can better intervene on the language processing and learning program, which in turn reduce the overload of the computational brain and boost the language learning. This review can provide some guidance for the design of educaitonal programs using syntactic priming as well as relevant research.

Keywords: Syntactic Priming, Language Comprehension, Language Production, Implicit Learning, Psycholinguistics

1. Introduction

Priming is a cognitive psychological term to define that an individual's exposure to one stimulus can affect the response to the subsequent stimulus without any awareness. The human brain can be analogous to a complex machine, consisting of billions of components called neurons. These neurons are connected in order and are function-oriented due to the different structural patterns

optimized by the nature. They can interact with each other conditionally, and these conditions are the "triggers" in the human brain function the same as priming. When the neurons are exposed to different conditions, they can make the spreading activation to form a tremendous network of a different kind of information processing (i.e., chain reaction). In language production, syntactic priming is a type of priming that the language process of a sentence (form-function mapping) will be facilitated after inducing the previous sentence with a similar syntactic structure [1]. Meanwhile, the lexicon is the basic unit of the language which contains the catalog of words. Whether it is for language production (syntax-based) or for language comprehension (semantic-based), the core consists of lexical words as a single unit. Lexical words play an important role in comprehending and structuring sentences and thus updating the concept of the external world. These so-called concepts are the form of semantic priming, while the flow of structured sentences is the form of syntactic priming. They interact with each other, enabling humans to interact with the external world. Implicit learning is the base of syntactic priming, which refers to the process of unconsciously acquiring knowledge about the structure of the environment. In addition, the syntactic priming effect can be accumulated by getting repeated exposure to different stimuli. It is supposed that lexical repetition will boost syntactic priming effects. In other words, the more times to implicitly learn from the stimuli, the stronger the syntactic priming effect will be.

To figure out the mechanism of priming effects, the most popular research in this area adapts some models or perspectives. Content priming is described as the phenomenon that represents mental activities of the information or content more accessible when people perceive it, and contains a variety of forms, including semantic, affective, goal, and behavioral priming [2]. The main model to investigate content priming is the associative model, which provides associative pathways to reveal different interactions between two different primers to form a complicated relationship network. Regardless of what specific models are used to study priming, they mutually share two assumptions. The first assumption is priming can make the information previously stored in the human brain more accessible. The second assumption is the primed content is diagnostic, which means the more relevant it is to the response, the more likely it will influence such response. Since priming is a relatively broad topic and strongly related to all stages of a human information processing system, any person who has normal cognitive functions and the ability to form common sense toward the world can be the focused group in the study as long as the universal priming effect can function properly. To understand the systematic mechanism of syntactic priming as the area of priming, this review discussed the relationship between implicit language learning and priming. It also includes the impacts of priming on language comprehension and the effects of syntactic priming on the link between language comprehension and production. This paper can provide some suggestions for the development of language learning tools using syntactic priming.

2. The Effects of Syntactic Priming on Language Learning

2.1. Implicit Language Learning and Priming

Implicit language learning is strongly related to how relevant the primed content is to the target content, represented by the adjacency or the attachment of the primed and target words [3]. However, syntactic priming is immune to the order effect of the domain-general (other than the domain of language) implicit learning to some extent. In the previous research, the sentence of the structure the first noun phrase (NP1) and the second noun phrase (NP2) were fully studied. It is interesting that the grammatical number of the verb after "who" is ambiguous, since it can either attach to NP1 or NP2. When the relative clause is attached to NP1, it is identified as a non-adjacent or high attachment. When the relative clause is attached to NP2, it is identified as an adjacent or low attachment. There are two main tasks needed to be completed, the Serial Reaction Time task (SRT)

and Sentence Completion Task. In the SRT task, the participants responded to the experimental stimuli in a different order by the form of the random positions of the dog image among three circles. At the same time, participants were asked to make predictions of target images based on the prior positions to do an explicit knowledge test. In sentence completion task design, the goal was to complete sentence fragments and the results were analyzed to determine if the relative clause modifies NP1 or NP2. In the SRT task, the results varied between adjacent dependency conditions and non-adjacent dependency conditions. For adjacent dependency conditions, the response time of the participants was shorter in the predictable trial (i.e., in order) than that in unpredictable trials (i.e., random), and there was a negative correlation between repetition times and the response time. For non-adjacent dependency conditions, the same results were found as well. Moreover, the accuracy of the result in the explicit knowledge test was so low that it suggested participants failed to form the explicit knowledge regarding the position of the dog image although the evidence of the implicit learning was shown. In the sentence completion task, there was no obvious evidence in adjacent and non-adjacent conditions regarding the syntactic priming effect. Therefore, implicit learning out of language domain may not induce syntactic priming, which means that implicit learning is independent of syntactic priming in some cases, at least through the observation.

Syntactic priming is more sensitive when only exposed to the stimulus [4]. It will be better for both the first (L1) and the second (L2) language learning, if applying lexical repetition training at the same time to help the form-function mapping and language comprehension, potentially through error-based learning between the expected and unexpected syntactic structure. The previous study explored the syntactic priming effect of miniature artificial languages to learn how to process languages. The experimental group received verb repetition, while the control group did not. Each group of participants completed two tasks: reading aloud the sentences matching the picture presented and performing a comprehension matching pictures and sentences. The result shown participants could read aloud the sentences more quickly after receiving the verb or syntax repetition information. It was also possible for language learners to acquire novel word orders and new lexical items very quickly. Verb and syntactic priming effects were found for the overall reading-aloud times of the sentences, indicating the efficiency of the language-processing system online. A similar pattern of syntactic priming effects for novel structures could be found in a miniature language, which was often observed in children, both in comprehension and production. During L1 acquisition and processing, similar patterns were evident in syntactic priming effects for novel structures in a miniature language. Therefore, both L1 and L2 learning can be improved by the acquired syntactic priming effect, especially by which the novel structure embodies. Verb repetition, as a mediator, can boost the learning efficiency of the artificial language through error-based learning.

2.2. Impacts of Priming on Language Comprehension

Regarding language comprehension, syntactic priming is the manifestation containing both the lexical overlap content and the sentence structure content [5]. Nonetheless, syntactic priming can be analyzed in different dimensions, and the mechanisms within these dimensions can be separated and operated orthogonally, so it is believed that the syntactic priming effect can be facilitated in different ways, potentially other than structural and lexical priming effect integration. To determine whether cumulative structural priming (without any specific lexical information) and lexically mediated priming (lexical overlap) are created in comprehension by the same process, it is important to understand the parallel relationship between structural priming and lexical priming. The previous study identified the mechanisms that deliver structural facilitation by investigating whether the same mechanisms that produced long-lasting changes in comprehenders' responses to syntactic structure information also delivered structural facilitation resulting from lexical and

structural overlap. Participants read challenging sentences that were reduce-relative in five eye-tracking sessions (garden-path). The lexical boosting effect emerged when the total fixation times decreased continuously. However, there was little variation in the strength of syntactic priming effects among sessions, suggesting that the two types of facilitation identified in previous study were distinct and work in opposite directions. On this basis, although semantic element played a role as the connector between language comprehension and syntactic priming effect, either lexical or structure path could dominate the overall effect. Since this study is still limited to only two areas in language comprehension, it is likely for other factors, in which different mechanisms underlying different activation parts of the brain, to influence the syntactic priming effect and facilitate language processing and learning once again.

A single prime of language comprehension without lexical repetition is enough to trigger priming, and the lexical content as a partial mediator, is not the determinant of syntactic priming [6]. The previous study investigated whether syntactic priming develops in comprehension independently of lexical repetition and participants' expectations. There were two conditions in the experiment: the homogeneous condition, where the same syntactic structure was repeated, and the heterogeneous condition, where actives and passives were pseudo-randomly organized. If participants noticed syntactic similarities between sentences that followed one another, the homogeneous condition will have priming effects. If structural priming (syntactic priming) was independent of participant expectations, the heterogeneous condition would have priming effects. Participants performed better under the homogeneous condition than they did under the heterogeneous condition, proving that structural priming could occur independently of lexical priming. Furthermore, it was found that even when participants did not exhibit expectation adaptation in the heterogeneous condition, the structural priming effect could still take place without the interference of lexical repetition. However, because of the variations in reaction times between the two circumstances, syntactic repetition and participants' expectations of the syntactic structure encouraged a stronger structural priming effect. Therefore, this structural priming effect can be driven by a single prime and just one structural repetition, without the need for lexical repetition.

When it comes to Wh-questions, Which-object questions have a stronger syntactic priming impact on women than Who-object questions do [7]. In practice, rather than Who- subject by determining the precise neural network processing, asking patients who had cognitive impairments additional Which-object questions helped them recover more quickly. In the previous study, which examined the neural correlates of syntactic Malay women's language processing, participants matched a variety of binary visual pictorial stimuli with two main types of Wh-questions: Who-subject questions and Which-object questions. These stimuli were used to access the central processing of language, attention, and memory through the manipulation of pictures. An EEG sensor with high spatial density was used to capture Event-Related Potentials (ERP). The findings shown that the right hemisphere's temporal and parietal regions, which were stimulated by object-question stimuli, had greater N400 amplitudes. The outcome should be universal because N400 is frequently employed in psycholinguistic research to confirm the immediate impacts of semantic content during language processing and because the sample size is sufficient.

3. The Effects of Syntactic Priming on the Link between Language Comprehension and Production

As the decrease in neural activities (i.e., repetition suppression effect) can be observed independently for the sentence structure and the lexical repetition, it is likely for syntactic priming to yield the link between language comprehension and production discovered by the functional magnetic resonance imaging (fMRI) study [8]. The previous study used fMRI to measure the neural

correlates of syntactic priming and the lexical boost effect during sentence comprehension and production. Inferior frontal gyrus (IFG) and middle frontal gyrus (MTG) were strongly related to the adaptation of structural repetition, for both active and passive voice, in settings with repeated verbs. However, only passive phrases adapted when there weren't any repeated verbs. Both production and understanding shown the same fMRI adaptation effects, indicating that the same neural network was involved in both production and comprehension of sentences. When actives had a recurrent verb, but not when they had a new verb, fMRI adaptation to syntactic recurrence took place. There was no lexical boost in passive voice; instead, both passives with repeated verbs and passives with unique verbs exhibit an fMRI adaptation to syntactic repetition. On the other hand, lexical repetition was rarely seen when syntactic priming in production is. However, the neuroimaging data revealed that the mechanisms of syntactic priming between language comprehension and language production were similar with the fact that none of the syntactic adaptation effects could have interactions in Region of Interest (ROI) analysis although they differed in the susceptibility to syntactic priming. Syntactic repetition did not interact with modality repetition when verb repetition was present. This demonstrates that syntactic repetition inside and across processing modalities facilitates syntactic processing in the brain to the same amount. As a result, syntactic priming has similar processes between language comprehension and production.

The so-called comprehension or production is merely the manifestation form of the language, and the direction is qualitatively reversible [9]. In the previous study, there were two experiment conditions: In the Comprehension-to-Production priming, participants listened to either active or passive sentences before describing the target images in either manner. However, in the Production-to-Comprehension priming, participants described a picture of the sentence production before listening to the target sentence. At the same time, the participants' EEG signals were recorded to measure the neural mechanism. When passive sentences were primed compared to unprimed in Production-to-Comprehension priming, N400 was decreased. These findings suggest that production and comprehension share processing elements and are related. It can be well speculated that the input regardless of language comprehension or production, as long as it can initiate the top-down processing in the brain to map the target with high dependencies, the priming effect in the link of language comprehension and production will be induced.

Given that language comprehension and production are intercorrelated, the social factors concerning language processing also contribute to syntactic priming on account of the same mechanism of the bidirectional link between comprehension and production [10]. Specifically, both the dialogue sender and recipient in the communicative context can benefit from the priming effect from one to another. The previous study seeks to determine whether having a (shared) desire to communicate affects syntactic processing during overt language production and comprehension. To ensure the validity of the findings, participants in the experiment saw both "comprehension photographs" and "production photographs," and each person was paired with another "naive" participant. It was found that if speaker A was strongly/weakly primed by speaker B, then speaker B was similarly primed by speaker A. Therefore, being in a communicative context affects syntactic processing, and this influence is reciprocal: speakers affect one another. The flow of language comprehension and production is thus provided for each participant by the communicative social context, reinforcing the syntactic priming effect.

4. Limitation and Future Direction

Although this study universalizes what syntactic priming is and how it can be linked with implicit learning, language comprehension, and language production, the previous experiment are still incapable of controlling external variables well, even if some systematic experimental methods were used, such as between-subject, within-subject design, and counterbalancing. Since the topic of

syntactic priming itself is abstract, and any cognitive activities related to the human brain may affect the final results of the experiment as moderating variables to distort the relationship between syntactic priming and its real determinants, so a systematic experimental design is in demand to control all extraneous variables (e.g., interference and inhibition effects or anti-priming), and to realize the point-to-point mapping. One possibility is that it is through the metacognitive level for participants to get a sense of what the expectations of the experiment or experiment biases are. If so, it needs to consider how large it will affect syntactic priming when the experiment unfolds and how to minimize such effect. Especially for the repetition part, participants will get exposed to the same or similar stimuli from time to time, and it is very likely for them to penetrate from the perspectives of experimenters, boosting the syntactic priming effect as a result. Another consideration is the separation of implicit learning and syntactic priming. According to the definition, syntactic priming is an implicit cognitive process to facilitate the same structure fill-in in a sentence. Nevertheless, SRT and sentence completion tasks reveal there is no direct relationship between implicit learning and syntactic priming, at least they are not in a dot-to-dot relationship, which means implicit learning might be divided into sub-levels or different parts as independent variables. Participants do incline to the predictive order after repetition in the SRT task, but it is still not sure about equivalency that such inclinations share the same nature with syntactic priming. Plus, there might be potential mediators in which can be presented as implicit learning to lead to syntactic priming. Domain-general implicit learning other than the domain of language may be another variation of learning, and whether it can trigger syntactic priming is still needed to be examined more deeply. More importantly, it is acknowledged that lexical repetition acts as the pivot of syntactic priming, but the mechanism is still unclear regarding if it accounts for explicit learning of words to intentionally remember or to subsequently induce implicit learning in terms of language comprehension.

Unfortunately, the mechanism of the priming effect the previous researchers investigated was still unclear to gain further insight. The previous studies only focused on the macro analysis of content and process of priming effects but failed to use systematic strategies to study the area of priming. Since priming can be divided into a lot of sub-categories, it remains on the superficial level. Future research could figure out the specificity of the lexical boost effect for the patients who both damage their explicit memory or implicit memory of the primed sentence. It is also worth noticing that some neurological measurements are used in the experiment like N400, but they are all based on the premise that the degree of syntactic priming effect can be directly visualized from physical tools, not the certainty of any correlation or causation exist between syntactic priming and brain anatomy or neurological activities. Future research should further investigate and explain the relationship. In this way, as syntactic priming is deemed to be an unconscious process, it could be a means to reduce the computational load associated with syntactic processing, and the first and second language learning will be facilitated in the psycholinguistic area. At the technical level, syntactic priming can be used for AI voice assistants to optimize the algorithms learning.

5. Conclusion

To sum up, as a new branch of priming, syntactic priming is affected by many confounding variables, pushing the stress to study systematically. Through some scientific research means, the concept of abstract priming can be transformed into concrete and visual observation methods, such as the reaction time and the accuracy of different psychological tasks operating on the computer. However, the relevant research needs to make greater improvements in controlling variables and clarifying causality to better study the impact of syntactic priming on language processing and learning, including the potential relationship with implicit learning, the influence on language comprehension, the interactions, and the reversibility between language comprehension and

production. As a qualified mediator, lexical content can boost the syntactic priming effect to a certain extent, and it can also operate independently from language comprehension in parallel with structural content. On the other hand, analysed by some brain imaging methods, such as fMRI and EEG, it is found language comprehension and production belong to a very similar bi-directional operation mechanism and are subserved by the same neuron infrastructure. This review can provide some insights for the application of syntactic priming in the areas of artificial intelligence and language learning.

References

[1] *Syntactic priming. (n.d.). Syntactic Priming - an overview. ScienceDirect Topics. Retrieved from https://www.sciencedirect.com/topics/psychology/syntactic-priming*

[2] *Janiszewski, C. and Wyer Jr, R.S. (2014). Content and process priming: A review. Journal of consumer psychology, 24(1), 96-118.*

[3] *Wang, F.H. and Kaiser, E. (2022). Linguistic Priming and Learning Adjacent and Nonadjacent Dependencies in Serial Reaction Time Tasks. Language Learning.*

[4] *Weber, K., Christiansen, M.H., Indefrey, P. and Hagoort, P. (2019). Primed from the start: Syntactic priming during the first days of language learning. Language Learning, 69(1), 198-221.*

[5] *Tooley, K.M. and Traxler, M.J. (2018). Implicit learning of structure occurs in parallel with lexically-mediated syntactic priming effects in sentence comprehension. Journal of Memory and Language, 98, 59-76.*

[6] *Giavazzi, M., Sambin, S., de Diego-Balaguer, R., Le Stanc, L., Bachoud-Lévi, A.C. and Jacquemot, C. (2018). Structural priming in sentence comprehension: A single prime is enough. PloS one, 13(4), e0194959.*

[7] *Zaidil, N.N., Begum, T., Rauf, R.A., Ying, J.H., Reza, F. and Al-Marri, F. (2018). Syntactic language processing among women-An EEG/ERP study of visual pictorial stimuli. In 2018 IEEE-EMBS Conference on Biomedical Engineering and Sciences (IECBES) (pp. 520-522). IEEE.*

[8] *Segaert, K., Kempen, G., Petersson, K.M. and Hagoort, P. (2013). Syntactic priming and the lexical boost effect during sentence production and sentence comprehension: An fMRI study. Brain and language, 124(2), 174-183.*

[9] *Litcofsky, K.A. and Hell, J.G.V. (2019). Bi-directional evidence linking sentence production and comprehension: a cross-modality structural priming study. Frontiers in psychology, 10, 1095.*

[10] *Schoot, L., Menenti, L., Hagoort, P. and Segaert, K. (2014). A little more conversation–the influence of communicative context on syntactic priming in brain and behavior. Frontiers in psychology, 5, 208.*