N400 Crosslinguistic Similarities and Differences for Bilinguals in Semantic Processing

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Abstract. N400 is a crucial ERP component indexing lexical-semantic access or post-lexical semantic integration. Previous studies have employed N400 as a vital component to investigate how bilinguals conduct semantic processing of L1 and L2 under various conditions. This paper, via systematic review of recent empirical studies (2018-2025), aims to synthesize crosslinguistic similarities and differences in N400 elicited from bilinguals and to reveal bilinguals' neural mechanism of semantic processing reflected by their N400 patterns. Results show a similar basic neural mechanism and compensatory mechanism for both L1 and L2 semantic processing, as well as a different semantic and environment sensitivity between L1 and L2. Furthermore, moderating effects of individual proficiency, linguistic distance and emotional valence are discovered on crosslinguistic N400 patterns and semantic processing. Specifically, L2 proficiency changes processing into L1-like neural patterns, and emotional valence asymmetrically impacts L1 and L2. These findings suggest a dynamic bilingual semantic system where neural correlates are shaped by an interplay of linguistic, cognitive, and affective factors.

Keywords: N400, bilingual semantic processing, crosslinguistic, similarities, differences

1 Introduction

The semantic processing mechanism has aroused great interest in cognitive linguistics. Recent studies have focused on bilinguals' neurophysiological patterns in crosslinguistic semantic processing, utilizing N400 as an index indicating different brainwave patterns under various stimuli [1, 2].

N400 is a monophasic negative brainwave peaking 300-500 milliseconds after stimuli onset with a broad scalp distribution, most pronounced in the centro-parietal region with a deflection over the right hemisphere [3]. Since its first discovery in 1980, N400 as an ERP (event-related potential) component has been proven to be a crucial index reflecting the difficulty of the activation of language representations during lexical-semantic retrieval or post-lexical semantic integration into the preceding context. Previous studies have investigated basic N400 effects in semantic processing, observing a significantly increased N400 amplitude and a prolonged N400 latency in accordance

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with an increasing difficulty of lexical-semantic access or semantic integration[2]. In terms of bilingualism, typical N400 effect exists during semantic processing of both native (L1) and non-native (L2) language, whereas in general, L2 semantic processing elicits a larger N400 amplitude and a longer N400 latency relative to that in L1 [4].

Recent years have witnessed a growing scholarly interest in the interplay of N400 characteristics between languages and a multitude of variables, such as semantic depth[5], emotional stimuli[6] and individual differences[7]. Nonetheless, in recent years, there has been no comprehensive literature review with respect to multiple N400 effects in bilingualism, the latest one in 2017, and there remain some controversial research results. Therefore, it is necessary to systematically synthesize up-to-date research results and providing possible explanations for conflicting ones.

The present study aims to review of recent research into crosslinguistic similarities and differences of N400 characteristics in bilingual semantic processing, especially under moderating effects of other factors. This paper may further provide neurophysiological evidence for bilingual semantic processing models (e.g., RHM, revised hierarchical model, and BIM+, bilingual interactive activation model plus) and assist the improvement of bilingual teaching strategies.

2 Methodology

The present study is a systematic review, integrating results of empirical research from 2018 to 2025 to address the following research questions:

(1) What are the crosslinguistic similarities and differences of N400 in terms of amplitude, latency and scalp distribution?

(2) What is the neural mechanism of semantic processing reflected by N400 crosslinguistic characteristics?

This study refers to the PRISMA 2009 flow diagram to select references. References mainly derive from the database PubMed NLM (all fields: N400 semantic bilingual), Web of Science Core Collection (title/keywords/abstract: N400 semantic bilingual) and CNKI (topic search: N400 semantic bilingual crosslinguistic, in Chinese). After identification and removal of duplicate, 258 records are included. Considering the latest comprehensive literature review is in 2017[4], 108 records after 2017 are screened out for further examination. The inclusion criteria are 1) examination of both L1 and L2 processing, and 2) comparison of N400 between the two languages. Against these criteria, the researcher read titles and abstracts carefully and retained 28 records (four in Chinese and 24 in English). During full-text reading, two additional records from the research citation are included. At last, 30 records (four in Chinese and 26 in English) are included for inductive thematic analysis, with three records failing to find full text and merely read abstracts. Via inductive thematic analysis, the results in these articles are separated into different themes such as moderating effect of language proficiency, emotional effects, influence of semantic complexity on N400 crosslinguistic characteristics.

3 Results

3.1 Crosslinguistic Similarities and Differences of N400 Patterns

Similarities Of N400 Patterns Between L1 And L2.

Crosslinguistic Similarities in Code-switching.

Several studies provide insights into N400 crosslinguistic similarities in different code-switching directions. Language switching in both directions (L1-L2 and L2-L1) elicits an N400 effect not only in the visual condition, but also in natural auditory discourses, with an earlier and wider distributed N400 effect [7]. Moreover, when the stimulus onset asynchrony (SOA) is as short as 50 milliseconds [8], no N400 amplitude difference is observed for both language switching directions, indicating that the shallow semantic processing mechanism shares a similarity between the two switching directions.

Crosslinguistic Similarities Under Various Environments.

Specific environments exert similar impacts on L1 and L2 semantic processing. Semantic context of speech perception in noise test shows that under noisy conditions and high-constraint context conditions, both L1 and L2 elicit a smaller N400 amplitude and a shorter N400 peak latency compared to quiet and low-constraint conditions [2]. As to emotional environment, research has found that under positive emotion, both L1 and L2 elicit a larger N400 amplitude, indicating a larger impact of positive emotions on both L1 and L2 semantic processing[9].

Differences Of N400 Patterns Between L1 And L2.

N400 Characteristics Under the Impact of Language Divergence.

Language structure and system play a pivotal role in manipulating crosslinguistic N400 patterns and semantic processing. Research that zero in on sub-lexical elements has revealed a larger N400 amplitude for L1 than L2 words with transposed letters [10]. In respect of the internal structure of language, a larger N400 effect is elicited in L2 than in L1 final word incongruency by highly proficient Hindi-English bilinguals, which is an implication that languages with SVO word order are apt to be more efficient in terms of semantic predictability than those with SOV word order [11]. The taxonomic distance between languages plays a role with a larger N400 amplitude gap between the more distant French (L1) and English (L2) than between the closer French (L1) and Spanish (L2). It suggests that larger taxonomic distance attributes to larger semantic processing gap between L1 and L2 [12].

Interplay Between N400 Crosslinguistic Differences and Semantic Complexity.

Recent research has focused on metaphor processing mechanisms of bilinguals, in which L1 and L2 differ in terms of N400 amplitude in various semantic complexity levels. Nevertheless, the results exhibit a discrepancy. Some studies reveal that N400 amplitude demonstrates an incremental graded effect in processing L1 literal sentences,

unconventional similes, novel metaphors and anomalous sentences, while in L2 the N400 amplitude converges for non-literal conditions [5]. In contrast, other studies report that both L1 and L2 processing demonstrate an N400 graded effect for literal meaning, conventional metaphor, unconventional metaphor and anomalous meaning [13]. The discrepancy could be attributed to the diversity of experimental materials. One research observing a converged N400 amplitude for L2 focuses on simile and unconventional metaphor [5], whereas a graded N400 effect is elicited by L2 conventional and unconventional metaphors [13], suggesting that a cognitive distance rather than a formal distance augments more difficulty to extension of semantic concepts and semantic integration. Moreover, participants' L2 proficiency could also bring about contradictory cross-experiment results.

Moderating Effect of Language Proficiency on Crosslinguistic N400 Differences.

Several studies have shed light on the moderating effects of L2 proficiency in N400 crosslinguistic discrepancies, without a consensus. In some research, a smaller N400 amplitude for L2 is elicited by advanced L2 learners compared with intermediate learners in processing script-level or sentence-level inconsistencies [1; 14]. However, one study reports a larger N400 amplitude and a shorter N400 peak latency for L2 word-image inconsistency elicited by bilinguals with higher proficiency [7]. Differences in experimental materials and tasks may result in the inconsistency. Studies involving script-level inconsistency processing adopt a language decision task [10] or a reading aloud task [1], which require less semantic processing, and materials are words with transposed letter [10] or with letters existing in both two different alphabets (Cyrillic and Roman alphabet)[1]. Consequently, the attenuated N400 amplitude reflects the increasing flexibility of lexical-semantic processing, which corresponds with a higher L2 proficiency. Some other studies with semantic judgement task on sentence level[14] suggest easier semantic processing for bilinguals with higher L2 proficiency. In contrast, one study with opposite N400 results adopts a picture-word semantic matching task [7], which requires relatively fewer cognitive resources compared to sentence-level processing. Therefore, the enhanced N400 amplitude for highly proficient participants reflects a deeper semantic processing. There also lacks agreement on whether language switching display symmetrical N400 patterns between two switching directions for highly proficient bilinguals [15; 16]. Regarding age of L2 acquisition, interestingly, one survey discovers a larger N400 amplitude in L2 processing for early bilinguals comparing to late ones [2].

Emotional Effects on N400 Crosslinguistic Differences.

The interplay between language and emotion remains a heated research domain, providing insightful results of N400 crosslinguistic discrepancies. Positive and negative emotional stimuli differently impact crosslinguistic N400 patterns. L2 semantic processing elicits a typical N400 effect in both positive and negative emotional environments, whereas L1 varies under positive and negative mood, with N400 amplitude smaller in positive mood [6]. Nevertheless, in one research no emotion-language interplay is observed. A possible explanation is that under general world knowledge relative to specific semantic context, different emotional valence may impact L1 and L2 more

similarly; and in this experiment, the N400 effect is driven by world-knowledge plausibility manipulations rather than by specific word expectancy manipulations. [17]. With regard to language switching direction, an increased N400 amplitude is observed during L2-to-L1 switching under positive emotion, as well as during L1-to-L2 switching under negative emotion[9]. Emotional words are also proven to have an interaction effect with languages. Among Chinese-English bilinguals [18], both L1 positive and negative nouns evoke an N400 with smaller amplitude compared to neutral nouns, while for L2, only the N400 amplitude of positive emotion-label words is significantly smaller than that of neutral nouns. In general, positive emotions tend to exert a larger influence on L1 switching than on L2 switching, whereas negative emotions affect L2 switching more. Overall, L1 is taken as more sensitive to emotional stimuli and emotional properties of words.

3.2 Neural Mechanism of Crosslinguistic Semantic Processing Reflected by N400

Bilinguals' Common Neural Mechanism in L1 And L2.

There exists common neural mechanism in L1 and L2 semantic processing. L1 and L2 share similar semantic processing mechanism when confronting with both phonological [2] and orthographical [1] disruption. Both demonstrate greater dependency on the top-down access of semantic processing. Moreover, both L1 and L2 are sensitive to semantic context and emotional environment. Their semantic processing are both enhanced by highly constrained semantic context [2] and positive emotion [9].

Crosslinguistic Processing of Various Semantic Complexity Levels.

With the increment of semantic complexity, more cognitive resources are needed for semantic processing. Similes, as a more explicit comparison form, require less retrieval of long-term memory and attentional resources during semantic processing [5], while metaphors are more implicit and abstract, especially unconventional metaphors, which bear larger distance from daily utterance compared to conventional ones [13]. For L1, familiarity to language allows adequate differentiation of various semantic complexity levels, while the immaturity of semantic comparison mechanism of L2 results in more cognitive resource consumption and converged semantic processing of different complexity levels[5].

Moderating Effects of Proficiency in Bilinguals' Semantic Processing.

Proficiency exerts an impact on semantic processing mechanism for L1 and L2 in different ways. Generally, L2 semantic processing mechanism of bilinguals with higher L2 proficiency resembles more to L1 mechanism, with a better lexical-semantic integration and relying more on automatic, direct, top-down semantic processing rather than lexical-based, bottom-up semantic processing. Specifically, higher L2 proficiency stands for higher flexibility to orthographic codes [10], a denser lexical-semantic network [18], a faster access to L2 semantic representations as well as deeper and more refined semantic processing [7]. However, a lower L2 proficiency is more beneficial to

L1 semantic processing, implying a trade-off effect between L1 and L2[14]. In terms of age of acquisition, interestingly, early bilinguals recruit more cognitive resources for L2 semantic processing than late ones to reach a deeper semantic processing and maintain their performance [2].

Interplay Between Emotions and Languages.

The impact of emotional stimuli varies on semantic processing of L1 and L2, and languages differ in terms of their sensitivity to emotional properties. Both positive and negative emotions exert an impact on semantic processing, but they differ in terms of mechanism. Positive emotions provide a sense of security [9], boost a more flexible, heuristic thinking pattern [6] and is more closely interrelated with semantic network [18], whereas negative emotions benefit narrowed and detail-oriented cognitive processing [6]. Moreover, concepts in L1 are generally deemed to be more strongly connected with emotions relative to L2 [18], which is more impervious to mood effects due to emotion regulation mechanism [6]. Consequently, L1 is more sensitive to emotional stimuli and emotional connotation, especially positive ones. With regard to language switching, L2-to-L1 switching is promoted by positive emotions via the release of L1 inhibitory control, while negative emotions facilitate L1-to-L2 switching through excessively allocating attention resource to new information and suppressing interference from L1 [9].

4 Conclusions

The study systematically reviews previous studies on N400 crosslinguistic patterns of bilinguals from recent research and gains a better understanding of bilinguals' neural mechanism for L1 and L2 semantic processing. Bilinguals' N400 manifests diverse and complex patterns under different conditions during semantic processing. N400 pattern demonstrates L1-L2 crosslinguistic similarities under challenging auditory and visual environment. Both of L1 and L2 rely more on top-down semantic processing and overall context, suggesting similar compensatory mechanism for semantic processing difficulty. However, N400 patterns differ in terms of sensitivity to various semantic complexity levels as well as different emotions, with bilinguals in general displaying a more refined semantic processing mechanism for L1 than L2. Moreover, linguistic taxonomic and typological distance, as well as individual L2 proficiency moderate N400 crosslinguistic patterns, with higher proficiency and smaller language distance leading to smaller L1-L2 N400 discrepancy.

Future work could elucidate the implication of other factors as well as refine experimental methodology. Firstly, although some attempts have been made to examine the impact of language differences on bilinguals' crosslinguistic semantic processing, a systematic understanding is still warranted. Therefore, one research direction is to systematically explore how specific typological and taxonomic divergence among different languages influences L1 and L2 semantic processing. Secondly, in case of emotional stimuli, negative emotions are not classified in previous studies. Thereby, future studies are recommended to assess the impact of specific emotions (e.g., anger, sadness,

fear) on semantic processing of bilinguals. thirdly, future research could further probe into the difference between two types of emotional stimuli applied in previous research (face picture and animated film) in terms of their durability and intensity of emotional arousal. Finally, previous studies interpret an elevated N400 amplitude as either increased difficulty or depth of semantic processing, but this divergence seems to be moderated by the overall difficulty of experimental materials, which could be another direction for future research.

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