Neural dynamics of animacy processing in language comprehension: ERP evidence from the interpretation of classifier–noun combinations

Yaxu Zhang [a,b,*], Jinlu Zhang [a,1], Baoquan Min [c]

[a] Department of Psychology, Peking University, Beijing 100871, China
[b] Key Laboratory of Machine Perception (Ministry of Education), Peking University, Beijing 100871, China
[c] Xuanwu Hospital, Capital Medical University, Beijing 100053, China

ARTICLE INFO

ABSTRACT

An event-related potential experiment was conducted to investigate the temporal neural dynamics of animacy processing in the interpretation of classifier–noun combinations. Participants read sentences that had a non-canonical structure, *object noun + subject noun + verb + numeral-classifier + adjective*. The object noun and its classifier were either (a) congruent, (b) incongruent, but matching in animacy, or (c) incongruent, mismatching in animacy. An N400 effect was observed for both incongruent conditions, but not for additional mismatch in animacy. When only data from participants who accepted the non-canonical structure were analyzed, the animacy mismatch elicited a P600 but still no N400. These findings suggest that animacy information is not used immediately for semantic integration of nouns and their classifiers, but is used in a later analysis reflected by P600. Thus, the temporal neural dynamics of animacy processing in sentence comprehension may be modulated by the relevance of animacy to thematic interpretation.

1. Introduction

Things in the world, such as humans, animals, and artifacts, and nouns denoting them, can differ in animacy. The human brain also appears to honor the property of animacy. For example, brain-damaged patients with category-specific semantic deficits can be disproportionately impaired for living things compared with non-living things, or the reverse: disproportionate impairment for non-living things compared with living things (for reviews and theoretical discussion, see Capitani, Laiacona, Mahon, & Caramazza, 2003; Caramazza & Mahon, 2003; Mahon & Caramazza, 2009). In addition, evidence from functional neuroimaging studies indicates that there are distinct regions of the brain involved to the response to animals and tools, the typical living and non-living things, respectively (e.g., Chao, Haxby, & Martin, 1999; see Martin (2007) for review).

During the past decades, numerous studies have investigated the role of noun animacy during on-line sentence comprehension, by examining both the processing of complex or syntactically ambiguous sentences and the processing of simple, syntactically unambiguous sentences. For example, some eye-tracking studies (e.g., Clifton et al., 2003; Ferreira & Clifton, 1986; Trueswell, Tanenhaus, & Garnsey, 1994) have demonstrated the influence of the animacy of sentence-initial noun phrase on the resolution of local syntactic ambiguity between main verb and reduced relative constructions, as in the sentence *The defendant/evidence examined by the lawyer turned out to be unreliable*, although the exact time course of the use of the animacy information remains a matter of debate (see Hsieh, Boland, Zhang, & Yan, 2009 for the use of noun animacy in revolving local ambiguity between two more complex syntactic interpretations).

By measuring eye movements, some other studies have demonstrated that syntactic complexity effects, that is, object-relative clauses being harder to process than subject-relative clauses, can be modulated by the animacy of the sentential subject and the noun within the relative clause (e.g., Mak, Vonk, & Schriefers, 2002, 2006; Traxler, Morris, & Seely, 2002; Traxler, Williams, Blozis, & Morris, 2005). Specifically, the difficulty associated with (complex) object relatives was reduced or even eliminated when the sentential subject was inanimate and the noun within the relative clause was animate, as in the sentence *The movie that the director watched received a prize at the film festival.*

Recently, two claims have been made about the role of animacy in sentence comprehension. One is that animacy information may be used in a heuristic way sometimes, resulting in a purely

* Corresponding author at: Department of Psychology, Peking University, Beijing 100871, China. Fax: +86 10 6276 1081.
E-mail address: yxzhang@pku.edu.cn (Y. Zhang).
[1] Present address: Institute of Psychology, Chinese Academy of Sciences, Beijing 100101, China.

animacy-based assignment of thematic roles (Hoeks, Stowe, & Doedens, 2004; Kuperberg, Kreher, Sitnikova, Caplan, & Holcomb, 2007; Kuperberg, Sitnikova, Caplan, & Holcomb, 2003). The evidence for this claim comes mainly from event-related brain potential (ERP) studies showing that animacy-related thematic role violations, in which a verb that required an animate agent was actually preceded by an inanimate subject noun phrase, as in the sentences *The meal was <u>devouring</u>...* (Kim & Osterhout, 2005) and *At breakfast the eggs would <u>plant</u>...* (Kuperberg et al., 2007), elicited P600 effects but no N400 effects (see Kuperberg (2007) for a review of studies observing such a pattern). The P600 effects were interpreted as probably reflecting the conflict between the output of the animacy heuristic and the output of the syntactic analysis (for discussion, see Kuperberg, 2007; Kuperberg et al., 2007).

The other claim is even stronger, in which animacy functions as a type of prominence information that influences the establishment of interpretive relations between agent/actor and patient/undergoer arguments even in simple, syntactically unambiguous, and both syntactically and semantically well-formed sentences (e.g., Philipp, Bornkessel-Schlesewsky, Bisang, & Schlesewsky, 2008; Roehm, Schlesewsky, Bornkessel-Schlesewsky, Frisch, & Haider, 2004; see Bornkessel-Schlesewsky and Schlesewsky (2009) for review). For example, Philipp et al. (2008) found a larger N400 for an inanimate agent argument compared to an animate agent argument when they were encountered after an animate patient argument during Chinese sentence comprehension (see Roehm et al., 2004 for the same N400 effects in German). The authors also provided further evidence suggesting that these N400 responses are not due to lexical difference between animate and inanimate nouns. Instead, they have been taken as reflecting the computation of thematic relationship between arguments (see Frisch & Schlesewsky, 2001 for N400 effects reflecting how animacy and case markings interact in the thematic interpretation of German embedded structures).

Note that the animacy N400 reviewed above has suggested a rapid use of animacy information in thematic processing, including both the assignment of thematic roles for nouns and the establishment of thematic relationships between verbs and their arguments (see Bornkessel-Schlesewsky & Schlesewsky, 2009; Kuperberg, 2007 for a brief review of how noun animacy influences case markings of a specific noun according to its thematic role in the grammar of some languages). For thematic processing, there is typically a close link between the animacy of a noun and the thematic role that the noun plays: the agent/actor tends to be high and the patient/undergoer low in animacy (see Bornkessel-Schlesewsky & Schlesewsky, 2009). This may be the reason why animacy information has been shown to be used very rapidly for sentence interpretation (determining "who does what to whom").

In a very recent ERP study in Polish, a language in which the animate/inanimate distinction is reflected in the inflectional morphology of nouns, Szewczyk and Schriefers (2011) directly compared the ERP effects of animacy and semantic violations. The animacy violations were realized by a conflict between the actual animacy value of the object noun and the expected animacy value based on the preceding context, as in the Polish version of *Although it was late autumn and bitter cold, little John was running in the backyard with his neck bare. His worried grandma prepared some wool and knitted **an employee** for her grandson*. For the semantic violations, the object noun was semantically incongruent with the preceding context, but there was no conflict of animacy, as in "... knitted **a medicine** for her grandson". Although the N400 effects did not differ between the two types of violation, a larger P600 was observed for animacy violations compared to semantic violations. It was therefore concluded that animacy and other "non-

grammaticalized", semantic features are processed differently.[2] So far, however, little has been known about whether, as a basic semantic feature, animacy is used immediately in real time processing of word combinations in which one word modifies another, but without thematic processing being involved. It should be if animacy information is invariably prominent in real time combination of individual words in a sentence, regardless of the nature of the role it plays.

In the present study, we investigated the role of animacy in processing Chinese classifier–noun combinations, which do not involve thematic role assignments or the establishment of thematic relationships. In Chinese, a classifier language, noun classifiers conceptually classify the referent of the noun according to its semantic features, such as animacy, shape (length, roundness, etc.), and size. A noun classifier is obligatory when the noun is counted or is used in a demonstrative structure (Li & Thompson, 1981; also see Saalbach & Imai, 2007). In other words, nouns cannot be directly modified by numerals or demonstratives. Instead they are modified by a numeral-classifier combination, similarly to the way mass nouns are quantified in English, as in the Chinese numeral classifier–noun combination *san liang qiche* (three CL-liang [classifier indicating ground vehicles] cars, 'three cars') or *na liang qiche* (that CL-liang car, 'that car') (for a detailed description of Chinese classifier system, see Gao & Malt, 2009; Zhang, 2007).

In linguistic theory, there is a debate as to whether noun classifiers are functional elements (e.g., Cheng & Sybesma, 1999, 2005; Muromatsu, 1998) or semantic elements (e.g., Wu & Bodomo, 2009). According to the former view, noun classifiers in Chinese, a language that has no articles/determiners, carry out some of the functions of determiners that exist in other languages, including a deictic function. In contrast, according to the latter view, noun classifiers are contentful, rather than functional, morphemes indicating the semantic classes of nouns; hence, they impose selectional restrictions on the scope of the noun and help to disambiguate word meaning ambiguity (also see Saalbach & Imai, 2007). In other words, meaningfulness is one of the defining properties of noun classifiers, as suggested by Wu and Bodomo (2009).

Chinese have hundreds of noun classifiers, most of which are used with more than one noun. In addition, often several different classifiers can go with the same noun. More relevant to the present study, some classifiers are used with inanimate nouns only, such as *liang* [classifying ground vehicles] and *ben* [classifying objects that are bound into a book-like form], although others are used with both animate and inanimate nouns, such as *tiao*, which classifies long things and goes with both some animal nouns (snake, fish, dog, etc.) and some artifact nouns (rope, towel, trousers, etc.). In addition, the number of classifiers that can be used with animate (human and animal) nouns is about 10, which is much less than the number of classifiers that can go with inanimate nouns (see Gao & Malt, 2009).[3]

Although a few studies have investigated the nature of mental representation and/or non-linguistic cognitive consequences of Chinese noun classifiers, including the influence on categorization,

---

[2] Szewczyk and Schriefers (2011) argued that in their study the animate/inanimate distinction has no consequences for thematic processing. However, in the example for animacy violations just described, the object noun "*employee*" contained an animacy violation not only in terms of discourse context, but also in terms of thematic constraint, since the main verb "*knitted*" requires an inanimate noun as its object argument. Thus, thematic processing was actually involved, though the extent is not very clear.

[3] Among the quite small number of classifiers that can occur with animate nouns, about half of them (*pi*, *zhi*, *tiao*, *dai*, and *wei*) can also occur with inanimate nouns and thus are ambiguous in terms of animacy. For example, the classifier *pi* goes with both horse and cloth, *zhi* with both tiger and boat and *tiao* with both snake and trousers. For this reason, only unambiguous, inanimate classifiers were used in the present study.