Worlds shaped by words: a cross-linguistic investigation into the neural mechanisms of lexico-syntactic feature production

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CHAPTER 6

General discussion

This dissertation investigates the processing mechanisms of lexico-syntactic features from a cross-linguistic perspective, focusing on classifiers in Mandarin Chinese and grammatical gender in German. Through a series of noun phrase production experiments employing the *picture-word interference* (PWI) paradigm and the *blocked cyclic naming* (BCN) paradigm, we collected behavioural and EEG data from native speakers of Mandarin Chinese, native speakers of German, and Chinese learners of German.

The experiments presented in this dissertation were designed to address four core research questions. First, can the activation of classifier features be reliably detected during the production of quantifier-classifier phrases in Mandarin (**Chapters 2** and **3**)? Second, do the semantic features encoded in Chinese classifiers, specifically the visual shape information associated with shape classifiers, play a role in the production process (**Chapter 3**)? Third, when a learner's L1 lacks grammatical gender features present in the L2, to what extent can late L2 learners acquire and develop mechanisms for processing such L2 lexico-syntactic features (**Chapter 4**)? Finally, do semi-lexical nouns that have partially lost content-word properties and acquired characteristics of function words still activate the grammatical gender features associated with them (**Chapter 5**)? The present chapter summarises the main findings from the earlier chapters, explores their theoretical implications, discusses the limitations of the current studies, and outlines potential future research directions.

6.1.   Discussion of chapter findings

6.1.1.   The activation of classifiers during Chinese noun phrase production

Chapter 2 employed the PWI paradigm to investigate the processing of classifiers in native Mandarin Chinese speakers (see J. Wang, Witteman, & Schiller, submitted-b). Participants were asked to produce quantifier-classifier phrases while two key variables were manipulated: classifier congruency and semantic relatedness between target and distractor items. Compared to earlier studies on the same topic, this experiment introduced several methodological improvements, including refinement of stimulus materials, using mass univariate permutation tests to identify regions of interest, and applying (generalised) linear mixed-effects models for statistical analysis. The results revealed robust *classifier congruency* and *semantic interference effects*, replicating prior findings (Huang & Schiller, 2021; Wang et al., 2019). Specifically, naming latencies were significantly longer for classifier-incongruent and semantically related distractors than classifier-congruent and semantically unrelated conditions. The ERP data revealed N400-like components associated with both effects, with a slight difference in their temporal onset. Replicating the *classifier congruency effect* within the PWI paradigm provides further evidence that classifier information associated with nouns is automatically activated and selected during lexical access in Mandarin Chinese.

Chapter 3 extended this inquiry through the BCN paradigm, where classifier-congruent (homogeneous) and incongruent (heterogeneous) blocks were compared (see J. Wang, Witteman, and Schiller, 2025). The results demonstrated a robust *classifier congruency effect*: target stimuli paired with incongruent classifiers elicited significantly longer naming latencies than congruent ones. This pattern closely mirrors the *gender congruency effect* observed in the BCN paradigm (Vigliocco et al., 2002). Additionally, these stimuli evoked more positive ERP waveforms in the P300 and P600 time windows. The P300 may signify increased cognitive load during contextual updating when classifier expectations are violated (Donchin, 1981), while the P600 may reflect syntactic re-analysis demands (Friederici, 1995; Kaan et al., 2000; Osterhout et al., 1994; Osterhout & Holcomb, 1992). Together with the results from **Chapter 2**, this study offers converging evidence for the automatic activation of classifier features during lexical access when producing noun phrases. *Classifier congruency effects* emerged robustly across both PWI and BCN paradigms during Mandarin noun phrase production, mirroring the *gender congruency effects* in Indo-European languages. This parallelism suggests that grammatical gender and classifiers, distinct typological manifestations of nominal classification systems, may engage analogous cognitive mechanisms during lexical access.

6.1.2. Semantic information in classifier processing

While the observed classifier-gender parallels in congruency effects demonstrate possible shared lexico-syntactic activation mechanisms, a critical distinction warrants emphasis: Unlike grammatical gender systems characterised by largely arbitrary syntactic assignment (Corbett, 1991), Mandarin classifiers retain semantic features that constrain their possibilities of collocating with nouns (Shi, 1996; Tai, 1994; Tai & Chao, 1994; Tai & Wang, 1990). Consequently, it is plausible that these preserved semantic features play an active role in the cognitive processing of classifiers. Existing research has mostly manipulated congruency at the level of the

whole classifiers, with relatively few studies investigating the role of the semantic features inherent within classifiers themselves (Wang et al., 2024).

In **Chapter 3**, we manipulated the shape similarity of classifiers in each block to investigate whether the visual shape information encoded in shape classifiers is involved in the production of quantifier-classifier phrases (see J. Wang, Witteman, and Schiller, 2025). A *shape interference effect* was observed using the BCN paradigm: participants exhibited slower naming latencies when the shape features of classifiers were similar than when the shapes were dissimilar. In the EEG data, shape-dissimilar stimuli elicited an N400-like component, supporting findings by Bi et al. (2010). This result suggests that visual shape information embedded in classifiers is processed during the production of quantifier-classifier phrases, in addition to the classifier itself. We further explored the time course of visual shape information processing by collecting EEG data. Our results indicate that this activation originates at the lexical level rather than the pre-lexical level, suggesting that visual shape information is integrated during lexical retrieval.

The observed involvement of visual shape information during lexical retrieval suggests that processing lexico-syntactic features in Chinese may engage lower-level semantic feature processing. This finding aligns with collocation rules in language use where nouns and their associated classifiers exhibit semantic constraints. Prior research supports the view that classifier processing involves not only syntactic but also semantic information (Zhang et al., 2012; Zhou et al., 2010). Therefore, even though classifiers and grammatical gender share functional similarities in categorising nouns and are activated as lexico-syntactic features during noun phrase production, it remains important to acknowledge their differences.

6.1.3. Grammatical gender activation during L2 noun phrase production

Chapter 4 investigated the processing of lexico-syntactic features by late L2 learners whose L1 lacks a grammatical gender system (see J. Wang, Witteman, & Schiller, submitted-a). Two German noun phrase naming experiments using the PWI paradigm were conducted with native Chinese speakers learning German as an L2. Experiment 1 manipulated gender congruency and semantic relatedness between target and distractor nouns, while Experiment 2 manipulated gender congruency and phonological relatedness. *Gender congruency effects* were observed only in the EEG data, not in the naming latencies. Additionally, the *semantic interference effect* and *phonological overlap effect* were evident in the ERP results. The activation of grammatical gender occurred later than both semantic processing and phonological encoding.

The absence of a *gender congruency effect* in behavioural responses aligns with the predictions of the *Interpretability Hypothesis* (IH) (Tsimpli, 2003; Tsimpli & Dimitrakopoulou, 2007). The IH proposes that uninterpretable syntactic features absent in the learner's L1 are particularly challenging for late L2 learners to acquire native-like proficiency. While the L2 learners in our study demonstrate a cognitive mechanism for processing lexico-syntactic features in their L1 (namely Chinese classifiers, as shown in **Chapters 2** and **3**), grammatical gender in German is a distinct and novel feature for them. As discussed in **Chapter 3**, the classifier system in

Chinese differs from the gender system in German. Grammatical gender in German is a morpho-syntactic feature of nouns, and the mapping between gender and determiner forms is often arbitrary and semantically opaque, making it difficult for L2 learners to interpret. As such, gender-marked determiners pose a unique challenge for native Chinese speakers. However, consistent with IH's allowance for feature checking, our ERP findings confirm that learners can activate grammatical gender information during lexical access. This activation, similar to patterns observed in native German speakers, occurs after phonological encoding (Bürki et al., 2016).

The dissociation, in which grammatical gender information is activated but does not influence naming latencies, supports the predictions made by the *Missing Surface Inflection Hypothesis* (MSIH) (Prévost & White, 2000). The MSIH proposes that while L2 learners can acquire abstract syntactic features, they frequently encounter difficulties mapping them onto their correct morpho-phonological forms during online production. Our data reflect that while late Chinese learners of German develop a neural representation of German grammatical gender, enabling its activation during lexical retrieval, the processes governing the efficient selection and morpho-phonological realisation of gender-marked determiners remain vulnerable to interfering with the naming of the target nouns.

6.1.4. Multiple processing routes for accessing grammatical gender in semi-lexical nouns

Building upon evidence that lexico-syntactic features are automatically activated during lexical access of regular nouns across languages and speaker populations (**Chapters 2-4**), **Chapter 5** extends this inquiry to determine whether processing routes diverge for non-canonical (semi-lexical) nouns (see J. Wang, Witteman, & Schiller, re-submitted). Employing a PWI paradigm, we manipulated both gender congruency and the lexical category of distractor nouns. Specifically, half of the distractor nouns were regular nouns, while the other half could combine with target nouns to form German pseudo-partitive constructions and were therefore classified as semi-lexical nouns. Analysis of naming latencies showed the *gender congruency effect* varied between semi-lexical and regular noun conditions, with the effect being significantly stronger for semi-lexical nouns compared to regular nouns.

The strong *gender congruency effect* observed in the semi-lexical condition may reflect the hybrid lexical status of semi-lexical nouns, which exhibit properties of both content and function words. In German pseudo-partitive constructions (e.g., "*das Glas$_{NEU}$ Wein$_{MAS}$*", the glass of wine), the first noun (N1) loses its referential meaning as a physical object (i.e., "glass") and instead functions as a quantificational unit that measures the mass noun (N2) "wine" (Corver & Van Riemsdijk, 2001; Emonds, 1985; Ross, 1972, 2004; Selkirk, 1997; Van Riemsdijk, 1998). Given this reduction in referential specificity, it was unclear whether such semi-lexical words could still activate grammatical gender features during language production. The significant *gender congruency effect* observed in this condition suggests, however, that semi-lexical nouns retain access to lexico-syntactic features in a manner comparable to canonical lexical nouns.

While N2 (Wein) serves as the semantic head of the phrase, N1 (Glas) functions as the syntactic head, determining gender and number agreement with the

determiner in pseudo-partitive constructions (Löbel, 1989; Rutkowski, 2007; Selkirk, 1997). Thus, semi-lexical nouns exhibit morpho-syntactic properties of function words. These constructions are undergoing grammaticalization (Koptjevskaja-Tamm, 2001; Rutkowski, 2007) and are analysed as unified lexical units rather than compositional phrases formed by two independent nouns. According to the assumptions of function word processing proposed by the *Levelt-Roelofs-Meyer* (LRM) model (Levelt et al., 1999), semi-lexical nouns within pseudo-partitive constructions may be activated not only through their own lemma representations but also indirectly via the associated regular noun (N2) or through a stored *superlemma* node in the mental lexicon that encodes the entire construction (Sprenger et al., 2006). The strong *gender congruency effect* observed for semi-lexical nouns may be attributed to grammatical gender activation along multiple processing routes. In addition to the pathway shared with regular nouns, grammatical gender features associated with semi-lexical nouns may also receive activation either from the N2 or from a phrase-level *superlemma* node. The heightened activation of grammatical gender features likely intensifies competition between gender-incongruent targets and distractors during noun phrase production.

The traditional dichotomous classification of content words and function words is widely accepted in linguistic theory. However, the present findings provide empirical evidence that grammatical gender in semi-lexical nouns may be accessed through distinct processing mechanisms compared to regular nouns. This supports the view that semi-lexical nouns may constitute a distinct lexical category (Koptjevskaja-Tamm, 2001; Selkirk, 1997; Van Riemsdijk, 1998). More broadly, these results align with the theoretical perspective that lexical categories are better conceptualised as existing along a continuum rather than as strictly discrete classes (Ross, 1972).

In summary, this dissertation has examined the cognitive mechanisms underlying the activation of lexico-syntactic features through various experimental paradigms. It has explored lexico-syntactic feature processing across languages, speaker populations, and lexical categories. Classifiers and grammatical gender are nominal classification systems that have similarities and differences in how they categorise nouns, form phrases, and how they are activated and selected during language production. Acquiring a nominal classification system in a second language, especially when such a system is absent in the learner's first language, requires reshaping the mapping between linguistic categories and conceptual representations. Although this process is challenging, it has been shown to be achievable.

6.2. Limitations and future directions

While this dissertation provides new insights into the cognitive processing of lexico-syntactic features, several limitations should be acknowledged. First, the findings are based on a specific sample of participants. Further research involving more diverse populations is needed to assess the generalizability of the results. The current investigation focused on processing classifiers in Mandarin Chinese and grammatical gender in German. However, many other languages also employ classifiers or grammatical gender systems. For example, Japanese and Thai use classifiers, while Swedish and Romanian possess grammatical gender. Applying the current experimental paradigms to a broader range of typologically diverse languages

would allow for a more comprehensive cross-linguistic comparison and deepen our understanding of how such systems are processed.

Secondly, the L2 learner group studied in this dissertation was limited in proficiency, age of acquisition, and linguistic background. It remains unclear whether more proficient learners or those who acquired German before the critical period would exhibit different processing patterns for grammatical gender. A multitude of factors influences second language acquisition. Variables such as age, proficiency level, exposure duration, and learning strategies may all affect the acquisition of grammatical features, particularly when the features are uninterpretable and absent from the learner's first language. Future research should examine how these factors interact to facilitate or constrain acquisition and processing in late bilinguals.

Thirdly, the linguistic structures examined in this dissertation were relatively constrained. The picture-naming tasks involved noun phrases such as "numeral + classifier + noun" in Mandarin or "determiner + noun" in German. More complex noun phrases incorporating adjectives, numerals, or inflectional morphology were not addressed. Similarly, the study of semi-lexical nouns focused exclusively on German pseudo-partitive constructions. It remains to be determined whether other semi-lexical words, such as prepositions, also engage multiple activation pathways during production.

Finally, the study primarily relied on behavioural and EEG data. While EEG provides excellent temporal resolution for tracking real-time language processing, it offers limited spatial resolution regarding the neural sources of observed effects. Future research could benefit from integrating complementary neuroimaging techniques, such as fMRI or MEG, to more precisely localise the neural substrates involved in the activation and selection of lexico-syntactic features. Neuroimaging studies have shown that the superior part of Broca's area (specifically, Brodmann Area 44) is involved in the selection of grammatical gender during determiner production (Heim et al., 2009). Building on these findings, future research could examine whether L2 learners, especially those whose L1 does not encode grammatical gender, engage in similar neural mechanisms. Additionally, it would be worth investigating whether classifier selection in Mandarin recruits the same cortical regions or engages additional areas, particularly those implicated in semantic integration, given the semantic features often encoded by classifiers.

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