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German-dominant Vietnamese heritage speakers use semantic constraints of German for anticipation during comprehension in Vietnamese

Aine Ito[1,2], Huong Thi Thu Nguyen[1] and Pia Knoeferle[1,3,4]

[1]Department of German Studies and Linguistics, Humboldt-Universität zu Berlin, Berlin, Germany; [2]Department of English, Linguistics and Theatre Studies, National University of Singapore, Singapore, Singapore; [3]Berlin School of Mind and Brain, Berlin, Germany and [4]Einstein Center for Neurosciences Berlin, Berlin, Germany

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Corresponding author:
Aine Ito
Department of English, Linguistics and Theatre Studies
National University of Singapore
Block AS5, 7 Arts Link, 117570
Singapore
Email: aine.ito@nus.edu.sg

Abstract

To test effects of German on anticipation in Vietnamese, we recorded eye-movements during comprehension and manipulated i) verb constraints (different vs. similar in German and Vietnamese) and ii) classifier constraints (absent in German). In each of two experiments, participants listened to Vietnamese sentences like "Mai **mặc** một ***chiếc*** áo." ('Mai **wears** a ***[classifier]*** shirt.'), while viewing four objects. Between experiments, we contrasted bilingual background: L1 Vietnamese–L2 German late bilinguals (Experiment 1) and heritage speakers of Vietnamese in Germany (Experiment 2). Both groups anticipated verb-compatible and classifier-compatible objects upon hearing the verb/classifier. However, when the (verb) constraints differed (e.g., Vietnamese: *mặc* 'wear (a shirt/#earrings)' – German: *tragen* 'wear (a shirt/earrings)'), the heritage speakers were distracted by the object (earrings) compatible with the German (but not the Vietnamese) verb constraints. These results demonstrate that competing information in the two languages can interfere with anticipation in heritage speakers.

Introduction

During comprehension, first language (L1) speakers can use linguistic (e.g., lexical) constraints to anticipate upcoming content or specific words (Kuperberg & Jaeger, 2016; Pickering & Gambi, 2018). For second language (L2) speakers, this may be difficult because comprehension is more cognitively demanding in non-dominant L2 than L1 (Segalowitz & Hulstijn, 2009; for a review, see Ito & Pickering, 2021). Following Kaan (2014), another source for delayed anticipation in a non-dominant language is competition of representations of the dominant and non-dominant languages (among others). Bilinguals may activate representations of their dominant language when processing their non-dominant language (Dijkstra & van Heuven, 2002; Spivey & Marian, 1999; Thierry & Wu, 2007). If the representations are different in the two languages, they may compete and interfere with anticipation. Anticipation in a non-dominant language may also experience delay when the dominant language does not have equivalent representations (e.g., Vietnamese has classifiers, whereas German does not) (Dussias et al., 2013), especially if the proficiency in the non-dominant language is not high (Kroll & Stewart, 1994), as bilinguals presumably process representations of their dominant (vs. non-dominant) language more efficiently.

In line with the above accounts, bilinguals are less likely to use constraints that are different in their two languages or absent in their dominant language for anticipation (Dussias et al., 2013; Hopp, 2013). Moreover, different constraints may have distinct consequences for anticipatory processing. When lexical constraints of the verb differ between the two languages, bilinguals may co-activate both and anticipate objects that meet these constraints (Kroll & Tokowicz, 2001; Ma et al., 2017). For example, upon hearing the Vietnamese verb *mặc* ('wear'), German–Vietnamese bilinguals might anticipate both a shirt and earrings because the German translation-equivalent of the Vietnamese verb *mặc* ('tragen') is compatible with both objects. This sensitivity to German verb constraints (co-activating the German verb *tragen* upon hearing the Vietnamese verb *mặc*) is predicted by models of bilingual lexical access (Dijkstra & van Heuven, 2002; Kroll et al., 2010; Kroll & Stewart, 1994). L1 Vietnamese users should anticipate a shirt, but not earrings since earrings in Vietnamese require a different verb *đeo* ('wear').

If bilinguals' dominant language has no translation-equivalent of words in their non-dominant language, they cannot access them via their dominant language. The lack of translation-equivalent may delay anticipation because bilinguals process their dominant language more efficiently

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(FitzPatrick & Indefrey, 2010; Hanulová et al., 2011). For example, Vietnamese classifiers constrain upcoming words and their object referents. L1 Vietnamese speakers may use such constraints to anticipate upcoming objects, in line with evidence from Chinese and Japanese (Grüter et al., 2020; Mitsugi, 2018; Tsang & Chambers, 2011). German–Vietnamese bilinguals may anticipate the same content as L1 Vietnamese speakers, as there is no competing information in German. However, such anticipation may be delayed because German, unlike Vietnamese, does not have these kinds of classifiers (see Trenkic et al., 2014 for related evidence on anticipation in L2 English for L1 article-lacking Chinese).

We tested influences of German on anticipation based on verbs (different vs. similar constraints) and classifiers (German-absent constraints) during Vietnamese comprehension. Participants were L1 Vietnamese (dominant) - late L2 German bilinguals and heritage Vietnamese speakers in Germany. Heritage speakers are unbalanced bilinguals who started acquiring a language which is not the majority language in the community at home, and they later acquired and became dominant in the majority language (Polinsky & Kagan, 2007). In our study, heritage speakers were Vietnamese living in Germany who became dominant in German. We were thus able to test for an effect of language dominance (Vietnamese-dominant vs. German-dominant) with similar age of acquisition of Vietnamese. Despite the early onset of acquisition, heritage speakers have shown non-native like production and comprehension performance (Montrul et al., 2008).

Language processing when constraints are absent in the dominant language

Many studies found that L2 speakers whose L1 does not have a gender-marking system are less likely to use gender information for comprehension compared with L1 speakers. For example, gender-marked articles facilitated processing of an upcoming noun in L1 Spanish but not L1 English (L2 Spanish) users: Lew-Williams and Fernald (2010) showed participants two same-gender (*la pelota*, 'a ball$_{\text{-fem}}$', *la galleta* 'a cookie$_{\text{-fem}}$') or different-gender (*la pelota*, 'a ball$_{\text{-fem}}$', *el zapato*, 'a shoe$_{\text{-masc}}$') referents and played sentences like *Encuentra la$_{\text{-fem}}$ pelota$_{\text{-fem}}$* (English: 'Find the$_{\text{-fem}}$ ball$_{\text{-fem}}$'). In Spanish, article and noun agree in gender, permitting anticipating noun (referent) gender based on the article. L1 speakers inspected the article-gender-matching noun referent quicker for different- than same-gender referents, but L2 speakers did not, suggesting they did not use L1(English)-absent gender information in the same way for anticipating the noun (referent). Foucart et al. (2014) showed that when bilinguals' L1 and L2 had gender systems with the same rules, L2 speakers anticipated gender of a highly predictable noun just like L1 speakers. Together these findings are consistent with the idea that the lack of gender in L1 may interfere with online processing of gender in L2.

L2 speakers' online use of gender information seems to depend on their L2 proficiency. Dussias et al. (2013) investigated processing of Spanish article-noun phrases in L1 Spanish and L2 Spanish (L1 English) speakers. High-proficiency L2 speakers used article gender to quickly direct their eyes to a gender-matching referent, but the low-proficiency L2 speakers did not (see also Hopp, 2013; Hopp & Lemmerth, 2018). Moreover, Fuchs (2022a, 2022b) found that heritage speakers whose dominant language does not have a gender-marking system used gender to facilitate comprehension in the heritage language. Thus, heritage speakers may be able to use constraints that are absent in their dominant language for anticipation during heritage language processing.

Other studies found that intermediate L2 speakers can use L1-absent classifier constraints for anticipation like L1 speakers. Mitsugi (2018) investigated an online use of Japanese classifiers using sentences with a noun phrase like *san-bon-no kasa* ('three$_{\text{-classifier-genitive}}$ umbrellas'). In her study, the target objects matched the semantic class of the classifier (e.g., the classifier for an umbrella is used for long and thin objects). Both L1 Japanese and L2 Japanese (L1 English) speakers anticipated classifier-consistent targets. The inconsistent findings in gender- and classifier-processing studies could be due to the type of constraint (syntactic vs. semantic).

Considering semantic constraint, classifiers can be used for nouns outside their semantic class (e.g., the Chinese classifier *tiao* is used for long and flexible objects like a rope but can also be used for a dog). In addition, the semantic class of a classifier is not deterministic (e.g., the classifier *tiao* cannot be used for a wristwatch, which could be described as long and flexible). Grüter et al. (2020) found that L1 Chinese speakers relied on classifier constraints to anticipate appropriate objects even when they did not fit into the classifier's semantic class (e.g., a dog) (replicating Tsang & Chambers, 2011). L2 Chinese speakers (whose L1 had no classifier system) similarly anticipated appropriate objects but were distracted by inappropriate objects that fit into the semantic class (e.g., a wristwatch). L2 speakers may rely more heavily on the semantic class of a classifier than L1 users. Considering the potential effects of the type of constraint, we only manipulated semantic constraints (cf. stimuli section).

Language processing when constraints differ between dominant and non-dominant languages

When bilinguals process constraints that differ between their two languages, activation of the competing information (Spivey & Marian, 1999) may interfere with anticipation (Kaan, 2014). Foucart and Frenck-Mestre (2011) tested gender processing in L1 French and L2 French (L1 German) speakers. Both French and German have a gender-marking system, but their translation-equivalents do not necessarily belong to the same gender (a chair is feminine in French and masculine in German). They recorded EEGs while participants read sentences with correct (e.g., *la$_{\text{-fem}}$ chaise$_{\text{-fem}}$*; 'the$_{\text{-fem}}$ chair$_{\text{-fem}}$') or incorrect gender marking (e.g., *le$_{\text{-masc}}$ chaise$_{\text{-fem}}$*; 'the$_{\text{-masc}}$ chair$_{\text{-fem}}$'). At the noun, both groups showed a P600 effect (more positive-going mean event-related brain potential amplitudes for incorrect vs. correct condition), suggesting they detected the violation. However, when the noun had a different gender in German, only a subset of the L2 group showed the P600 effect (Experiment 1). In addition, the L2 French (unlike the L1 German) group showed no P600 effect when the gender mismatched between a noun and an adjective (e.g., *les$_{\text{-pl.}}$ chaises$_{\text{-fem}}$ blancs$_{\text{-masc}}$*; 'the$_{\text{-pl.}}$ chairs$_{\text{-fem}}$ white$_{\text{-masc}}$', 'the white chairs', *les$_{\text{-pl.}}$ petits$_{\text{-masc}}$ chaises$_{\text{-fem}}$*; 'the$_{\text{-pl.}}$ small$_{\text{-masc}}$ chairs$_{\text{-fem}}$'). The authors interpreted the lack of P600 effects in L2 French speakers as reflecting difficulty in processing French-specific plural gender-marking for adjectives (in German, gender is not distinguished for adjectives in the plural). Alternatively, it could be difficulty associated with less-accurate or late acquisition of adjectival phrases (compared to determiner-noun phrases) in German learners of French. Thus, conflicting gender information in L1 and L2 seems to interfere with gender processing in L2 to some extent.

Related research by Grüter and Hopp (2021) manipulated the sentence structure to establish a one-to-one linear mapping

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between the English translation-equivalent for one interpretation of globally-ambiguous German *wh*-questions but not the other (e.g., *Was leckt das Känguru?*; 'What licks the kangaroo?' or 'What does the kangaroo lick?' vs. *Was hat das Kangaroo geleckt?*; 'What has licked the kangaroo?' or 'What has the kangaroo licked?'). L1 English–L2 German speakers were more likely to interpret the question *Was leckt das Känguru?* as a subject *wh*-question 'What licks the kangaroo?' than the question *Was hat das Kangaroo geleckt?*, suggesting that they preferred the interpretation consistent with the linearly mapped English translation equivalent. In contrast, L1 German–L2 English speakers showed no such preference, suggesting that the knowledge of L1 has a stronger influence on L2 processing than vice versa.

Van Bergen and Flecken (2017) investigated anticipation based on constraints of placement verbs in Dutch. The Dutch verbal system distinguishes between two verbs depending on whether a placed object is standing (*zetten*) or lying (*leggen*). Another verb *plaatsen* does not specify the end-state position. Thus, the end-state position of the object is predictable based on the constraints of *zetten* and *leggen* but not *plaatsen*. German similarly specifies the end-state position in placement verbs, whereas English and French do not. L1 Dutch and L2 Dutch (L1 German, English or French) speakers listened to Dutch sentences with a placement verb (e.g., *De jongen zette/legde/plaatste kort geleden een fles op de tafel.*; 'The boy put$_{\text{-stand}}$/put$_{\text{-lie}}$/put$_{\text{-general}}$ recently a bottle on the table.'), while viewing objects on a table (one standing upright, one lying flat, and two further objects). L1 Dutch and L2 Dutch (L1 German) speakers but not L2 Dutch (L1 English or French) speakers showed a fixation bias towards the standing over lying object after hearing *zette* (*put$_{\text{-stand}}$*) but not after hearing *plaatste* (*put$_{\text{-general}}$*) or *legde* (*put$_{\text{-lie}}$*). Thus, L2 speakers whose L1 had similar mappings for placement verbs (German) were better at using verb constraints for anticipation than L2 speakers whose L1 had different verb constraints (English or French). However, based on this study, it is difficult to distinguish whether the reduced anticipation in L2 Dutch (L1 English or French) speakers was because they could not use L2-specific constraints efficiently, or because they used constraints of the English/French translation-equivalent. It is also unclear whether the findings generalise to different verbs because Van Bergen and Flecken (2017) only used the above-mentioned placement verbs.

We tested whether verb-based anticipation while listening to Vietnamese sentences is affected by German in cases when verb constraints are different between Vietnamese and German. We assessed this question in two participant groups: L1 Vietnamese–L2 German speakers and German-dominant heritage speakers of Vietnamese. Considering the finding that effects of dominant L1 on non-dominant L2 are stronger than vice versa (Grüter & Hopp, 2021), the effect of a German translation-equivalent may be larger in German-dominant heritage speakers of Vietnamese than in L1 Vietnamese–L2 German speakers.

The current study and predictions

We tested anticipation in L1 Vietnamese–L2 German speakers (Experiment 1) and Vietnamese heritage speakers in Germany (Experiment 2) using constraints that are specific to Vietnamese and constraints that are absent in German. We manipulated verbs to test online processing of different (vs. similar) constraints and classifiers to test online processing of German-absent constraints.

We used the visual-world paradigm, which can capture people's anticipation based on linguistic and visual information and its time-course (Huettig et al., 2011). Participants listened to simple subject-verb-object sentences (e.g., *Mai mặc một chiếc áo.*; 'Mai wears a [classifier] shirt.'), while viewing four objects: target, competitor and two distractors. To test anticipation using competing information in Vietnamese and German, we selected Vietnamese verbs that had either different or similar constraints to their German translation-equivalent (cf. stimuli section). This manipulation allowed the novel investigation into whether bilinguals use constraints of a German translation-equivalent when they anticipate upcoming words and their object referents during Vietnamese comprehension. If participants efficiently use the Vietnamese verb constraints, we expect them to fixate objects that are compatible with the verb (Altmann & Kamide, 1999). However, if they use the German verb constraints, we expect them to additionally fixate objects that are compatible with the German translation-equivalent verb. The latter finding would support Kaan's (2014) hypothesis that co-activation of the non-target language interferes with anticipation in the target language. When the Vietnamese verb and its translation-equivalent in German have similar constraints, we do not expect any interference from German, so we may find similar anticipation in the two groups.

To test anticipation using German-absent constraints, we manipulated the competitor object by depicting a competitor that does or does not take the same classifier as the target object. When the competitor does not share the classifier with the target, we expect participants to fixate the target over the competitor upon hearing the classifier (Mitsugi, 2018). When the competitor shares the classifier with the target (i.e., both were compatible with the classifier), we expect participants to fixate both the target and the competitor equally over the distractors upon hearing the classifier.

While our study had a 2 by 2 design, our focus was main effects of the verb-mapping and the classifier. The only interaction we expected was the modulation of the effect of classifier constraints by the verb-mapping; when the classifier was compatible with both the target and the competitor, we expected that both objects would be equally more likely to be fixated than the distractors. However, the fixation on the competitor might be reduced if the preceding verb was compatible with the target only and participants used the verb constraints to anticipate the target. We expected no interaction before the presentation of the classifier.

Experiment 1

Experiment 1 tested whether L1 Vietnamese–L2 German speakers use verb- and classifier constraints as soon as they became available for anticipation.

Methods

Participants

Thirty L1 Vietnamese–L2 German late bilinguals (5 males) who had normal or corrected-to-normal vision participated in the experiment at the Humboldt-Universität zu Berlin. Table 1 summarises the characteristics of the participants. All participants spoke English, but they reported they were more proficient in German than English. Before coming to the laboratory,

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Table 1. A summary of participant characteristics. The SDs are in brackets. For the other languages participants speak, the numbers in the brackets are the number of participants who listed that language.

	L1 Vietnamese-L2 German group (Experiment 1)	Heritage speaker group (Experiment 2)
Age (years)	24.4 (3.1)	25.3 (3.4)
Years spent in Vietnam	20.7 (2.5)	1.4 (1.7)
Years spent in Germany	3.4 (1.8)	22.9 (3.8)
Self-rated proficiency for Vietnamese	9.7 (.6)	6.3 (1.3)
Self-rated proficiency for German	6.9 (1.1)	9.6 (.6)
Age of acquisition for Vietnamese (years)	0 (0)	.1 (.4)
Age of acquisition for German (years)	19.7 (3.6)	2.7 (1.5)
Other languages participants speak (the number of participants)	English (30), Chinese (5), French (4), Italian (2), Spanish (2)	English (30), French (19), Spanish (5), Chinese (3), Korean (2), Japanese (2), Portuguese (1), Italain (1), Latin (1)

participants took a 15-minute German test adapted from ActiLingua German Online Test (https://www.deutsch-lernen.com). Participants who scored 70% or above were invited to the experiment, so the group was relatively homogeneous in terms of their German proficiency. All processes contributing to this work comply with the ethical standards of the psycholinguistics lab at the Humboldt-Universität zu Berlin, which were approved by German Linguistic Society (Deutsche Gesellschaft für Sprachwissenschaft).

Stimuli

The auditory stimuli comprised 48 critical sentences and 40 filler sentences. Each of the critical sentences belonged to one of the two verb-mapping conditions (24 sentences with a different-mapping verb and 24 sentences with a similar-mapping verb, cf. Figure 1). In the DIFFERENT-MAPPING-VERB CONDITION, the main verb had two distinct form-meaning mappings compared to its translation-equivalent in German (one form captured both meanings). For example, the Vietnamese verb *mặc* ('wear') can take a

Verb condition	Classifier condition	Example sentence					Target (classifier)	Competitor (classifier)
Different mapping	Shared	*Mai* Mai	***mặc*** wears	*một* a	*chiếc* [classifier]	*áo.* shirt.	shirt (*chiếc*)	earring (*chiếc*)
	Not shared	*Mai* Mai	***mặc*** wears	*một* a	*chiếc* [classifier]	*áo.* shirt.	shirt (*chiếc*)	earrings (*đôi*)
Similar mapping	Shared	*Mai* Mai	*phơi* dries	*một* a	*cặp* [classifier]	***áo.*** shirt(s).	shirts (*cặp*)	dresses (*cặp*)
	Not shared	*Mai* Mai	*phơi* dries	*một* a	***cặp*** [classifier]	*áo.* shirt(s).	shirts (*cặp*)	dress (*chiếc*)
			Verb		Classifier	Object		

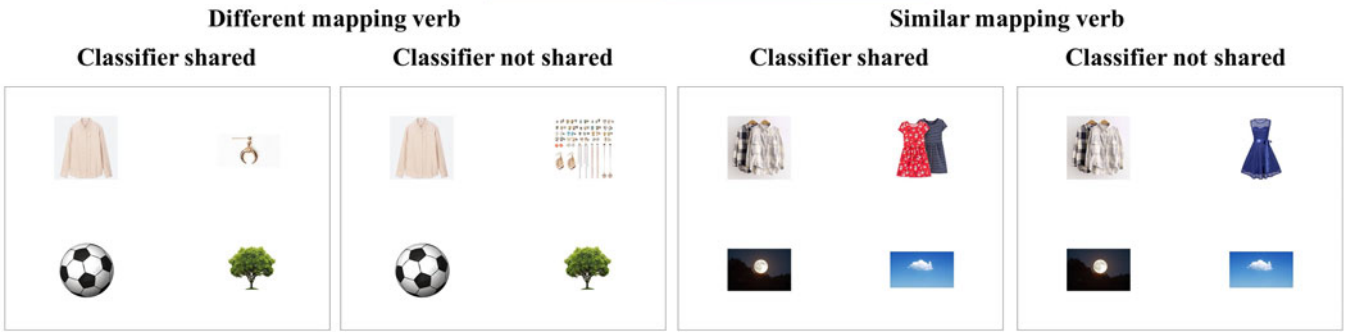

Figure 1. Example stimuli. The upper panel shows example sentences for each condition and target and competitor object names. The word at which the target can be uniquely identified is shown in bold in the example sentences. The coloured regions indicate three critical time windows (light blue = verb window, light orange = classifier window, light yellow = object window). The analysed windows were shifted 200 ms forward (see eye-tracking data coding and analysis section for details). The classifier that each object takes is shown in the brackets. The lower panel shows example visual scenes for each condition. The competitor object was varied across the classifier-shared and not-shared conditions.

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shirt but not an earring as a grammatical object, whereas the German verb *tragen* ('wear') can take both a shirt and an earring as a grammatical object. In the SIMILAR-MAPPING-VERB CONDITION, the main verb had a similar-mapping to its translation-equivalent in German. For example, the Vietnamese verb *phơi* ('dry') and the German verb *trocknen* ('dry') take a similar set of nouns as their grammatical object. The sentences were processed in Praat, so that each word always lasted for one second and the onset of each word was identical across all sentences. The filler sentences had an identical syntactic structure to the critical sentences and varied in the number of objects that were plausible to be mentioned after the verb and the classifier.

Each sentence was paired with a display containing four objects: target, competitor, and two distractors (Figure 1). The target (e.g., a shirt/shirts) was compatible with the main verb and the classifier, and the distractors (e.g., a football, a tree) were incompatible with the main verb and the classifier in both verb-mapping conditions. The competitor was compatible with the verb in the SIMILAR-MAPPING VERB CONDITION (e.g., a dress/dresses), but not in the DIFFERENT-MAPPING VERB CONDITION (e.g., an earring/earrings). Crucially, the competitor in the different-mapping condition was compatible with the German translation-equivalent of the verb to test a transfer effect from German. The competitor image was varied across the classifier conditions; the competitor was compatible with the classifier in the CLASSIFIER-SHARED CONDITION and incompatible in the CLASSIFIER-NOT-SHARED CONDITION. As discussed in the introduction, a classifier's semantic class may not always match the features of the objects it takes (Grüter et al., 2020), but we only used classifier-noun combinations that matched in the semantic class (e.g., when the classifier's semantic class was clothing, we did not use a non-clothing object that was compatible with the classifier as the target/competitor). Thus, the target was predictable based on the semantic constraints of the classifier.

Procedure

Participants listened to the sentences and clicked on the object mentioned in the sentence. Their eye movements were recorded using an EyeLink 1000 Plus Desktop mount eye-tracker sampling at 500 Hz. Two experiment lists were constructed. Each list contained 24 different-mapping verbs and 24 similar-mapping verbs. Within each verb type, half of them belonged to the classifier-shared condition (the other half the classifier-not-shared condition), so each participant received the same number of trials per condition. The locations of the target and the competitor were counterbalanced, so that they appeared at each quadrant equally frequently. Calibration and validation were performed before the practice session, and if necessary, before the main experiment and after a short break. Each trial began with a drift check, followed by a 1000 ms preview of the scene. The scenes were presented on a monitor at a resolution of 1024×768 pixels.

To control for any group differences in cognitive skills (cf. Rommers et al., 2015), participants completed five subsets of the WAIS (Wechsler Adult Intelligence Scale)-Test after the eye-tracking experiment: picture-completion test, digit-symbol coding, digit-span test, similarities, and vocabulary test (Wechsler, 2008). In the picture-completion test, participants saw six pictures and pointed out a missing element in each picture (e.g., no water spilling over from a tilted cup) without time limit. In the digit-symbol coding, participants saw ten digits with a unique corresponding symbol for each digit. They then saw a sequence of digits and drew a corresponding symbol for as many digits as possible in the given order within two minutes. In the digit-span test, participants heard 2-7 numbers and repeated the numbers in the mentioned order or backwards. In the similarities test, participants heard two words and indicated what they have in common (e.g., *Auge-Ohr*; 'eye-ear'). In the vocabulary test, participants named as many animal names as possible and as many words that start with the letter "l" in one minute each. These tests were administered in German for all participants – we made this change from our pre-registration because the Vietnamese tests were not freely available. The experiment took about one hour.

Results

Comprehension task

The mean accuracy for the task to click the mentioned object was 99% ($SD = 1.4$).

Eye-tracking data coding and analysis

We computed the proportion of time spent fixating on each object for each 50 ms bin relative to the sentence onset and converted them into log-ratios (Arai et al., 2007), because the fixation proportions for different objects are not linearly independent of one another. (If we compare fixation proportions to different objects, the analysis will violate the statistical assumption that observations should be independent from one another.) We calculated the log-ratio for bias towards the target over the competitor [log((fixation proportion on target + .5)/(fixation proportion on competitor + .5))] and the log-ratio for bias towards the competitor over the distractors [log((fixation proportion on competitor + .5)/(mean fixation proportion on distractors + .5))]. Fixations were regarded as falling on an object if they fell in the area of 300 × 300 pixels surrounding the object. The bins that contained only blinks were coded as NA.

We analysed the log-ratio data using linear mixed-effects models testing the main effects and the interaction of verb-mapping and classifier with the maximal random-effects structure justified by the design (Barr et al., 2013). All models converged. The categorical variables were sum-coded (verb-mapping: different = 1, similar = -1, classifier: not-shared = 1, shared = -1). We ran this model in three pre-defined time windows: the verb window (from the verb onset + 200 ms to the classifier onset + 200 ms), the classifier window (from the classifier onset + 200 ms to the noun onset + 200 ms), and the noun window (from the noun onset + 200 ms to the sentence offset + 200 ms). The 200 ms lag was added to account for time to initiate saccades (Saslow, 1967). We regarded an effect or an interaction as significant if the associated absolute *t*-value was larger than or equal to 2.

Eye-tracking data: pre-registered fixation proportion analysis

Figure 2 plots results from Experiment 1. Tables with all statistical results are available in the supplementary file (LME_output.pdf). The analysis in the verb window revealed no effect or interaction of interest on the TARGET VS. COMPETITOR log-ratio but revealed a significant effect of verb-mapping on the COMPETITOR VS. DISTRACTOR log-ratio, $\beta = -.062$, $SE = .018$, $t = -3.4$. This effect indicates a stronger fixation bias towards the competitor over the distractors when the verb was constraining towards both the target

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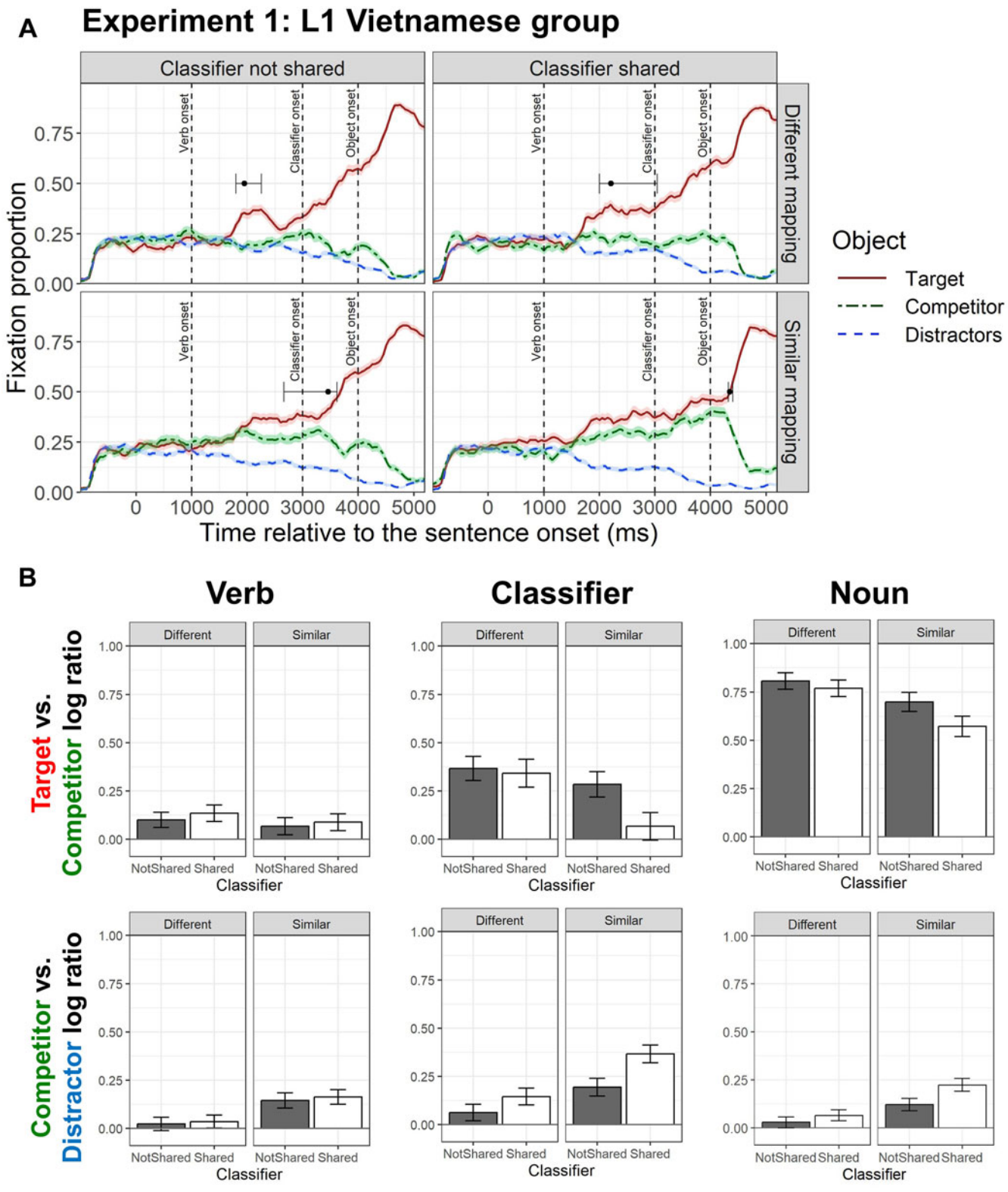

Figure 2. Results from Experiment 1 (L1 Vietnamese-L2 German group). (A) The mean fixation proportions for the target, competitor and distractor objects (averaged between the two distractors) in each condition. The fixation proportion for the distractors was the average of the fixation proportions for the two distractors. Time 0 on the x-axis shows the sentence onset. The transparent thick lines are error bars representing standard errors. The divergence points between fixations on the target and the competitor and 95% confidence intervals for each condition are shown on each plot. (B) The TARGET VS. COMPETITOR and COMPETITOR VS. DISTRACTORS log-ratio for each verb-mapping condition (different vs. similar) and classifier condition (shared vs. not-shared) in the verb, classifier, and noun windows. The error bars represent 95% confidence intervals.

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and the competitor (competitor 27% vs. distractor 15%) than when it was constraining only towards the target (competitor 21% vs. distractor 18%), suggesting that participants used the verb constraints for anticipation.

The analysis on the TARGET VS. COMPETITOR log-ratio in the classifier window revealed a significant interaction of verb-mapping by classifier, $\beta = -.048$, $SE = .017$, $t = -2.8$, and significant main effects of verb-mapping, $\beta = .089$, $SE = .031$, $t = 2.9$, and classifier, $\beta = .061$, $SE = .019$, $t = 3.2$. Follow-up analyses revealed that the effect of classifier was significant in similar-mapping verbs, $\beta = .011$, $SE = .025$, $t = 4.3$, but not in different-mapping verbs, $t = .5$. In similar-mapping verbs, the fixation bias towards the target over the competitor was stronger when the classifier was compatible only with the target (target 50% vs. competitor 25%) than when the classifier was compatible with both the target and the competitor (target 43% vs. competitor 36%). This suggests that participants used classifier constraints to anticipate the target when the verb did not disambiguate between the target and the competitor. In contrast, classifier constraints had no effect when the preceding verb was constraining only towards the target. The analysis in the classifier window on the COMPETITOR VS. DISTRACTOR log-ratio revealed significant main effects of verb-mapping, $\beta = -.088$, $SE = .021$, $t = -4.3$, and classifier, $\beta = -.064$, $SE = .014$, $t = -4.6$. The verb-mapping effect suggests a stronger fixation bias towards the competitor over the distractors when the verb was constraining towards the competitor as well as the target (competitor 31% vs. distractors 8%) than when it was constraining towards only the target (competitor 20% vs. 11%). The classifier effect suggests a stronger fixation bias towards the competitor over the distractors when the classifier was compatible with both the target and the competitor (competitor 29% vs. distractors 8%) than when the classifier was compatible only with the target (competitor 22% vs. distractors 11%).

Finally, the analysis in the noun window on the TARGET VS. COMPETITOR log-ratio revealed significant effects of verb-mapping, $\beta = .076$, $SE = .018$, $t = 4.2$, and classifier, $\beta = .041$, $SE = .016$, $t = 2.5$. Thus, the fixation bias towards the target over the competitor was stronger when the verb was constraining only towards the target (target 78% vs. competitor 9%) than when it was constraining towards the target and the competitor (target 73% vs. competitor 16%), and when the classifier was compatible only with the target (target 77% vs. competitor 10%) than when it was also compatible with the competitor (target 74% vs. competitor 14%). The analysis on the COMPETITOR VS. DISTRACTOR log-ratio revealed significant effects of verb-mapping, $\beta = -.063$, $SE = .011$, $t = -5.6$, and classifier, $\beta = -.035$, $SE = .011$, $t = -3.1$. The verb-mapping effect suggests a stronger fixation bias towards the competitor over the distractors when the verb was contraining towards both the target and the competitor (competitor 16% vs. distractors 4%) than when it was constraining only towards the target (competitor 9% vs. 5%). The classifier effect suggests that the fixation bias towards the competitor over the distractors was stronger when the classifier was compatible with both the target and the competitor (competitor 14% vs. distractors 4%) than when it was compatible only with the target (competitor 10% vs. distractors 5%). In sum, L1 Vietnamese–L2 German late bilinguals used both verb- and classifier constraints for anticipation.

Eye-tracking data: exploratory divergence point analysis

We additionally conducted an exploratory divergence point analysis (Stone et al., 2020) to estimate when the looks to the target started to diverge from the looks to the competitor in each condition (the pre-registered analysis does not reveal *when* an effect started). This method uses a non-parametric bootstrap and allows an estimation of the onset of an effect and a statistical test of onset difference between conditions or participant groups.

For this analysis, we coded fixation proportion binomially for the target and competitor objects for each 20 ms bin (to capture fine-grained time-course differences) from the verb onset to the sentence offset (to capture both anticipatory and non-anticipatory fixations). We coded bins that contained only blinks as NA. We ran a one-sample *t*-test (against chance, i.e., .5) in each time bin aggregating over items. For a divergence point estimate, we took the first time bin of at least 10 consecutive time bins with significant *t*-values (i.e., an effect sustaining for at least 200 ms). We then resampled the data 2000 times within participants, time bin, and object (target/competitor) separately for each condition using a non-parametric bootstrap. A new divergence point was estimated after each resample, and the mean of all divergence points was taken as the mean divergence point (cf. Figure 2).

This analysis revealed that the estimated divergence point relative to the sentence onset was 2211 ms, 95% CI = [2000, 3040] in the different-mapping verb – classifier-shared condition (1211 ms after the disambiguating verb), 1951 ms, 95% CI = [1800, 2259] in the different-mapping verb – classifier-not-shared condition (951 ms after the disambiguating verb), 4348 ms, 95% CI = [4320, 4400] in the similar-mapping verb – classifier-shared condition (348 ms after the disambiguating object), and 3455 ms, 95% CI = [2660, 3620] in the similar-mapping verb – classifier-not-shared condition (455 ms after the disambiguating classifier). In both different-mapping verb conditions, the divergence point was earlier than the classifier onset, suggesting that participants used the verb constraints to anticipate the target. In the similar-mapping verb – classifier-not-shared condition, the divergence point fell between the classifier onset and object noun onset, suggesting that participants used the classifier constraints to anticipate the target. In the similar-mapping verb – classifier-shared condition, the divergence point was after the object noun onset, suggesting that participants identified the target upon hearing the target word.

Discussion

L1 Vietnamese–L2 German speakers exploited both Vietnamese verb and classifier constraints for anticipation. When they heard the verb, they showed a stronger fixation bias for the competitor over the distractors when the competitor semantically fit the verb than when it did not. When they heard the classifier, they showed a stronger fixation bias for the target over the competitor when only the target (vs. both target and competitor) met the classifier's constraints. When the target was the only semantically-fitting verb object, the fixation bias towards the competitor was not affected by the classifier. The exploratory divergence point analysis further revealed that the fixations to the target and competitor diverged during the verb window when only the target met the verb constraints, during the classifier window when only the target met the classifier constraints (and the competitor met the verb constraints), and during the noun window when both target and competitor met the verb- and classifier constraints. These findings suggest that L1 Vietnamese speakers used Vietnamese verb- and classifier constraints for anticipation, without sensitivity to German verb constraints.

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Experiment 2

Experiment 2 was identical to Experiment 1 except that we tested German-dominant heritage speakers of Vietnamese. We were interested in a) whether the knowledge of German interferes with anticipation based on verbs and b) whether the absence of classifiers in German delays classifier-based anticipation compared to Experiment 1.

Methods

Participants

Thirty Vietnamese heritage speakers who started learning both languages in Germany before age six (13 males) and had normal or corrected-to-normal vision participated in the experiment at the Humboldt-Universität zu Berlin. Before coming to the laboratory, participants took a 15-minute Vietnamese test adapted from the Vietnamese Language Studies Online Test (https://vlstudies.com). Participants who scored 70% or above were invited to the experiment. Two further participants were tested but were excluded from analysis because they almost never fixated (less than 20%) on any object in the analysed time windows.

Stimuli and procedure

The stimuli and the experiment procedure were identical to Experiment 1. Eight participants were tested without a chin rest (in a remote mode) following the lab hygiene concept introduced to safeguard against COVID-19.

Results

Comprehension task

The mean accuracy for the clicking task was 94.9% ($SD = 6.6$).

Eye-tracking data: pre-registered fixation proportion analysis

Figure 3 plots the results from Experiment 2. The analysis in the verb window revealed no effect or interaction of verb-mapping or classifier on the TARGET VS. COMPETITOR log-ratio but revealed a significant effect of verb-mapping on the COMPETITOR VS. DISTRACTOR log-ratio, $\beta = -.06$, $SE = .020$, $t = -3.2$. This effect was consistent with Experiment 1, indicating a stronger fixation bias towards the competitor over the distractors when the verb was constraining towards both the target and the competitor (competitor 27% vs. distractor 13%) than when it was constraining only towards the target (competitor 21% vs. distractor 17%).

The analysis in the classifier window on the TARGET VS. COMPETITOR log-ratio revealed a significant effect of classifier, $\beta = .06$, $SE = .023$, $t = 2.6$, indicating a stronger fixation bias towards the target over the competitor when the classifier was compatible only with the target (target 44% vs. competitor 24%) than when it was compatible with both the target and the competitor (target 39% vs. competitor 29%). Unlike in Experiment 1, there was no effect of verb-mapping or interaction of verb-mapping by classifier. The analysis on the COMPETITOR VS. DISTRACTOR log-ratio revealed significant effects of verb-mapping, $\beta = -.09$, $SE = .02$, $t = -4.5$, and classifier, $\beta = -.03$, $SE = .015$, $t = -2.3$, but the two factors did not interact. The verb-mapping effect suggests a stronger fixation bias towards the competitor over the distractors when the verb was constraining towards both the target and the competitor (competitor 31% vs. distractors 7%) than when it was constraining only towards the target (competitor 22% vs. distractors 11%). The classifier effect suggests a stronger fixation bias towards the competitor over the distractors when the classifier was compatible with both the target and the competitor (competitor 29% vs. distractors 9%) than when it was compatible only with the target (competitor 24% vs. distractors 9%).

The analysis in the noun window on the TARGET VS. COMPETITOR log-ratio revealed a significant effect of classifier, $\beta = .048$, $SE = .017$, $t = 2.7$, but there was no effect of verb-mapping or interaction of verb-mapping by classifier. The classifier effect indicates a stronger fixation bias towards the target over the competitor when the classifier was compatible only with the target (target 67% vs. competitor 15%) than when it was compatible with both the target and the competitor (target 63% vs. competitor 20%). The analysis on the COMPETITOR VS. DISTRACTOR log-ratio revealed significant effects of verb-mapping, $\beta = -.069$, $SE = .019$, $t = -3.7$, and classifier, $\beta = -.035$, $SE = .014$, $t = -2.5$. The two factors did not interact. The verb-mapping effect suggests a stronger fixation bias towards the competitor over the distractors when the verb was constraining towards both the target and the competitor (competitor 21% vs. distractors 3%) than when it was constraining only towards the target (competitor 14% vs. distractors 6%). The classifier effect suggests a stronger fixation bias towards the competitor over the distractors when the classifier was compatible with both the target and the competitor (competitor 20% vs. distractors 5%) than when it was compatible with only the target (competitor 15% vs. distractors 5%). Thus, heritage speakers also used both verb- and classifier constraints for anticipation, and the degree of anticipation was overall similar to L1 Vietnamese–L2 German speakers.

Eye-tracking data: exploratory divergence point analysis

Similar to Experiment 1, we analysed when the fixations to the target and the competitor started to diverge. We then computed Bayes factors to test whether the divergence points in each condition were different between the L1 Vietnamese group and the heritage speaker group following Stone et al. (2021). To obtain priors for this analysis, we specified a normal distribution centred in the middle of the window from the verb onset + 200 ms to the object noun onset + 200 ms, with a 95% probability of falling in this window. This window was chosen because we regarded eye movements to the target in this window as anticipatory eye movements (there was no cue for anticipation before this window and the target was mentioned after this window). This prior centred the probability of the group difference on zero, which is consistent with no difference between the groups.

The estimated divergence point relative to the sentence onset was 3808 ms, 95% CI = [3220, 4040] in the different-mapping verb – classifier-shared condition (2808 ms after the disambiguating verb), 3473 ms, 95% CI = [2780, 3720] in the different-mapping verb – classifier-not-shared condition (2473 ms after the disambiguating verb), 4445 ms, 95% CI = [4400, 4500] in the similar-mapping verb – classifier-shared condition (445 ms after the disambiguating object), and 3650 ms, 95% CI = [3600, 3700] in the similar-mapping verb – classifier-not-shared condition (650 ms after the disambiguating classifier) (cf. Figure 3).

These divergence points differed from those in Experiment 1 in the different-mapping verb – classifier-shared/not-shared conditions. The divergence point in these conditions was after the

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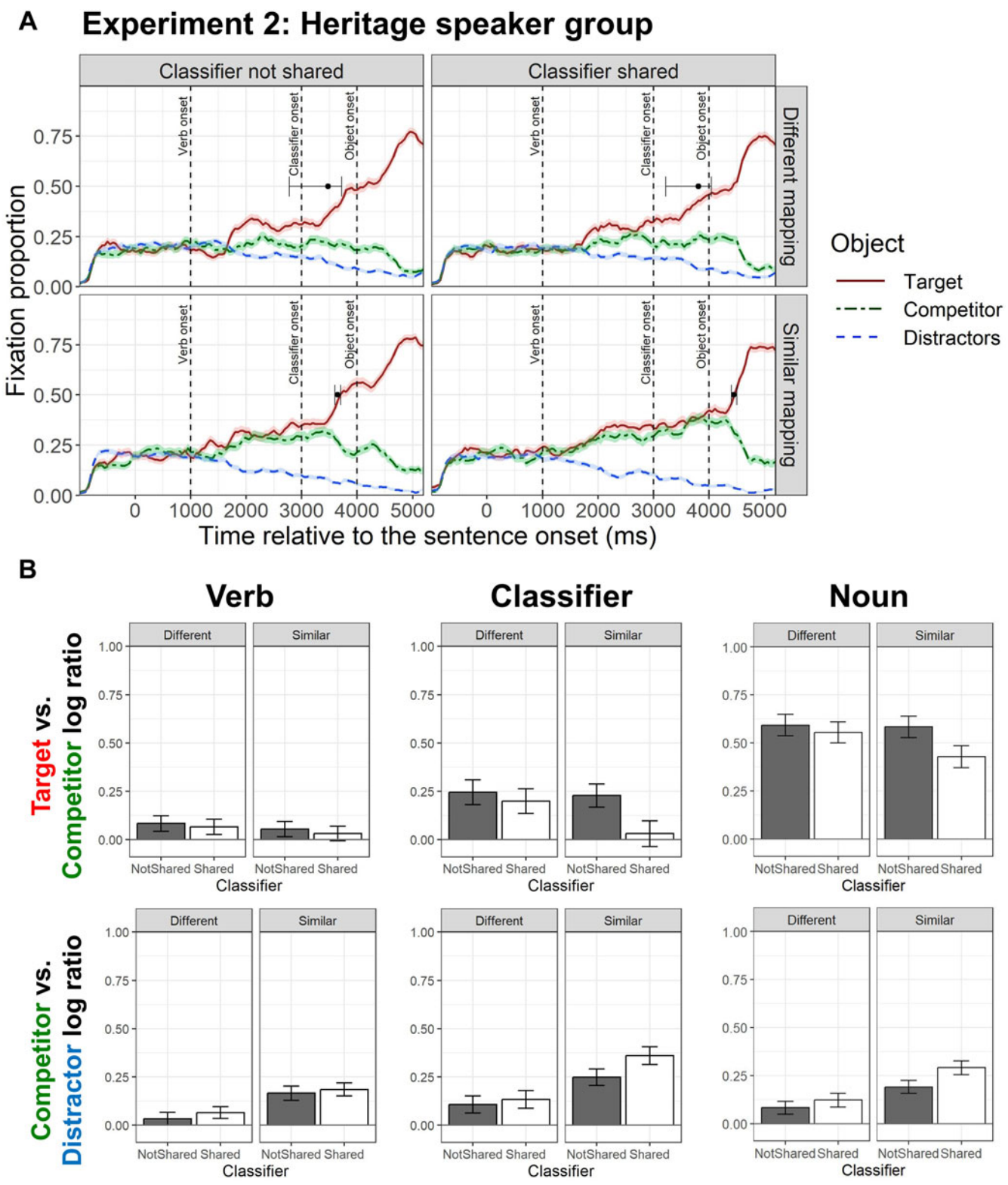

Figure 3. Results from Experiment 2 (heritage speaker group). (A) The mean fixation proportions for the target, competitor and distractor objects (averaged between the two distractors) in each condition. The fixation proportion for the distractors was the average of the fixation proportions on the two distractors. Time 0 on the x-axis shows the sentence onset. The transparent thick lines are error bars representing standard errors. The divergence points between fixations on the target and the competitor and 95% confidence intervals for each condition are shown on each plot. (B) The TARGET VS. COMPETITOR and COMPETITOR VS. DISTRACTORS log-ratio for each verb-mapping condition (different vs. similar) and classifier condition (shared vs. not-shared) in the verb, classifier, and noun windows. The error bars represent 95% confidence intervals.

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classifier onset (808 ms and 473 ms after the classifier onset in the classifier-shared and not-shared condition, respectively) in heritage speakers but before the classifier onset in L1 Vietnamese–L2 German speakers. Heritage speakers started looking at the target over the competitor 1597 ms later than L1 Vietnamese–L2 German speakers in the different-mapping verb classifier-shared condition (Bayes factor = 156), and 1522 ms later in the different-mapping verb – classifier-not-shared condition (Bayes factor = 75) (i.e., when the verb-mapping was different between Vietnamese and German). In the similar-mapping verb conditions, both groups showed similar divergence points. The divergence point fell in the classifier window when the classifier was only compatible with the target (350 ms before the object onset, vs. 545 ms in Experiment 1) (Bayes factor = .01), and in the noun window when the classifier was compatible with both the target and the competitor (445 ms after the object onset vs. 348 ms in Experiment 1) (Bayes factor = .02). Thus, when the competitor met the constraints of the German translation of the verb, verb-mediated anticipation in heritage speakers was delayed compared to that in L1 Vietnamese–L2 German speakers; by contrast, classifier-mediated anticipation occurred similarly quickly in both groups.

Eye-tracking data: pre-registered group comparison

We additionally tested an interaction of verb-mapping by classifier by group. For this analysis, we dropped the condition(s) that did not show a significant effect in the analyses for each group (following our pre-registration). To summarise the findings from both experiments, both groups showed a similar effect in the verb window. The TARGET VS. COMPETITOR fixation log-ratio did not differ as a function of verb-mapping or classifier, but there was a significant main effect of group, $\beta = .020$, $SE = .008$, $t = 2.3$, indicating that L1 Vietnamese–L2 German speakers were more likely to fixate the target over the competitor (target 32% vs. competitor 24%) than heritage speakers (target 29% vs. competitor 24%) in the verb window. Both groups were more likely to fixate the competitor over the distractors when the verb was (vs. was not) compatible with the competitor (as well as the target). A model testing a two-way interaction of verb-mapping by group on the COMPETITOR VS. DISTRACTORS fixation log-ratio did not show a significant interaction, $t = .03$, suggesting that the verb-mapping effect was similar in both groups.

In the classifier window, both groups were more likely to fixate the target over the competitor when the classifier was compatible only with the target than when it was compatible with both the target and the competitor. Only L1 Vietnamese–L2 German speakers showed a significant interaction of verb-mapping by classifier, indicating that the effect of classifier was significant when the verb was compatible with the competitor, too, but not when it was only compatible with the target. The three-way interaction of verb-mapping by classifier by group was not significant, $t = -.4$. However, there was a main effect of group, $\beta = .045$, $SE = .021$, $t = 2.2$, indicating that L1 Vietnamese–L2 German speakers were more likely to fixate the target over the competitor (target 49% vs. competitor 25%) than heritage speakers (target 41% vs. competitor 26%). Both groups were also more likely to fixate the competitor over the distractors when the verb or the classifier was compatible with the competitor than when they were not. The interactions of verb-mapping by group, $t = .2$, and classifier by group, $t = -1.5$, were not significant, suggesting that these effects did not differ substantially between the groups.

In the noun window, the L1 Vietnamese–L2 German group were more likely to fixate the target over the competitor when the verb or the classifier was incompatible (vs. compatible) with the competitor. The heritage speaker group also showed the effect of classifier, but no effect of verb-mapping. The interactions of verb-mapping by group, $t = 1.6$, or classifier by group, $t = -.4$, were not significant, suggesting that these effects did not differ substantially between the groups. However, there was a main effect of group, $\beta = .086$, $SE = .018$, $t = 4.8$, indicating that L1 Vietnamese–L2 German speakers were more likely to fixate the target over the competitor (target 75% vs. competitor 12%) than heritage speakers (target 65% vs. competitor 17%). The analysis on the COMPETITOR VS. DISTRACTORS fixation log-ratio showed that both groups were more likely to fixate the competitor over the distractors when the verb or the classifier was compatible with the competitor than when they were not. The interactions of verb-mapping by group, $t = .4$, or classifier by group, $t = .004$, were not significant, suggesting that these effects were similar in both groups. However, there was a main effect of group, $\beta = -.031$, $SE = .008$, $t = -3.8$, indicating that heritage speakers were more likely to fixate the competitor over the distractors (competitor 17% vs. distractors 5%) than L1 Vietnamese–L2 German speakers (competitor 12% vs. distractors 4%).

In summary, both groups showed overall qualitatively similar results, in that they used both verbs and classifiers for anticipation, but there were two notable differences. First, L1 Vietnamese–L2 German speakers were overall more likely to fixate the target over the competitor than heritage speakers across all the windows, suggesting that they were more efficient in disambiguating between the target and the competitor, irrespective of the verb-mapping/classifier condition. Second, heritage speakers were more likely to fixate the competitor over the distractors than L1 Vietnamese–L2 German speakers in the noun window, suggesting that they were more likely to be distracted by the competitor than L1 Vietnamese–L2 German speakers.

Cognitive tests

Table 2 summarises the cognitive test results. We tested whether these scores were significantly different between the groups using independent samples *t*-tests for the digit-symbol coding and digit-span tests (because the means were normally distributed) and Mann-Whitney-Wilcoxon tests for the picture-completion, similarities and vocabulary tests (because the means were not normally distributed). L1 Vietnamese–L2 German speakers scored significantly higher than heritage speakers in the digit-symbol coding test, $t(50.9) = 3.4$, $p = .001$. Heritage speakers scored significantly higher in the similarities test, $W = 160.5$, $p < .001$, and

Table 2. The results of the WAIS cognitive tests for each participant group.

Test	L1 Vietnamese-L2 German speakers (Experiment 1)	Heritage speakers (Experiment 2)
Picture completion	2.9 (0.9)	2.9 (0.9)
Digit symbol coding	88.2 (10.9)	76.1 (16.1)
Digit span	14.1 (2.2)	15.4 (3.3)
Similarities	10.6 (2.4)	13.4 (2.0)
Vocabulary	22.9 (5.4)	37.1 (8.2)

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in the vocabulary test, $W = 65.5$, $p < .001$. These differences arguably reflect the difference in German proficiency (as the cognitive tests were conducted in German), consistent with the self-rated proficiency in German. Heritage speakers scored slightly higher in the digit-span test than L1 Vietnamese–L2 German speakers, $t(49.9) = -1.8$, $p = .07$. The two groups scored similarly high in the picture completion test, $W = 442.5$, $p = .09$. Notably, heritage speakers scored consistently higher than L1 Vietnamese–L2 German speakers in the tests that required a high competence in German.

General discussion

We compared anticipatory use of verb constraints (different or similar between Vietnamese and German) and classifier constraints (absent in German) in L1 Vietnamese–L2 German bilinguals and German-dominant heritage speakers of Vietnamese. The fixation proportion analyses revealed that both groups used verb- and classifier constraints for anticipation to a similar degree, consistent with findings that people can use multiple linguistic cues to anticipate upcoming referents (Hopp, 2015; Kamide, Altmann, et al., 2003; Kamide, Scheepers, et al., 2003). However, the divergence point analysis revealed slower anticipation for different-verb constraints (Vietnamese and German) in heritage speakers than the L1 Vietnamese, suggesting they were sensitive to the German verb constraints. We discuss the similarities and differences between the two bilingual groups in turn.

Similarities in anticipation between the two groups

Verb constraints

For similar verb constraints (Vietnamese / German), heritage speakers anticipated verb-compatible objects as quickly as the L1 Vietnamese–L2 German speakers, suggesting similarities in the effects of verb constraints. When the verb constraints were different though, heritage speakers showed delayed anticipation compared to L1 Vietnamese–L2 German speakers (see below). However, they still started looking at the target over the competitor before the target word onset – in the different-mapping verb, classifier-shared condition, the only disambiguating cue (before the target was mentioned) was the verb constraint. Heritage speakers' anticipatory looks to the target suggest constraints of the Vietnamese verbs enabled anticipation.

Classifier constraints

Both participant groups used classifier constraints for anticipation to a similar extent (cf. the fixation proportion analyses) and similarly quickly (cf. the divergence point analyses). Thus, heritage speakers can use classifier constraints even if classifiers are absent in their dominant language. This may in turn suggest that the absence of equivalent constraints in the dominant language does not cause anticipation difficulty in heritage speakers. Grüter et al. (2020) tested anticipation based on classifier constraints (e.g., 'dog' for the Chinese classifier *tiao*, which is usually used for long and flexible objects). They found L2 speakers were distracted by objects that were grammatically incompatible but matched the semantic class of the classifier. In our study, the target objects always matched the (semantic class of the) classifier. Thus, it remains unclear whether heritage speakers can use classifier constraints to anticipate an object that mismatches the semantic class without being distracted by objects that match the semantic class but not grammar constraints.

Since we only manipulated semantic constraints, our data do not speak to whether heritage speakers can use other types of constraints (absent in their dominant language) for anticipation. For example, L2 speakers are often less likely than L1 speakers to use syntactic gender for anticipation, even when highly proficient (Hopp, 2013). Late L2 learners may have greater difficulty in using syntactic, or more detailed, word form information compared with semantic information even if they are advanced (Ito & Pickering, 2021). However, English-dominant heritage speakers of Spanish or Polish seem to use gender to facilitate online comprehension (Fuchs, 2022a, 2022b). In future research, it would be interesting to test whether heritage speakers exhibit native-like anticipation (using constraints that are absent in the dominant language) also for other levels of the language system.

Differences in anticipation between the two bilingual groups

Despite the overall similar degree of anticipation, the two bilingual groups in the present study differed in the speed of anticipation based on verbs that had different constraints in Vietnamese and German. L1 Vietnamese–L2 German speakers started looking at the target over the competitor before the classifier onset, suggesting that they used the verb constraints and excluded the competitor from the anticipated content. In contrast, heritage speakers kept looking at both objects after the classifier onset and started looking at the target over the competitor more than one second later than L1 Vietnamese–L2 German speakers. Thus, heritage speakers were distracted by the competitor that was compatible with the German verb constraints. This finding supports Kaan's (2014) claim that competing activation in the two languages of bilinguals can interfere with anticipation. Under this account, bilinguals activate translation-equivalents in the dominant language during non-dominant language comprehension (Oppenheim et al., 2018; Thierry & Wu, 2007). In the context of the current study, bilinguals hearing the Vietnamese verb *mặc* ('wear', which can take a shirt but not earrings as a grammatical object) activated the German translation-equivalent *tragen* ('wear', which can take both a shirt and earrings as a grammatical object), and the activated German verb constraints affected the content of their anticipation. If they only activated the Vietnamese verb constraints, they should anticipate a shirt but not earrings upon hearing the verb.

An alternative explanation for the interference effect from German is that representations of the dominant language affect representations in the non-dominant language in bilinguals during learning, but critically, not during online processing. According to this learning-based account (Costa et al., 2017, 2019), the lexicon of a language is different in monolinguals and bilinguals, in that the lexicon of bilinguals contains remnants of how the other language is structured. When German–Vietnamese bilinguals learn the Vietnamese verb *mặc*, they initially activate the German-equivalent verb *tragen* (assuming that they first learnt the word *tragen*) via spreading activation due to semantic relationships. This mapping during learning makes the representations in German (e.g., verb affordances) carry over to the Vietnamese lexicon. Thus, upon hearing the verb *mặc*, heritage speakers may be sensitive to the affordance of the verb *tragen* without activating the German translation-equivalent during processing.

Our findings cannot dissociate these accounts but suggest that difficulty in anticipation in the non-dominant language comes (partly) from the knowledge of the dominant language, and

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heritage speakers' anticipation may not be native-like even though they started acquiring the language very early. This is consistent with Molinaro et al. (2017), who found that L1 Basque–L2 Spanish early bilinguals showed a stronger sensitivity to gender transparency of predictable nouns than L1 Spanish–L2 Basque early bilinguals. In Spanish, the noun ending is diagnostic of grammatical gender in about 2/3 of the nouns (*-a* for feminine and *-o* for masculine nouns), whereas in Basque, noun endings, or post-nominal suffixes play an important role in syntactic analysis. When a constraining context (e.g., *I just left home and I don't remember if I closed*…, in Spanish) was followed by an article that matched or mismatched the expected noun in gender (e.g., $la_{\text{-fem}}$ or $el_{\text{-masc}}$, for the expected noun $puerta_{\text{-fem}}$, 'door'), both groups showed a larger N400 for the gender-mismatch article compared to the gender-match article, suggesting that both groups anticipated the gender of the noun. However, only the L1 Basque–L2 Spanish bilinguals showed an additional N200 effect for the gender-mismatch (vs. gender-match) article when the expected noun was gender-transparent. The N200 effect indicates that L1 Basque–L2 Spanish bilinguals detected the gender mismatch at a pre-lexical (word form) level, consistent with the hypothesis that they pay greater attention (than L1 Spanish–L2 Basque bilinguals) to post-nominal suffixes due to their role in syntactic analysis in Basque. This finding was interpreted as support for the idea that bilinguals are mainly tuned to their L1 characteristics and adapt their expectations to the L1 regularities. Our findings also support this idea and further demonstrate that not only grammatical or typological characteristics but also semantic constraints in the dominant language shape bilinguals' anticipation in the non-dominant language.

One explanation we cannot rule out is that heritage speakers were sensitive to English, not German, verb constraints. However, while all participants spoke English, no participants in our study reported being more proficient in English than in German. Considering the finding that more proficient language of bilinguals tends to exhibit stronger cross-linguistic interference (Blumenfeld & Marian, 2013), it is unlikely that the interference effect was primarily from English. One can doubt overall whether proficiency is a decisive factor for cross-linguistic interference since at least some studies have reported a null effect of proficiency in the presence of the effects of semantic constraints of the verb on anticipation (Chambers & Cooke, 2009).

Interestingly, L1 Vietnamese–L2 German speakers showed no sensitivity to the German verb constraints. We hypothesised this effect might occur as some studies found an effect of L2 on L1 processing in L2 speakers (Lagrou et al., 2011). While the effect of L2 on L1 processing seems weaker than the effect of L1 on L2 processing (Grüter & Hopp, 2021), it tends to be larger in highly proficient (vs. less proficient) L2 speakers (Blumenfeld & Marian, 2007, 2013). The similarities and vocabulary WAIS tests suggest that heritage speakers were more proficient in German than L1 Vietnamese–L2 German speakers. Thus, the lack of evidence for transfer from German in L1 Vietnamese–L2 German speakers could be because their German proficiency was not high enough for German representations to interfere with online processing in Vietnamese.

Alternatively (or additionally), the inconsistency with studies that found transfer from L2 may be due to a different locus of the transfer. Transfer effects have often been investigated by using inter-lingual homophones (e.g., English *pills* – German *Pilz*, 'mushroom') or cognates (e.g., English *tomato* – Dutch *tomato*) (Hoshino et al., 2010; Hoshino & Kroll, 2008; Libben & Titone, 2009; Shook et al., 2014; Spivey & Marian, 1999), so the transfer effect is expected on a word form level. In our study, the transfer effect was expected on the semantic level. The inconsistency could also be because our study investigated anticipatory use of these constraints, and transfer effects are more robust or detectable during word recognition than anticipatory processing based on a recognised word and its constraints. Finally, L1 Vietnamese–L2 German speakers' insensitivity to the German verb constraints may originate from them not knowing that the Vietnamese and German verb had different constraints (and always using the Vietnamese constraints).

One limitation of our study is that the findings about the time-course of anticipation are based on exploratory analyses. It is desired for future research to replicate these findings in a preregistered study and to test their generalisability to different groups of bilinguals or types of constraints. While it was difficult to recruit many participants for our study, our data are publicly available, and we encourage a meta-analysis investigating the degree to which cross-linguistic competition affects language anticipation. Additionally, the two groups of participants we tested differed not only in the language dominance but in the age of acquisition of German, self-rated proficiency of Vietnamese and German, and possibly other aspects. While our study was not designed to dissociate these possible factors, it would be interesting to investigate which factors contributed to the effects we found in future research.

Conclusion

We tested anticipatory use of verb- and classifier constraints in L1 Vietnamese–L2 German bilinguals and German-dominant heritage speakers of Vietnamese. Both groups anticipated objects that fit classifier constraints similarly quickly and well before they were mentioned. However, in anticipating object referents that fit verb semantic constraints, heritage speakers were slower than L1 Vietnamese–L2 German speakers when the constraints were different in Vietnamese and German. These results demonstrate that knowledge of the dominant language (German) affects anticipation in the heritage language (Vietnamese), and competition between the languages can account for delayed anticipation in bilinguals compared to monolinguals. For theories of mental representations and processes, these findings permit dissociating between comprehender groups that differ as little as the two groups we tested (these groups started acquiring Vietnamese at a similarly young age). The findings can also shape predictions about variability in comprehension when comprehenders experience variation in the formality of a situation, in register, dialect, or genre, among others. For register, as an example, we expect that much like a language user's background in the present experiments, knowledge about language use associated with a specific (e.g., formal or informal) situation might influence anticipation of upcoming (formal or informal) content. To what extent such situation-based register knowledge would interact (or not) with L2 proficiency is a further open question for research bridging the linguistic and cultural sciences and associated individual differences.

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Supplementary Material. For supplementary material accompanying this paper, visit https://doi.org/10.1017/S136672892300041X

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Appendix

Critical sentences with English translations and object names for each condition. A depiction of more than one objects is indicated as "(pl.)" in case there is no plural form of the word in English.

Item	Verb mapping	Classifier	Sentence (translation)	Target	Competitor	Distractor1	Distractor2
1	Different	Shared	Mai mặc một chiếc áo. (Mai wears a shirt.)	shirt	earring	tree	ball
1	Different	Not shared	Mai mặc một chiếc áo. (Mai wears a shirt.)	shirt	earrings	tree	ball
2	Similar	Shared	Mai phơi một cặp áo. (Mai dries shirts.)	shirts	dress	cloud	moon
2	Similar	Not shared	Mai phơi một cặp áo. (Mai dries shirts.)	shirts	dresses	cloud	moon
3	Different	Shared	Mai mặc một chiếc váy. (Mai wears a dress.)	dress	earring	beer	computer
3	Different	Not shared	Mai mặc một chiếc váy. (Mai wears a dress.)	dress	earrings	beer	computer
4	Similar	Shared	Mai phơi một cặp váy. (Mai dries dresses.)	dresses	shirts	mountain	river
4	Similar	Not shared	Mai phơi một cặp váy. (Mai dries dresses.)	dresses	shirt	mountain	river

(*Continued*)

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(*Continued.*)

Item	Verb mapping	Classifier	Sentence (translation)	Target	Competitor	Distractor1	Distractor2
5	Different	Shared	Nam chặt một khúc gỗ. (Nam chops wood.)	wood	fish	water	sun
5	Different	Not shared	Nam chặt một khúc gỗ. (Nam chops wood.)	wood	fishes	water	sun
6	Similar	Shared	Nam xếp một đống gỗ. (Nam arranges wood.)	wood (pl.)	bamboos	vase	spoon
6	Similar	Not shared	Nam xếp một đống gỗ. (Nam arranges wood.)	woods (pl.)	bamboo	vase	spoon
7	Different	Shared	Nam chặt một khúc tre. (Nam chops a bamboo.)	bamboo	fish	castle	fridge
7	Different	Not shared	Nam chặt một khúc tre. (Nam chops a bamboo.)	bamboo	fish (pl.)	castle	fridge
8	Similar	Shared	Nam xếp một đống tre. (Nam arranges bamboos.)	bamboos	wood (pl.)	apple	frog
8	Similar	Not shared	Nam xếp một đống tre. (Nam arranges bamboos.)	bamboos	wood	apple	frog
9	Different	Shared	Nam bọc một quyển sách. (Nam wraps a book.)	book	calendar	garden	street
9	Different	Not shared	Nam bọc một quyển sách. (Nam wraps a book.)	book	calendars	garden	street
10	Similar	Shared	Nam in một bức ảnh. (Nam prints a photo.)	photo	painting	bread	hat
10	Similar	Not shared	Nam in một bức ảnh. (Nam prints a photo.)	photo	paintings	bread	hat
11	Different	Shared	Mai bọc một quyển vở. (Mai wraps a notebook.)	notebook	calendar	forest	sea
11	Different	Not shared	Mai bọc một quyển vở. (Mai wraps a notebook.)	notebook	calendars	forest	sea
12	Similar	Shared	Mai in một bức tranh. (Mai prints a painting.)	painting	photo	boy	dog
12	Similar	Not shared	Mai in một bức tranh. (Mai prints a painting.)	painting	photos	boy	dog
13	Different	Shared	Nam bê một chồng sách. (Nam carries books.)	books	cookies	building	plane
13	Different	Not shared	Nam bê một chồng sách. (Nam carries books.)	books	cookie	building	plane
14	Similar	Shared	Nam treo một loạt ảnh. (Nam hangs photos.)	photos	paintings	fire	water
14	Similar	Not shared	Nam treo một loạt ảnh. (Nam hangs photos.)	photos	painting	fire	water
15	Different	Shared	Mai bê một chồng vở. (Mai carries notebooks.)	notebooks	cookies	bridge	van
15	Different	Not shared	Mai bê một chồng vở. (Mai carries notebooks.)	notebooks	cookie	bridge	van
16	Similar	Shared	Mai treo một loạt tranh. (Mai hangs paintings.)	paintings	photos	pagoda	supermarket
16	Similar	Not shared	Mai treo một loạt tranh. (Mai hangs paintings.)	paintings	photo	pagoda	supermarket
17	Different	Shared	Nam thái một củ khoai. (Nam cuts a potato.)	potato	peanut	oil	ice cream
17	Different	Not shared	Nam thái một củ khoai. (Nam cuts a potato.)	potato	peanuts	oil	ice cream

(*Continued*)

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(*Continued.*)

Item	Verb mapping	Classifier	Sentence (translation)	Target	Competitor	Distractor1	Distractor2
18	Similar	Shared	Nam xé một tờ giấy. (Nam tears a piece of paper.)	paper	newspaper	pencil	monkey
18	Similar	Not shared	Nam xé một tờ giấy. (Nam tears a piece of paper.)	paper	newspapers	pencil	monkey
19	Different	Shared	Mai thái một củ sắn. (Mai cuts a manioc.)	manioc	peanut	motorbike	statue
19	Different	Not shared	Mai thái một củ sắn. (Mai cuts a manioc.)	manioc	peanuts	motorbike	statue
20	Similar	Shared	Mai xé một tờ báo. (Mai tears a piece of newspaper.)	newspaper	paper	tank	duck
20	Similar	Not shared	Mai xé một tờ báo. (Mai tears a piece of newspaper.)	newspaper	papers	tank	duck
21	Different	Shared	Nam rửa một rổ khoai. (Nam washes potatoes.)	potatoes	towels	batteries	cake
21	Different	Not shared	Nam rửa một rổ khoai. (Nam washes potatoes.)	potatoes	towel	batteries	cake
22	Similar	Shared	Nam mua một tập giấy. (Nam buys paper.)	papers	newspapers	lip	giraffe
22	Similar	Not shared	Nam mua một tập giấy. (Nam buys paper.)	papers	newspaper	lip	giraffe
23	Different	Shared	Mai rửa một rổ sắn. (Mai washes maniocs.)	maniocs	towels	butter	chocolate
23	Different	Not shared	Mai rửa một rổ sắn. (Mai washes maniocs.)	maniocs	towel	butter	chocolate
24	Similar	Shared	Mai mua một tập báo. (Mai buys newspapers.)	newspapers	papers	eyes	church
24	Similar	Not shared	Mai mua một tập báo. (Mai buys newspapers.)	newspapers	paper	eyes	church
25	Different	Shared	Nam giặt một mảnh vải. (Nam washes a fabric.)	fabric	a piece of a broken bowl	cola	soup
25	Different	Not shared	Nam giặt một mảnh vải. (Nam washes a fabric.)	fabric	bowls	cola	soup
26	Similar	Shared	Nam trồng một cây chuối. (Nam grows a banana tree.)	banana tree	coconut tree	lamp	shoes
26	Similar	Not shared	Nam trồng một cây chuối. (Nam grows a banana tree.)	banana tree	coconut trees	lamp	shoes
27	Different	Shared	Mai giặt một mảnh chiếu. (Mai washes a sedge mat.)	sedge mat	a piece of a broken bowl	milk	clock
27	Different	Not shared	Mai giặt một mảnh chiếu. (Mai washes a sedge mat.)	sedge mat	bowls	milk	clock
28	Similar	Shared	Mai trồng một cây dừa. (Mai grows a coconut tree.)	coconut tree	banana tree	comb	table
28	Similar	Not shared	Mai trồng một cây dừa. (Mai grows a coconut tree.)	coconut tree	banana trees	comb	table
29	Different	Shared	Nam đeo một cái nhẫn. (Nam wears a ring.)	ring	pant	pan	cucumber
29	Different	Not shared	Nam đeo một cái nhẫn. (Nam wears a ring.)	ring	pants	pan	cucumber
30	Similar	Shared	Nam tưới một vườn chuối. (Nam waters banana trees.)	banana trees	coconut trees	pillow	drum
30	Similar	Not shared	Nam tưới một vườn chuối. (Nam waters banana trees.)	banana trees	coconut tree	pillow	drum

(*Continued*)

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(*Continued.*)

Item	Verb mapping	Classifier	Sentence (translation)	Target	Competitor	Distractor1	Distractor2
31	Different	Shared	Mai đeo một cái kính. (Mai wears glasses.)	glasses	pant	eggs	tower
31	Different	Not shared	Mai đeo một cái kính. (Mai wears glasses.)	glasses	pants	eggs	tower
32	Similar	Shared	Mai tưới một vườn dừa. (Mai waters coconut trees.)	coconut trees	banana trees	fan	lighter
32	Similar	Not shared	Mai tưới một vườn dừa. (Mai waters coconut trees.)	coconut trees	banana tree	fan	lighter
33	Different	Shared	Nam gói một bộ nhẫn. (Nam wraps rings.)	rings	chairs	wedding	football player
33	Different	Not shared	Nam gói một bộ nhẫn. (Nam wraps rings.)	rings	chair	wedding	football player
34	Similar	Shared	Nam bán một lô vải. (Nam sells clothes.)	clothes	sedge mats	music band	ocean
34	Similar	Not shared	Nam bán một lô vải. (Nam sells clothes.)	clothes	sedge mat	music band	ocean
35	Different	Shared	Mai gói một bộ kính. (Mai wraps glasses.)	glasses (pl.)	chairs	family	cave
35	Different	Not shared	Mai gói một bộ kính. (Mai wraps glasses.)	glasses (pl.)	chair	family	cave
36	Similar	Shared	Mai bán một lô chiếu. (Mai sells sedge mats.)	sedge mats	clothes	rubbish	butterfly
36	Similar	Not shared	Mai bán một lô chiếu. (Mai sells sedge mats.)	sedge mats	cloth	rubbish	butterfly
37	Different	Shared	Nam xách một giỏ xoài. (Nam carries mangos.)	mangos	grapes	ship	villa
37	Different	Not shared	Nam xách một giỏ xoài. (Nam carries mangos.)	mangos	grape	ship	villa
38	Similar	Shared	Nam ăn một quả xoài. (Nam eats a mango.)	mango	apple	bottle	bookshelf
38	Similar	Not shared	Nam ăn một quả xoài. (Nam eats a mango.)	mango	apples	bottle	bookshelf
39	Different	Shared	Nam xách một giỏ táo. (Nam carries apples.)	apples	grapes	train	elephant
39	Different	Not shared	Nam xách một giỏ táo. (Nam carries apples.)	apples	grape	train	elephant
40	Similar	Shared	Mai ăn một quả táo. (Mai eats an apple.)	apple	mango	graph	party
40	Similar	Not shared	Mai ăn một quả táo. (Mai eats an apple.)	apple	mangos	graph	party
41	Different	Shared	Nam bổ một trái cà. (Nam splits a tomato.)	tomato	banana	wall	juicer
41	Different	Not shared	Nam bổ một trái cà. (Nam splits a tomato.)	tomato	bananas	wall	juicer
42	Similar	Shared	Nam hái một chùm cà. (Nam plucks tomatoes.)	tomatoes	guavas	hourglass	heater
42	Similar	Not shared	Nam hái một chùm cà. (Nam plucks tomatoes.)	tomatoes	guava	hourglass	heater
43	Different	Shared	Mai bổ một trái ổi. (Mai splits a guava.)	guava	banana	grill	cup
43	Different	Not shared	Mai bổ một trái ổi. (Mai splits a guava.)	guava	bananas	grill	cup

(*Continued*)

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(*Continued.*)

Item	Verb mapping	Classifier	Sentence (translation)	Target	Competitor	Distractor1	Distractor2
44	Similar	Shared	Mai hái một chùm ổi. (Mai plucks guavas.)	guavas	tomatoes	fox	faucet
44	Similar	Not shared	Mai hái một chùm ổi. (Mai plucks guavas.)	guavas	tomato	fox	faucet
45	Different	Shared	Nam bửa một miếng bánh. (Nam splits a cake.)	cake	lime	fruit smoothies	cocktail
45	Different	Not shared	Nam bửa một miếng bánh. (Nam splits a cake.)	cake	limes	fruit smoothies	cocktail
46	Similar	Shared	Nam mua một khay bánh. (Nam buys cakes.)	cakes	ginger (pl.)	face	pyramid
46	Similar	Not shared	Nam mua một khay bánh. (Nam buys cakes.)	cakes	ginger	face	pyramid
47	Different	Shared	Mai bửa một miếng gừng. (Mai splits ginger.)	Ginger	lime	blanket	ink
47	Different	Not shared	Mai bửa một miếng gừng. (Mai splits ginger.)	Ginger	limes	blanket	ink
48	Similar	Shared	Mai mua một khay gừng. (Mai buys ginger.)	ginger (pl.)	cakes	hands	flood
48	Similar	Not shared	Mai mua một khay gừng. (Mai buys ginger.)	ginger (pl.)	cake	hands	flood

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