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L1 word order does not modulate predictive use of dative verb constraints in L2 Mandarin

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Abstract

This study investigates cross-linguistic influence in L2 prediction: specifically, the hypothesis that first language (L1) speakers of a verb-final language are less likely to use verb information for real-time prediction in a verb-medial (SVO) second language (L2; Şafak & Hopp, 2023). Two groups of L2 learners of Mandarin (L1 English, SVO; L1 Japanese/Korean, SOV) participated in a visual world eye-tracking experiment to measure their anticipatory fixations on upcoming arguments following dative verbs with categorical or gradient constraints. Results indicate both groups made predictive use of categorical constraints of non-alternating verbs, with no evident between-group differences. Following alternating verbs with gradient constraints, both groups showed a general predictive bias for prepositional dative constructions. These findings indicate that lack of experience with verb-based prediction in the L1 is not a hinderance to predictive use of verb-based cues in an L2.

Keywords: cross-linguistic influence, prediction, dative alternation, eye-tracking, Mandarin

1. Introduction

During real-time processing, listeners use a variety of cues to actively predict upcoming elements (e.g., Pickering & Gambi, 2018). Among these cues, constraints imposed by the verb on potential upcoming arguments have been widely investigated, especially with regard to semantic information on transitive verbs acting as predictive cues for upcoming direct objects, as in the seminal visual-world eye-tracking (VWP) experiments (e.g., *eat the cake* vs. *move the cake*) by Altmann and colleagues (e.g., Altmann & Kamide, 1999), and much subsequent work with both native (L1) and non-native (L2[1]) users of English and other SVO languages (e.g., Chambers & Cooke, 2009; Dijkgraaf et al., 2017; Mani & Huettig, 2012). These studies have shown that predictive use of verb information is characteristic of both L1 and L2 processing, yet effects are often smaller and/or temporally delayed when comparing L2 with L1 users (e.g., Chun & Kaan, 2019; Schlenter & Felser, 2021, Experiment 1; but cf. Dijkgraaf et al., 2017; Ito et al., 2018; for review, Kaan & Grüter, 2021; Schlenter, 2023).

A smaller set of studies has investigated the predictive use of constraints on ditransitive verbs for anticipating whether the first post-verbal argument will be a theme (in a prepositional object construction) or a recipient (in a double object construction). In English and other languages that have a so-called dative alternation (Malchukov et al., 2010; Pinker, 1989), such as Mandarin Chinese (Liu, 2006), some verbs can alternate between two (or more) constructions, while others are allowed to appear in only one of them. For example, the English verb *give* can appear in both prepositional object (PO) and double object (DO) constructions, as illustrated in (1) and (2); yet like most alternating verbs, *give* is biased towards one construction, in this case

[1] We use "L2" to refer to any language learned after early childhood, including second and subsequent languages.

DO, as reflected in relative corpus frequencies and production preferences in experimental contexts (Bresnan et al. 2007; Kaschak et al., 2011). The English verb *donate*, on the other hand, can only occur in PO, as shown in (3) and (4). In VWP experiments, L1 English speakers were found to generate predictions about upcoming arguments following both *categorical constraints* of *non-alternating* verbs (e.g., *donate*) and *gradient constraints/biases* of *alternating* verbs (e.g., *give*): They launched more anticipatory fixations on the theme argument after hearing non-alternating PO-only verbs than alternating ones (Scheepers et al., 2007), but made more predictive looks to the recipient following DO-biased alternating verbs (e.g., *give*) versus PO-biased ones (e.g., *send*, Tily et al., 2008; see also Şafak & Hopp, 2023).

(1) The businessman will give the money to the nun.

(2) The businessman will give the nun the money.

(3) The businessman will donate the money to the nun.

(4) *The businessman will donate the nun the money.

Zhu and Grüter (2025a) replicated these effects for L1 speakers of Mandarin, an SVO language with alternating dative verbs similar to English (see below for more detail), and found furthermore that classroom learners of Mandarin also used both categorical and gradient constraints of dative verbs predictively, with no evident reduction or delay compared to L1 users. By contrast, Şafak and Hopp (2023) found that while L1 German L2 learners of English used such constraints predictively in a manner indistinguishable from L1 English speakers, L1 Turkish L2 learners of English were "delayed in recruiting categorical verb information and were only selectively sensitive to gradient verb information" (p. 1234). Şafak and Hopp hypothesized that

the difference between the German and the Turkish learner groups was due to the fact that Turkish is a verb-final (SOV) language, and thus "L1 Turkish learners, unlike their L1 German counterparts, had difficulty integrating verb-selectional information to predict upcoming argument structure" (p. 1257).

Şafak and Hopp's (2023) findings suggest that cross-linguistic influence (CLI) from the L1 affects predictive processing in an L2. Given the well-attested role of CLI at various levels of L2 acquisition and processing, it does not appear surprising that CLI should extend to *predictive* processing. Yet only a limited number of studies to date have directly investigated the role of CLI in L2 predictive processing (for review, see Foucart, 2021; Schlenter, 2023). In the present study, we build upon the evidence from L2 Mandarin reported in Zhu and Grüter (2025a) to further investigate Şafak and Hopp's (2023) hypothesis that CLI at the level of basic word order affects the uptake of predictive cues on verbs in L2 processing. More specifically, we test the prediction that arises from their hypothesis that L2 learners of Mandarin whose L1 is verb-final will show reduced effects of prediction compared to learners whose L1 is also an SVO language. To this end, we conducted the same VWP experiment as Zhu and Grüter (2025a) with a group of L2 learners of Mandarin whose L1 was either Japanese or Korean, and compared the results from this group with those from a subset of the classroom learner group in Zhu and Grüter (2025a), more specifically those who were L1 English sequential L2 learners of Mandarin. The particular combination of languages involved in the present study has the additional advantage of eliminating a potential confound of typological (genetic) relatedness between L1 and L2 that could have played a role in Şafak and Hopp (2023), where the L1 that was found to confer positive CLI (German) was also more closely related to the L2 (English) than the L1 found to confer negative CLI (Turkish). In the present study, all L1s (Japanese, Korean and English) are

typologically unrelated to the L2 (Mandarin), thus controlling for typological distance and potential cognate facilitation on verb-based semantic prediction (Ito et al., 2025) and allowing for a more direct focus on CLI at the level of basic word order.

2. The role of cross-linguistic influence (CLI) in L2 predictive processing

Studies investigating the role of CLI in L2 (predictive) processing have predominantly focused on scenarios where a relevant morphosyntactic cue in the L2 is absent, or instantiated differently, compared to the L1. For example, Mitsugi and MacWhinney (2016) found that English-speaking L2 learners of Japanese did not use case-marking in Japanese predictively. Looking at a scenario where a grammatical feature is present but realized differently in L1 and L2, Hopp and Lemmerth (2018) found that intermediate-proficiency Russian-speaking learners of German showed predictive use of grammatical gender cues only in contexts where gender cues are also present (and of predictive use) in Russian.

Only a handful of studies to date have specifically investigated the role of CLI in L2 prediction through directly comparing L2 learners of different L1s on their real-time use of the same predictive cue. Frenck-Mestre et al. (2019) focused on the processing of case-marking in L2 Korean, comparing L1 speakers of Kazakh, which also marks case morphologically, with L1 speakers of French, which does not. Unlike the L1 Korean comparison group, neither L2 group showed predictive use of case-marking, yet the L1 Kazakh learners showed better overall performance in sentence-final interpretation than the L1 French learners, suggesting a role for CLI at least in downstream comprehension. By contrast, Feleke and Lohndal (2024) found predictive use of gender markers in L2 Amharic by L1 speakers of both Eastern Oromo, which also has gender, and Western Oromo, which does not; in addition, their analyses suggested a

facilitative role of CLI in that predictive looks emerged earlier among Eastern than among Western Oromo speakers. Similarly, Johannessen et al. (2025) reported earlier onsets of predictive effects arising from gender-marking in L2 Norwegian among L1 Russian and L1 Greek compared to L1 Turkish learners, consistent with Russian and Greek, but not Turkish, having grammatical gender.

In comparison to studies focusing on CLI at the level of morphosyntactic cues, relatively few studies have considered CLI in the context of predictive use of verb-related constraints. In a seminal VWP experiment, Van Bergen and Flecken (2017) investigated the predictive use of placement verb semantics in Dutch (e.g., *zetten* "put.STAND" and *leggen* "put.LIE"). Their results showed that L1 German learners of Dutch, like Dutch L1 speakers, made anticipatory fixations on objects consistent with the placement semantics of the verb, whereas L1 English and L1 French learners of Dutch did not. This presents evidence of CLI since German, but not English and French, has verbs that similarly encode placement semantics. The authors interpreted these results in the broader context of the role of previous linguistic experience in predictive processing. More specifically, they argued that experience with using a particular linguistic cue for predictive purposes in the L1 makes L2 users more likely to use analogous cues in the L2 predictively. This interpretation aligns well with variability in predictive processing reflecting variability in the (perceived) *utility* of potentially predictive cues for successful processing outcomes among different language users (Grüter & Rohde, 2021; Kaan & Grüter, 2021).

In their investigation of ditransitive verb constraints in L2 German mentioned earlier, Şafak & Hopp (2023) reached similar conclusions with regard to the influence of L1 word order on L2 learners' use of these verb cues for prediction. In a VWP experiment following the design

of Scheepers et al. (2007) and Tily et al. (2008), Şafak & Hopp (2023) found that L1 German speakers used both categorical and gradient verb constraints to predict upcoming arguments following ditransitive verbs in English, patterning with L1 English controls. By contrast, L1 Turkish speakers were delayed compared to both L1 German learners and L1 English controls in their predictive use of categorical constraints, and more selective in using gradient constraints in that they only showed converging prediction patterns with the L1 controls in trials with PO sentences, while consistently predicting theme arguments irrespective of verb bias in DO trials. Of note, the Turkish group had overall lower English proficiency than the German group as measured by the LexTALE test (Lemhöfer & Broersma, 2012); yet post-hoc analyses with only proficiency-matched Turkish and German speakers returned the same results. Şafak & Hopp (2023) thus attributed the differential predictive patterns between the two L2 groups to reduced prior experience in using verb information for prediction among the Turkish speakers compared to the German speakers; more specifically, "[b]ecause verbs cannot be predictive for their complements in L1 Turkish, their low utility function in the L1 may restrict the degree of their use for prediction in the L2" (p. 1257). Yet as noted earlier, German, the L1 with the relevant overlapping properties with L2 English, was also typologically more closely related with the L2, including cognate vocabulary, which could have contributed to the observed advantage of the German over the Turkish group in Şafak & Hopp's (2023) study (Ito et al., 2025).

Zhu and Grüter (2025a) extended the research on predictive use of categorical and gradient verb constraints to classroom learners of Mandarin (including sequential L2 and heritage learners), of which 37 were L1 English or English-dominant, and 27 were speakers of 11 other languages. CLI was not a focus of this study, and post-hoc comparisons between L1-English and L1-Other subgroups showed no differences between the two, with learners in both

groups predicting upcoming arguments according to corresponding verb constraints as quickly and to the same extent as L1 Mandarin speakers. Yet only very few learners in this study were L1/dominant speakers of a verb-final language. Thus to examine whether the CLI effects observed by Şafak & Hopp (2023) for the predictive use of dative verb constraints in L2 English extend to L2 Mandarin, we recruited an additional group of L1 Japanese and L1 Korean L2 learners of Mandarin, to allow us to test whether their use of these constraints would differ from the L1 English L2 learners of Mandarin in Zhu and Grüter (2025a).[2]

3. Word order and dative constructions in Mandarin, English, Japanese and Korean

Mandarin, the target language of this study, has basic SVO word order, and at least three different dative constructions (e.g., Liu, 2006). This study focuses on two of them, illustrated in (5) and (6), which have surface word orders analogous to the English DO and PO constructions in (1) and (2), respectively.[3] As in English, ditransitive verbs in Mandarin vary in the extent to

[2] We focused on L1 Japanese and Korean learners primarily because of their availability at our test sites. Since Japanese and Korean are both SOV languages, and very similar to each other with regard to relevant properties of ditransitives (see section 3), we decided to include learners with either of those L1s to increase sample size.

[3] A third construction, illustrated in (i), can be viewed as another double object construction (V-*gei* DO) in which *gei* combines with the preceding verb *song* to form a compound ditransitive verb that takes a recipient and then a theme as its two objects. We follow Chen et al. (2022) and set this construction aside, focusing only on the two constructions with simple (non-compound) verbs in (5) and (6).

(i) The V-*gei* double-object (DO) dative

Mali	**song-gei**	le	Dawei	yi	ge	liwu.
Mary	**give-gei**	PFV	David	a	CLF	gift

'Mary **gave** David a gift.'

In the VWP experiment, we ruled out the possibility of participants anticipating a V-*gei* DO construction by having the perfective marker *le* follow the simple verb in all experimental sentences so that a compound verb was no longer possible once *le* was encountered. As illustrated in (i), *le* must follow the entire compound verb and cannot precede *gei*.

which they can appear in different dative constructions. Verbs inherently signifying a sense of transfer (GIVE verbs) can appear in both, as illustrated in (5) and (6), but often have biases for one over the other (Chen et al., 2022), again similar to well-known verb biases in English (Bresnan et al., 2007). Yet differing from English, which has many DO-biased verbs (Jaeger & Snider, 2013), most Mandarin alternating verbs are PO-biased (Chen et al., 2022). By contrast, verbs of creation (MAKE verbs) can only occur in the PO construction, whereas verbs of communication (TELL verbs) can only appear in the DO construction.

(5) The double-object (DO) dative

Mali	**song**	le	Dawei	yi	ge	liwu.	
Mary	**give**	PFV	David	one	CLF	gift	

'Mary **gave** David a gift.' (PFV=perfective; CLF = general classifier)

(6) The prepositional object (PO) dative

Mali	**song**	le	yi	ge	liwu	gei	Dawei.
Mary	**give**	PFV	one	CLF	gift	*gei*	David

'Mary **gave** a gift to David.'

Both Japanese and Korean have basic SOV word order. The canonical word order in ditransitives in both languages is recipient-before-theme, with some variability in the (pre-verbal) order of arguments due to scrambling (Jung & Miyagawa, 2004; Kishimoto, 2007; Cho, 1994). Critically, however, verbs strictly occur in sentence-final position, and can thus not be used as a source for prediction of upcoming arguments in real-time processing.

4. The present study

4.1 Research questions and hypotheses

The goal of this study is to investigate the generalizability of Şafak & Hopp's (2023) findings regarding CLI in the predictive use of dative verb constraints in L2 to a different target language (Mandarin), with learners who are L1 speakers of languages that are both typologically unrelated to the L2. In analogy to Şafak & Hopp (2023), and considering the findings of Zhu and Grüter (2025a), we thus state two research questions:

- RQ1: Do L1 Japanese/Korean L2 learners of Mandarin, like the (mostly) L1 English L2 learners in Zhu and Grüter (2025a), generate predictions on the basis of categorical and gradient verb-selectional information in sentence processing?
- RQ2: Do differences in L1 word order modulate verb-based predictions?

In light of the hypothesis that L1 word order impacts the utility of verb-based cues for prediction in L2 processing, we expect that Japanese and Korean speakers, relative to their English-speaking counterparts, will show reduced and/or delayed use of verb constraints for real-time prediction in L2 Mandarin, due to their lesser experience with verb-based prediction in their L1.

4.2 Participants

Twenty L1 Japanese ($N = 18$) or L1 Korean ($N = 2$) L2 learners of Mandarin were recruited from advanced Chinese courses at a university in China. We excluded 4 Japanese speakers from all analyses because their overall tracking ratio in the visual world eye-tracking (VWP) experiment was lower than 70%, and another Japanese speaker whose accuracy in a secondary judgment task intended for attention checking during the VWP experiment was lower than 80%. We then

combined the data from the remaining 15 participants with those from 3 L1 Korean L2 learners (recruited from a university in the U.S.) from Zhu and Grüter (2025a), for a total of 18 participants in the Japanese/Korean group. We compared the results from these Japanese/Korean speakers with those from the 21 English-speaking L2 Mandarin learners in Zhu and Grüter (2025a), who were tested at two U.S. universities ($N = 20$) and a Chinese university ($N = 1$). All learners had been learning Mandarin for a minimum of 1.5 years at the time of testing, and all had normal or corrected-to-normal vision. All Japanese and Korean speakers reported experience learning English, which is typically introduced in primary or early secondary school in Japan and Korea. Table 1 provides demographics of the two L2 groups, which were comparable in age, age of Mandarin acquisition, and length of exposure in a Mandarin-speaking country. However, the Japanese/Korean speakers scored significantly higher than the English speakers on the Chinese LexTALE Test (LexTALE_CH, Chan & Chang, 2018), a character-based lexical decision task included as an overall measure of Mandarin proficiency.

Table 1

Participant demographics (means, standard deviations and ranges)

	Japanese/Korean (N = 18, *Male* = 3)	English (N = 21, *Male* = 10)	
Age	23.0 (SD = 3.2) (20–31)	22.9 (SD = 4.3) (19–36)	$t(37) = .08$, $p = .96$
Age of Mandarin acquisition	16.5 (SD = 4.2) (7–21)	16.3 (SD = 5.1) (6–27)	$t(37) = .14$, $p = .89$
Length of stay in a Mandarin-speaking country (in months)	11.2 (SD = 13.0) (1–60)	8.5 (SD = 14.4) (0–42)	$t(37) = .61$, $p = .55$
LexTALE_CH score (Corrected Accuracy, range: -60–60)	35.9 (SD = 7.0) (20–47)	11.3 (SD = 12.3) (-19–30)	$t(37) = 7.48$, $p < .001$

Note. The LexTALE_CH test comprised 60 real simplified Chinese characters and 30 nonce items. As recommended by Chan & Chang (2018), we scored it for Corrected Accuracy (CA) using the following formula: number of correct hits – 2 * number of false alarms.

4.3 Methods

Methods and procedure were identical to those in Zhu and Grüter (2025a). Prior to the in-person test session, participants completed two tasks online: a language background questionnaire (5–10 minutes), followed by a written sentence completion task (20–30 minutes) probing participants' verb bias with the experimental verbs in production. The production task was included to address a different set of research questions reported in more detail elsewhere (Zhu & Grüter, 2025b). For present purposes, findings from this task are relevant in so far as they indicate that both the Japanese/Korean and English speakers were aware of the constraints of MAKE and TELL verbs in Mandarin, as both groups supplied very low percentages of DO responses following MAKE

verbs (Japanese/Korean: 6%; English: 12%) and similarly very few PO responses following TELL verbs (Japanese/Korean: 2%; English: 2%). With the DO-biased GIVE verb, both groups produced more DO (Japanese/Korean: 42%; English: 50%) than PO (Japanese/Korean: 36%; English: 33%) sentences; whereas for the PO-biased verbs, both groups provided similar proportions of DO and PO continuations (Japanese/Korean: 24% DO and 23% PO; English: 25% DO and 22% PO).[4]

During the in-person test session, participants completed a visual world eye-tracking (VWP) experiment (~15 minutes) to test real-time prediction based on verb constraints, and then the LexTALE_CH test (5-10 minutes), during which they judged whether given characters are real simplified Chinese characters or not. All materials are available at https://osf.io/38tsv/.

4.3.1 The visual world eye-tracking (VWP) experiment

The experimental verbs used in this task are displayed in Table 2. Six non-alternating verbs, including 3 PO-only MAKE verbs and 3 DO-only TELL verbs, were used to examine prediction based on *categorical constraints*. Four alternating GIVE verbs, including 3 PO-biased verbs and 1 DO-biased verb, were used to test predictive use of *gradient constraints*.

[4] The percentages do not sum to 100% because participants also produced sentences in constructions other than DO or PO. See Zhu and Grüter (2025a, 2025b) for examples and further discussion.

Table 2

Experimental dative verbs

Non-alternating		Alternating	
MAKE (PO only)	**TELL (DO only)**	**GIVE (PO-biased)**	**GIVE (DO-biased)**
做 (*zuo4*, make)	教 (*jiao1*, teach)	借 (*jie4*, lend)	送 (*song4*, give/send)
画 (*hua4*, draw)	问 (*wen4*, ask)	租 (*zu1*, rent)	
炒 (*chao3*, fry)	告诉 (*gao4su*, tell)	分 (*fen1*, share)	

Note. Bias information of the alternating verbs is based on results of a written production task from Chen et al. (2022). According to Chen et al., DO-biased alternating verbs are rare in Mandarin, and their bias tends to be weak. Here we included the only DO-biased verb found in a Chinese textbook series widely used in U.S. universities (*Integrated Chinese*, Liu et al., 2021).

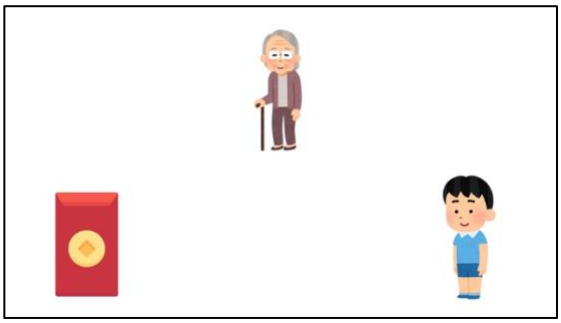
In the VWP experiment, participants listened to sentences mentioning referents (agent, theme, recipient, for experimental trials) in visual scenes while looking at the scenes depicting the three entities in a triangular pattern with target location counterbalanced across trials (Figure 1). Ten experimental verbs listed in Table 2 were each used three times to form a total of 30 experimental trials: MAKE verbs only appeared in PO sentences and TELL verbs only in DO sentences; PO-biased GIVE verbs each occurred twice in PO and once in DO sentences, whereas the DO-biased GIVE verb twice in DO sentences and once in a PO sentence.[5] The 30 experimental items were interweaved with 30 fillers comprising transitive, intransitive,

[5] This distribution was intended to reflect frequencies in the input beyond the experiment. As an anonymous reviewer rightly pointed out, however, we cannot exclude the possibility that these "distributional properties of the stimuli could in principle contribute to participants' expectations alongside verb-specific biases."

existential, passive and *ba* sentences. Two versions of the task were created, varying only in pseudo-randomized item order; participants were randomly assigned to one version.

Figure 1

Illustration of experimental item in VWP (PFV = perfective marker; CLF = general classifier)



	CR1	CR2							
Nainai	song	le	yi	ge	hongbao	gei	yi	ge	haizi.
grandma	give	PFV	one	CLF	red envelope	*gei*	one	CLF	kid
'Grandma gave a red envelope to a kid.'									

Note. The critical regions (CRs) for analysis are framed in the target sentence.

Sentences were recorded by a female native speaker of Mandarin and edited in Praat (Boersma & Weenink, 2022). Small segments of silence were inserted or removed between the perfective marker *le* and the numeral *yi* ('one') in some sentences to minimize temporal variability in the critical regions (CR) for analysis (Figure 1). The average verb duration (CR1) was 520 ms (SD = 56.4), while the post-verbal ambiguous window (CR2, from verb offset to onset of first post-verbal noun) averaged 1620 ms (SD = 59.6).

Participants started the task with instructions and two practice trials. For each trial, they previewed the visual scene for 1500ms and then heard the auditory stimuli; scenes remained on screen for 2000ms after sound offset. After half of the filler trials, as a general attention check, participants were asked to judge whether the auditory stimuli contained all three entities in the scene. Participants' eye gaze was recorded at 60 Hz via SMI Experiment Suite on an SMI remote eye tracker. Following the practice trials, the eye tracker was calibrated with a 9-point calibration grid for both eyes.

4.4 Data Analysis

Critically, we measure changes in fixation probability on the theme argument versus the recipient during two ambiguous time windows (CR1=verb, CR2=perfective aspect marker + numeral + general classifier, see Figure 1), which were offset by 200 ms from their respective acoustic onsets. Thus, CR1 starts from 200 ms after verb onset and ends 200 ms after the mean onset of the perfective marker *le,* with a duration of 520 ms; CR2 begins at the end point of CR1 and extends to the mean onset of the first post-verbal noun, for a duration of 1420 ms. The general classifier *ge* in CR2 was always compatible with both the recipient and the theme, rendering CR2 fully ambiguous, and thus enabling a probe for prediction effects in the strict sense, that is, before the acoustic onset of any disambiguating signal. In order to control for expected baseline preferences for looking at (animate) recipients compared to (inanimate) themes, we interpret *shifts* in the likelihood of fixations on the theme (relative to the recipient) *from CR1 to CR2* (rather than preferential looking to the theme or recipient within either CR) as evidence of verb-based prediction. From CR1 to CR2, we hypothesize that participants will look more at the theme after hearing PO-only MAKE verbs and PO-biased alternating verbs, yet fixate more on

the recipient following DO-only TELL verbs and the DO-biased alternating verb. It is thus the interaction between critical window (CR1, CR2) and verb type/bias that constitutes the most direct evidence of verb-based prediction over and above any other potentially pre-existing biases.

We recorded fixations within a rectangular area of interest (AOI) surrounding the corresponding entities (agent, recipient, theme) for target trials. As fixations at different AOIs are not independent of one another, we followed Ito & Knoeferle's (2022) suggestion and used *fixation bias*, that is, the log-ratio between fixations on the theme versus recipient as the dependent variable. Within each trial and CR, we calculated fixation bias with the following formula: log((fixation proportion on theme + .5) / (fixation proportion on recipient + .5)). We interpret change in fixation bias from CR1 to CR2 as evidence of prediction based on verb information. All analyses were conducted in R 4.2.2 (R Core Team, 2022) using the lmerTest package (Kuznetsova et al., 2017). All data and scripts are available at https://osf.io/38tsv/.

4.5 Results

After data exclusion explained earlier in section 4.2, the remaining participants showed high accuracy rates in the secondary judgment task (Japanese/Korean: 99.6%; English: 97.7%), indicating that they were listening to the sentences attentively during the VWP task.

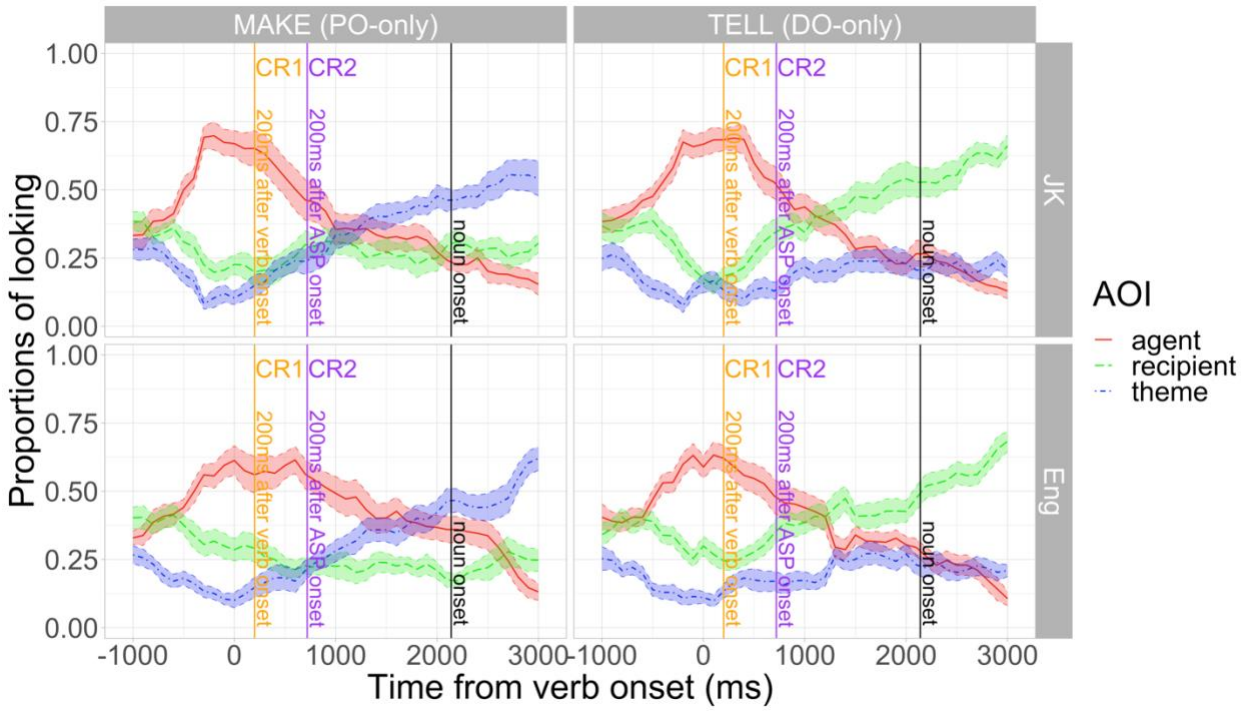
4.5.1 Categorical constraints of non-alternating verbs

Figure 2 presents participants' mean fixation proportions on the 3 AOIs (agent, recipient, and theme) in trials with PO-only MAKE verbs and DO-only TELL verbs. Participants showed an overall fixational preference for the recipient over the theme before the onset of CR1, reflecting the general human tendency for looking more at animate beings than inanimate objects.

However, within CR1, i.e., the verb region, participants appeared to already start directing their eye gaze towards the targets consistent with the categorical constraints of MAKE versus TELL verbs: Both in the Japanese/Korean and in the English group, the visualization in Figure 2 suggests a tendency for fixations towards the theme to increase more steeply than those to the recipient early in CR1 following MAKE verbs, whereas following TELL verbs, we see a steeper increase in looks to the recipient during the same time frame. This fixational divergence seemed to be fully fledged in CR2, our expected prediction window, during which the two L2 groups both looked more to the theme following MAKE verbs, and fixated more on the recipient following TELL verbs, suggesting that both groups were making respective predictions based on the categorical constraints of these two types of non-alternating verbs, with no evident differences between the two groups.

Figure 2

Categorical constraints: proportion of looks to three areas of interest by verb type and group. 0 ms is verb onset. Error bands represent 95% confidence interval. AOI = area of interest; CR = critical region; JK = Japanese/Korean; Eng = English



Mixed-effect linear regression models corroborated the patterns shown in Figure 2. The omnibus model (Table 3) included critical region (CR, -.5 = CR1, .5 = CR2), verb type (-.5 = MAKE, .5 = TELL), group (Japanese/Korean = -.5, English = .5) and their interactions as sum-coded fixed effects. All statistical models reported in this study include the random effect structure that returned the lowest AIC value. Crucially, the omnibus model indicated a significant interaction between CR and verb type (β= *-.32, p < .001*). We then split the data by CR and verb type and ran follow-up models (see Tables A1-A2 in the Appendix), which suggested that verb type modulated fixation bias in CR2 (β=*-.37, p=.03*), but not in CR1 (β=*-.05, p=.72*); from CR1

to CR2, participants significantly increased fixations towards the theme following MAKE verbs (*β=.21, p<.001*) and towards the recipient following TELL verbs (*β=-.11, p=.01*). None of these models returned any effects or interactions with group.

In light of the fact that the Japanese/Korean group scored higher than the English group on the independent proficiency task (LexTALE_CH, Table 1), we also ran exploratory analyses to probe for a potential role of proficiency. We fitted a model with LexTALE_CH scores (centered at the sample mean) as an additional predictor (Table 4). LexTALE_CH score significantly interacted with verb type (*β=-.12, p=.045*) and group (*β=.13, p=.032*) . Follow-up models by verb type (see Table A3 in the Appendix) suggested that participants of higher proficiency tended to look significantly more to the theme across CRs in trials with PO-only MAKE verbs (*β=.21, p=.016*), yet marginally more to the recipient across CRs in trials with DO-only TELL verbs (*β=-.14, p=.089*), implying that with increase in L2 proficiency, predictive looks following verbs with categorical constraints increased in the expected direction. Follow-up models by group (see Table A4 in the Appendix) indicated that English speakers with higher proficiency had significantly more fixations on the theme across CRs and verb types, whereas more proficient Japanese/Korean speakers showed numerically fewer fixations on the theme overall, causing the group by LexTALE_CH score interaction.

Table 3

Omnibus model output for fixation bias following verbs with categorical constraints

Predictors	*Estimate*	*SE*	*95% CI*	*t*	*p*
(Intercept)	-0.07	0.07	-0.20 – 0.07	-0.99	0.338
CR	0.05	0.03	-0.01 – 0.11	1.53	0.125
Verb type	-0.21	0.14	-0.48 – 0.07	-1.47	0.160
Group	0.02	0.03	-0.05 – 0.09	0.60	0.553
CR * Verb type	-0.32	0.06	-0.44 – -0.19	-5.04	**<0.001**
CR * Group	0.07	0.06	-0.06 – 0.19	1.05	0.295
Verb type * Group	0.07	0.08	-0.10 – 0.24	0.84	0.409
CR * Verb type * Group	-0.05	0.13	-0.30 – 0.20	-0.41	0.681

Formula: lmer (log-ratio fixation bias ~ CR * Verb type * Group + (1 + Verb type | participant) + (1 | item))

Table 4

Output of model for fixation bias following verbs with categorical constraints including proficiency

Predictors	*Estimate*	*SE*	*95% CI*	*t*	*p*
(Intercept)	-0.02	0.07	-0.16 – 0.13	-0.23	0.817
CR	0.04	0.06	-0.08 – 0.15	0.62	0.538
Verb type	-0.18	0.15	-0.46 – 0.11	-1.21	0.241
Group	0.00	0.06	-0.11 – 0.12	0.05	0.960
LexTALE	-0.01	0.03	-0.07 – 0.05	-0.20	0.839
CR * Verb type	-0.35	0.12	-0.58 – -0.12	-2.99	**0.003**
CR * Group	-0.02	0.12	-0.25 – 0.21	-0.17	0.865
Verb type * Group	-0.12	0.12	-0.35 – 0.11	-1.05	0.295
CR * LexTALE	-0.06	0.06	-0.18 – 0.06	-0.95	0.344
Verb type * LexTALE	-0.12	0.06	-0.24 – -0.00	-2.01	**0.045**
Group * LexTALE	0.13	0.06	0.01 – 0.25	2.15	**0.032**
CR * Verb type * Group	-0.13	0.24	-0.59 – 0.33	-0.56	0.578
CR * Verb type * LexTALE	-0.05	0.12	-0.29 – 0.19	-0.44	0.659
CR * Group * LexTALE	-0.04	0.12	-0.28 – 0.20	-0.33	0.738
Verb type * Group * LexTALE	0.06	0.12	-0.18 – 0.30	0.49	0.622
CR * Verb type * Group * LexTALE	-0.10	0.24	-0.58 – 0.38	-0.40	0.687

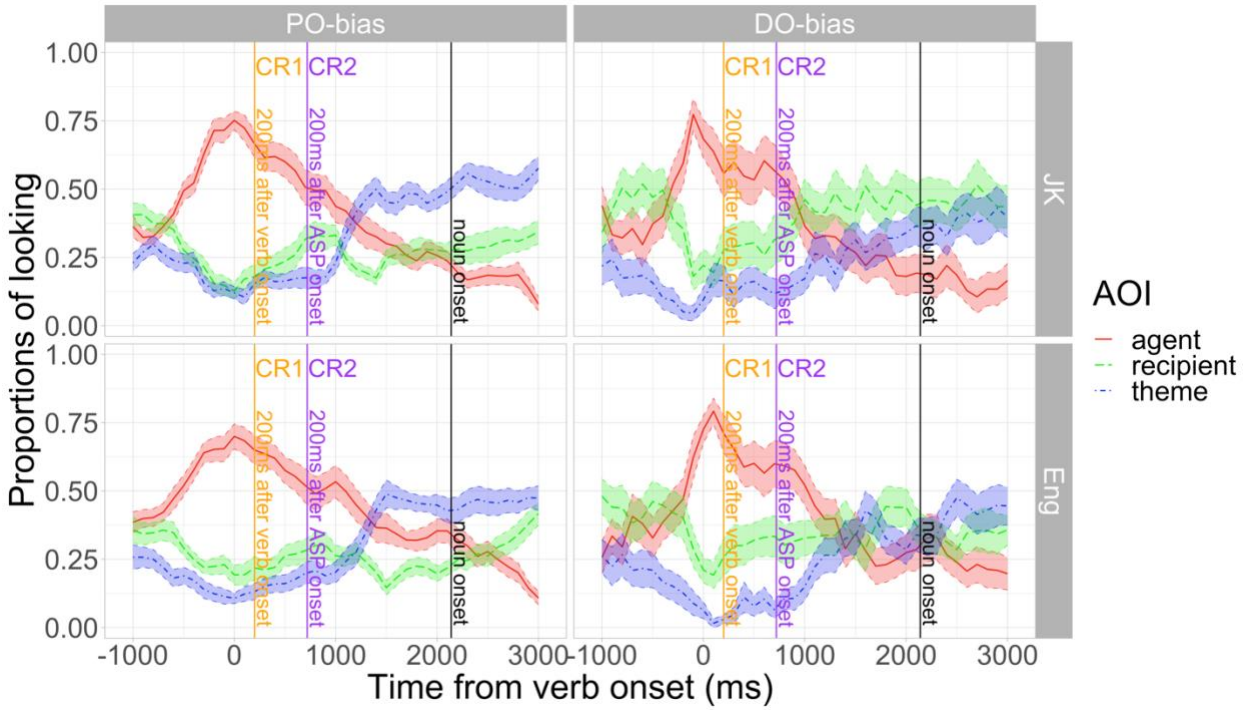
Formula: lmer (log-ratio fixation bias ~ CR * Verb Type * Group * Scale(LexTALE score) + (1 | item))

4.5.2 Gradient biases of alternating verbs

Figure 3 shows participants' fixation proportions in trials with alternating verbs. Both Japanese/Korean and English speakers fixated more on the animate recipient than the inanimate theme in CR1, although this fixational preference for the recipient appeared more pronounced following the DO-biased TELL verb. In CR2, both groups increased their fixations towards the theme following PO-biased verbs, consistent with the expected prediction patterns based on the bias of these verbs. However, with the sole DO-biased verb, the two groups seemed to behave differently: the Japanese/Korean group maintained their looking preference for the recipient in CR2, while the English group overall increased their looks to the theme instead.

Figure 3

Gradient constraints: Proportion of looks to three areas of interest by verb bias and group. 0 ms is verb onset. Error bands represent 95% confidence interval. AOI = area of interest; CR = critical region; JK = Japanese/Korean; Eng = English



We fitted an omnibus mixed-effect linear regression model (Table 5) containing CR (-.5 = CR1, .5 = CR2), verb bias (-.5 =DO, .5 = PO), group (Japanese/Korean = -.5, English = .5) and their interactions as fixed effects. The interaction between CR and verb bias did not reach significance (β= .13, p = .11). The model revealed a significant main effect of CR (β=*.15, p<.001*) only, suggesting that from CR1 to CR2, participants exhibited an overall fixational increase towards the theme argument irrespective of verb bias. There was also a marginal interaction between CR and group (β=*.15, p=.082*). In light of the relative sparsity of these data,

especially with regard to the single DO-biased verb, it is likely that this study does not have sufficient power to reliably detect interactions. To cautiously further probe the apparent difference between the Japanese/Korean versus English speakers in Figure 3 regarding the DO-biased verb, we proceeded to fit exploratory follow-up models by group (see Table A5 in the Appendix). These models corroborated the between-group contrast seen in Figure 3. Within the English group, there was only a significant main effect of CR (*β=.23, p<.001*), reflecting their overall prediction of a theme irrespective of gradient verb bias. In the Japanese/Korean group, by contrast, a marginal CR by verb bias interaction (*β=.24, p=.051*) emerged, based on which we fitted further exploratory follow-up models by CR and verb bias (see Tables A6–A7 in the Appendix), which suggested that the Japanese/Korean speakers tended to look more to the theme argument following the PO-biased verbs (*β=.20, p=.001*), while their looking pattern did not change following the sole verb of DO bias (*β=-.04, p=.781*).

We also fitted an exploratory model with LexTALE_CH scores (centered) as an additional fixed effect (see Table A8 in the Appendix). This model returned no significant effects or interactions.

Table 5

Omnibus model output for fixation bias following verbs with gradient biases

Predictors	*Estimate*	*SE*	*95% CI*	*t*	*p*
(Intercept)	-0.08	0.09	-0.25 – 0.09	-0.93	0.374
CR	0.15	0.04	0.07 – 0.24	3.66	**<0.001**
Verb bias	0.19	0.17	-0.15 – 0.53	1.10	0.298
Group	0.00	0.04	-0.08 – 0.09	0.10	0.920
CR * Verb bias	0.13	0.08	-0.03 – 0.30	1.59	0.112
CR * Group	0.15	0.08	-0.02 – 0.31	1.74	0.082
Verb bias * Group	-0.01	0.08	-0.17 – 0.16	-0.06	0.949
CR * Verb bias * Group	-0.21	0.17	-0.54 – 0.12	-1.27	0.203

Formula: lmer (log-ratio fixation bias ~ CR * Verb bias * Group + (1 | participant) + (1 | item))

5. Discussion

The goal of this study was to further examine the role of CLI in L2 speakers' predictive use of verb-based cues during real-time sentence processing. More specifically, we aimed to test the hypothesis put forth by Şafak and Hopp (2023) that L2 learners whose L1 is verb-final (SOV) are less likely to use verb-based cues for predictive processing in an SVO L2 than learners whose L1 is also an SVO language. In a visual world eye-tracking experiment with 18 L1 Japanese/Korean and 21 L1 English L2 learners of Mandarin, we found that both learner groups made predictive use of *categorical* constraints of non-alternating verbs to anticipate upcoming arguments, with no evident modulation by L1 background. For alternating verbs, we observed an overall predictive preference to look at the theme, reflective of a general expectation for PO constructions, consistent with the overall PO-bias of ditransitive verbs in Mandarin (Chen et al., 2022). No robust between-group differences emerged for alternating verbs either. We acknowledge, however, that the absence of between-group differences must be interpreted with caution given the small sample sizes in this study, and thus limited statistical power to detect such differences, especially as reflected in interactions (Staub, 2025). Notably, however, exploratory analyses suggested a tendency for predictive looks to be modulated by gradient verb bias in the Japanese/Korean group, but not in the English group, similar to what was observed for L1 Mandarin speakers in Zhu and Grüter (2025a). In other words, it was the learners with a verb-*final* L1 that patterned, at least descriptively, more like the L1 Mandarin comparison group, contrary to the hypothesis under investigation that expects learners with a verb-final L1 to make less use of verb-selectional information for predicting upcoming arguments than learners with a verb-medial L1.

Returning to the two research questions stated earlier, the findings from this study indicate that L1 speakers of verb-final languages are able to use verb-based cues for prediction in L2 processing (RQ1), and we found no evidence that they do so to a lesser extent than learners whose L1 is also an SVO language (RQ2). With regard to RQ1, our findings are consistent with Şafak and Hopp's (2023) observation that L1 Turkish speakers did use constraints on ditransitive verbs in L2 English predictively, albeit to a lesser extent than L1 German learners and native speakers of English. Importantly, the findings from both studies align in illustrating that lack of experience with verb-based prediction in L1 is not a hinderance to using verb-based cues for prediction in L2 processing. They also align with recent findings presented by Hwang and Kim (2025), which as far as we are aware and somewhat surprisingly, is the first study that has included L1 speakers of a verb-final language (Korean) in a VWP experiment with constraining and non-constraining transitive verbs (i.e., the *eat/move the cake* paradigm) in an SVO language (English). As Hwang and Kim (2025) showed, L1 Korean speakers used verb-based cues predictively with high-frequency monotransitive verbs in English, but unlike the L1 English comparison group, they did not do so with lower-frequency verbs. To what extent these L1-L2 differences are due to the verb-final nature of the learners' L1 remains open, however, as to the best of our knowledge, no study to date has directly compared two L2 groups whose L1s differ in basic word order in this experimental paradigm with monotransitive verbs.

These observations further align with a recent report by Jackson et al. (2025), who investigated to what extent L2 learners of a verb-second (V2) language (German) were able to use cues on a verb in V2 position to anticipate post-verbal arguments. L2 learners were all L1 speakers of non-V2 languages (mostly English). Results suggested that, despite being reliably delayed when compared to L1 speakers of German, the L2 group exhibited qualitatively similar

prediction patterns as the L1 group, i.e., they used semantic constraints of the verb in V2 position to predict both post-verbal objects in SVO sentences and post-verbal subjects in AdverbVS(O) sentences, despite the absence of the latter syntactic configuration in their L1.

Collectively, these findings provide consistent and unambiguous evidence that the absence of a particular word order configuration in the L1 is not a hinderance to using cues in such configurations predictively in an L2. The collective evidence is less clear, however, when it comes to the potentially modulating role of CLI from L1 word order. Şafak and Hopp (2023) found that L1 Turkish (SOV) speakers showed delayed and only selectively sensitive use of dative verb constraints for predictive processing in L2 English when compared to both L1 German learners and native English controls. By contrast, we found that both L1 Japanese/Korean and L1 English learners of L2 Mandarin used such constraints predictively, with no robust evidence of between-group differences, and with both L2 groups showing predictive patterns that were similar overall to those observed for L1 Mandarin speakers in Zhu and Grüter (2025a). What might account for the differential findings between the current study and Şafak & Hopp (2023), which both focused on ditransitive verb constraints in VWP experiments of similar design?

One possibility, mentioned earlier, is that (genetic) typological relatedness between L1 and L2 played a role. As recently shown by Ito et al. (2025), cognates can facilitate predictive processing, at least among lower proficiency L2 users. It is thus possible that cognate facilitation contributed to the advantage of the L1 German over the L1 Turkish group in Şafak and Hopp (2023), given the typological relation and substantial number of cognates between German and English. In the present study, by contrast, all L1s were typologically unrelated and did not share cognates with the L2. While we cannot logically exclude that this factor played a role in the

differential outcomes of the two studies, we do not believe that it can fully account for the overall pattern of results: If the L1-like pattern observed in Şafak and Hopp's (2023) L1 German group was the result of cognate facilitation, then we would have expected that neither, rather than both, L2 groups in the present study would show such patterns.

Another possibility that we acknowledge and cannot fully exclude is that the smaller sample sizes in the present study compared to those in Şafak and Hopp (2023) did not provide sufficient statistical power to detect relevant interactions with group. We note, however, with categorical constraints, not even trends for between-group differences for categorical constraints emerged in either the visualization (Figure 2) or the model output (Table 3). As for gradient constraints, non-significant trends for predictive looking emerged, indicated by a marginal 2-way interaction between CR and group (Table 5), apparent also in the visualizations of the data (Figure 3); the direction of these trends, however, points in the direction of the Japanese/Korean (SOV) group, rather than the English (SVO) group, aligning more closely with the L1 Mandarin group in Zhu and Grüter (2025a). We therefore believe it is unlikely that reduced effects in the Japanese/Korean viz-a-viz the English learner group, as predicted by the hypothesis under investigation, would emerge with larger samples.

It may also be the case that the Japanese/Korean speakers in this study had higher L2 proficiency, and thus potentially better prediction skills, than the Turkish speakers in Şafak and Hopp (2023). This conjecture is difficult to test since we have no means for directly comparing proficiency in L2 English and L2 Mandarin. In terms of language experience, another important factor shaping cross-linguistic influence (Cunnings, 2026), the Turkish group in Şafak and Hopp (2023) had earlier age of acquisition (AoA, $M = 9.97$, $SD = 1.48$; p. 1239) and thus longer length of instruction in English than the Japanese/Korean speakers in the current study did for Mandarin

(AoA: *M* = 16.5, *SD* = 4.2, Table 1). For length of exposure in the L2 environment, however, the Japanese/Korean speakers in the present study reported, on average, almost one year of residence in a Mandarin-speaking country (*M* = 11.2 months, *SD* = 13.0, Table 1), while the Turkish speakers in Şafak and Hopp (2023) mostly had no experience living in an English-speaking country (*M* = 0.11 months, *SD* = 0.67; p. 1239). It is thus possible that CLI from word order in the L1 is at play at earlier stages of L2 development, but can be overcome with extended immersive L2 experience, a proposal that must remain for future studies to further investigate, ideally employing longitudinal designs.

Yet another consideration is the potentially facilitating influence from English as a global L2 among the Japanese and Korean learners of Mandarin in the present study. Most of these participants likely learned English as a foreign language in primary or early secondary school in Japan and Korea, before they started learning Mandarin. Their prior experience with another SVO language thus might support their use of verb-based cues for prediction in Mandarin, consistent with previously observed effects of CLI from L2 to L3 in other domains (Rothman et al., 2019). To the best of our knowledge, no research to date has examined CLI from L2 to L3 in the context of predictive processing. An intriguing avenue for future studies will thus be to systematically examine CLI in verb-based prediction between multilinguals' different languages, for instance, whether L1 speakers of a verb-final language benefit from prior experience learning an L2 with SVO order when it comes to verb-based prediction in a later acquired L3 that also has SVO order.

Another factor that requires further investigation in the context of CLI and L2 predictive processing is the role of proficiency. While some studies have reported generally greater effects of prediction for learners with higher proficiency of the target language, many have not (e.g.,

Nguyen & Grüter, 2025; for review, see Kaan & Grüter, 2021). The absence of L2 proficiency effects is particularly notable in studies that have looked at the predictive use of verbal cues in L2 processing (e.g., Chun & Kaan, 2019; Dijkgraaf et al., 2017, 2019; Ito et al., 2018; Jackson et al., 2025). With regard to dative verbs, an early study by Wolk et al. (2011), who conducted the VWP experiment from Tily et al. (2008) with L1 German L2 learners of English, reported descriptively that L2 proficiency mediated prediction in accordance with gradient constraints of alternating verbs, with a higher proficiency group fully demonstrating the expected effects, while a lower proficiency group only partially showed these effects. Whereas L2 proficiency was not examined as a modulating factor in Şafak and Hopp (2023), Zhu and Grüter (2025a) conducted exploratory analyses including scores from the LexTALE_CH test, and reported no consistent modulation of prediction effects by this measure of proficiency in L2 Mandarin. In the present study, similar exploratory models provided some suggestive evidence that learners became better at using categorical constraints for prediction with increasing Mandarin proficiency, yet there was no evidence that proficiency modulated prediction following gradient verb biases. It is possible that the somewhat higher proficiency of the Japanese/Korean group in this study increased the overall range of proficiency, and thus better allowed for modulating effects to emerge. Nonetheless, we emphasize that effects of proficiency in the present study were only partial and suggestive, and we must leave it to future work to more systematically assess if and to what extent L2 proficiency plays a role in modulating effects of CLI from L1 word order on predictive processing in L2.

Finally, in addition to the relatively small sample sizes in the present study, another limitation is that only a few verbs in each type of constraint were included. In particular, only a single DO-biased verb could be included, given the scarcity of such verbs in Mandarin in

vocabulary that L2 learners could be assumed to be familiar with. Therefore, our findings, especially those regarding verbs with gradient constraints, must remain tentative and require replication in future research.

6. Conclusion

In sum, the present study did not find evidence to support the hypothesis put forth by Şafak and Hopp (2023) that L1 speakers of a verb-final language are less likely to use verb information for real-time prediction during L2 processing due to lesser experience with verb-based prediction in the L1. Instead, results from a visual-world eye-tracking experiment suggested that speakers of verb-final languages (Japanese and Korean) used categorical and – to a lesser extent – gradient verb constraints for real-time prediction in L2 Mandarin, with no evidence of reduced prediction when compared to L1 English L2 learners of Mandarin. Lack of experience with verb-based prediction in the L1, therefore, does not appear to be a hinderance to using verb-based cues predictively in L2 processing. In contrast to more consistent reports of CLI on predictive processing at the level of lexical semantics and cognates (Ito et al., 2025; Van Bergen & Flecken, 2017), CLI from L1 word order on the predictive use of verb-based information in L2 processing appears to be less consistent, and/or overcome at earlier stages of L2 development than those represented in the present study. The role of CLI at different levels of linguistic representation, at different stages of L2 development, as well as between different later learned languages, present fertile areas for future research on predictive processing among multilingual language users.

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Competing interests

The authors declare none.

Data availability statement

All materials, data and analysis scripts for this study are available at https://osf.io/38tsv/.

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Appendix

Table A1

Model output for fixation bias by CR (categorical constraints)

Predictors	*Estimate*	*SE*	*95% CI*	*t*	*p*
		CR1			
(Intercept)	-0.09	0.07	-0.22 – 0.04	-1.43	0.171
Verb type	-0.05	0.13	-0.30 – 0.21	-0.36	0.721
Group	-0.01	0.05	-0.12 – 0.09	-0.20	0.839
Verb type * Group	0.09	0.09	-0.09 – 0.28	1.01	0.315
		CR2			
(Intercept)	-0.04	0.08	-0.20 – 0.11	-0.56	0.586
Verb type	-0.37	0.15	-0.67 – -0.06	-2.36	**0.031**
Group	0.05	0.05	-0.04 – 0.14	1.12	0.269
Verb type * Group	0.04	0.09	-0.12 – 0.21	0.52	0.602

Formula: lmer (log-ratio fixation bias ~ Verb Type * Group + (1 | participant) + (1 | item))

Table A2

Model output for fixation bias by Verb Type (categorical constraints)

Predictors	*Estimate*	*SE*	*95% CI*	*t*	*p*
		MAKE verbs (PO only)			
(Intercept)	0.03	0.10	-0.17 – 0.24	0.34	0.743
CR	0.21	0.04	0.12 – 0.30	4.63	**<0.001**
Group	-0.01	0.05	-0.12 – 0.09	-0.28	0.784
CR* Group	0.09	0.09	-0.08 – 0.27	1.03	0.303
		TELL verbs (DO only)			
(Intercept)	-0.17	0.09	-0.36 – 0.01	-1.82	0.104
CR	-0.11	0.04	-0.20 – -0.02	-2.49	**0.013**
Group	0.06	0.05	-0.05 – 0.16	1.01	0.318
CR* Group	0.04	0.09	-0.13 – 0.21	0.45	0.651

Formula: lmer (log-ratio fixation bias ~ CR * Group + (1 | participant) + (1 | item))

Table A3

*Model output for fixation bias by Verb Type to explore **proficiency effects** (categorical constraints)*

Predictors	*Estimate*	*SE*	*95% CI*	*t*	*p*
MAKE verbs (PO only)					
(Intercept)	0.07	0.11	-0.14 – 0.28	0.64	0.536
CR	0.21	0.08	0.05 – 0.38	2.59	**0.010**
Group	0.07	0.09	-0.12 – 0.25	0.69	0.492
LexTALE	0.06	0.05	-0.04 – 0.15	1.14	0.261
CR * Group	0.04	0.17	-0.28 – 0.37	0.26	0.796
CR * LexTALE	-0.03	0.09	-0.20 – 0.14	-0.38	0.707
Group * LexTALE	0.10	0.10	-0.09 – 0.29	1.02	0.316
CR * Group * LexTALE	0.01	0.17	-0.33 – 0.35	0.06	0.950
TELL verbs (DO only)					
(Intercept)	-0.11	0.10	-0.31 – 0.10	-1.02	0.326
CR	-0.14	0.08	-0.30 – 0.02	-1.70	0.089
Group	-0.06	0.10	-0.26 – 0.14	-0.58	0.564
LexTALE	-0.07	0.05	-0.17 – 0.03	-1.29	0.204
CR * Group	-0.09	0.16	-0.41 – 0.24	-0.52	0.602
CR * LexTALE	-0.08	0.09	-0.25 – 0.08	-0.99	0.321
Group * LexTALE	0.16	0.10	-0.04 – 0.36	1.54	0.133
CR * Group * LexTALE	-0.09	0.17	-0.42 – 0.25	-0.52	0.605

Formula: lmer (log-ratio fixation bias ~ CR * Group * Scale(LexTALE score) + (1 | participant) + (1 | item))

Table A4

*Model output for fixation bias by Group to explore **proficiency effects** (categorical constraints)*

Predictors	*Estimate*	*SE*	*95% CI*	*t*	*p*
		Japanese/Korean			
(Intercept)	-0.08	0.07	-0.21 – 0.06	-1.12	0.279
CR	0.01	0.05	-0.08 – 0.11	0.31	0.754
Verb type	-0.24	0.14	-0.51 – 0.02	-1.79	0.092
LexTALE	-0.03	0.03	-0.08 – 0.02	-1.11	0.283
CR * Verb type	-0.29	0.09	-0.47 – -0.10	-3.07	**0.002**
CR * LexTALE	-0.02	0.05	-0.11 – 0.08	-0.35	0.730
Verb type * LexTALE	-0.07	0.05	-0.16 – 0.03	-1.43	0.153
CR * Verb type * LexTALE	-0.00	0.09	-0.19 – 0.18	-0.00	0.996
		English			
(Intercept)	-0.06	0.07	-0.20 – 0.09	-0.79	0.442
CR	0.08	0.04	-0.00 – 0.17	1.93	0.055
Verb type	-0.17	0.15	-0.46 – 0.12	-1.16	0.265
LexTALE	0.05	0.02	0.00 – 0.09	2.12	**0.034**
CR * Verb type	-0.34	0.09	-0.51 – -0.18	-4.02	**<0.001**
CR * LexTALE	-0.06	0.04	-0.14 – 0.02	-1.39	0.165
Verb type * LexTALE	-0.07	0.04	-0.16 – 0.01	-1.67	0.095
CR * Verb type * LexTALE	-0.08	0.09	-0.25 – 0.09	-0.92	0.360

Formula for Japanese/Korean speakers: lmer (log-ratio fixation bias ~ CR * Verb type * Scale(LexTALE score) + (1 | participant) + (1 | item)); Formula for English speakers: lmer (log-ratio fixation bias ~ CR * Verb type * Scale(LexTALE score) + (1 | item))

Table A5

Model output for fixation bias by group (gradient constraints)

Predictors	*Estimate*	*SE*	*95% CI*	*t*	*p*
		Japanese/Korean			
(Intercept)	-0.08	0.08	-0.24 – 0.08	-1.01	0.336
CR	0.08	0.06	-0.04 – 0.20	1.31	0.190
Verb bias	0.19	0.16	-0.13 – 0.51	1.18	0.265
CR * Verb bias	0.24	0.12	-0.00 – 0.48	1.96	**0.051**
		English			
(Intercept)	-0.08	0.10	-0.27 – 0.11	-0.82	0.429
CR	0.23	0.06	0.11 – 0.34	3.96	**<0.001**
Verb bias	0.19	0.19	-0.18 – 0.56	0.99	0.344
CR * Verb bias	0.03	0.11	-0.20 – 0.25	0.23	0.815

Formula: lmer (log-ratio fixation bias ~ CR * Verb Bias + (1 | participant) + (1 | item))

Table A6

Model output for fixation bias by CR for Japanese/Korean speakers (gradient constraints)

Predictors	*Estimate*	*SE*	*95% CI*	*t*	*p*
		CR1			
(Intercept)	-0.12	0.09	-0.30 – 0.06	-1.35	0.205
Verb bias	0.07	0.18	-0.29 – 0.43	0.40	0.700
		CR2			
(Intercept)	-0.04	0.09	-0.21 – 0.13	-0.49	0.636
Verb bias	0.31	0.17	-0.03 – 0.66	1.79	0.103

Formula for CR1: lmer (log-ratio fixation bias ~ Verb Bias + (1 | participant) + (1 | item));

Formula for CR2: lmer (log-ratio fixation bias ~ Verb Bias + (1 | item))

Table A7

Model output for fixation bias by Verb Bias for Japanese/Korean speakers (gradient constraints)

Predictors	*Estimate*	*SE*	*95% CI*	*t*	*p*
		PO bias			
(Intercept)	0.01	0.07	-0.13 – 0.16	0.18	0.859
CR	0.20	0.06	0.08 – 0.32	3.28	**0.001**
		DO bias			
(Intercept)	-0.18	0.19	-0.55 – 0.20	-0.95	0.442
CR	-0.04	0.11	-0.26 – 0.18	-0.36	0.718

Formula: lmer (log-ratio fixation bias ~ CR + (1 | item))

Table A8

Output of model for fixation bias following verbs with gradient constraints including proficiency

Predictors	*Estimate*	*SE*	*95% CI*	*t*	*p*
(Intercept)	-0.02	0.09	-0.20 – 0.16	-0.23	0.818
CR	0.10	0.08	-0.05 – 0.26	1.35	0.178
Verb bias	0.13	0.18	-0.23 – 0.50	0.73	0.480
Group	-0.02	0.08	-0.18 – 0.13	-0.30	0.763
LexTALE	-0.01	0.04	-0.10 – 0.07	-0.32	0.753
CR * Verb bias	-0.03	0.15	-0.33 – 0.27	-0.19	0.851
CR * Group	0.11	0.15	-0.19 – 0.41	0.71	0.480
Verb bias * Group	0.05	0.15	-0.25 – 0.35	0.33	0.743
CR * LexTALE	-0.03	0.08	-0.19 – 0.13	-0.35	0.725
Verb bias * LexTALE	0.03	0.08	-0.13 – 0.19	0.39	0.698
Group * LexTALE	0.15	0.08	-0.01 – 0.32	1.79	0.080
CR * Verb bias * Group	0.13	0.31	-0.47 – 0.74	0.43	0.664
CR * Verb bias * LexTALE	0.21	0.16	-0.10 – 0.53	1.31	0.189
CR * Group * LexTALE	-0.13	0.16	-0.45 – 0.18	-0.81	0.416
Verb bias * Group * LexTALE	-0.14	0.16	-0.46 – 0.18	-0.87	0.383
CR * Verb bias * Group * LexTALE	-0.39	0.32	-1.02 – 0.24	-1.21	0.228

Formula: lmer (log-ratio fixation bias ~ CR * Verb Bias * Group * Scale(LexTALE score) + (1 | participant) + (1 | item))