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When gender meets number: facilitative processing of one vs. two features on Spanish definite articles

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Research on real-time language comprehension has shown that speakers of various language backgrounds can use a pre-nominal morphosyntactic cue to facilitate the lexical retrieval of an upcoming noun. The present study takes the next step in this domain, investigating facilitative processing when two morphosyntactic cues to the target noun are available: gender and number. We conduct an eye-tracking study using the Visual World Paradigm, and we compare baseline and heritage speakers to determine how language experience modulates the relative weighting of multiple cues. We find evidence of facilitative processing of plural articles for both groups, not only when both features are informative cues to the target, but also when only one of the features is informative. This suggests that listeners access each morphosyntactic feature independently, which is a particularly noteworthy finding for the heritage group, who have been argued not to do so in prior offline studies. However, we find that language experience impacts the relative weighting of the two cues. When gender and number are compatible with different competitors and are thus in direct conflict, baseline speakers shift more to gender competitors, whereas heritage speakers do not. Additionally, when each feature uniquely identifies the target, in some contexts baseline speakers may attend to only the gender feature, whereas heritage speakers may attend to only the number feature. Taken together, these results suggest that baseline speakers may weight abstract grammatical gender more strongly, while heritage speakers may rely more on the semantically salient feature.

KEYWORDS

bilingualism, eye-tracking, gender, number, Spanish

1 Introduction

Humans engage in prediction at various levels of cognition, and recent years have seen a surge in research on prediction in language, including as driven by morphosyntactic features. Converging results demonstrate that during language comprehension, listeners are able to access an agreement feature encoded on a pre-nominal element such as an article, adjective, or verb, and rapidly integrate it into the process of word recognition to facilitate the retrieval of a subsequent noun. The morphosyntactic features that are used by comprehenders in this way include grammatical gender

(ex. Guillelmon and Grosjean, 2001; Wicha et al., 2004; Lew-Williams and Fernald, 2007, 2010; Hopp and Lemmerth, 2018; Brouwer et al., 2017; Fuchs, 2022), case (ex. Karaca et al., 2024; Meir et al., 2024), animacy (Fuchs, 2025), and classifiers (ex. Grüter et al., 2020; Nguyen and Grüter, 2024).

Work in the domain of facilitative processing¹ of morphosyntactic features has also explored the role of language experience, investigating not only monolingual populations but also bilingual groups with different acquisition trajectories. This has been particularly impactful in work on heritage bilingualism.² Heritage speakers (HSs) are individuals whose exposure to the heritage language is typically restricted to the home and family environment. Their heritage language thus develops with limited input, and in adulthood HSs are typically dominant in the societal language. In the heritage language, their competence diverges from that of baseline speakers in various ways, and offline studies have pointed to morphosyntactic agreement as a particularly vulnerable domain in heritage languages (Scontras et al., 2015). However, emerging evidence suggests that HSs' real-time facilitative processing of morphosyntactic agreement is remarkably similar to that of baseline populations (ex. Sekerina, 2015; Fuchs and Sekerina, 2025; Fuchs, 2021; Fuchs and Zeng, 2024; Fuchs et al., 2025; Keating, 2022, 2025; Karaca et al., 2024; Meir et al., 2024).

Still, most studies in this domain with both monolingual and bilingual populations have isolated the facilitative processing of a single morphosyntactic feature (exceptions include Coloma et al., 2023; Christou et al., 2020; Fuchs, 2025). Meanwhile, cross-linguistically, it is very common for agreement marking to index agreement in more than one morphosyntactic feature. Thus, as the field progresses, it is important to investigate how facilitative processing proceeds when multiple morphosyntactic cues to the subsequent noun are available, and how the relative weighting of these cues may be affected by language experience. We address this gap by investigating the facilitative processing of number and gender in adult baseline speakers and HSs of Spanish.

2 Background

2.1 Gender and number features

Both gender and number are morphosyntactic features that can trigger agreement on related elements, but gender is an abstract categorizing feature of nouns,³ while number reflects real-world

properties of the noun's referent. The processing of agreement resolution in gender and number has been studied when they occur on their own as well as when they co-occur. Evidence from such studies suggests that grammatical gender is represented in the mental lexicon (Levelt et al., 1999; Sá-Leite and Lago, 2024) and that, during real-time processing, comprehenders are sensitive to gender agreement, as evidenced by difficulty in processing agreement mismatches on articles, adjectives, and verbs (for a recent overview focused on Spanish, see Beatty-Martínez and Dussias, 2019). Studies on the real-time processing of number agreement demonstrate that number features are also actively represented and resolved. Evidence from agreement attraction effects in the processing of subject-verb agreement is particularly rich and suggests that encountering a number-inflected predicate initiates a search in memory for a number-matching element (ex. Wagers et al., 2009; for work on Spanish see Lago et al., 2015).

When number and gender co-occur, monolingual comprehenders process these two features independently. Independent processing of number and (semantic) gender has been observed in work on the processing of pronouns (ex. Carminati, 2005; Xu et al., 2013) and relative pronouns (Biondo et al., 2023). In Swahili, in which verbal agreement occurs on a portmanteau morpheme that reflects the subject's gender and number (commonly referred to as the noun class marker in the Bantu language family), baseline speakers are sensitive to independently manipulated errors in number and in gender, whereas L2 speakers are sensitive to errors in number only (Spinner et al., 2018). In Spanish, Antón-Méndez et al. (2002) found that gender agreement on a predicative adjective was computed independently of number by baseline speakers, and errors in gender did not influence number processing. Similarly, Fuchs et al. (2015) found that baseline Spanish speakers perceived agreement mismatches on a predicative adjective in both number and gender to be more degraded than agreement mismatches in only one feature, providing additional evidence that number and gender are processed independently. It remains an open question whether these features are also accessed independently during facilitative processing.

2.2 Morphosyntactic features in heritage language processing

Morphosyntactic agreement has been a central topic in work on heritage languages, as HSs are known to diverge from baseline speakers in production and comprehension of agreement marking (e.g. Montrul, 2008; Montrul et al., 2008; Montrul and Potowski, 2007; Polinsky, 2008; Scontras et al., 2018). This is commonly observed in the domain of grammatical gender, where HSs often assign the non-target gender to nouns, typically overextending the default gender (e.g., Montrul et al., 2008; Montrul and Potowski, 2007). However, a growing body of research has revealed that HSs' processing of gender agreement in online tasks is qualitatively more similar to that of baseline speakers than would be expected based on their performance in offline studies (e.g., Fuchs, 2021; di Pisa et al., 2022; Luque et al., 2023; see also Section 2.4). It is hypothesized that, despite HSs' surface-level divergence in production and comprehension of morphosyntactic elements, their

1 Though "anticipatory", "predictive", and "facilitative" processing are sometimes used interchangeably, they make slightly different claims about the timing of the onset of effects. Because the exact timing of effects is not crucial to the present work, we adopt the more general term "facilitative processing" (Huettig, 2025).

2 Work on traditional second-language learners is outside of the scope of the present paper, but for an overview of recent work on facilitative processing among L2 learners we point the reader to Schleiter (2023).

3 With the exception of work on pronouns with human referents mentioned briefly in this section, the present research focuses on grammatical gender as an abstract, arbitrarily assigned property of nouns that have no sex-differentiable features [ex. *la mesa* "the table(F)"; *el libro* "the book(M)"], rather than nouns with semantic gender [ex. *la gallina* "the hen(F)", *el gallo* "the rooster(M)"] (Corbett, 1991).

early and naturalistic acquisition of the heritage language fosters the development of target-like facilitative processing (ex., Grüter et al., 2012; Montrul et al., 2014; Fuchs, 2021). Additionally, real-time processing studies give insight into how language processing unfolds incrementally, and eye-tracking studies in the Visual World Paradigm are particularly well-suited for investigations of HSs' linguistic competence, as they reduce reliance on metalinguistic judgments and literacy, known to be a challenge in offline studies of heritage languages (Bayram et al., 2020).

In the domain of number, HSs also show sensitivity to agreement (Foote, 2011; Jegerski and Fernández Cuenca, 2025; Sagarra and Rodriguez, 2022), with divergence from the baseline with respect to number agreement observed more within the nominal phrase than in the verbal domain (Albirini et al., 2013; Alexiadou et al., 2023). A limited number of studies investigates HSs' performance when two morphosyntactic features co-occur. Results from these studies suggest that adult HSs produce errors more frequently than do baseline speakers in this context (see Fernández-Dobao et al., 2025, for work on child HSs of Spanish). In spontaneous production, HSs of Arabic frequently overgeneralize default gender and number (i.e., masculine singular) in both verbal and adjectival agreement (Albirini et al., 2011, 2013). In an offline comprehension task, Scontras et al. (2018) found that HSs of Spanish perceived mismatches in agreement in both gender and number to be equally degraded relative to mismatches in only one feature, in contrast to findings for baseline Spanish speakers in Fuchs et al. (2015), discussed above. The authors interpret these results as evidence that HSs may not process gender and number independently. However, prior online studies have already shown that HSs' real-time facilitative processing of one morphosyntactic feature is more similar to that of the baseline than is observed in offline studies. It is therefore possible that a study on HSs' facilitative processing of two features—with higher temporal resolution and reduced reliance on metalinguistic judgments—may also reveal less divergence in this domain than expected based on evidence from offline studies.

2.3 Facilitative processing of morphosyntactic features

Facilitative processing is typically investigated using eye-tracking in the Visual World Paradigm (VWP) (Tanenhaus et al., 1995). Numerous studies on facilitative processing of gender consistently reveal that, upon hearing a gender-marked element (ex. Spanish definite determiners *el_M* or *la_F*), listeners fixate more on images corresponding to nouns that match the gender of that element, sometimes even before the onset of the target noun in the auditory prompt. This demonstrates that during real-time comprehension, listeners can rapidly access an abstract feature on an agreement morpheme and integrate it into the process of word recognition to facilitate retrieval of the subsequent noun. This has been observed in adult baseline speakers of Spanish (Lew-Williams and Fernald, 2007, 2010), German (Hopp and Lemmerth, 2018), Dutch (Brouwer et al., 2017), and Polish (Fuchs, 2024), among many other languages, as well as for adult HSs of languages such as Russian (Sekerina, 2015; Fuchs and Sekerina, 2025), Spanish

(Fuchs, 2021; Fuchs and Zeng, 2024; Keating, 2022), and Polish (Fuchs, 2022). However, work on the facilitative processing of number is much scarcer, with one study on German that found that both adults and children used early cues to number on the noun stem, such as vowel alternations, to disambiguate the target (Grandon et al., 2024).

Given that it is common for languages to mark agreement in both gender and number, an important next step is to consider how facilitative processing proceeds when a pre-nominal element indexes agreement in two morphosyntactic features, i.e., the element contains two possible cues to the subsequent noun. Facilitative processing in this context is not all-or-nothing. Depending on the featural properties of available candidates, it may be the case that each cue uniquely identifies the target noun—we refer to this as a doubly-informative context. However, if one feature uniquely identifies the target but the other is compatible with more than one candidate noun, then only one of the cues is informative. Moreover, if each feature is compatible with a different subset of candidate nouns, then both features are informative, but they conflict. Observing how facilitative processing proceeds in each of these contexts can reveal whether listeners access each morphosyntactic feature independently and whether they weight one cue more strongly than the other.

To our knowledge, only three studies have investigated possible facilitative effects of two morphosyntactic features on a single element. Two of these investigated gender and number on Spanish plural definite and indefinite articles.⁴ Christou et al. (2020) compared Spanish-speaking monolingual typically-developing (TD) children and children diagnosed with developmental language disorder (DLD), as well as adults. They found that all three groups were able to use articles to predict the upcoming noun, although age modulated the timing and strength of prediction in the DLD group. Coloma et al. (2023) conducted a longitudinal comparison of TD monolingual children and children diagnosed with DLD. At age 5–6, only the TD children showed facilitative processing. At age 6–7, both groups showed evidence of facilitative processing, although the effect emerged earlier and was stronger for the TD children. Still, neither Christou et al. (2020) nor Coloma et al. (2023) differentiated their results based on whether the articles were informative in one or both features. In the third study, on baseline speakers of Polish, Fuchs (2025) found that during facilitative processing of cues to gender and animacy encoded on a portmanteau adjectival suffix, the presence of competitors matching one but not both of the cues reduced looks to the target, suggesting that animacy and gender were independently activated.

A limited number of other studies on facilitative processing has included multiple pre-nominal cues to the target noun, but these were not designed to directly test the interplay of two features. Ito et al. (2023) investigated processing of two semantic features in Vietnamese-German bilinguals and found that both HSs and

⁴ We note that singular articles—investigated in much of the previous work on Spanish cited in the current section—do indeed index (singular) number, but given that plurality of candidates in the displays was not manipulated in these studies, the experimental context rendered the number cue consistently uninformative.

late bilinguals used verbal and classifier cues to anticipate the upcoming noun. Their results suggest that the integration of two (semantic) cues may differ between these groups: HSs were more influenced than the baseline group by competing verbal cues from German translational equivalents. Similarly, Prystauka et al. (2024) investigated HSs' anticipatory processing in Russian, with a lexico-semantic cue on a pre-nominal verb and a morphosyntactic gender cue on a pre-nominal adjective, but they did not find effects of the gender manipulation. Fuchs and Sekerina (2025) investigated facilitative processing of two pre-nominal gender cues in Heritage Russian, one on a verb and one on an adjective. However, the absence of a single-cue control condition prevented them from being able to test for a cumulative effect of two gender cues. To our knowledge, our study is the first to investigate the facilitative processing of two morphosyntactic features while manipulating properties of competitors to create contexts in which one or both features on the article are informative or in which both features are informative but conflict.

2.4 Present study and research questions

We investigate the facilitative processing of number and gender in baseline speakers and HSs of Spanish. In this language, feminine is typically considered to be the marked gender, while masculine is the default (Harris, 1991), and the singular is morphologically unmarked, while the plural is overt and morphologically derived from the singular stem (e.g., Battistella, 1990). The determiner system makes these contrasts fully visible, with four distinct forms encoding the gender and number profile of the noun phrase: *el* (masculine singular), *la* (feminine singular), *los* (masculine plural), and *las* (feminine plural). Determiners in Spanish occur pre-nominally, and adjectives occur post-nominally in the unmarked word order, so these determiner forms provide immediate cues to the noun. The facilitative processing of gender on singular articles in Spanish has been studied across a range of populations (Lew-Williams and Fernald, 2007, 2010; Fuchs, 2021; Fuchs and Zeng, 2024; Fuchs et al., 2025; Keating, 2022, 2025; Dussias et al., 2013; Pérez-Leroux et al., 2024), laying a critical foundation on which to build our research questions and predictions, as follows:

RQ1: Do listeners use plural definite articles (*los/las*) facilitatively?

RQ2: Is the gender or number feature weighted more heavily during processing?

RQ3: Do baseline speakers and HSs differ in their facilitative processing of plural definite articles?

Prior work (Coloma et al., 2023; Christou et al., 2020) suggests that the answer to RQ1 should be affirmative, at least for the baseline population in doubly-informative contexts. Building on this, we manipulate properties of the competitor to investigate whether facilitative processing also takes place when the articles are informative in only one feature, as this would indicate that each feature is accessed independently during facilitative processing. Moreover, when articles are doubly-informative and each cue uniquely identifies the target, we may see a cumulative effect of accessing both features, i.e., a stronger facilitative effect when articles are doubly-informative as compared to when they are

informative in only one feature. However, we may also find that in these contexts listeners attend to one feature over the other, in which case facilitative processing in two features may be reducible to facilitative processing in one feature.

We also ask whether one feature is weighted more heavily than the other (RQ2). If this is the case, then we expect listeners to show a bias toward competitors matching one of the features when the number and gender feature conflict, i.e., when they are compatible with different subsets of candidate nouns.

As for whether language experience impacts facilitative processing of two features, differences between HSs and baseline speakers (RQ3) may arise with respect to RQ1 and/or RQ2. For RQ1, informed by prior work that suggests that baseline Spanish speakers process number and gender features independently during agreement resolution (Fuchs et al., 2015), but HSs do not (Scontras et al., 2018), we may find evidence of independent processing for baseline speakers but not HSs. However, given converging evidence that HSs' facilitative processing of a single morphosyntactic feature is target-like (ex. gender, case; see Section 2.3), we may expect HSs to also pattern with the baseline population in this study. For RQ2, given that number is semantically salient whereas gender is abstract, we expect to find evidence that the number feature is weighted more heavily than gender for the HSs but not the baseline group, given broader evidence that bilingual speakers with less exposure to the target language generally tend to rely more on semantically salient cues than abstract grammatical ones (ex. Clahsen and Felser, 2018; Cummings, 2017; White et al., 2004; Parshina et al., 2022).

In investigating these questions specifically in Spanish, we note that an important distinction must be made between masculine and feminine plural articles. Cross-linguistically, when an element marks agreement in two morphosyntactic features, this may be encoded on a single portmanteau morpheme or on independent morphemes. The Spanish plural definite articles (masc.: *los*; fem.: *las*) may differ in this respect. In *las*, these features clearly unfold sequentially: *-a* encodes feminine agreement with the upcoming noun, and *-s* encodes agreement in the plural. In *los*, the situation is a bit more nuanced. The article can analogously be decomposed into three morphemes (*l-o-s*). However, during incremental processing, it may be that cues to gender and number become available simultaneously. Within the constrained space of possible pre-nominal definite articles (*el, la, los, las*), the sequence */lo/* is sufficient to uniquely identify masculine plural targets. Thus, although the morpheme *-o* formally encodes gender only, during real-time processing listeners can in principle already at *-o* access cues both to the gender (masculine) and to the number (plural) of the subsequent noun. There may therefore be differences between processing of *los* and *las*, motivating us to analyze results separately for the two articles in Section 4.

3 Materials and methods

3.1 Experimental conditions

Trials in the experimental study each had three images: Images were arranged into displays based on their gender (M or F) and number (SG or PL), with five conditions, in a 5 x

TABLE 1 Experimental conditions for M PL and F PL targets, along with illustrative examples of corresponding experimental nouns.

Condition	Target: M PL ex. <i>los techos</i> “the roofs”		Target: F PL ex. <i>las reglas</i> “the rulers”	
	Competitor	Distractor	Competitor	Distractor
Uninformative	M PL <i>los ganchos</i> “the hooks”	F SG <i>la vela</i> “the candle”	F PL <i>las cartas</i> “the letters”	M SG <i>el sombrero</i> “the hat”
Number-informative	M SG <i>los cepillos</i> “the hairbrushes”	F SG <i>la campana</i> “the bell”	F SG <i>la mesa</i> “the table”	M SG <i>el queso</i> “the cheese”
Gender-informative	F PL <i>las banderas</i> “the flags”	F SG <i>la mochila</i> “the backpack”	M PL <i>los cerebros</i> “the brains”	M SG <i>el martillo</i> “the hammer”
	Distractor-1	Distractor-2	Distractor-1	Distractor-2
Doubly-informative	F SG <i>la bandera</i> “the flag”	F SG <i>la cuchara</i> “the spoon”	M SG <i>el puño</i> “the fist”	M SG <i>el columpio</i> “the swing”
	Competitor-1	Competitor-2	Competitor-1	Competitor-2
Competition	M SG <i>el puño</i> “the fist”	F PL <i>las ruedas</i> “the wheels”	F SG <i>la manzana</i> “the apple”	M PL <i>los quesos</i> “the cheeses”

5 x 2 design.⁵ In the uninformative, gender-informative, and number-informative conditions, in addition to the target, there was a distractor, which differed from the target in both gender and number, and a competitor; the critical manipulation was in the gender and number of the competitor (Table 1). In the uninformative condition, the competitor was the same gender and number as the target. Each of the three informative conditions will be compared to this condition to determine whether plural articles are used facilitatively (RQ1). In the number-informative condition, the competitor matched the target in gender but not number; analogously, in the gender-informative condition, the competitor matched the target in number but not gender. In the doubly-informative condition, there were two distractors in the display, i.e., both non-targets mismatched the target in gender and number. In the final condition, the competition condition, each trial had a target and two competitors: one matched the target in number, and the other matched the target in gender. Preference toward either of these competitors informs the answer to RQ2.

3.2 Materials

Twenty masculine and 20 feminine nouns corresponding to concrete, picturable objects were selected as target items. Each noun started with a consonant other than /s/ or /l/ to ensure clear phonological boundaries between the article and the target noun. All nouns were transparent for gender, i.e., masculine nouns ended in *-o* and feminine nouns ended in *-a*. Grayscale images representing each noun were combined into visual displays corresponding to the experimental conditions (Table 1); to create a plural target, competitor, or distractor, the corresponding singleton

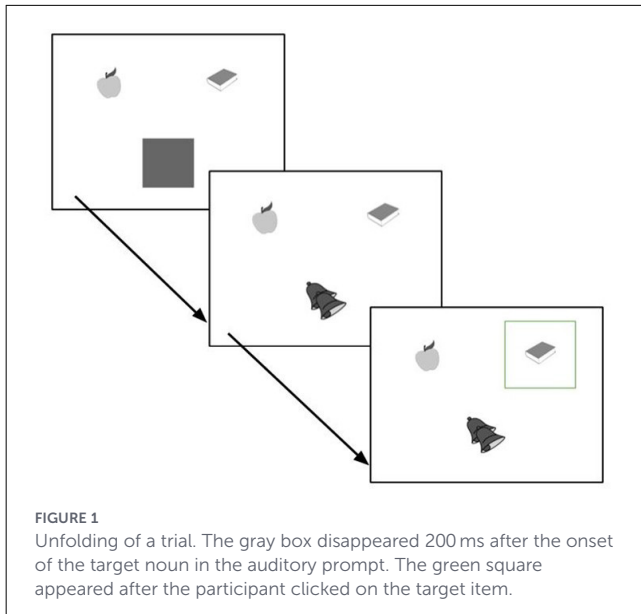
image was placed in the relevant location in the display twice, slightly overlapping (Figure 1; cf. Christou et al., 2020).⁶ Images were arranged into 400 displays: there were 20 nouns in each of the two genders, and each noun occurred once as a singular target and once as a plural target, across five conditions (20 x 2 x 2 x 5). These displays were pseudo-randomly arranged into two experimental lists of 200 displays/trials each. Within each list, each condition and target type (M SG, F SG, M PL, F PL) occurred an equal number of times. The assignment of each particular noun to lists was random, and some nouns occurred an equal number of times as targets in both lists, while others occurred four times in one list and six in the other.

Auditory prompts were of the form *Indica {el/la/los/las} [target noun]*. (“Indicate the_{MSG/FSG/MPL/FPL} [target noun].”). Stimuli were first recorded in their entirety by a Spanish-English bilingual speaker from Colombia living in the US at the time of recording. Single tokens of each of *Indica* (925 ms), *el* (508 ms), *la* (504 ms), *los* (527 ms), and *las* (510 ms) were extracted from these recordings and concatenated with singular and plural tokens of each target noun to create the final auditory stimuli, ensuring simultaneous onset of critical auditory information across all stimuli.

Each trial unfolded in the following way, illustrated in Figure 1. In lieu of a fixation cross, the cursor was reset to the center of the screen prior to the start of the trial. Once the display appeared, there was 500 ms of silent looking time prior to the onset of the auditory prompt. We implemented a target-absent variant of the Visual World Paradigm that incorporated the Covered Box Paradigm (Schwarz et al., 2016; Fuchs, 2025; Fuchs et al., 2025; Huettig and Altmann, 2005), wherein one of the images was covered by an opaque gray square from the start of the trial until 200 ms after

⁵ All experimental materials, as well as data and code used for analysis, are available in the online OSF repository for this study at https://osf.io/cp8zg/overview?view_only=f890278418104fc19b46a42a4d76b561.

⁶ It is worth noting that the plural stimuli cover more area, resulting in a more visually dense part of the display relative to any singular images, which may influence looking behavior for non-linguistic reasons (Carter and Luke, 2020). We discuss this potential limitation in Section 5.4.



the onset of the target noun in the auditory prompt. This was critical for the competition condition, in which it was important for the target to be visually absent as the article unfolded, allowing participants more opportunity to fixate on the two competitors. For counterbalancing, the opaque square occurred in all trials, equally split between covering the target and covering the distractor (in the doubly-informative condition this amounted to covering one of the two distractors; in the competition condition it was one of the two competitors). Participants were instructed to click on the image corresponding to the noun they heard in each trial; once the participant clicked, a green box appeared around the target item. Each trial lasted 4 seconds in total.

3.3 Participants

Eighty-two Spanish-English bilinguals living in Los Angeles, California were recruited for the study. Inclusion criteria stated that participants had to be at least 18 years old, have grown up speaking Spanish with one or both parents, and fulfill one of the following three criteria: (a) be born in and live in a Spanish-speaking country until age 18; (b) be born in a Spanish-speaking country and move to the US prior to age 6; or (c) be born in the US. Participants who reported living in a Spanish-speaking country until age 18 were classified as late Spanish-English bilinguals, henceforth the baseline group ($n = 23$; mean age: 24.4; $sd = 5.8$), with mean age of arrival to the US at 22.7 years ($sd = 5.7$). Although they also have competence in English, the key characteristic of their language experience is abundant input in Spanish through adolescence and high school. Participants who reported being born in the US or being born in a Spanish-speaking country and moving to the US prior to age 6 were classified as HSs ($n = 53$; mean age: 20.2; $sd = 2.2$), with mean age of arrival to the US at 0.9 years ($sd = 2.1$). Data was excluded from 6 participants who did not match inclusion criteria for either group.

3.4 Procedure

Participants were tested individually in a lab in a university setting. Participants read an information sheet and gave their informed consent to participate in the study. They then completed an oral picture-naming task, in which they were presented with each of the images used in the eye-tracking task and were asked to name each image using an article and a noun while their voice was recorded. This task was used to assess familiarity with experimental target nouns for the purposes of data cleaning and pre-processing (ex. di Pisa et al., 2022; Fuchs, 2021; see Section 4.1).

Following the picture-naming task, participants completed the eye-tracking VWP task. They sat approximately 36 inches away from a 24-inch screen, with their head stabilized. Participants' gaze was tracked monocularly, and participants completed a 9-point calibration of the SR Research Eyelink 1000 Plus eyetracker. Instructions were provided in written form in Spanish, with optional clarification provided orally in English. Participants were pseudo-randomly assigned to one of the two experimental lists. They completed three practice trials prior to completing three blocks of experimental trials, all drawn from the same list. Participants were given a self-timed break after the first block and after the second block (67 trials each), to mitigate participant fatigue. Trial order was randomized for each participant, and calibration was repeated prior to each experimental block.

After the eye-tracking task, participants completed additional tasks measuring language proficiency and background. They first completed a semantic verbal fluency task in Spanish (Lezak et al., 2012), consisting of a practice category ("fruit") and three test categories ("vegetables", "clothing items", "musical instruments"). Participants had 60 seconds to name as many words in Spanish in each category as they could think of. The order of test categories was randomized. Participants performed the task on a laptop, and their voice was recorded. Participants also completed the LexTALE-Esp (Izura et al., 2014), which is the Spanish version of the LexTALE, on pen and paper, and a modified version of the Language Experience and Proficiency Questionnaire (LEAP-Q) (Kaushanskaya et al., 2020; Marian et al., 2007), also using pen and paper. Results of an individual-differences analysis of our data based on these proficiency measures are reported elsewhere (Fuchs et al., 2025).

4 Results

4.1 Data preparation

Eye-tracking data was processed and prepared using SR Research DataViewer (SR Research Ltd, 2025) and with R package *eyetrackingR* version 0.2.0 (Dink and Ferguson, 2015) using R version 4.1.2 (R Core Team, 2021). We first describe the data cleaning procedure for the informative and uninformative conditions, followed by the competition condition. For the (un)informative conditions, data was analyzed for trials in which the square covered the distractor item, to be consistent with

prior work on facilitative processing of grammatical gender, in which the target and competitor are both visible. Additionally, for each participant, data was excluded from any trials for which participants were unable to provide a correct label for the target and/or competitor item in the oral picture naming task, or for which the participant provided a dialectal variant (ex. unintended *la frutilla* for intended *la fresa* “the strawberry”) or a label that was correct but did not align with the intended lexical item [ex. *el sobre* “envelope(M)” for *la carta* “the letter(F)”. This is also consistent with procedure in prior work on facilitative processing for HSs and ensures interpretability of results as having to do with processing of lexical and morphosyntactic information rather than familiarity, or lack thereof, with one of the candidate nouns (ex. *di Pisa et al., 2022; Fuchs, 2021, 2022*). This removed 31% of the data for the baseline group and 60% of the data for HSs, resulting in an average of 137 trials per participant in the baseline group ($sd = 17$) and an average of 80 trials per participant in the HS group ($sd = 34$). Data preparation proceeded differently for the competition condition. Data was analyzed for trials in which the square covered the target item, to mimic target-absent experimental paradigms (Schwarz et al., 2016; Fuchs, 2025; Huettig and Altmann, 2005). Additionally, for each participant, data was excluded if they were unable to provide the correct label for the target or either of the competitors.

Statistical analyses comparing proportion of looks to target in informative and uninformative conditions from the onset of the article to the average peak of the fixation curve (2800 ms) implemented cluster-based permutation analyses (CPAs), with data permuted 1000 times (Ito and Knoeferle, 2023; Maris and Oostenveld, 2007). Data were split by group and binned into 50-ms time bins. In each time bin, generalized mixed effects models were fitted to the data predicting the empirical logit of the proportion of fixations to the target by condition, with random intercepts grouped by participant and by item. When analyzing results for the plural articles, to first test for facilitative use of the articles in informative conditions, condition was a four-level categorical variable dummy-coded with the uninformative condition as the baseline. In the secondary analysis, to compare the doubly-informative condition to conditions in which the article was informative in only one gender, data was subset to the informative conditions only and dummy-coded with the doubly-informative condition as the baseline. To correct for two analyses run on the data for each target type (M PL, F PL), we applied a Bonferroni correction to all p -values. Statistical procedure for analyzing the competition condition is discussed in Section 4.2.4.

4.2 Cluster-based permutation analyses

4.2.1 Facilitative use of gender on singular articles

We first examine the results for the singular articles *el* (masculine) and *la* (feminine). Although this is not central to the present research questions, we aim to test whether our results

replicate the commonly observed facilitative effect of gender on singular articles for both groups (cf. Section 2.3). To do this, we subset the data to singular target items and to the uninformative and gender-informative conditions, which correspond directly to those compared in prior work.⁷ The resulting two-level categorical variable for condition was treatment-coded. Consistent with the remainder of analysis, we test for an effect of condition separately for the two articles.

Participants' proportion of fixations to the target item compared across conditions is presented in Figure 2. For the baseline group, the CPA for masculine singular targets found a significant cluster for the effect of condition in the expected direction at 1,925–2,025 ms (cluster mass statistic = 13.7, $p = 0.009$). An analogous analysis of data for looks to feminine singular targets found a significant cluster indicating more looks to target in gender-informative conditions at 1,975–2,225 ms (cluster mass statistic = 37.4, $p < 0.001$).

For HSs, the CPA for looks to masculine singular targets found a significant cluster indicating more looks to target in the gender-informative condition than the uninformative condition at 2,075–2,575 ms (cluster mass statistic = 88.9, $p < 0.001$). A similar model for looks to feminine singular targets did not find any significant clusters for the effect of condition.

4.2.2 Facilitative processing of plural articles: masculine *los*

Proportion of looks to masculine plural targets across conditions is presented in Figure 3, and an overview of results is presented in Table 2. We begin by reporting results for the baseline group. The CPA found three significant clusters for the contrast between uninformative and doubly-informative conditions. In the period between 1,725 and 1,875 ms from the onset of the trial, participants looked to targets more in the uninformative condition (cluster mass statistic = 37.2, $p = 0.002$).⁸ In the periods between 2,125 and 2,375 ms (cluster mass statistic = 59.9, $p = 0.002$) and between 2,575 and 2,725 ms (cluster mass statistic = 20.7, $p = 0.006$), participants looked to targets more in the doubly-informative condition. The CPA also found more looks to targets in the number-informative condition than in the uninformative condition at 2,075–2,525 ms (cluster mass statistic = 127.0, $p = 0.002$). Finally, the analysis identified significant clusters for the

⁷ We note here that we will not analyze the data for singular target items to test for the facilitative use of number (alone or combined with gender). Although singular articles may encode a (singular) number feature, facilitative use of this number feature may be difficult to observe. This is because upon processing a singular article, participants' gaze may also shift to a gender-matching plural competitor not because they are not attending to the number feature but because the plural competitor is composed of two images, each of which in principle is singular and matches the gender of the article. As suggested by an anonymous reviewer, the analysis comparing uninformative conditions and doubly-informative conditions is now included in the Supplementary material.

⁸ See Section 5.2 for a discussion of the unexpected high proportion of early looks to the target in the uninformative condition that are driving the observed effects in the opposite direction of what was expected in this analysis.

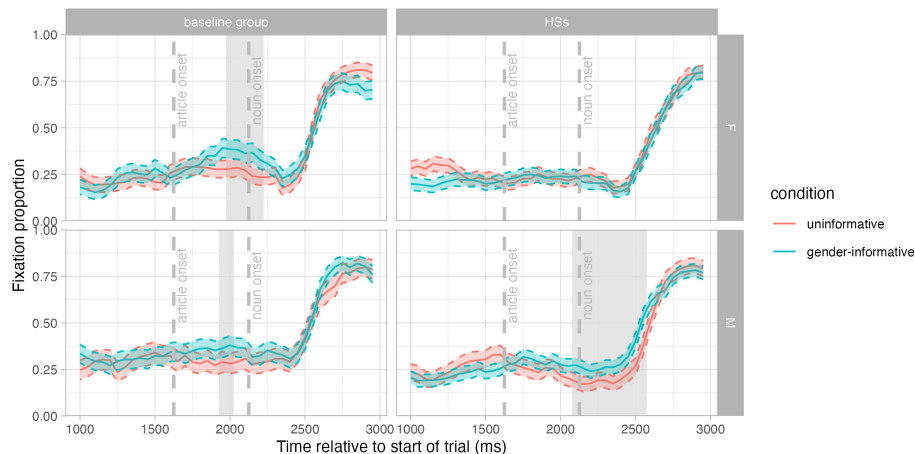


FIGURE 2
Proportion of looks to singular targets. Significant clusters are shaded in gray.

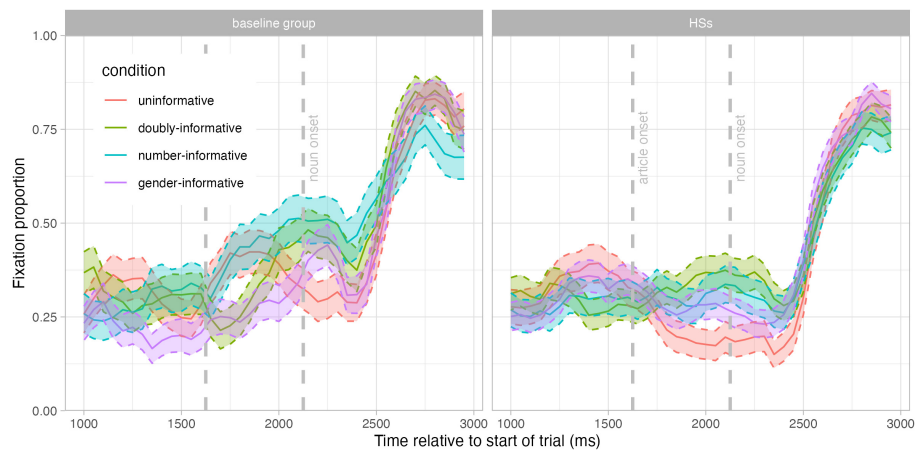


FIGURE 3
Proportion of looks to masculine plural targets (M PL) across informative and uninformative conditions.

contrast between the uninformative and the gender-informative condition. At 1,675–2,025 ms, participants looked more to targets in the uninformative condition (cluster mass statistic = 70.5, $p = 0.002$), and at 2,175–2,275 ms participants looked more to targets in the gender-informative condition (cluster mass statistic = 27.1, $p = 0.002$).

In the secondary analysis, the CPA identified two significant clusters for the contrast between doubly-informative and number-informative conditions. At 1,725–1,925 ms, participants looked to targets more in the number-informative condition than the doubly-informative condition (cluster mass statistic = 39.5, $p = 0.002$). At 2,625–2,725 ms (cluster mass statistic = 20.4, $p = 0.006$), participants looked more to targets in the doubly-informative condition. The model also found a significant cluster for the contrast between doubly-informative and gender-informative conditions, in that at 2,025–2,175 ms participants looked more to

targets in the doubly-informative condition (cluster mass statistic = 30.0, $p = 0.002$).

For the HSs, the first CPA found a significant cluster for more looks to targets in the doubly-informative condition than the uninformative condition at 1,825–2,475 ms (cluster mass statistic = 230.0, $p = 0.002$). The model also found a significant cluster for the contrast between the uninformative and number-informative conditions, with more looks to targets in the number-informative condition at 1,825–2,475 ms (cluster mass statistic = 100.0, $p = 0.002$). Finally, the model found two significant clusters for the contrast between uninformative and gender-informative conditions, with more looks to target in the gender-informative condition at 1,925–2,125 ms (cluster mass statistic = 34.1, $p = 0.002$) and at 2,375–2,625 ms (cluster mass statistic = 45.0, $p = 0.002$).

TABLE 2 Overview of results of CPA analyses comparing looks to masculine plural (M PL) targets across informative and uninformative conditions.

Contrast	Baseline group		HSs	
	Cluster	Direction of effect	Cluster	Direction of effect
doubly-inf > uninf.	1,725–1,875 ms	Reverse	1,825–2,475 ms	Expected
	2,125–2,375 ms	Expected		
	2,575–2,725 ms	Expected		
num-inf. > uninf.	2,075–2,525 ms	Expected	1,825–2,475 ms	Expected
gen-inf. > uninf.	1,675–2,025 ms	Reverse	1,925–2,125 ms	Expected
	2,175–2,275 ms	Expected	2,375–2,625 ms	Expected
double-inf > num-inf.	1,725–1,925 ms	Reverse	–	–
	2,625–2,725 ms	Expected		
double-inf > gen-inf.	2,025–2,175 ms	Expected	2,025–2,325 ms	Expected

The secondary analysis for HSs identified a significant cluster indicating more looks to target in the doubly-informative than the gender-informative condition at 2,025–2,325 ms (cluster mass statistic = 55.3, $p = 0.002$). No significant clusters were identified for the contrast between doubly-informative and number-informative conditions.

4.2.3 Facilitative processing of plural articles: feminine *las*

Proportion of looks to feminine plural targets across conditions is presented in Figure 4, and an overview of results is presented in Table 3. The primary analysis found that at 2,475–2,575 ms, participants in the baseline group looked more to targets in the doubly-informative than the uninformative condition (cluster mass statistic = 16.3, $p = 0.006$). The analysis also identified significant clusters for the contrast between uninformative and number-informative conditions. At 2,075–2,425 ms, participants looked more to targets in the number-informative condition than the uninformative condition (cluster mass statistic = 54.6, $p = 0.002$), while at 2,725–2,775 ms they looked more to targets in the uninformative condition (cluster mass statistic = 17.8, $p = 0.004$). Finally, the analysis identified a significant cluster indicative of more looks to targets in the gender-informative condition as compared to the uninformative condition at 2,375–2,625 ms (cluster mass statistic = 61.8, $p = 0.002$).

The secondary analysis for the baseline group identified two significant clusters for the contrast between doubly-informative and number-informative conditions: at 2,075–2,325 ms (cluster mass statistic = 31.6, $p = 0.002$), participants looked more to targets in the number-informative condition, while at 2,525–2,775 ms (cluster mass statistic = 40.7, $p = 0.002$) they looked more to targets in the doubly-informative condition. The model did not identify any significant clusters for the contrast between the doubly-informative condition and the gender-informative condition.

For HSs, the primary analysis identified two significant clusters for the contrast between uninformative and doubly-informative conditions. At 1,725–2,075 ms (cluster mass statistic = 69.7, $p = 0.002$) and at 2,425–2,675 ms (cluster mass statistic = 72.2,

$p = 0.002$), participants looked more to targets in the doubly-informative than the uninformative condition. The model also identified a significant cluster indicating more looks to target in the number-informative condition than the uninformative condition at 2,275–2,675 ms (cluster mass statistic = 211.0, $p = 0.002$). Finally, the model identified a significant cluster indicating more looks to target in the gender-informative condition than in the uninformative condition at 2,425–2,675 ms (cluster mass statistic = 31.3, $p = 0.002$).

The secondary analysis for HSs identified two significant clusters for the contrast between doubly-informative and number-informative conditions. At 1,725–1,875 ms (cluster mass statistic = 21.8, $p = 0.012$), participants looked more to targets in the doubly-informative condition, while at 2,325–2,475 ms (cluster mass statistic = 35.0, $p = 0.002$) they looked more to targets in the number-informative condition. The model also found two significant clusters indicating more looks to the target in the doubly-informative condition than in the gender-informative condition—the first cluster was at 1,725–1,975 ms (cluster mass statistic = 35.1, $p = 0.002$) and the second was at 2,575–2,635 ms (cluster mass statistic = 11.8, $p = 0.046$).

4.3 Competition condition

To test whether participants were biased more toward number or gender competitors (RQ2), we analyze data from the competition condition. Following Ito and Knoeferle (2023) and Zhu and Grüter (2024), we compute fixation bias toward the gender competitor over the number competitor using the following formula: $\log((\text{proportion of looks to gender competitor} + 0.5)/(\text{proportion of looks to number competitor}))$.⁹ The resulting values are plotted in Figure 5.

We note that even prior to the onset of the article, participants in both groups and for both masculine and feminine articles

⁹ Per Ito and Knoeferle (2023), a small value such as 0.5 is included in the formula when computing fixation bias that involves two elements that occur on the screen at the same time.

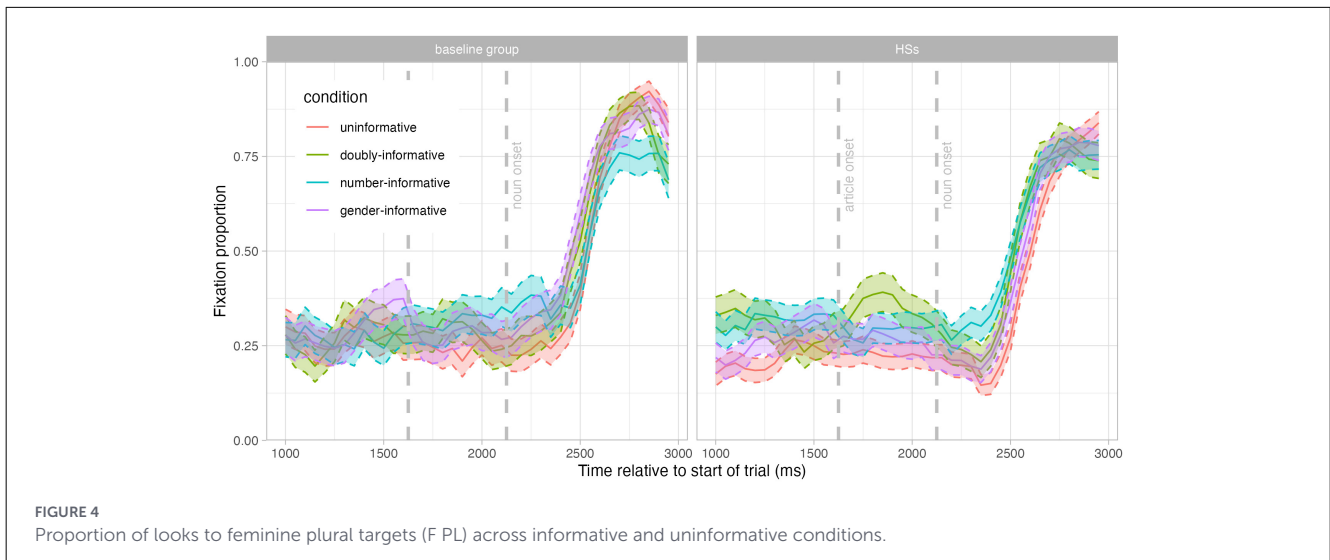


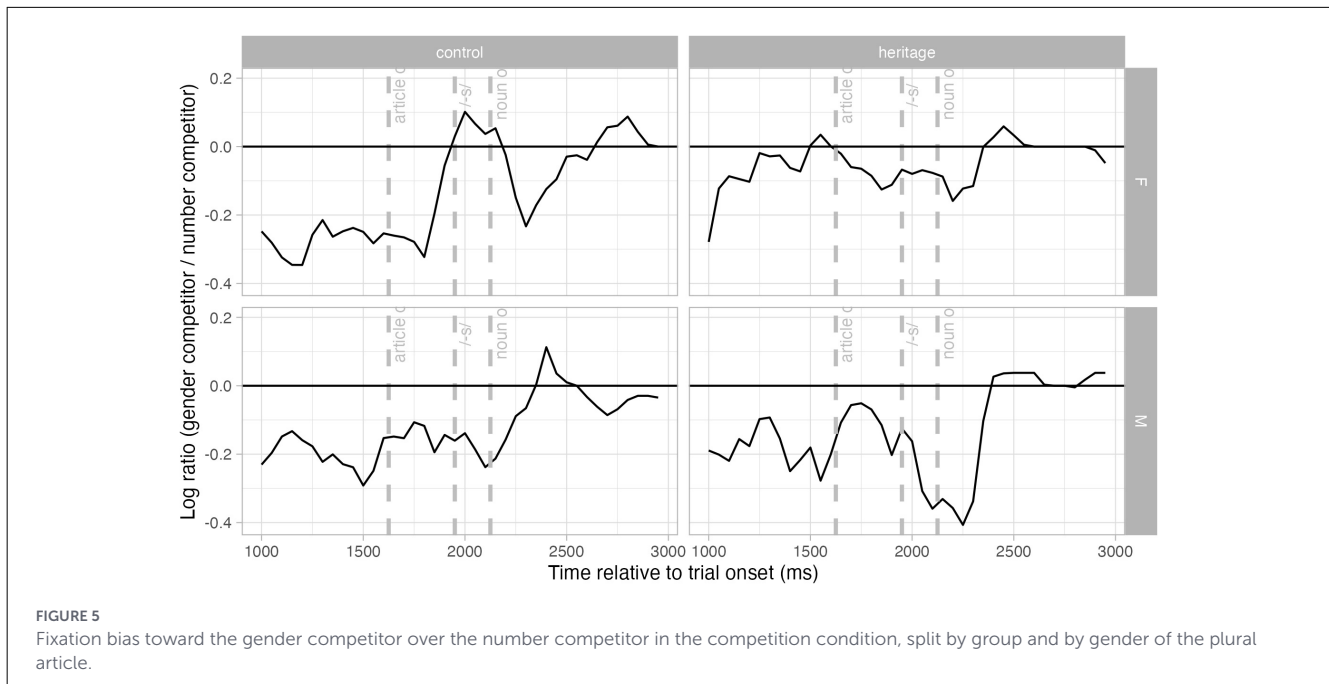
TABLE 3 Overview of results of CPA analyses comparing looks to feminine plural (F PL) targets across informative and uninformative conditions.

Contrast	Baseline group		HSs	
	Cluster	Direction of effect	Cluster	Direction of effect
doubly-inf. > uninf.	2,475–2,575 ms	Expected	1,725–2,075 ms	Expected
			2,425–2,675 ms	Expected
num-inf. > uninf.	2,075–2,425 ms	Expected	2,275–2,675 ms	Expected
	2,725–2,775 ms	Reverse		
gen-inf. > uninf.	2375–2,625 ms	Expected	2,425–2,675 ms	Expected
doubly-inf > num-inf.	2,075–2,325 ms	Reverse	1,725–1,875 ms	Expected
	2,525–2,775 ms	Expected	2,325–2,475 ms	Reverse
double-inf > gen-inf.	-	-	1,725–1,975 ms	Expected
			2,575–2,635 ms	Expected

show a non-zero bias toward the number competitor. We address potential broader implications of this finding in Section 5.4. For the present analysis, rather than analyzing absolute bias toward the gender competitor, we test for relative shifts in bias toward the gender competitor as each article unfolds. To do this, again following Ito and Knoeferle (2023) and Zhu and Grüter (2024), we use linear models to predict the log ratio (fixation bias), with group, region, and their interaction as predictors. Region is a categorical variable with three levels: the pre-critical region (200 ms), the article onset region (containing /lo/ (315 ms) or /la-/ (340 ms)), and the plural marking region (170 ms for los and 140 ms for las). Region is forward-difference coded such that the first contrast tests for a difference between the pre-critical region and the article onset region, and the second contrast tests for the difference between the article onset region and the plural marking region. Following the same procedure as for the CPAs, we conduct separate analyses for each group and each plural article.

For feminine plural las, the model reveals that the baseline group’s bias toward the gender competitor increased from the pre-critical region to the article onset region ($\beta = 0.129$, $SE = 0.40$, $t = -3.25$, $p = 0.008$) and again from the article onset region to the plural marking region ($\beta = 0.195$, $SE = 0.043$, $t = -4.54$, $p < 0.001$). HSs showed a decrease in bias toward the gender competitor from the pre-critical region to the article onset region ($\beta = -0.045$, $SE = 0.014$, $t = 3.16$, $p = 0.009$) but no change from the article onset to the plural marking.

For the masculine plural los, baseline participants showed an increase in bias toward the gender competitor from the pre-critical region to the article onset region ($\beta = 0.047$, $SE = 0.017$, $t = -2.754$, $p = 0.019$), but no change from the article onset region to the plural marking region. HSs showed no significant changes in bias while processing los, though a marginal decrease in bias toward the gender competitor occurred between the article onset region and the plural marking region ($\beta = -0.053$, $SE = 0.029$, $t = 1.81$, $p = 0.098$).



5 Discussion

The discussion is organized as follows: in Section 5.1, we first discuss the replication of prior work in our results (Section 5.1). We then discuss our findings regarding the facilitative processing of plural articles (RQ1) and whether we observe any group differences in this respect (RQ3) (Section 5.2), followed by a discussion of the relative weighting of number and gender during the processing of plural articles (RQ2) and, once again, whether we observe any group differences in this respect (RQ3) (Section 5.3).

5.1 Facilitative processing of gender on singular articles

Results for facilitative use of gender on singular definite articles, as reported in Section 4.2.1, show that the baseline group looked more to targets in gender-informative than uninformative conditions for both masculine *el* and feminine *la*. This is evidence of facilitative processing of gender consistent with prior work on baseline Spanish speakers that used singular articles (ex. Lew-Williams and Fernald, 2007, 2010; Grüter et al., 2012; Dussias et al., 2013; Fuchs, 2022). HSs, however, showed the facilitative effect for masculine *el* but not feminine *la*. This result is a partial replication of prior work on facilitative processing in Heritage Spanish, in which facilitative processing of gender was observed but asymmetries between genders were not reported (Fuchs, 2022; Keating, 2022, 2025; Fuchs and Zeng, 2024; Pérez-Leroux et al., 2024). However, as we reported in Section 4.2.3, HSs did show facilitative processing of feminine gender in the gender-informative condition for the feminine plural article *las* (as discussed further below). Thus, it would be premature to say HSs in our study did not show facilitative processing of feminine gender overall. To investigate whether the facilitative effect of feminine was observed

for HSs in the plural but not singular article, we conducted a *post hoc* investigation of our stimuli. We determined that our stimuli do not present any noticeable acoustic differences in vowel quality between *la* (F1: 823Hz; F2: 1627Hz) and *las* (F1: 835Hz; F2: 1664Hz), and any differences in vowel length (in *la*: 358 ms; in *las*: 257 ms) would suggest processing of gender should be easier for *la* (longer vowel) than *las* (details available in [Supplementary material](#)). More broadly, our experimental design does differ from prior work in a few ways, including the number of items on the screen and the incorporation of the Covered Box Paradigm. We speculate that the increased complexity of the task could lead to smaller effects and therefore higher likelihood of Type II error, which may be behind the lack of an observed facilitative effect for HSs for *la*.

5.2 Facilitative processing of Spanish plural definite articles

Our first research question (RQ1) asked whether speakers process plural definite articles (*los/las*) facilitatively. As reported in Sections 4.2.2 and 4.2.3, we consistently find that participants in both groups look more to target items in the three informative conditions compared to the uninformative condition (we will discuss occasional effects in the opposite direction below). We take this to be evidence that, overall, both groups use plural articles for facilitative processing. Our results align with the results reported for the adult Spanish baseline speakers in Coloma et al. (2023), and we extended this finding to adult HSs.

One of the novel contributions of our study is that we differentiated between conditions in which the article is informative in one vs. two features. Importantly, for both groups, facilitative effects were evident both when the article was doubly-informative and when it was informative in only one feature. Facilitative

processing of number in the number-informative condition is notable because it had not previously been investigated in either population (though see Section 5.4 for possible limitations). Facilitative processing of gender in the gender-informative condition for both masculine and feminine articles is also significant. It not only replicates prior findings regarding facilitative processing of gender in both baseline and heritage populations (for Spanish see Fuchs, 2022; Keating, 2022, 2025; Fuchs and Zeng, 2024; Pérez-Leroux et al., 2024), but also strengthens these findings, demonstrating that even in the presence of a semantically salient number feature, both baseline speakers and HSs still access the abstract gender agreement cue and integrate it into the process of word recognition. This is especially significant for the HSs: despite the established view that grammatical gender is a vulnerable domain in heritage languages, and despite evidence from offline studies that HSs of Spanish may not process gender independently from number (Scontras et al., 2018), we find evidence that HSs are able to process these two features independently during real-time comprehension.

However, we note a few instances in which we observe an effect in the opposite direction from what was anticipated. First, we address unexpectedly early increases in looks to M PL targets for the baseline group in the uninformative condition (Figure 3). For the uninformative condition, a follow-up investigation of our materials and results revealed that, for M PL targets, this condition had an imbalance in the number of analyzed trials in which the target appeared in the top left position in the display, which viewers tend to look at first due to left-to-right reading habits (Salverda et al., 2011). This imbalance in the distribution of analyzed trials is likely an unanticipated result of necessary exclusions of data in which participants labeled the target and/or competitor differently from what was intended in the experimental design, combined with randomization in the location of the target across trials. *Post-hoc* analysis of the uninformative condition for M PL targets not in the top-left position in the displays (available in [Supplementary material](#)) yields the expected patterns, i.e., significant clusters for contrasts between the informative conditions and the uninformative condition in the expected direction only. The exception is the number-informative condition for HSs, though statistical results may be limited by a large reduction in sample size once trials with targets in the top-left position in the display are excluded for this *post hoc* analysis.

Next, we observed an early increase in proportion of looks to M PL targets for the baseline group in the number-informative condition, leading to an unanticipated contrast in the reverse direction relative to the doubly-informative condition. We suggest that this indicates that in the number-informative condition, the baseline group was able to quickly rule out the M SG competitor as *los* unfolded. In the context of the present study, this may be because a M SG competitor is the only type of candidate that would not be compatible with an article whose onset is /l/. Another, though not mutually exclusive, explanation is that gaze patterns toward the (masculine) plural target in this condition may be inflated by a non-linguistic bias toward more dense images on the screen (Mannan et al., 1997, see also discussion in Section 5.4).

Finally, we note that we observed a late unexpected increase in looks to F PL targets for the baseline group in the uninformative

condition relative to the number-informative condition. However, this small cluster occurred close to the peak of the fixation curve and followed a large cluster for the contrast between these two conditions in the expected direction, so we refrain from interpreting it further.¹⁰

In considering whether language exposure modulates facilitative processing of gender and number on plural articles, we consider the extent to which HSs' facilitative processing differs from that of the baseline (RQ3). It is important to first underscore the key similarity that we observed: both groups showed facilitative use of plural articles, including in contexts in which the article is informative in only one feature, indicative of independent access to gender and number features. Differences between the groups arise in the comparison of the doubly-informative condition to gender- or number-informative conditions. For the baseline group, we find a stronger facilitative effect of *los* when it is doubly-informative than when it is informative in either gender or number. Meanwhile, for HSs, the doubly-informative condition for *los* shows a stronger effect than the gender-informative condition, but not the number-informative condition. For *las*, we see the opposite pattern: the baseline group shows more looks to target in the doubly-informative condition as compared to the number-informative condition, but we observe no differences between the doubly-informative condition and the gender-informative condition. By contrast, HSs show a stronger effect for doubly-informative *las* than in either gender- or number-informative conditions. In aggregate, these results suggest that when two features are both informative to the target, these may each be accessed and thus yield a cumulative effect that is stronger than facilitative processing in one feature alone. This is consistent with findings for the facilitative processing of gender and animacy (Fuchs, 2025), extends the results to gender and number, and demonstrates these processing strategies are available to HSs as well.

On the other hand, we do observe divergences between the two groups in how the processing of two features may unfold. For the baseline group, facilitative processing of gender and number together on *las* is reducible to facilitative processing of gender alone; for HSs, facilitative processing of gender and number together on *los* is reducible to facilitative processing of just number. This suggests that in certain circumstances, even when both features are informative to the target, listeners may

¹⁰ We also refrain from further interpreting the temporal dynamics of effects reported in this section. Although we refer to certain effects as occurring early or late, this is used to indicate onset of effects relative to each other, rather than relative to specific cut-offs that might be interpreted as indicative of specific stages of word processing, in particular predictive processing. Recent work on the Visual World Paradigm suggests that the cut-off historically used to set windows for analysis that would suggest predictive processing (up to 200 ms after the onset of the noun) is not in fact reliable. Additionally, while the results of the CPAs in Section 4 show significant clusters for effects of condition with various onsets, confidence intervals obtained from Divergence Point Analyses analyzing looks to target versus competitor within each informative condition (see [Supplementary material](#)) do not provide evidence for divergence points early enough to reliably argue for predictive processing, especially given the uncertainty regarding the appropriate cut-off point. We hope that future work on the processing of number and gender agreement features might test the temporal dynamics of these effects more directly.

attend to just one of the features. In this case, HSs show a preference for the semantically salient number feature, while the baseline group shows a preference for the gender feature. This is evident in that, for the HSs, the number-informative condition resembles the doubly-informative condition when number and gender information unfold simultaneously (during *los*), but this preference for number may be mitigated when the two features unfold sequentially (during *las*), which may allow an effect of gender to emerge. Meanwhile, we see a different pattern for the baseline group because, as *las* unfolds, the gender feature that unfolds first is sufficient for identifying the target item in both gender-informative and doubly-informative conditions; the number feature on *las* may be redundant in the doubly-informative condition if the gender feature is processed efficiently, and it is uninformative in the gender-informative condition. We consider more direct evidence for the relative weighting of the two features, as well as any group differences, in the next section.

5.3 Relative weighting of number vs. gender cues

We now turn to results directly informing whether number or gender is weighted more heavily when both features are available as informative cues (RQ2). In the competition conditions, the two candidates visible in the display were a gender competitor and a number competitor, until the target was revealed 200 ms after the auditory onset of the noun in the prompt. Both HSs and the baseline group showed an initial preference for the plural competitor, likely due to a non-linguistic preference for visual elements that take up more area (see Section 5.4); we can therefore only interpret shifts in bias in the direction of the gender competitor, as only these are reliably interpreted as linguistically driven. For both *los* and *las*, the baseline group showed a clear shift in bias toward the gender competitor as the article unfolded. HSs, however, showed no increase in bias toward the gender competitor for either article, only a marginal decrease in bias toward the gender competitor, i.e., an increase in bias toward the number competitor.

Overall, these results inform both RQ2 and RQ3: number and gender cues are not always weighted equally when both are informative, and their relative weighting may be modulated by language experience. Specifically, baseline Spanish speakers may weight gender information more strongly than do HSs, and when gender and number are pitted directly against each other, HSs show a reduced reliance on gender information. This in turn is consistent with a general preference for semantically salient features over abstract grammatical features in language processing in a non-dominant language (ex. Clahsen and Felser, 2018; Cunnings, 2017; White et al., 2004; Parshina et al., 2022).

5.4 Limitations

We consider two possible challenges that may arise in the interpretation of our results. As we alluded to above, our results from the competition condition show a preference for the plural candidate even before the onset of informative linguistic cues.

Previous VWP work on plural noun processing in German likewise found a bias toward plurals (Grandon et al., 2024). These looks likely reflect non-linguistic processing that happens early in each trial as participants preview the visual scene. There are known biases in visual processing that direct visual attention to more visually salient display areas (ex. Koch and Ullman, 1985; Itti and Koch, 2000) or more visually dense areas (Mannan et al., 1997). Our plural stimuli were more visually dense than their singular counterparts, because the plural stimuli consisted of two partially overlapping drawings of the target item, though we note that the same is true of the stimuli in Christou et al. (2020) and Coloma et al. (2023).

This visually-driven preference for plural stimuli is a limitation of our study, and indeed generally a limitation for manipulations of number in the VWP. Awareness of this bias also informed our analytical approach, motivating certain strategies to mitigate possible inflation of effects due to non-linguistic bias. First, as discussed earlier, in the competition condition (in which the number competitor is plural and the gender competitor is singular), we interpret only relative shifts toward the gender competitor, rather than absolute bias toward either competitor.

Second, in comparisons of informative and uninformative conditions, we cannot rule out the possibility that visual bias may be inflating looks to target even after informative linguistic cues unfold in the number-informative and doubly-informative conditions, both of which involve a plural target and a singular competitor. Here, our implementation of the Covered Box Paradigm gives us the opportunity to verify our results. The Covered Box Paradigm was crucial for the competition condition and was initially implemented in the other conditions only for reasons of counterbalancing. In our main analysis, informative and uninformative trials in which the box covers the target were excluded, because they entail somewhat different processing mechanisms: looks toward the target are in fact looks toward an opaque square where the target is expected to be revealed later. We therefore avoid treating trials with a covered target as equivalent to trials in which the target is visible. Still, we conducted a follow-up analysis on covered-target trials to see if patterns replicate, which provides some independent evidence that results for number-informative and doubly-informative conditions in the main analysis are not overly inflated by visual bias. This follow-up analysis is presented in the [Supplementary material](#). Results fully replicate for the baseline group; for HSs, results replicate for *las* and for *los* in the number-informative condition, though not in the doubly-informative condition for *los* (or in the gender-informative condition for *los*, though this one is unrelated to visual bias). Overall, we take this to suggest that while non-linguistic bias may be subtly affecting gaze patterns after informative linguistic cues unfold, we can still interpret the results of our study with respect to the research questions. More broadly, while the VWP is an excellent tool for investigating language processing across populations (see Section 2.2), we caution that the role of non-linguistic biases constitutes an important consideration. Ideally, future work should obtain converging results from a complementary experimental paradigm.

Another potential limitation is the fact that plurality in Spanish is realized as the suffix *-s*, and dialectal and idiolectal variation in */s/* reduction (SR) is a well-known challenge for research on

Spanish. SR is the phenomenon in which Spanish speakers aspirate or fully elide /s/ at the end of syllables (Lipski, 1999). In the context of our study, it is conceivable that listeners who do not frequently produce or hear word-final /s/ sounds themselves may not process an overt plural /s/ morpheme the same way as do other listeners. For the purposes of the present study, we decided neither to control for this variable nor to exclude any participants who may exhibit SR, following previous work (ex. Antón-Méndez et al., 2002; Foote, 2011; Jegerski and Fernández Cuenca, 2025; Sagarra and Rodríguez, 2022; Scontras et al., 2018). Our primary motivation is evidence that an individual's usage of SR does not influence their processing of plural markers (Miller and Schmitt, 2010). From a practical perspective, we are unable to reliably distinguish participants based on their production and/or exposure to SR. Speech samples collected in the oral language proficiency tasks (Section 3.4) did not contain the kinds of environments in which SR is typically observed. The language background questionnaire collected information about the dialects spoken by participants' caregivers, but it is known that country of origin, region within that country, socioeconomic status, and educational background all play some role in individual variation in SR (Jajo-Yacoub and Ramirez, 2023; Lipski, 1999; Miller and Schmitt, 2010; Núñez Méndez, 2022). Additionally, given that our participants live in the US, it would be difficult to control for the dialect(s) speakers may be exposed to beyond the home, where dialects are likely to be mixed. Still, we suggest this topic as a potential area of further research at the intersection of psycholinguistics and sociolinguistics.

5.5 Conclusions and implications

The present study investigated the processing of two morphosyntactic features—gender and number—on pre-nominal definite articles in Spanish. Although the facilitative processing of these articles has been considered in prior work, the current study is the first to manipulate properties of the competitor to observe whether facilitative processing takes place when both or only one of the features are informative cues. Results show that listeners exhibit facilitative processing in all contexts, suggesting that when two morphosyntactic cues are available, listeners are able to access each feature independently. We observe this pattern for speakers with a range of cumulative exposure to the target language: both baseline Spanish speakers, who had rich input to Spanish through adolescence and schooling, and HSs of Spanish, whose acquisition trajectory is distinguished by constrained input and a competing grammar. Our findings are particularly noteworthy for the HSs. Prior work has shown that HSs pattern with baseline speakers in their real-time facilitative processing of gender (in isolation from other morphosyntactic features), despite commonly observed divergences in production and offline comprehension (see Section 2.2). Our results strengthen these findings, demonstrating that HSs maintain target-like facilitative processing of grammatical gender even in the presence of a co-occurring number cue. This is contrary to expectations from work on HSs' production and offline comprehension of agreement when gender and number co-occur (Section 2.2).

Where we see divergences between the two groups and thus the possible impact of differences in language exposure is in the relative weighting of the two features. When gender and number cues were compatible with different competitors, baseline speakers shifted more to the gender competitor, but HSs did not, suggesting that HSs may weight number more heavily than do baseline speakers. Consistent with this, for the baseline group, facilitative processing of doubly-informative articles was reducible in some contexts to facilitative processing of gender alone, but for the HSs it was reducible to facilitative processing of number alone. This aligns with existing evidence that non-dominant bilingual speakers (ex. L2 learners, HSs) of a language may prioritize semantically salient cues over abstract grammatical ones (Clahsen and Felser, 2018; Cunnings, 2017; White et al., 2004; Parshina et al., 2022). We note, however, that despite the known strengths of the VWP in investigating the linguistic knowledge of populations with variable literacy in the target language, non-linguistic biases in visual processing require caution in interpreting the effects of the number manipulation. Nevertheless, as research on facilitative processing continues to progress, we hope that future work will similarly test the interplay of multiple morphosyntactic cues, reflecting the reality that, cross-linguistically, agreement features often co-occur on pre-nominal elements.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found in the article/Supplementary material.

Ethics statement

The studies involving humans were approved by University of Southern California IRB, Application #UP-22-01091. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin because the study was determined to be exempt. Participants were provided with an information sheet, consistent with procedure for studies determined to be exempt by the USC IRB.

Author contributions

ZF: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Visualization, Writing – original draft, Writing – review & editing. EE-T: Investigation, Writing – original draft, Writing – review & editing. LP: Investigation,

Writing – original draft, Writing – review & editing. LM: Investigation, Writing – original draft, Writing – review & editing. AR: Investigation, Writing – original draft, Writing – review & editing.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships

that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/flang.2026.1760372/full#supplementary-material>

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