SPANISH PSYCHOLINGUISTICS IN THE 21ST CENTURY

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SPANISH PSYCHOLINGUISTICS IN THE 21ST CENTURY

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Editorial: Spanish psycholinguistics in the 21st century

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Editorial on the Research Topic
Spanish psycholinguistics in the 21st century

The year 2022 marks the 500th anniversary of the death of Antonio de Nebrija, the first Hispanic humanist. With scientific rigor as the standard of his activity, Nebrija not only wrote the first grammar of Spanish (thus being the first written grammar of a modern European language), but also worked as a translator, lexicographer, linguist, and historian, among others. In the essence of Antonio de Nebrija, a humanist concerned with the scientific study of grammar, lexicon, and orthography, we surely find one of the foundational bases of a series of scientific areas that, years later, have resulted in what we now know as psycholinguistics and applied linguistics.

Using the example of the multiplicity of interests of Antonio de Nebrija as a humanist scientist devoted to the study of Spanish more than 500 years ago, today we can see how research on the second most widely spoken language in the world, used by nearly 500 million people, is in exceptional health. More and more laboratories are flourishing inside and outside Spanish-speaking countries that dedicate their research work to generating knowledge about language processing and production, using their vernacular language as a spearhead. Moreover, in recent years we have observed how many international research centers located in countries where Spanish is not one of the official languages have also oriented part of their scientific activity to the study of Spanish. Hence, it is not difficult to find centers specialized in the psycholinguistic or neurolinguistic study of people who speak Spanish as their first language, just as it is not difficult to find laboratories that explore the learning and processing of Spanish as a second language, additional language, heritage language or foreign language.

Whether for its processing or learning as a first language or as an additional language, Spanish constitutes in itself a wealth of particularities of great socio-linguistic relevance that makes it an incessant source of research questions. Both because of the constitution of its lexicon influenced by the Romans, Arabs, Celts, and other cultures, and because of the large number of dialectal varieties that expand in different continents, Spanish is a privileged language that allows psycholinguistic approaches to socio-linguistic aspects questions. Moreover, its prototypical subject-verb-object syntactic structure and the possibility of pro-dropping of the subject, together with the inflectional complexity of the language that requires high agreement demands, places Spanish in an advantageous position to explore linguistic processes that would be difficult (if not impossible) to investigate in different languages.

This being the case, it is not surprising that the beginning of the twenty-first century has represented a clear transition toward the professionalization of experimental research in Spanish psycholinguistics and neurolinguistics with the aim of shedding light on the cognitive processes that underlie the acquisition, learning, perception, or production of language. The growing interest in the use of Spanish as a tool for cracking the code of the linguistic macrosystem or of some of the associated processes, as well as the progressive appearance and consolidation of research centers and laboratories in social contexts where Spanish plays a relevant role (whether as a majority language or not), has been reflected in the increase in the number of related scientific publications. By way of illustration, a search carried out in June 2022 in a commonly used scientific portal such as Scopus, using "Spanish," "language," and "cognition" as search terms in the title, keywords, and abstract of the available sources, shows that from 2000 to 2020 the increase in publications was an impressive 900%. Of the total number of publications found, slightly more than half correspond to the areas of Psychology (21.4%), Medicine (22.4%), and Neuroscience (11.5%). Importantly, in order to understand the transdisciplinary nature of the work carried out in Spanish Psycholinguistics, it is important to highlight that the areas of Social Sciences (15.8%) and Arts and Humanities (15.6%) also account for a very significant portion of the scientific activity carried out. After the XV International Symposium of Psycholinguistics held in Madrid in June 2021 and aligned with the multiple interests of dozens of research groups around the world (as was also the case with the multiple interests of Antonio de Nebrija), this Research Topic offers an overview of the state of the main lines of experimental research on Spanish psycholinguistics.

The XV International Symposium of Psycholinguistics had more than 200 attendees and nearly 150 different participating institutions, and with 72 poster presentations and 79 oral communications, in addition to the keynote lectures, it demonstrated that scientific research in psycholinguistics, neurolinguistics, and applied linguistics on Spanish or in Spanish is at a moment of splendor, and the collection of articles that we present here give a good account of this.

Using various methodologies such as eye-tracking and electrophysiology, recent research in psycholinguistics has employed Spanish as the language to better understand linguistic, cognitive, and societal concepts in native and bilingual contexts. This Research Topic offers a case of the paradigmatic example of an overview of this work.

With the focus on word recognition processes, Marcet et al. examined whether the slower word processing times recently observed when accent marks were omitted [e.g., *carcel* derived from *cárcel* (prison)] was due to the experimental designs used or to the fact that accent-marked vowels are represented by the same orthographic units during word recognition and reading. They concluded that the effect is task-dependent, suggesting that the omission of accent marks may not generate a reading cost. Word recognition processes were also put to the test, in this case in bilingual contexts, in the article by Comesaña et al. They investigated whether the flexible letter position coding observed during native word recognition (e.g., *cholocate* misread as chocolate; see Perea et al., 2008) occurs similarly during bilingual word recognition. Their results revealed differences depending on the language cue and have implications for the models of bilingual word recognition. Regarding syntactic processing, Baron et al. examined grammatical gender processing in school-age Spanish-English bilingual children using a visual-world paradigm. They observed an asymmetry in the usage of gendered articles that was modulated by the frequency of use of the bilinguals' two languages. Finally, in relation to second language processing, Margaza and Gavarró studied the expression and position of subjects in Greek speakers of Spanish, and they report results that go against the predictions of different versions of the Interface Hypothesis (e.g., Sorace and Filiaci, 2006).

A different series of articles in this Research Topic focus on emotions and emotional language processing, illustrating a great deal of attention put on this topic by Spanish psycholinguists (see Hinojosa et al., 2020). In their article, Veitez et al. tried to unravel the mystery about the negative valence bias by evaluating the contribution of arousal to unpleasant word recognition. Their event-related brain potential (ERP) data obtained in a lexical decision task revealed the mediating role played by arousal in the emergence of the negative valence effects in word recognition. In a study exploring oscillatory activity, Santaniello et al. examined the impact of approach and avoidance motivational systems in the processing of emotional words. To do so, they compared frontal alpha asymmetries and brain oscillations triggered by anger and fear words. Their results suggested that motivational features play a role in the representation and processing of emotional words. Finally, Hatzidaki and Santesteban presented data from another ERP study showing that number agreement is sensitive to the affective nature of semantic information. Interestingly, their data clarified the different stages of language processing at which emotional information may impact syntactic parsing.

Lastly, two of the articles presented in the current Research Topic focused on the societal changes that could impact language processing. The research article by Pilgun et al. explored the perception of the COVID-19 pandemic by users of Spanish, German, and Russian. The analysis of large databases built from various social sources using a neural network approach revealed similarities and differences across the speakers of the languages in relation to various aspects such as attitudes toward vaccination. Finally, in their article, Planelles Almeida et al. compiled a dataset of oral interactions in Spanish by migrants and refugees from underrepresented countries and different language backgrounds. Their dataset represents an important tool for researchers in psycholinguistics who study L2 spoken language comprehension and processing.

As we can see, this Research Topic is a good example of the variety of methodological and theoretical approaches to the study of language in the Spanish psycholinguistic field. From compilations of oral productions in interactions with non-native speakers of the language to analyses of brain potentials or neural oscillations to explore the interface between language and emotion, and to studies on orthographic processing, this collection of articles shows the good scientific health that this field currently enjoys, and the solid commitment that is being made to the internationalization of results from dozens of research teams working in areas related to the cognitive science of language. Due to its history and development, and due to the relevance that the research groups focusing on Spanish Psycholinguistics have gained internationally, we are certain that the different lines of work of these laboratories will continue to allow us to address translinguistic questions of high scientific significance. Moreover, our analysis of the current situation of the specific area of Spanish Psycholinguistics makes us believe that we are already on a journey directed toward understanding the reality of overcoming the barriers of the WEIRD societies (Western, Educated, Industrialized, Rich, and Democratic; see Henrich et al., 2010). In a scientific world in which generalized Anglocentrism continues to prevail, the progressive advance of the work carried out in the field of Spanish Psycholinguistics can help break down knowledge barriers, achieving higher rates of representativeness, especially if we consider the sociolinguistic richness of Spanish.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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ORIGINAL RESEARCH
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Disentangling the Role of Deviant Letter Position on Cognate Word Processing

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The way of coding letter position has been extensively assessed during the recognition of native words, leading to the development of a new generation of models that assume more flexible letter position coding schemes compared to classical computational models such as the interactive activation (IA) model. However, determining whether similar letter position encoding mechanisms occur during the bilingual word recognition has been largely less explored despite its implications for the leading model of bilingual word recognition (multilink) as it assumes the input-coding scheme of the IA model. In this study, we aimed to examine this issue through the manipulation of the position of the deviant letter of cognate words (external and internal letters). Two experiments were conducted with Catalan–Spanish bilinguals (a masked priming lexical decision task and a two-alternative forced-choice task) and their respective monolingual controls. The results revealed a differential processing for the first letter in comparison to the other letters as well as modulations as a function of language cue, suggesting amendments to the input-coding scheme of the multilink model.

Keywords: letter-position encoding, cognate recognition, multilink, masked priming lexical decision task, 2-alternative forced-choice task

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INTRODUCTION

In the last few decades, the way of coding letter position during visual native (L1) word recognition has been intensively examined (see, for instance, Chambers, 1979; Andrews, 1996; Perea et al., 2005; Gómez et al., 2008; see also Davis and Lupker, 2017 for an overview). The results of the studies on experimental effects such as letter transposition (e.g., judge-jugde), letter migration (e.g., beard-bread), letter substitution (e.g., face-fame), subset/superset (e.g., faulty-faculty), and backward priming (e.g., ecaf-face) uncovered that not all the letter positions in a word are equally processed. Thus, and contrary to the postulates of classical computational models (interactive activation [IA] model, McClelland and Rumelhart, 1981; Rumelhart and McClelland, 1982; dual-route cascaded [DRC] model, Coltheart et al., 2001; multiple readout model [MROM], Grainger and Jacobs, 1996), which assumed location-specific letter coding (i.e., they do not assign a special role to any letter position, and hence the positions are perfectly encoded), letters occupying middle and external positions within the word seem to be preferentially computed, showing a W-shaped function (e.g., Tydgat and Grainger, 2009; Ziegler et al., 2010)[1]. This phenomenon was explained by factors such as visual acuity (decreases from the fixation point toward more peripheral locations, see Anstis, 1998), and crowding effects (letters that occupy external positions in the string are processed more efficiently because they are flanked by only one letter). Thus, for instance, using a variety of three-field techniques (Humphreys et al., 1988) in which a visible-related or unrelated prime (in lowercase letters) was followed by a briefly (67 ms) presented uppercase word, Perea (1998) found larger priming effects (i.e., the difference between unrelated and related primes) for pairs of words whose deviant letter occupied an internal position (e.g., state-stale) than for pairs of words whose deviant letter was at the external (e.g., reach-react).

Overall, the findings collected on letter position coding during L1 word recognition led to the development of a new generation of models of visual word recognition, which employ more flexible orthographic input-coding schemes than those of classical models (e.g., LTRS model, Adelman, 2011; noisy Bayesian reader model, Norris et al., 2010; overlap model, Gómez et al., 2008; spatial coding model, Davis, 2010). For instance, according to the overlap model (Gómez et al., 2008), the identity of letters follows a normal distribution over the position. This way, the letter "D" in JUDGE is associated with position three but also, to a lesser degree, with positions two and three. As a result, compared to replacement-letter non-words (e.g., JUPTE AND JUDGE), transposed-letter non-words are more confusable with their base words (e.g., JUGDE and JUDGE) as it was empirically demonstrated in several languages and using different tasks and procedures (Perea et al., 2011; see Comesaña et al., 2016, for an overview; Yang et al., 2021; for differences between Indo-European and Semitic and Sino-Tibetan languages). Interestingly, this uncertainty about the position is reduced over time, therefore, distributions over positions only occur during the initial encoding process (i.e., when letter strings are presented very briefly and masked). Gómez et al. (2008) used a two-alternative forced-choice perceptual identification task−2AFCT (Ratcliff et al., 1989)—with manipulations of letter transpositions and letter replacements to examine the fit of the model to data. The lexical status of the stimuli presented (words vs. non-words) was also manipulated. In this task, participants are presented with a brief stimulus letter string (a cue), for ∼50 ms, followed by a mask and then by two test letter strings (the cue and the foil), and have to decide which of the two test strings was presented earlier. The authors found a greater accuracy for the manipulations in which the first letter was altered than for the manipulations involving internal letters (e.g., sail-rail and slat-scat, respectively) regardless of the lexical status of stimuli (see Ratcliff, 1981, for the similar results) although the overall performance was better for target words than for non-target words. However, they failed to observe a preferential processing for the last letter over the internal ones (i.e., the accuracy for items varying in the last letter was similar to that for items varying in an internal letter). The authors stated that the absence of such preferential processing might be caused due to cue duration as this advantage was shown in previous studies using a cue duration >60 ms (the cue duration adopted by Gómez et al., 2008). The findings were taken as evidence of the importance of first letters for word recognition as Rayner and Pollatsek held several decades ago (Rayner and Pollatsek, 1989; Rayner et al., 2006; see also Tydgat and Grainger, 2009, for empirical support to the hypothesis of visual field specificity of receptive fields responsible for the first-position advantage). Nonetheless, the overlap model fitted the data pretty well (the fitting parameters for all the experiments conducted by the authors can be found in Gómez et al., 2008, p. 9, 46).

Another family of visual word recognition models makes similar predictions by assuming that there is a layer of "open bigrams" between the letter and word levels (open-bigram model, Grainger and van Heuven, 2004; multiple-route model, Grainger et al., 2012; and SERIOL model, Whitney, 2001). According to these models, transposed-letter words are more confusable than replacement-letter words because they share more open bigrams, which make them more similar at a perceptual level (e.g., JUDGE and JUGDE share more open bigrams [all except DG and GD] that JUDGE AND JUPTE). These models have more troubles, however, in accounting for backward priming effects (ecaf-face) observed in Sino-Tibetan languages (for more details, see Yang et al., 2021).

Although the way of coding letter position has been extensively examined in the literature on L1 word recognition, it has not been fully assessed in non-native or second language (L2) reading despite being a key issue for the front end of the leading model of bilingual visual word recognition: The multilink model (Dijkstra et al., 2019). Indeed, although multilink is a relevant model characterized by an integrated lexicon with a non-selective lexical access, it cannot account for the aforementioned effects (e.g., transposed-letter effects and letter substitution) as it incorporates, for the sake of simplicity, the same letter codification scheme as that of the IA model (i.e., a "position-specific" coding scheme). That is, it assumes that the positions of the letters are established very early in processing, and hence no letter position has a special role over the others. According to the model, the bottom-up activation of bilingual lexical representations is mainly determined by their overlap with the input. The aim of the present study was to test the front end of the multilink model by manipulating the deviant letter position of Spanish–Catalan cognate words (i.e., the translation equivalents that share the form besides the meaning). It is worth noting here that, although Catalan and Spanish are both alphabetic languages, the former has a deeper orthography than the latter. Such differences could impact letter position coding, an issue that we wanted to assess here. This is because cross-linguistic influences during the early stages of visual word recognition, especially from L1 to L2, are very well-documented (see, for instance, Sebastián-Gallés et al., 2006; Comesaña et al., 2012, 2015; Timmer and Schiller, 2012; Chen et al., 2020; Yang et al., 2021, for evidence of L1 influences on the orthographic coding system during L2 reading). In any case, if the multilink model is right, Spanish–Catalan cognate words like *cifra*-*xifra* (number)

[1] It should nevertheless be noted that whereas the first-position advantage for letter strings is a robust phenomenon, the middle-position and final-position advantage has not always been observed and seems to be modulated by task requirements (see Tydgat and Grainger, 2009, for more details).

and *danza-dansa* (dance), which differ in the position of the deviant letter, would be processed in the same way because both pairs differ in just one letter while maintaining the same degree of orthographic overlap (an normalized Levenshtein distance (NLD) of 0.80 for both word pairs). However, this seems not to be the case attending either to the results obtained from the monolingual domain (e.g., Mason, 1982; Tydgat and Grainger, 2009; Perea, 2015) or to the results obtained from a few bilingual studies developed so far in this matter (Font, 2001; Velan and Frost, 2007; Witzel et al., 2011; Lin and Lin, 2016; Chen et al., 2020; Yang et al., 2021; see, however, Comesaña et al., 2018, for null effects of the letter position on L2 cognate word recognition).

In a recent study, Lin and Lin (2016) focused on the processing of transposed-letter non-words to examine if transposition effects could be observed in native and non-native languages regardless of cross-language script. Chinese-English and Spanish-English bilinguals performed a mouse tracking trace task in which they had to decide whether a displayed item presented for 500 ms was a word or non-word by clicking with the mouse the "YES" or "NO" button. The results revealed transposed-letter effects in both L1 and L2 (i.e., participants took longer time to reject transposed-letter non-words as real words [lihgt, created from light] compared to replacement-letter non-words [lijst from light]). This effect was shown by the mouse trajectories as transposed-letter non-words were more strongly pulled toward the unselected alternative response option "YES" compared to replacement-letter non-words, revealing a lexical attraction to their base word and thus a greater processing speed cost. The magnitude of the transposed-letter effect was, however, modulated by the neighborhood size (items with fewer neighbors produced a larger effect than items with more neighbors; see Forster et al., 1987; Perea and Rosa, 2000; Kinoshita et al., 2009, for similar results in the monolingual domain), and by differences in script (the effect was higher for cross-script languages, probably because the position coding component of the orthographic coding system in Chinese is much more flexible than that of alphabetic languages; see Yang et al., 2021). Although the results of this study about letter position coding were interesting, they were found in case of non-words. As the processing of words and non-words follows different pathways (see Coltheart et al., 2001; see also Carreiras and Perea, 2002; Davis and Lupker, 2006), the question that remains unclear is whether or not the mechanism used by bilinguals to code letter position information in L2 words is essentially the same as that used by monolinguals in L1 words. One may think *a priori* that there is no reason to anticipate the differences in the orthographic processing of alphabetic languages in L2 or L1. However, the results obtained from the scarce research on this matter are inconclusive.

To the best of our knowledge, there are only two studies so far on letter position coding with bilinguals who used L2 words instead of non-words (Font, 2001; Comesaña et al., 2018). Both used the same task (lexical decision task) with bilinguals who speak languages with similar scripts, but obtained inconsistent results. Font (2001) examined letter position coding in French-Spanish bilinguals who were asked to decide whether or not a string of letters was a real Spanish (L2) word. Target words were French-Spanish cognates and their controls (non-cognate words—translation equivalents without form overlap like *maison*-casa [house]). The author observed that participants were faster to recognize cognate words in which the deviant letter position was at the end (e.g., texte-texto, the French and the Spanish words for *text*) than when it was within the word (e.g., usuel-usual, *usual*). Interestingly, the facilitation effect observed for cognates when compared to non-cognates was modulated by word frequency. Thus, when cognates had a low frequency in both languages, the facilitation effect for cognates whose deviant letter was in the middle of the words disappeared and tended toward inhibition.

In combination of a subsequent and highly controlled lexical decision study with the masked priming technique (English targets were preceded by the masked 50 ms related or unrelated European Portuguese [EP] primes; e.g., *coala*-KOALA vs. *passe* [pass]-KOALA), Comesaña et al. (2018) found no modulations in the size of the masked priming effect between EP cognate words that differ at the beginning vs. at the end of the word (e.g., *coala*-koala and *papel*-paper, respectively). The authors stated that, although the results were, *a priori*, consistent with the postulates of the multilink model, more research considering other letter positions and task requirements was needed. Indeed, the absence of differences between both groups of cognates could have been either due to the preferential processing of external letters already observed in the monolingual domain (e.g., Tydgat and Grainger, 2009) or to the feedback activation from a semantic to word form (note that both types of words share the meaning besides the form, and hence the feedback activation from the meaning to the form could be explained by the absence of differences between conditions). Another third and simpler possibility has to do with the fact that the masked priming effects are usually difficult to obtain under such fine-grained manipulations, as pointed out by Gómez et al. (2008, p. 21), especially when prime-target lexical frequency is matched as it was the case in the study of Comesaña et al., 2018 (see Perea, 1998 for evidence of modulations in the size of priming effects as a function of deviant letter position when the frequency of primes was higher than that of targets). These three hypotheses were examined in the carried out experiments.

In total, the main aim of the present research was to test the postulates of the front end of the multilink model regarding the way of coding the letter position during cognate word recognition by manipulating the position of the deviant letter (external and internal letters) of cognate words while maintaining constant their degree of orthographic overlap as well as the other variables that affect cognate processing. For that purpose, we carried out two studies with Catalan–Spanish bilinguals (Experiments 1a and 2a) and their respective monolingual controls (Experiments 1b and 2b) by using the most commonly employed tasks in the study of letter position coding during L1 and L2 word recognition [i.e., the masked priming lexical decision task (Experiment 1), and the 2AFCT (Experiment 2)]. The use of two different tasks allowed us to examine if the effects were modulated by task requirements.

In both tasks, five experimental conditions were created according to the location of the deviant letter: (a) initial (*xifra*-CIFRA [number]); second (*llebre*-LIEBRE [hare]);

TABLE 1 | Mean level of proficiency in the four linguistic skills in Spanish (standard deviation in parentheses) of the participants of Experiment 1a and Experiment 1b.

	Experiment 1a		Experiment 1b
	Catalan	Spanish	Spanish
Skills	Mean (*SD*)	Mean (*SD*)	Mean (*SD*)
Listening	6.97 (0.16)	6.95 (0.22)	6.59 (0.67)
Speaking	6.79 (0.61)	6.33 (0.90)	6.38 (0.71)
Reading	6.90 (0.38)	6.79 (0.47)	6.53 (0.62)
Writing	6.74 (0.68)	6.59 (0.64)	6.41 (0.61)
Average	6.85 (0.39)	6.67 (0.43)	6.48 (0.54)

The anchor points for the 7-point Likert scale were 1 = "very poor," and 7 = "native."

middle (*ploma*-PLUMA [feather]); penultimate (*dansa*-DANZA [dance]); and last (*rostre*-ROSTRO [face]). The predictions of the experiments were straightforward. We anticipated that the tenets of the multilink model regarding the encoding of letter position were not correct, and hence the differences between cognates as a function of deviant letter position in both tasks were expected. More precisely, if L2 word processing varies as a function of letter position (an unequivocal index of flexibility during letter position coding), a differential processing for cognates whose deviant letter occupy the first position within the word in comparison with cognates whose deviant letter in any other position would be observed at least in the more perceptual task (i.e., the 2AFCT).

EXPERIMENT 1A

The aim of the first experiment was to replicate the study of Comesaña et al. (2018) with Catalan–Spanish cognate words that vary in external letters (e.g., xifra-cifra and rostre-rostro), and to extend it to cognate words whose deviant letter is within the word (e.g., llebre-LIEBRE, ploma-PLUMA, and dansa-DANZA). If letter position during L2 word recognition matters and the masked priming procedure with a brief prime duration (50 ms) is robust enough to capture the manipulations of letter position, we expected to find greater priming effects for cognates whose deviant letter is within the word as it was observed using L1 neighbor words through the use of a three-field technique with unmasked primes (see Perea, 1998).

Method

Participants

About 40 undergraduate students (34 women and 6 men, mean age 22.3 years, SD = 6.4) from the Universitat Rovira i Virgili (Tarragona, Spain) participated in the experiment in exchange for academic credits (all of them signed an informed consent). The students were highly proficient Catalan–Spanish bilinguals and had Catalan as their dominant and preferred language. To assess their proficiency in both languages, they were asked to complete a questionnaire in which they had to rate their ability in listening, speaking, reading, and writing by using a seven-point Likert scale (1 = "very poor," 7 = "native"; see **Table 1**).

To evaluate their language dominance, they were asked to indicate which of the two languages was preferred and was used more frequently in different contexts (listening, speaking, reading, and writing). To make their ratings, they were provided with another seven-point Likert scale, where one was "Only in Catalan" and seven was "Only in Spanish." The mean ratings of preference and frequency showed that Catalan was the dominant language of the participants: preference (M = 3.24, SD = 0.73, range = 1.75–5) and frequency (M = 2.96, SD = 0.70, range = 2–4). It is worth noting here that four is the middle point of the scale, which indicates a total equality in the preference and usage of both languages.

Design and Materials

Critical stimuli consisted of 240 Catalan prime-Spanish target translation pairs. Half of these pairs were Catalan–Spanish cognate translations (e.g., *correu-correo* [mail], respectively), and the other half were non-cognate translations (e.g., *blat-trigo* [wheat]). Cognate translation pairs were divided into five experimental conditions according to the position of the letter in which the translation equivalents had a difference (hereafter, *deviant letter position*): initial position (e.g., *xifra-cifra* [number]), second position (e.g., *llebre-liebre* [hare]), middle position (e.g., *ploma-pluma* [feather]), penultimate position (e.g., *dansa-danza* [dance]), and last position (e.g., *rostre-rostro* [face]). Targets from cognate and non-cognate conditions, as well as among cognate conditions, were matched in frequency, word length, and the number of orthographic neighbors (all $ps > 0.42$; see **Table 2** for stimuli characteristics). These values were taken from the EsPal database (Duchon et al., 2013).

Likewise, primes from cognate and non-cognate conditions, as well as among cognate conditions, were equated in frequency, word length, and the number of orthographic neighbors (all $ps > 0.43$). However, given that primes were Catalan words, we obtained their values from a different source of that of targets (i.e., NIM database, Guasch et al., 2013). Both the frequencies of Spanish target words ($M = 1.11$) and Catalan prime words ($M = 1.15$) were based on the logarithm of the frequency per million words and did not differ significantly from each other, $t < 1.8$. In addition, the orthographic overlap between cognate targets and their primes, measured as NLD

TABLE 2 | Characteristics of the stimuli used in the experiment (standard deviations are shown in parentheses).

	Log frequency (0.03–2.84)			Word length (2–10)			Neighbors (0–29)			NLD (0.00–0.89)
	Trans.		Unrel.	Trans.		Unrel.	Trans.		Unrel.	
Condition	T	P	P	T	P	P	T	P	P	
Cognates, initial	1.04	1.07	1.06	6.5	6.5	6.5	4.71	7.17	6.33	0.84
	(0.43)	(0.41)	(0.41)	(1.25)	(1.25)	(1.25)	(3.28)	(4.58)	(5.16)	(0.03)
Cognates, second	1.19	1.18	1.13	6.25	6.25	6.63	5.17	9.67	9.92	0.83
	(0.63)	(0.58)	(0.39)	(1.36)	(1.36)	(1.44)	(4.30)	(6.62)	(6.95)	(0.03)
Cognates, middle	1.14	1.16	1.12	6.38	6.38	6.33	5.5	8.92	8.04	0.83
	(0.43)	(0.45)	(0.60)	(1.41)	(1.41)	(1.37)	(4.87)	(5.28)	(6.55)	(0.04)
Cognates, penultimate	1.04	1.14	1.08	6.63	6.63	6.42	4.46	7.96	7.46	0.84
	(0.56)	(0.42)	(0.41)	(1.44)	(1.44)	(1.38)	(3.16)	(4.91)	(6.19)	(0.04)
Cognates, last	1.26	1.2	1.16	6.08	6.08	6.08	5.54	7.5	7.38	0.83
	(0.59)	(0.41)	(0.41)	(1.35)	(1.35)	(1.35)	(6.39)	(4.60)	(6.48)	(0.04)
Non-cognates	1.08	1.15	1.14	6.52	6.31	6.32	4.75	9.04	9.83	0.2
	(0.50)	(0.54)	(0.54)	(1.50)	(1.81)	(1.82)	(3.84)	(9.68)	(10.02)	(0.14)

For cognate conditions, the position of the deviant letter is indicated after the comma. The range of values per variable is indicated below the variable name. Trans., Translation condition; Unrel, Unrelated condition; T, Target; P, Prime.

(Levenshtein, 1966; Schepens et al., 2012), was the same among cognate conditions, $F_{(4,119)} = 0.64$, $p = 0.64$, but different between cognate and non-cognate conditions (0.84 and 0.20, respectively, $t = 47.94$). Finally, given that orthotactical markers (the sublexical properties of words, which are specific to one of the two languages of an bilingual) reduce cross-linguistic transfer (Sebastián-Gallés et al., 2006; Casaponsa et al., 2019), in this study, this factor was controlled as much as possible across conditions.

On the other hand, we selected 240 Catalan words to create the unrelated prime conditions. Each of these words was of the same length and approximately the same frequency as the Catalan prime it replaced (e.g., *canal* [channel], and was selected as an unrelated prime for the pair *ploma-pluma* [feather]). Hence, the primes for translation and unrelated conditions were equivalent in log frequency and word length (all *ps* > 0.59). Finally, a set of 240 orthographically non-legal words were created by replacing one letter from cognate and non-cognate Spanish words (e.g., the non-word *birro* was created from the non-cognate word *barro* [mud], whereas the non-word *tero* was created from the cognate word *cero*, "zero"). Word length was matched as much as possible between non-word targets ($M = 6.7$) and word targets ($M = 6.44$), $t < 1.7$. Each non-word target was preceded by a Catalan word prime. Half of these primes were the Catalan translation of the Spanish word that was used to create the non-word (e.g., *fang*, which is the translation of the Spanish word *barro*, served as prime for the non-word *birro*). The other half were unrelated primes of the same length and frequency like the related primes. This was done to maintain a similar orthographic overlap between primes and targets in non-word conditions as that used in word conditions. Finally, we constructed two counterbalanced lists of stimuli so that the 240 target words appeared under the two priming conditions (translation or unrelated) across participants, but the participants did not see any prime or target more than once. That is, if a target was presented with its translation prime on the first list, it was presented with its unrelated prime on the second list and *vice versa*.

Procedure

The experiment was run using the DMDX software (Forster and Forster, 2003). All participants completed a lexical decision task. Each trial consisted of the following steps. Firstly, a forward mask (e.g., "##########") with the same length as the longest word of the prime-target pair was presented (i.e., 10 characters). The mask remained on the center of the screen for 500 ms, and was then replaced by the prime stimulus. The prime was presented for 50 ms in lowercase and was replaced with an uppercase target, which was a string of letters representing either a word or non-word. At that point, participants had to decide whether the target was a Spanish word or not by pressing one of the two buttons of a keypad as a fast and possible attempt not to commit errors. The string of letters remained on the screen until the response of participants or a timeout of 2,500 ms. After that, a new trial was displayed to be preceded by a 1,000 ms interval. Each participant was presented with a different random order of stimuli. There were 480 experimental trials and 12 practice trials. Experimental trials were divided into four blocks. Between the blocks, participants were allowed to take a short break.

Results and Discussion

We removed the data from the four participants with more than 15% of the errors (two participants in each list). Thus, the final sample was 36 participants. In addition, reaction times that exceeded 2 SD of the mean of each participant and those faster than 300 ms or slower than 2,000 ms were removed (6.3% of the whole). Then, we calculated the mean of response times (RTs)

TABLE 3 | Mean response times (RTs; in milliseconds) and percentage of errors (% E) in the different experimental conditions of Experiment 1a.

	Translation		Unrelated		Priming effects	
	RT	%E	RT	%E	RT	%E
Cognates, initial	765.90 (19.65)	8.23 (1.8)	811.31 (20.46)	9.92 (1.5)	45.41	1.69
Cognates, second	736.10 (18.46)	4.34 (0.94)	770.90 (17.41)	6.190 (1.54)	34.80	1.85
Cognates, middle	733.96 (15.35)	5.12 (1.01)	788.15 (17.03)	12.52 (1.84)	54.19	7.40
Cognates, penultimate	708.87 (17.83)	4.05 (1.26)	772.11 (15.01)	4.06 (1.09)	63.24	0.01
Cognates, last	735.86 (16.43)	9.37 (2.21)	769.26 (16.34)	11.55 (2.09)	33.40	2.18
Non-cognates	753.27 (14.12)	4.71 (0.64)	767.26 (15.91)	5.23 (0.91)	13.99	0.52

Standard errors are presented in parentheses.

for the correct responses and the mean of error rates (%E) across experimental conditions (see **Table 3**). Both RTs and %E were analyzed using ANOVAs[2]. Alpha was set to 0.05 for all analyses, and multiple comparisons were Bonferroni corrected. Two analyses were carried out: The first one examined the cognate status effect (i.e., if there were differences between cognates and non-cognates as well as if masked priming effects were greater for the former ones, as typically observed in the literature). The second one, restricted to cognate words, examined the critical question at stake (i.e., if the priming effect size was modulated by the position of the deviant letter).

Cognate Status

In the first ANOVA, target words were analyzed using a cognate status (cognate or non-cognate) × prime relatedness (translation or unrelated) × list of stimuli (list 1 or 2) design. In the analysis by participants, cognate status and prime relatedness were a within-group factor, and list of stimuli was included as a between-group factor. In the analysis by items, prime relatedness and list of stimuli were included as a within-group factor, whereas cognate status was a between-group factor. Only the analyses that were significant by subjects and items are reported.

ANOVA showed a main effect of prime relatedness as translation primes (mean RTs = 745 ms; mean %E = 5.45%) facilitated word recognition in comparison to unrelated primes (mean RTs = 775 ms, mean %E = 7.04%) in latency data, $F_{1(1,35)} = 42.42$, MSE = 32,620, $p < 0.001$, $\eta^2_{\mathrm{p}} = 0.55$, $F_{2(1,238)} = 46.45$, MSE = 122,438, $p < 0.001$, ${\eta_p}^2 = 0.16$, and in error data, $F_{1(1,35)} = 8.88$, MSE = 89.02, $p = 0.005$, ${\eta_p}^2 = 0.20$, $F_{2(1,238)} = 7.90$, MSE = 300.68, $p = 0.005$, ${\eta_p}^2 = 0.03$. In addition, a significant effect of cognate status appeared in error data, $F_{1(1,35)} = 30.2$, MSE = 237.52, $p < 0.001$, ${\eta_p}^2 = 0.46$, $F_{2(1,238)} = 4.03$, MSE = 757.27, $p = 0.046$, ${\eta_p}^2 = 0.02$, but not in latency data (both ps > 0.77, mean RTs for cognates = 759 ms, mean RTs for non-cognates = 760 ms), indicating that cognate words were recognized less accurately (M = 7.53%) compared to non-cognate words (M = 4.97%). This inhibitory effect for cognate over non-cognate words usually appear when identical cognates are not included in the experimental list, as it was the case here [see Comesaña et al. (2015) for an overview of list composition effects in cognate processing; also Comesaña et al. (2012) for converging electrophysiological evidence]. Furthermore, the analysis of the latency data revealed an interaction between prime relatedness and cognate status, $F_{1(1,35)} = 14.60$, MSE = 9,349, $p = 0.001$, ${\eta_p}^2 = 0.29$, $F_{2(1,238)} = 16.93$, MSE = 44,638, $p < 0.001$, ${\eta_p}^2 = 0.07$. Although there was a significant priming effect (i.e., the difference between unrelated and translation conditions) for both cognates and non-cognates (all ps < 0.05), the effect was significantly larger for the former in comparison to the latter, as expected (46.22 and 13.99 ms, respectively), $t_{1(35)} = 3.82$, $p = 0.001$, $t_{2(238)} = 4.12$, $p < 0.001$.

Deviant Letter Position

In the second ANOVA, only cognate target words were analyzed using a deviant letter position (initial, second, middle, penultimate, or last) × prime relatedness (translation or unrelated) × list of stimuli (lists 1 or 2) design. In the analysis by participants, deviant letter position and prime relatedness were treated as within-group factors, whereas list of stimuli was included as a between-group factor. In the analysis by items, prime relatedness and list of stimuli were included as within-group factors, and deviant letter position was treated as a between-group factor. The results revealed a main effect of prime relatedness in latency data as translation primes (mean RTs = 736 ms, mean %E = 6.22%) facilitated word recognition with respect to unrelated primes (mean RTs = 782 ms, mean %E = 8.85%), $F_{1(1,35)} = 58.15$, MSE = 192,240, $p < 0.001$, ${\eta_p}^2 = 0.62$, $F_{2(1,234)} = 63.15$, MSE = 166,741, $p < 0.001$, ${\eta_p}^2 = 0.21$, and in error data, $F_{1(1,35)} = 8.10$, MSE = 619.11, $p = 0.007$, ${\eta_p}^2 = 0.19$, $F_{2(1,234)} = 11.56$, MSE = 431.81, $p = 0.001$, ${\eta_p}^2 = 0.05$.

The main effect of deviant letter position was significant in the analysis of error data, $F_{1(4,140)} = 11.97$, MSE = 536.56, $p < 0.001$, ${\eta_p}^2 = 0.26$, $F_{2(5,234)} = 2.34$, MSE = 433.11, $p = 0.043$, ${\eta_p}^2 = 0.05$. Cognate words with the deviant letter in the first and last position had a higher percentage of errors (9.08 and 10.46%, respectively) in comparison with cognates whose deviant letter position was within the word (second and penultimate: 5.27 and 4.06%, respectively, all ps < 0.05). No significant differences were found between cognate words with the deviant letter in the first and last position as well as between cognate words with the deviant letter in the second and penultimate position (all ps > 0.05). In addition, cognates with the deviant letter

[2]In addition to ANOVAs, we also analyzed the data of the four experiments by means of linear mixed-effects models. The results followed the same pattern like ANOVAs. The data and scripts used for the linear mixed-effect analyses are available in the following link: https://osf.io/mqhu5/?view_only=94cdf0d86e0b4e7e8b2757e33f6a78ce.

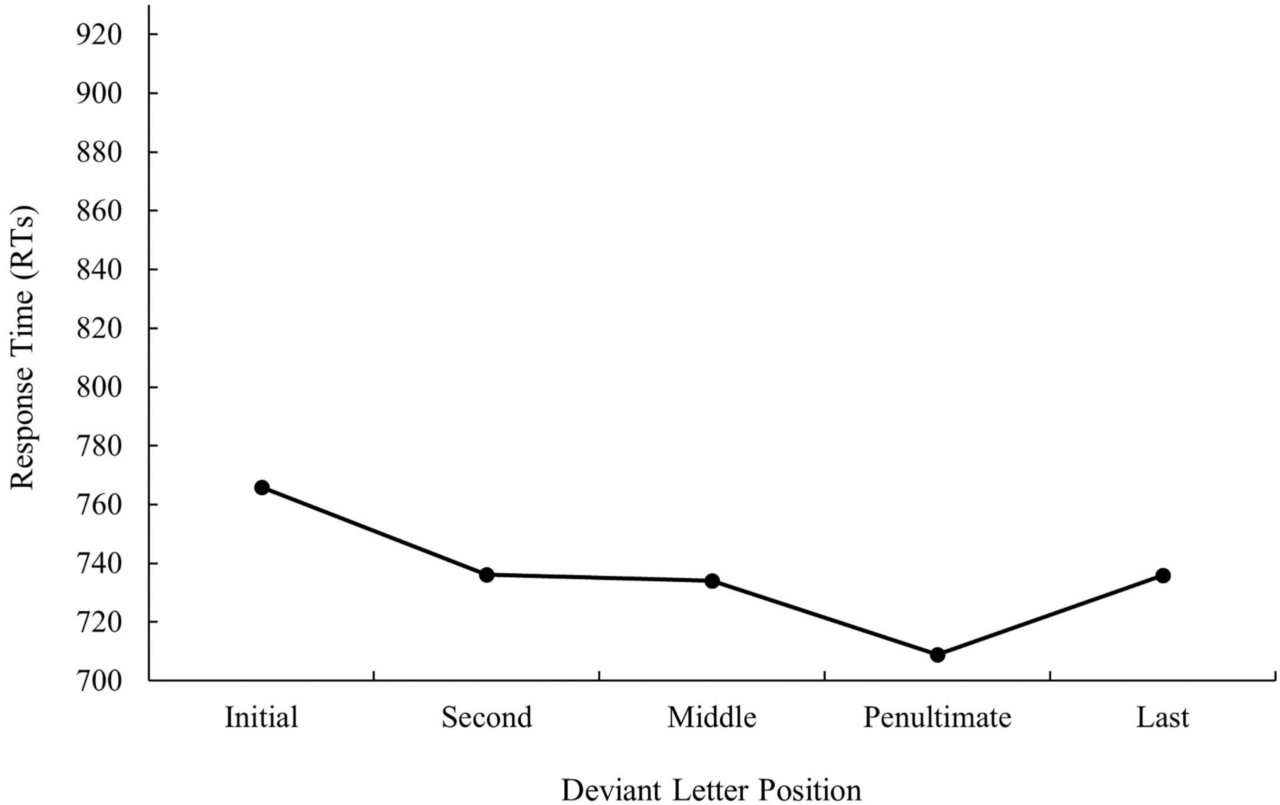

FIGURE 1 | Mean response times (RTs; in ms) for cognate words in the related condition according to its deviant letter position in Experiment 1a.

in the penultimate place were more accurately recognized than cognates whose deviant letter was in the middle (4.06 and 8.82%, respectively, $p < 0.05$). The graphical representation of deviant letter position in the translation condition on RTs and % of errors is shown in **Figures 1**, **2**, respectively.

That is, when considering the main effect of deviant letter position, cognate words in which external and middle letters were the deviant, produced less precise responses in comparison to internal letters regardless of prime type, showing the W-shaped function observed in the monolingual domain with a target search task (see, for instance, Mason, 1982) or the bare-probe identification procedure (i.e., when a target letter presented previously within a letter string has to be identified after the presentation of a bare-probe signaling the position of report; see Tydgat and Grainger, 2009). However, the interaction effect between deviant letter position and prime relatedness was not significant either in latency or in error data (all *p*s > 0.1), and hence no differences on the priming effect size regarding the position of the deviant letter were observed.

The null effect of deviant letter position on the magnitude of priming is consistent with the findings found in the study of Comesaña et al. (2018) with EP-English bilinguals. Note that we followed a similar procedure in the selection of materials as that followed by Comesaña et al. (2018) (i.e., cognate words from different conditions were carefully matched for a number of important sublexical and lexical variables that affect processing). Besides, although in the monolingual domain, there are some studies showing modulations in priming effects as a function of deviant letter position when the prime is visible (see Perea, 1998), these effects are usually small and difficult to obtain when the prime is brief (50 ms) and masked, as pointed out by Gómez et al. (2008, p. 21). The usage of a more perceptual task, such as the 2AFCT, may be therefore more informative. In this task, the differences in accuracy among experimental conditions are usually large and graded and thus easily measurable. Indeed, flexible input-coding schemes such as the overlap model were originally applied to data from perceptual tasks like the 2AFCT with the manipulations of letter replacements and letter transpositions (see Gómez et al., 2008). Therefore, the aim of the second experiment was to further examine letter position coding during cognate word recognition through the use of a 2AFCT.

However, before presenting the 2AFCT experiment and establishing firm conclusions, it is important to examine the contribution of meaning overlap in the results found in Experiment 1a (note that the words used were translation equivalents, and hence they shared the meaning besides the form). The overlap in meaning across cognate conditions may have attenuated the differences attributed to deviant letter position in the masked priming effect. Experiment 1b was precisely designed to explore this issue through the replication

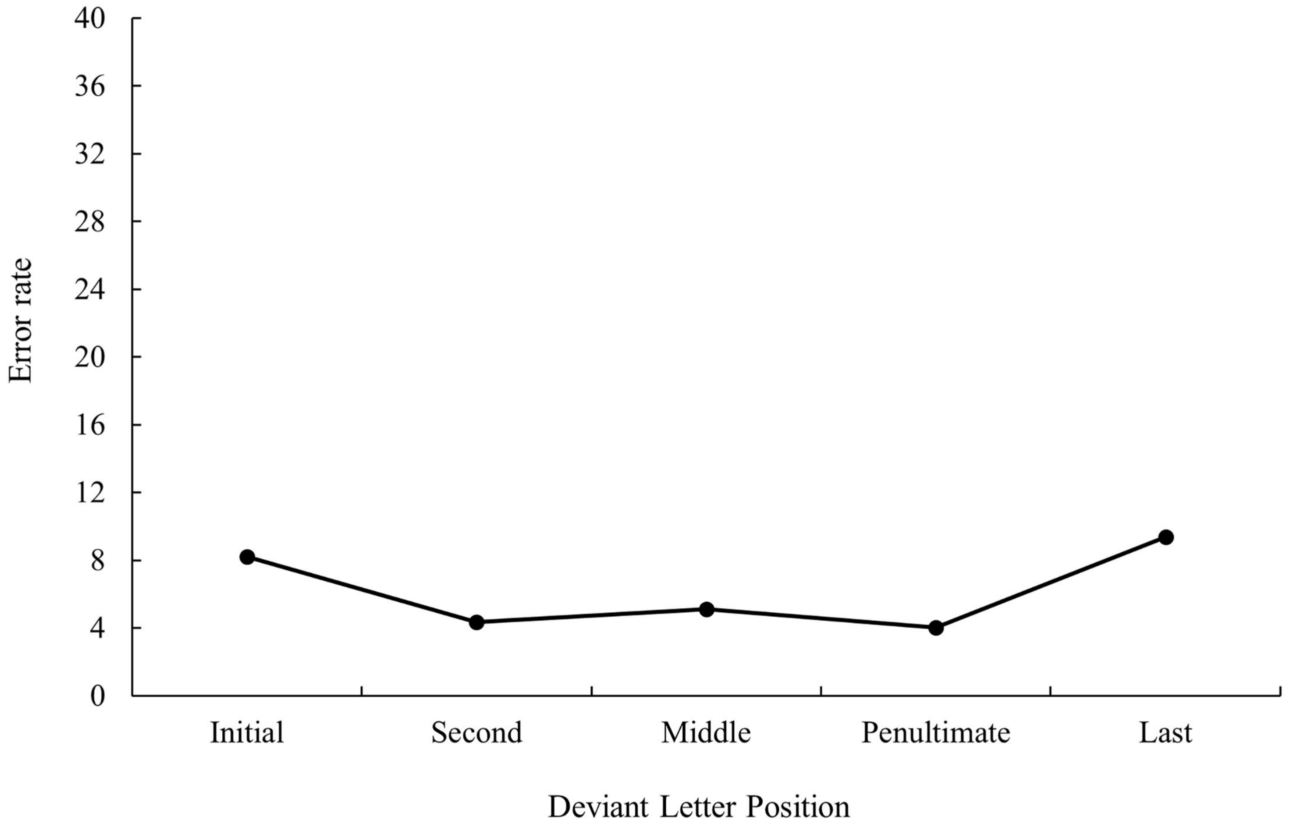

FIGURE 2 | Mean error rate (in percentage) for cognate words in the related condition according to its deviant letter position in Experiment 1a.

of Experiment 1a with a control group of native speakers of Spanish with no knowledge of Catalan. In this way, we canceled the influence of meaning overlap between prime and target pairs as the primes for monolinguals were non-words. We expected to find a similar pattern of results with cognate words as that observed with Catalan–Spanish bilinguals if meaning overlap was not affecting the findings. Additionally, this experiment allowed us to rule out the possible influence of artifacts in the materials. If they are well-constructed, priming effects would be restricted to cognate words due to the presence of form overlap between the prime and target, and would not be observed with non-cognates (see, for instance, Forster, 1987; also Perea and Lupker, 2003, for more details on masked form priming).

EXPERIMENT 1B

Method

Participants

About 32 native speakers of Spanish (26 women and 6 men, mean age 22.84 years, SD = 3.47) participated in the experiment in exchange for academic credits. They were undergraduate students from the University of Granada (Granada, Spain). Participants were asked to fill in a questionnaire similar to that of Experiment 1, in which they had to rate their ability in several languages (i.e., Spanish, English, French, and Catalan) in listening, speaking, reading, and writing by using a seven-point Likert scale (1 = "very poor" in the assessed skill, 7 = "native"). According to the ratings of the questionnaire, none of the participants had knowledge of Catalan. Fluency of participants in Spanish is reported in **Table 1**.

Materials and Procedure

The same set of materials and procedure as in Experiment 1a were used in this experiment.

Results and Discussion

None of the participants were removed from the analyses based on their error rate (all participants made <15% of the errors). As mentioned in Experiment 1a, RTs that exceeded 2 SD of the mean of each participant and those faster than 300 ms or slower than 2,000 ms were removed (<6% of the whole). Then, we calculated the mean RTs for the correct responses and the mean %E across experimental conditions (see **Table 4**). We conducted the same analyses as in Experiment 1a.

Cognate Status

Latency data analyses showed a main effect of prime relatedness as targets preceded by related primes were recognized faster (751 ms) than targets preceded by control unrelated primes (776 ms), $F_{1(1,31)} = 30.82$, MSE = 19,227, $p < 0.001$, $\eta_p{}^2 =$

TABLE 4 | Mean response times (RTs; in milliseconds) and percentage of errors (% E) in the different experimental conditions of Experiment 1b.

	Translation		Unrelated		Priming Effects	
	RT	%E	RT	%E	RT	%E
Cognates, initial	783.72 (31.11)	6.39 (1.26)	812.34 (29.59)	6.13 (1.71)	28.62	–0.26
Cognates, second	756.69 (27.63)	2.34 (0.86)	775.22 (28.20)	3.14 (0.90)	18.53	0.80
Cognates, middle	741.29 (24.50)	6.01 (1.41)	772.86 (25.73)	6.94 (1.41)	31.57	0.93
Cognates, penultimate	723.47 (24.45)	1.09 (0.52)	780.25 (28.58)	2.98 (1.09)	56.78	1.89
Cognates, last	727.96 (24.87)	7.95 (2.26)	772.10 (25.01)	5.67 (1.47)	44.14	–2.28
Non-cognates	755.69 (24.05)	3.02 (0.49)	768.79 (25.72)	4.12 (0.66)	13.10	1.10

Standard errors are presented in parentheses.

0.50, $F_{2(1,238)} = 35.62$, MSE = 79,242, $p < 0.001$, $\eta_p{}^2 = 0.13$. As expected, the main effect of cognate status was not significant either in RTs or in %*E* (all *p*s > 0.05). In addition, as suggested by the interaction between prime relatedness and cognate status on latency data, $F_{1(1,31)} = 6.56$, MSE = 4,169, $p = 0.02$, $\eta_p{}^2 = 0.18$, $F_{2(1,238)} = 10.89$, MSE = 24,233, $p = 0.001$, $\eta_p{}^2 = 0.04$, such relatedness effect was observed only for cognates (all *p*s < 0.05). No other significant main effects or interactions were found either for RTs or for %*E*.

Deviant Letter Position

ANOVA showed a main effect of prime relatedness in latency data as targets preceded by translation primes were recognized faster than targets preceded by unrelated primes (747 and 783 ms, respectively), $F_{1(1,31)} = 30.48$, MSE = 103,260, $p < 0.001$, $\eta_p{}^2 = 0.50$, $F_{2(1,115)} = 38.57$, MSE = 95,559, $p < 0.001$, $\eta_p{}^2 = 0.25$ (the effect was not significant in the analysis of error data; all *p*s > 0.05). Although the main effect of deviant letter position was not significant either in the analysis of latency data or in the analysis of error data, the pattern was very similar to that of bilingual participants from Experiment 1a, as can be seen in **Figures 3**, **4** (for latency and error data, respectively). Its non-significance may be due to the low number of subjects in comparison with those from Experiment 1a along with the high variability observed. Indeed, on analyzing the data for monolinguals and bilinguals within the same model, the effect disappears[3].

As presented in Experiment 1a, there were no modulations in masked priming effects as a function of deviant letter position, either in the latency or in error data (all $p > 0.05$).

The results of this subexperiment were clear-cut: priming effects in the native speakers of Spanish who had no knowledge of Catalan were essential due to a form overlap between the prime and target (as no effect was observed for non-cognates) and were not modulated by deviant letter position. Indeed, the pattern of results was similar to that observed in Experiment 1a with bilinguals. This allowed us to rule out the existence of artifacts in the materials.

The most relevant result of Experiment 1 was the replication of the null effect of deviant letter position in masked priming (Comesaña et al., 2018). Although the absence of interaction between the two factors does not legitimate us to do planned comparisons across conditions, it is important to note that in both populations (monolinguals and bilinguals), the size of masked priming tended to be greater for cognates varying in the middle letter. In addition, the magnitude of the effect was very similar in bilinguals and monolinguals (55 and 56 ms, respectively). Besides, when considering the main effect of deviant letter position, both groups of participants showed a W-shaped function (although it was only significant for the bilingual group; see **Figures 1–4**). Overall, the cognates that differ in their first letter were slower and less precisely recognized than the other cognate conditions regardless of the prime type. This could be possible due to the existence of similar mechanisms underlying the way in which letter position is coded in L1 and L2. We recognize, however, that we should be cautious with this interpretation due to the absence of modulations in the size of priming across conditions, and hence a second experiment was needed. We decided to carry out a more perceptual task: the 2AFCT in which a cue word (e.g., *cerveza* [beer]) was briefly presented (50 ms) and followed by the same word (*cerveza*) and its Catalan translation (*cervesa*). Participants had to guess which of the two words was presented previously. We opted for this task not only because it seems to be more informative than the masked priming lexical decision task (note that the differences in accuracy among experimental conditions are usually large and graded and thus easily measurable; see Gómez et al., 2008), but also because, in this way, we could assess whether the results were modulated by task requirements using the same prime duration across tasks (50 ms).

EXPERIMENT 2A

The aim of this second experiment was to further examine the way of coding letter position in bilingual word recognition by using a more perceptual task, i.e., a 2AFCT (participants had to guess between the two target alternatives, the one was previously presented for 50 ms). The predictions were as follows: if internal

[3]We initially analyzed the data for monolinguals and bilinguals within the same model. The results barely differ from the separate analysis. However, there are some subtle differences between the pattern of results from the two groups, which complicate the presentation, reading, and interpretation of the results when the data from both groups are presented in the same model. This is mainly due to the presence of second- and third -order interactions, which can be somewhat difficult to interpret. Therefore, for the sake of clarity, we have decided to present the results individually for each language group.

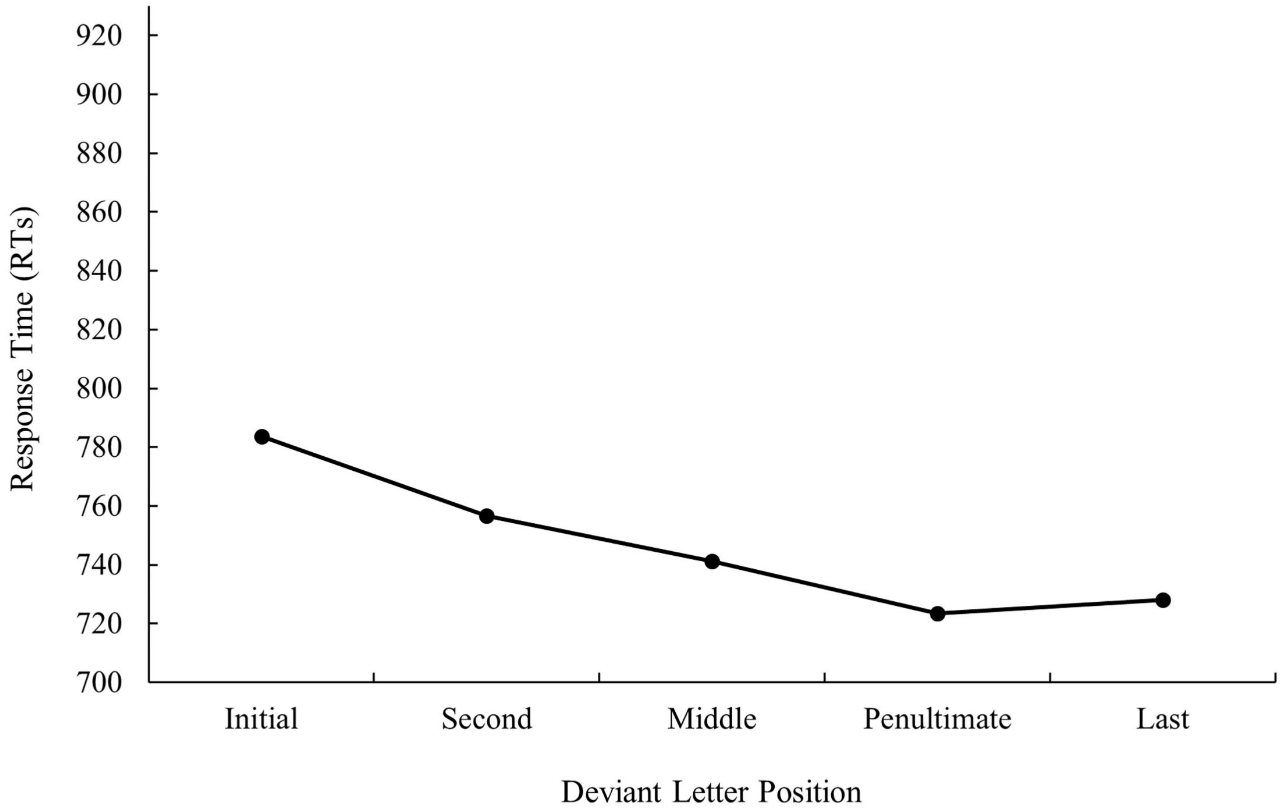

FIGURE 3 | Mean response times (RTs; in ms) for cognate words in the translation condition according to its deviant letter position in Experiment 1b.

letters have a higher perceptual noise than external and middle ones and, as a consequence, a higher confusability, the pattern of results would be just the opposite as that observed using the masked priming lexical decision task (i.e., an inverted W-shaped function). This is because, whereas in the masked priming technique, the higher the similarity between the two strings (prime-target), the higher the activation of the target, and hence the faster the responses, in the 2AFC task the higher the similarity of the two alternatives, the slower the responses as it is difficult to distinguish between the two very similar alternatives. That is, cognates varying in internal letters exhibit slower responses and more errors than those varying in external and middle letters. Although, it is worth noting here that as we used a cue duration lower than 60 ms, and the differences between cognate conditions may reach significance only when considering the first-letter condition (see Gómez et al., 2008).

Method

Participants

About 40 undergraduate students (39 women and 1 men, mean age 21.03 years, SD = 3.76) from the Universitat Rovira i Virgili (Tarragona, Spain) participated in the experiment in exchange for academic credits (all of them signed an informed consent). These participants were very similar to those who participated in Experiment 1, all of them being highly proficient Catalan–Spanish bilinguals. None of the participants in Experiment 2a took part in Experiment 1a. To assess their proficiency in both languages, as well as their frequency of use and preference for each language, participants were asked to complete the same questionnaire as that used in Experiment 1a (see **Table 5**). The mean questionnaire ratings of preference and frequency showed that Catalan was the dominant language of the participants: preference (M = 3.30, SD = 0.72, range = 1–4) and frequency (M = 3.42, SD = 0.63, range = 2–4.75). Bearing in mind that four is the middle point the seven-point Likert scale, which indicates a total equality in the preference and usage both languages (1 = "Only in Catalan" and 7 = "Only in Spanish").

Materials

The 240 Catalan–Spanish translation pairs similar to those in Experiments 1a and 1b were used in this experiment.

Procedure

The experiment was run using the DMDX software (Forster and Forster, 2003). Participants completed a 2AFC task similar to that used by Gómez et al. (2008). Each trial began with a fixation point ("+") displayed at the center of the screen for 500 ms. After that, a word in uppercase letters (hereafter cue word) was presented for 50 ms. It was one of the two members of the critical

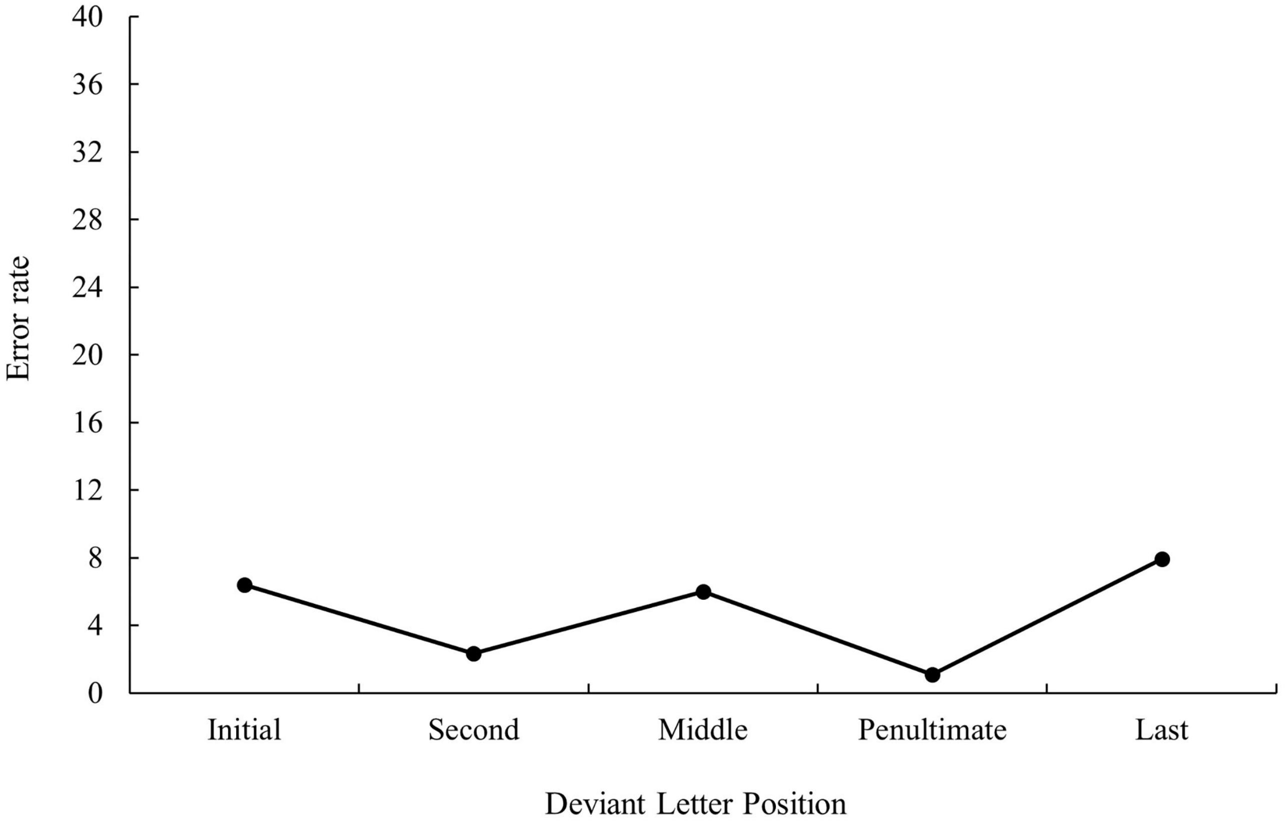

FIGURE 4 | Mean error rate (in percentage) for cognate words in the related condition according to its deviant letter position in Experiment 1b.

TABLE 5 | Mean level of proficiency in the four linguistic skills in Catalan and Spanish (standard deviation in parentheses) of the participants of Experiment 2a and Experiment 2b.

	Experiment 2a		**Experiment 2b**
	Catalan	**Spanish**	**Spanish**
Skills	**Mean (*SD*)**	**Mean (*SD*)**	**Mean (*SD*)**
Listening	6.95 (0.22)	6.92 (0.32)	6.69 (0.59)
Speaking	6.92 (0.35)	6.92 (0.30)	6.34 (0.87)
Reading	6.92 (0.35)	6.91 (0.34)	6.63 (0.61)
Writing	6.85 (0.43)	6.92 (0.31)	6.22 (0.75)
Average	6.91 (0.34)	6.92 (0.32)	6.47 (0.70)

The anchor points for the 7-point Likert scale were 1 = "very poor," and 7 = "native."

pairs (i.e., either the Catalan word, *cervesa*, or the Spanish word, *cerveza* [beer]). The cue word was immediately masked with segments of letters. Then, the two words in lowercase letters appeared simultaneously below the mask, one to its right and another to its left. These words were the masked (cue) word and its translation (e.g., *cervesa-cerveza*). Participants had to decide which of the two words was presented before the mask (i.e., which was the cue word). They were instructed to press the right button of a keypad if the target word was the one that is located on the right, and to press the left button if it was the one that is located on the left. After response or timeout (3,000 ms), the next trial started automatically. We constructed four different versions of the experiment to counterbalance the language of the cue (i.e., Catalan or Spanish) and its position (i.e., left or right) across participants. Therefore, each participant saw each cue only once. There were 240 experimental trials and 12 practice trials. Experimental trials were divided into three blocks. Between blocks, participants could take a short break.

TABLE 6 | Mean response times (RTs; in milliseconds) and percentage of errors (% E) in the different experimental conditions of Experiment 2a.

	Catalan cue		Spanish cue		Total	
	RT	%E	RT	%E	RT	%E
Cognates, initial	815.35 (22.30)	16.18 (1.85)	791.25 (24.59)	16.29 (2.60)	803.3 (23.40)	16.23 (2.24)
Cognates, second	901.02 (28.38)	30.45 (2.26)	888.08 (24.43)	31.25 (2.52)	894.55 (26.32)	30.85 (2.38)
Cognates, middle	888.12 (26.97)	25.40 (2.43)	864.59 (21.95)	24.17 (2.53)	876.35 (24.50)	24.78 (2.46)
Cognates, penultimate	935.81 (30.39)	46.75 (3.21)	877.98 (23.71)	26.90 (2.06)	906.89 (27.49)	36.82 (3.14)
Cognates, last	903.62 (25.34)	24.79 (2.71)	868.90 (25.82)	26.81 (2.8)	886.26 (25.57)	25.80 (2.74)
Non-cognates	742.69 (19.56)	8.09 (1.12)	720.18 (18.38)	6.69 (1.15)	731.43 (18.94)	7.39 (1.13)

Standard errors are presented in parentheses.

Results and Discussion

The data from the three participants having more than 30% of the errors (each from a different version of the experiment) were discarded from analyses. In addition, RTs faster than 250 ms or slower than 1,600 ms were removed (<4% of the whole). Then, we calculated the mean RTs for the correct responses and the mean of %E across experimental conditions (see **Table 6**).

Data were analyzed using ANOVAs. Alpha was set to 0.05 for all analyses, and multiple comparisons were Bonferroni corrected. As in Experiment 1, two analyses were conducted: The first one examined the cognate status effect (i.e., if there were differences between cognates and non-cognates). The second one was restricted to cognate words and examined the critical question at stake (i.e., if cognate words with an internal deviant letter are worse recognized than cognates with the external or middle deviant letter, especially the first letter, revealing an inverted W-shaped function typically observed in the monolingual domain).

Cognate Status

In the first analysis, target words were analyzed using a cognate status (cognate or non-cognate) × language cue (Catalan or Spanish) design. In the analysis by participants, both factors were treated as a within-group factor, whereas in the analysis by items, language cue was treated as a within-group factor and cognate status was included as a between-group factor. ANOVA showed a main effect of cognate status: participants took longer time and committed more errors in discriminating cognates (mean RTs = 868 ms, mean %E = 26.90%) than non-cognates (mean RTs = 731 ms, mean %E = 7.39%), $F_{1(1,36)} = 144.12$, MSE = 690,675, $p < 0.001$, $\eta_p{}^2 = 0.80$, $F_{2(1,478)} = 269.64$, MSE = 4,701,425, $p < 0.001$, $\eta_p{}^2 = 0.36$, and $F_{1(1,36)} = 369.93$, MSE = 14,079, $p < 0.001$, $\eta_p{}^2 = 0.91$, $F_{2(1,478)} = 310.14$, MSE = 92,550, $p < 0.001$, $\eta_p{}^2 = 0.40$, for RT and errors, respectively. This result was expected as cognate words share the form, and hence discriminating them is more difficult than discriminating non-cognate words. In addition, a main effect of language cue was found, as Spanish cues (mean RTs = 787 ms, mean %E = 15.88%) were identified fastly and with less errors than Catalan cues (mean RTs = 813 ms, mean %E = 18.40%), $F_{1(1,36)} = 20.57$, MSE = 25,769, $p < 0.001$, $\eta_p{}^2 = 0.36$, $F_{2(1,478)} = 10.60$, MSE = 131,282, $p = 0.001$, $\eta_p{}^2 = 0.02$, and $F_{1(1,36)} = 5.56$, MSE = 235.02, $p = 0.024$, $\eta_p{}^2 = 0.13$, $F_{2(1,478)} = 6.28$, MSE = 1,467, $p =$ 0.013, $\eta_p{}^2 = 0.01$, for RT and errors, respectively. No interaction was observed between cognate status and language (all ps > 0.05).

Although the faster and more precise responses to Spanish cues compared to Catalan cues led to an unexpected result because Spanish was the language labeled as the less preferred one, one plausible explanation comes up. Because Catalan was indeed a preferred language by the participants, Catalan cues may have provided more activation to their Spanish translations than the other way around. Therefore, Spanish words behaved as better competitors hampering the posterior identification of Catalan words.

Deviant Letter Position

In the second analysis, we compared cognate words, which differ in the position of their deviant letter, with a deviant letter position (first, second, middle, penultimate, or last) × language cue (Catalan or Spanish) design. In the analysis by participants, both factors were within-group, whereas in the analysis by items, language cue was treated as a within-group factor and deviant letter position was included as a between-group factor. ANOVA on RTs yielded a main effect of deviant letter position, $F_{1(4,144)} = 11.02$, MSE = 123,154, $p < 0.001$, $\eta_p{}^2 = 0.23$, $F_{2(4,235)} = 9.96$, MSE = 158,700, $p < 0.001$, $\eta_p{}^2 = 0.1$ as cognate words with the deviant letter in the first position were identified faster than the rest of cognate words (all ps < 0.005) (see **Figure 5**).

Similarly, the effect of deviant letter position was also significant in the analysis of error data, $F_{1(4,144)} = 22.02$, MSE = 4,321, $p < 0.001$, $\eta_p{}^2 = 0.38$, $F_{2(4,235)} = 13.22$, MSE = 5,458, $p < 0.001$, $\eta_p{}^2 = 0.78$. Pairwise comparisons showed that cognate words with the deviant letter in the first position were identified more precisely than cognate words in the other four conditions (all ps < 0.05). In addition, the identification of cognate words with the deviant letter in the penultimate position had more errors than cognate words with the deviant letter in any other position (all ps < 0.05; although the comparison between the penultimate and second position was not significant in the analysis by items). As it can be seen from **Figures 5**, **6**, these results showed an expected inverted W-shaped function both in the latency and error data and, therefore, replicate the findings observed in the monolingual domain (see Gómez et al., 2008).

In addition, the results showed a main effect of language cue, both in the latency, $F_{1(1,36)} = 10.67$, MSE = 86,742, $p =$ 0.002, $\eta_p{}^2 = 0.23$, $F_{2(1,235)} = 4.75$, MSE = 76,343, $p = 0.03$,

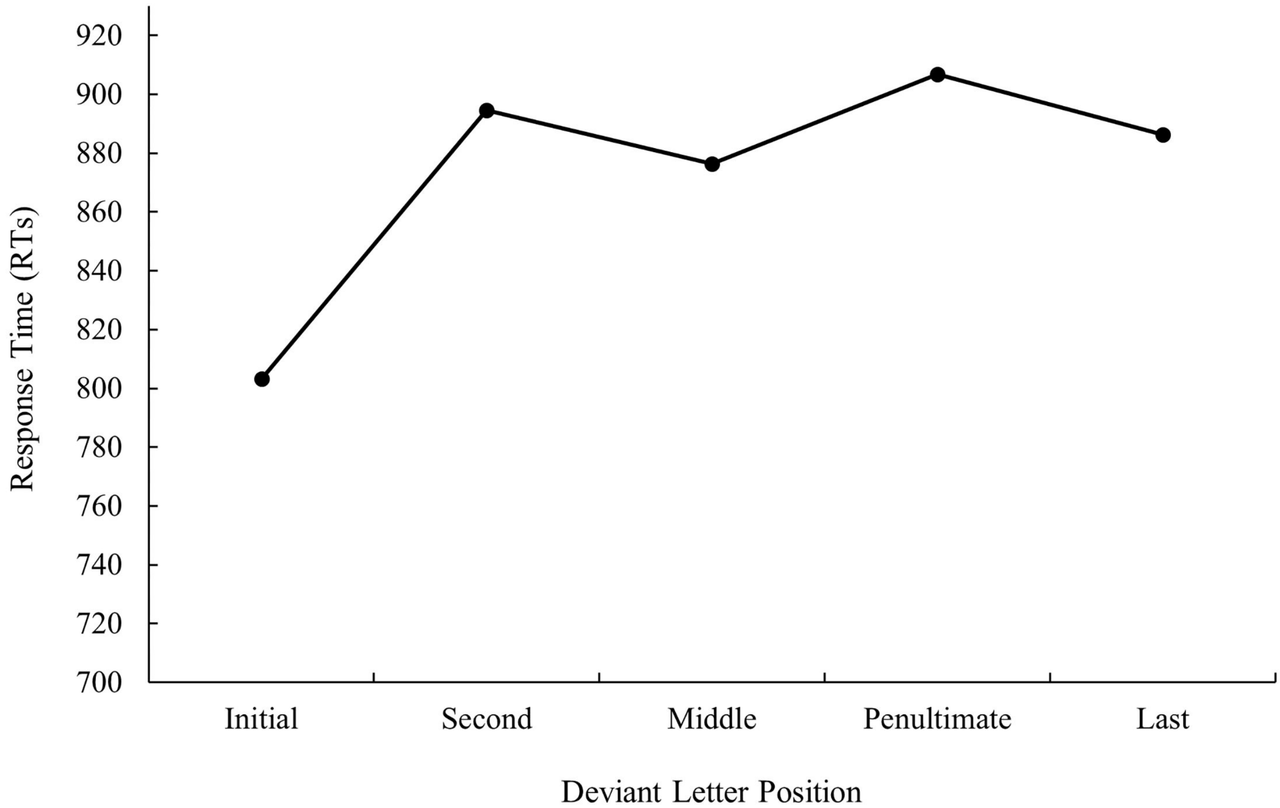

FIGURE 5 | Mean response times (RTs; in ms) for cognate words according to its deviant letter position in Experiment 2a.

$\eta_p{}^2 = 0.02$, and error data, $F_{1(1, 36)} = 3.91$, MSE = 1,219, $p = 0.056$, $\eta_p{}^2 = 0.10$, $F_{2(1, 235)} = 4.26$, MSE = 1,477, $p = 0.04$, $\eta_p{}^2 = 0.02$. Spanish cues (mean RTs = 858 ms, mean %E = 25.08%) were identified faster and with less errors than Catalan cues (mean RTs = 889 ms, mean %E = 28.71%). Furthermore, the interaction between deviant letter position and language cue reached significance in the analysis of error data, $F_{1(4, 144)} = 10.73$, MSE = 1,547, $p < 0.001$, $\eta_p{}^2 = 0.23$, $F_{2(4, 235)} = 5.70$, MSE = 1,979, $p < 0.001$, $\eta_p{}^2 = 0.09$. Pairwise comparisons revealed that cognate words with the deviant letter in the penultimate position showed a different pattern of error rates between languages. Specifically, Catalan cues with the deviant letter in the penultimate position were identified with more errors than cognate words in the other four conditions, whereas Spanish cues with the deviant letter in the penultimate position did not differ in the rest of conditions. Although this result is interesting and potentially reveal a differential processing in the way of coding letter position during the recognition of Catalan and Spanish words by bilinguals, the truth is that the pattern of results was pretty similar in both languages (i.e., an inverted W-shaped function; see **Table 7**). The fact that participants had been faster and more precise when the cue was presented in Spanish, possibly attenuating the differences across conditions. This would indicate that Spanish words worked as better discriminating cues than Catalan words probably because they provide less activation to their Catalan translations as we mentioned before. If this is the case, then a control group of native speakers of Spanish with no knowledge of Catalan should show a more robust effect of deviant letter position when the cues are presented in Catalan. Note that for these participants, the Catalan cues would be non-words, and hence no sign of lexical interference from these cues to Spanish words would be expected. In other words, an activation from non-word cues to words would be higher than the other way around as words never activate non-words. To examine this issue, Experiment 2b was conducted with a group of Spanish monolinguals.

EXPERIMENT 2B

Method

Participants

About 32 native speakers of Spanish (28 women and 4 men, mean age 21.47 years, SD = 2.02) participated in the experiment in exchange for academic credits. None of the participants took part in any of the previous experiments. They were undergraduate students from the University of Granada (Granada, Spain). Participants were asked to fill in a questionnaire similar to that of Experiment 1, in which they had to rate their ability in several languages (i.e., Spanish, English, French, and Catalan) in listening, speaking, reading, and writing by using a seven-point

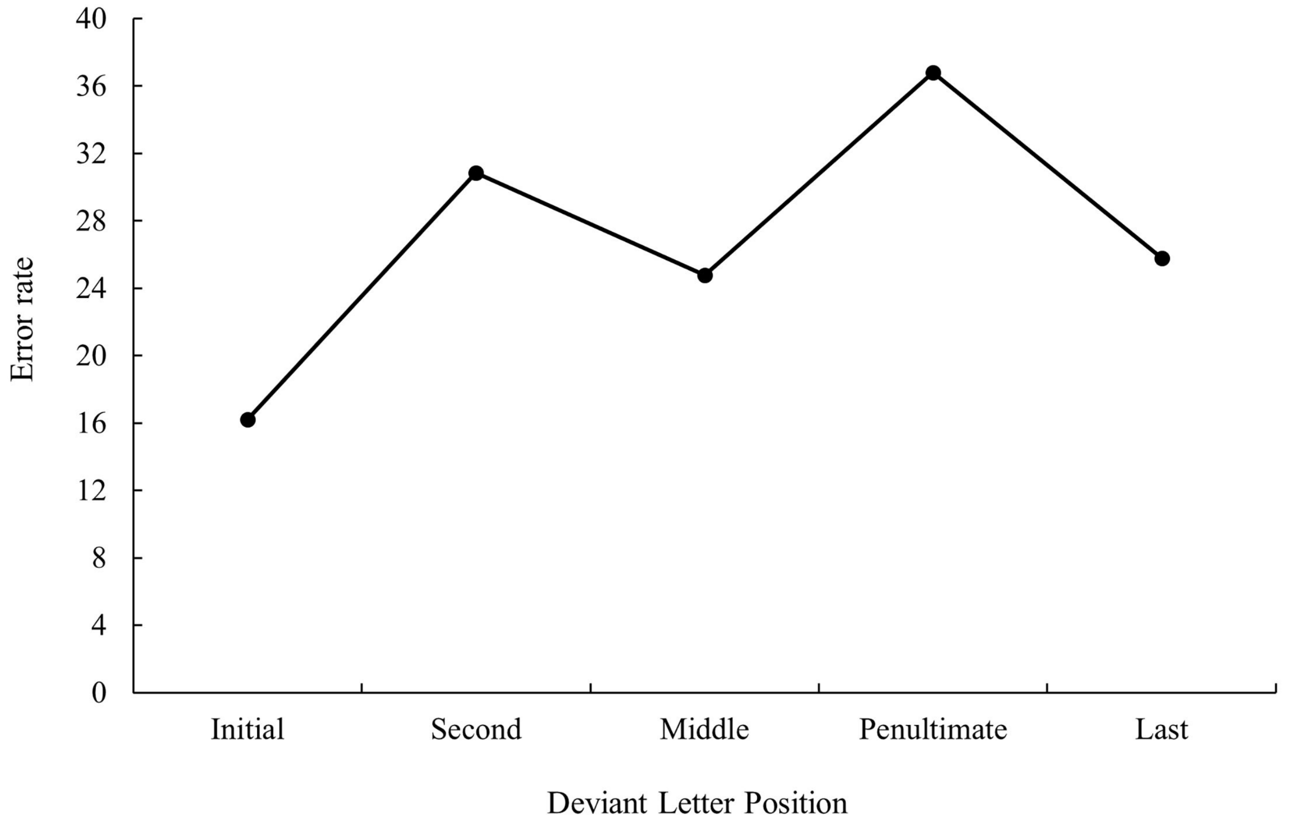

FIGURE 6 | Mean error rate (in percentage) for cognate words according to its deviant letter position in Experiment 2a.

TABLE 7 | Mean response times (RTs; in milliseconds) and percentage of errors (% E) in the different experimental conditions of Experiment 2b.

	Catalan cue		Spanish cue		Total	
	RT	%E	RT	%E	RT	%E
Cognates, initial	841.59 (22.01)	23.66 (2.79)	794.1 (22.26)	16.55 (2.68)	817.84 (22.03)	20.11 (2.75)
Cognates, second	912.89 (29.22)	43.95 (3.44)	881.63 (21.32)	22.99 (2.73)	897.26 (25.08)	33.47 (3.64)
Cognates, middle	892.73 (26.28)	33.44 (4.62)	865.33 (29.50)	19.47 (2.43)	879.03 (27.34)	26.45 (3.84)
Cognates, penultimate	954.02 (41.40)	54.25 (3.85)	862.41 (32.08)	18.40 (2.37)	908.22 (37.13)	36.32 (4.67)
Cognates, last	873.35 (34.04)	30.00 (4.15)	856.92 (28.38)	17.96 (2.74)	865.13 (30.54)	23.98 (3.62)
Non-cognates	786.88 (23.26)	9.94 (1.36)	716.94 (20.03)	5.19 (0.87)	751.91 (22.19)	7.56 (1.20)

Standard errors are presented in parentheses.

Likert scale (1 = "very poor" in the assessed skill, 7 = "native"). According to the ratings of the questionnaire, none of the participants had knowledge of Catalan. The fluency in Spanish of participants is reported in **Table 5**.

Materials and Procedure

The materials and procedure are the same as those used in Experiment 2a.

Results

The data from the four participants with more than 30% of the errors (each from a different experimental version of the experiment) were discarded from analyses. In addition, RTs faster than 250 ms or slower than 1,600 ms were removed (<5% of the whole). Then, we calculated the mean RTs for the correct responses and the mean %E across experimental conditions (see **Table 7**). We conducted the analyses similar to those in Experiment 2a.

Cognate Status

The results showed a main effect of cognate status, indicating that participants took longer and did more errors in identifying cognates (mean RTs = 875 ms; mean %E = 28.07%) than non-cognates due to their form overlap (mean RTs = 752 ms; mean

%$E = 7.56\%$), $F_{1(1,27)} = 278.11$, MSE = 421,479, $p < 0.001$, $\eta_p^2 = 0.91$, $F_{2(1,476)} = 46.15$, MSE = 69,080, $p < 0.001$, $\eta_p^2 = 0.09$, and $F_1(1,27) = 226.28$, MSE = 11,771, $p < 0.001$, $\eta_p^2 = 0.89$, $F_{2(1,478)} = 347.38$, MSE = 99,750, $p < 0.001$, $\eta_p^2 = 0.42$, for RT and errors, respectively. A main effect of language cue was also observed: Spanish cues (mean RTs = 785 ms, mean %E = 12.13%) were identified faster and with less errors than Catalan (and thus non-word) cues (mean RTs = 842 ms, mean %E = 23.5%), $F_{1(1,27)} = 44.27$, MSE = 92,531, $p < 0.001$, $\eta_p^2 = 0.62$, $F_{2(1,476)} = 46.15$, MSE = 690,793, $p < 0.001$, $\eta_p^2 = 0.09$, and $F_{1(1,27)} = 41.11$, MSE = 3,618, $p < 0.001$, $\eta_p^2 = 0.6$, $F_{2(1,478)} = 106.85$, MSE = 29,492, $p < 0.001$, $\eta_p^2 = 0.18$, for RT and errors, respectively, probably because of the effect of lexicality as only Spanish cues were words for these participants. In addition, an interaction between cognate status and language was found in error data, $F_{1(1,27)} = 35.99$, MSE = 1,226, $p < 0.001$, $\eta_p^2 = 0.57$, $F_{2(1,478)} = 32.19$, MSE = 8,885, $p < 0.001$, $\eta_p^2 = 0.06$. This interaction showed that, although the effect of language appeared for cognate and non-cognates, the effect was larger for the former (mean %E = 17.98 and 4.75%, respectively, all ps < 0.05).

Deviant Letter Position

ANOVA on latency data showed a main effect of deviant letter position, $F_{1(4,104)} = 9.11$, MSE = 66,837, $p < 0.001$, $\eta_p^2 = 0.26$, $F_{2(4,233)} = 5.31$, MSE = 111,897, $p < 0.001$, $\eta_p^2 = 0.08$. Translation pairs with the deviant letter in the first position were identified faster than those with the deviant letter in the other positions (all ps < 0.05) (see **Figure 7**).

The effect of deviant letter position was also significant in the analysis of error data, $F_{1(4,108)} = 14.13$, MSE = 2,520, $p < 0.001$, $\eta_p^2 = 0.34$, $F_{2(4,235)} = 10.19$, MSE = 4,081, $p < 0.001$, $\eta_p^2 = 0.15$. Translation pairs with the deviant letter in the penultimate position were identified with more errors than those with the deviant letter in the first, middle, and last position (all ps < 0.05). In addition, translation pairs with the deviant letter in the second position were identified with more errors than those with the deviant letter in the first and last position (all ps < 0.05) (see **Figure 8**).

Finally, a main effect of language cue was found, both in the latency, $F_{1(1,26)} = 13.56$, MSE = 106,672, $p = 0.001$, $\eta_p^2 = 0.34$, $F_{2(1,233)} = 9.91$, MSE = 199,288, $p = 0.002$, $\eta_p^2 = 0.04$, and error data, $F_{1(1,27)} = 43.1$, MSE = 22,640, $p < 0.001$, $\eta_p^2 = 0.61$, $F_{2(1,235)} = 93.85$, MSE = 35,375, $p < 0.001$, $\eta_p^2 = 0.29$. Spanish cues (mean RTs = 852 ms, mean %E = 19.08%) were identified faster and with less errors than Catalan (non-word) cues (mean RTs = 897 ms, mean %E = 37.06%). In addition, and as expected, a significant interaction between deviant letter position and language cue was observed in the analysis of error data, $F_{1(4,108)} = 9.86$, MSE = 1,742, $p < 0.001$, $\eta_p^2 = 0.27$, $F_{2(4,235)} = 7.69$, MSE = 2,900, $p < 0.001$, $\eta_p^2 = 0.12$. The effect of deviant letter position was only found with Catalan (and thus non-word) cues: Stimuli pairs with the deviant letter in the penultimate position were identified with more errors than those with the deviant letter in the first, middle, and last position (all ps < 0.05); in addition, stimuli pairs with the deviant letter in the second position were identified with more errors than those with the deviant letter in the first and last position (all ps < 0.05).

It seems that the effect of deviant letter position is higher when there is less lexical competition. This finding is consistent with that observed by Lin and Lin (2016): the lesser the number of orthographic neighbors is the higher the transposition effect will be (see also the studies by Forster et al., 1987; Perea and Rosa, 2000; Kinoshita et al., 2009, in the monolingual domain).

GENERAL DISCUSSION

The present study was designed to test the input-coding scheme of the multilink model (Dijkstra et al., 2019) by manipulating the deviant letter position of Catalan–Spanish cognate words. The most commonly employed tasks in the study of letter position coding during word recognition were used: The masked priming lexical decision task (Experiments 1a and 1b), and the 2AFCT (Experiments 2a and 2b). For the sake of simplicity, the multilink assumes that the positions of the letters in a word are established very early in processing, and hence no letter position has a special role over the others. The findings of the experiments presented here with Catalan–Spanish bilinguals who refuse this tenet showing that letters occupying the first position are preferentially processed in comparison to letters in any other position (Experiments 1a and 2a) as it occurs with monolinguals during word recognition (Experiment 1b and 2b). Therefore, the mechanism used by bilinguals to code letter position information seems to be similar to that used by monolinguals, at least when the two languages are alphabetic and were acquired early in life (see Yang et al., 2021 for the differences across languages with a different script). The privileged role of the first letter over the others during word recognition is reflected in the most influential (and more flexible) input-coding schemes developed in the monolingual domain, such as the overlap model (Gómez et al., 2008), the SERIOL model (Whitney, 2001), or the SOLAR model (Davis, 1999). Thus, for instance, in the overlap model, the estimated similarity between Catalan–Spanish cognate words that vary in their first-letter positions is lower than the estimated similarity for cognate words whose deviant letter is in any other position (e.g., 1.14 for xifra-cifra [number], 1.57 for llebre-liebre [hare], 1.59 for ploma-pluma [feather], 1.69 for dansa-danza [dance], and 1.70 for rostre-rostro [face]). These values were calculated by considering the parameters reported in Gómez et al. (2008, Experiment 1). Similarly, in the SOLAR model, the estimated similarity between the cognate words that vary in their first-letter position is lower than for the other cognate conditions (e.g., 0.71 for xifra-cifra [number], 0.88 for llebre-liebre [hare], 0.86 for ploma-pluma [feather], 0.86 for dansa-danza [dance], and 0.75 for rostre-rostro [face]). These values were obtained from Colin Davis' Match Calculator application (available at http://www.pc.rhul.ac.uk/staff/c.davis/Utilities/MatchCalc/).

The first-letter advantage observed in bilinguals (especially in Experiment 2 with the 2AFCT) and monolinguals suggests that initial letter is the most informative one regarding word identity. Although *a priori* we could think that these findings reflect an early sequential, beginning-to-end, orthographic processing,

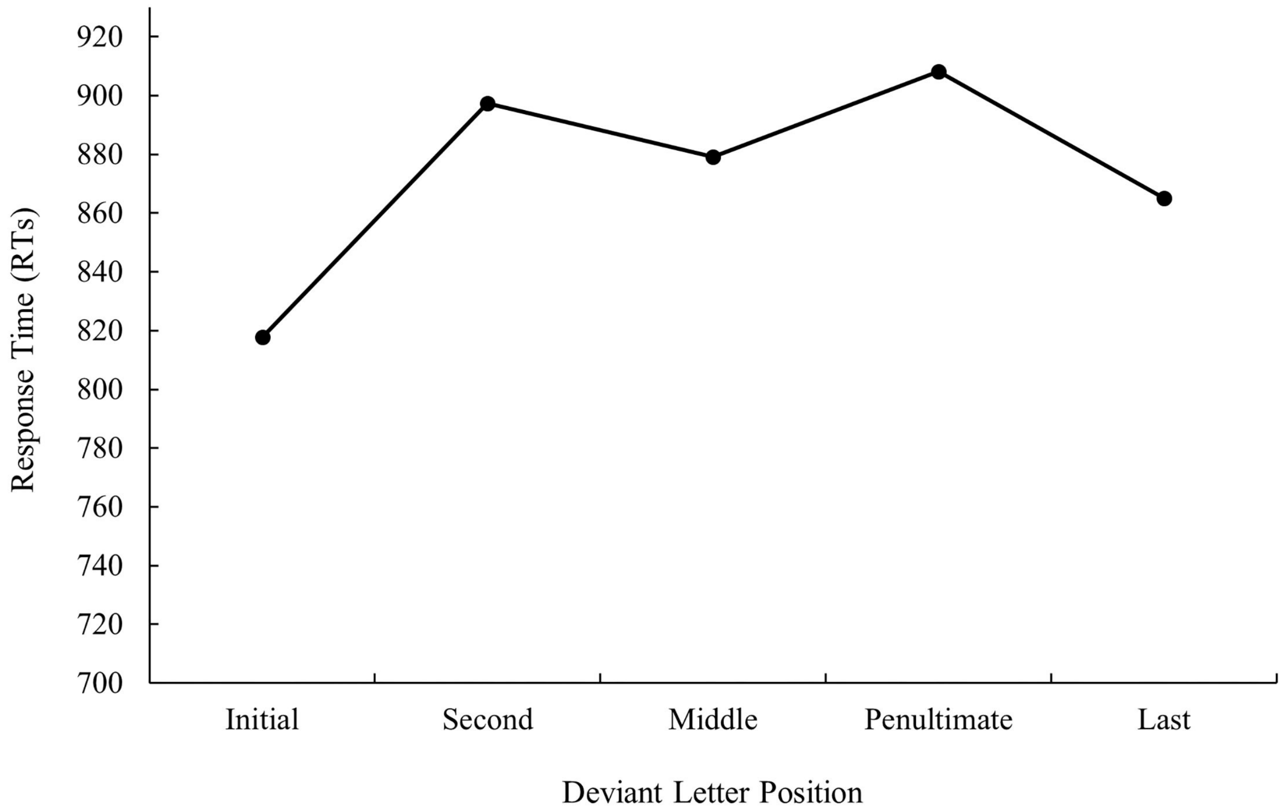

FIGURE 7 | Mean response times (RTs; in ms) for cognate words according to its deviant letter position in Experiment 2b.

a result appears to rule out this hypothesis: The inverted W-shaped function observed in the 2AFCT instead of a linear trend. Indeed, although the differences across cognate conditions have reached a significance on latency and error data only when considering the first-letter word, the absence of a last-letter advantage on latency may have been due to the cue duration used (50 ms). As pointed out by Whitney (2001), whereas studies showing a final-letter advantage involved presentation durations ≥75 ms, those in which a final-letter advantage did not occur involved presentation durations of 50 ms or less. In this field of study, Gómez et al. (2008) also failed to observe the final-letter advantage using a cue duration of 60 ms. The first-letter advantage is, therefore, more robust and can be, as per Tydgat and Grainger (2009), due to the changes in the size and shape of receptive fields (more elongated receptive fields to first-letter detectors). These changes would arise to optimize processing at the first-letter position, at least in Roman alphabetic languages (the languages in which the first-letter advantage was observed). This is because first letters provide more constraints on lexical identity and are also critical for translating an orthographic code into a phonological one (note that correct graphemes can be computed only with precise order information). In addition, Johnson et al. (2007) suggest that the identification of the initial letter but not the other letters of a word may be dependent on the absolute letter position. Whatever be the underlying mechanism responsible for such preferential processing, what is clear is that the input-coding scheme of the multilink model should accommodate these findings as well as other empirical evidence with bilinguals (Witzel et al., 2011; Lin and Lin, 2016; Yang et al., 2021), by assuming either a certain degree of perceptive noise when assigning letters to positions (similar to the overlap model developed in the monolingual domain (Gómez et al., 2008) or the activation of open bigrams (see, for instance, Grainger et al., 2006).

We recognize, however, that more research considering different languages as well as more bilingual populations (e.g., balanced, unbalanced, and speaking languages with more or less similar scripts) is needed before implementing a new input scheme in the multilink model as some modulations in letter position coding were found as a function of language (more or less preferred). Indeed, even when lexical word frequencies were matched across languages, the responses in the 2AFCT were faster and more precise with the less preferred language (Spanish) cue words. Besides and more important, the effect of deviant letter position seemed to be more robust when the cue led to a lesser degree of lexical competition (Spanish cues in Experiment 2a and Catalan cues in Experiment 2b). Because Catalan is a preferred language by the participants, Catalan words could have provided more activation to their Spanish translations. As a consequence, lexical competition between the two-word readings

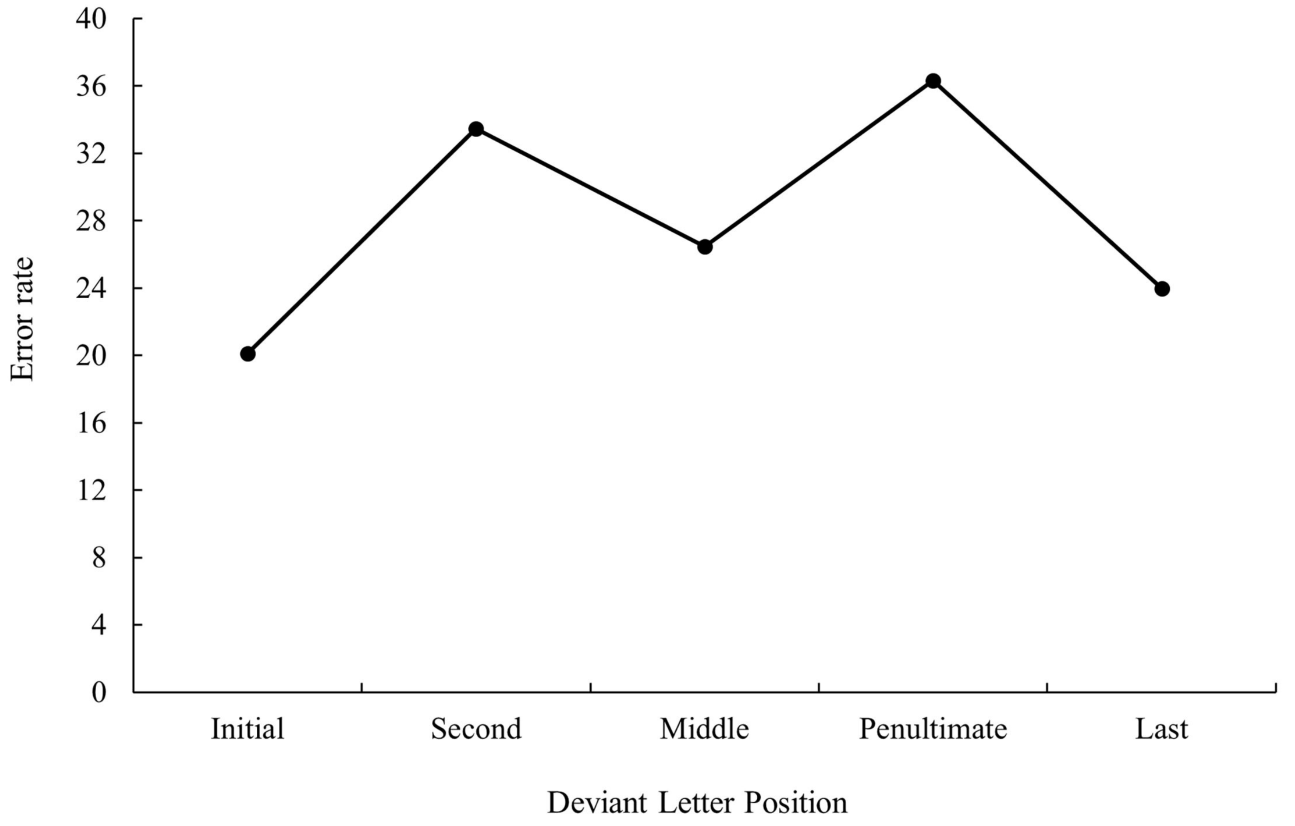

FIGURE 8 | Mean error rate (in percentage) for cognate words according to its deviant letter position in Experiment 2b.

highly reflected a greater confusability in word identification. As stated by the multilink model, this is consistent with the idea of an asymmetrical cross-linguistic cognate activation in sequential bilinguals, which can be extended to early bilinguals whenever they make a differential usage of the spoken languages. In other words, compared to their Catalan counterparts, Spanish words may work as better cues for word identification. This seems to be the case because cues are acting as non-words (the Catalan words for the Spanish monolinguals from Experiment 2b), the effect of deviant letter position is robust. Similarly, if we had used higher frequency values of cue Spanish words with bilinguals, it would be expected a greater competition in a similar way as happening in the monolingual domain with neighbor words (see Perea, 1998).

Another important issue for future research is to examine in further detail to what extent the flexibility of the orthographic coding scheme depends on the different languages known by a bilingual person as well as on the degree of L2 proficiency. This is because, whereas the first-letter advantage appeared in Roman alphabetic languages, it does not appear in other alphabetic languages like Thai (see Perea et al., 2011; Winskel et al., 2012; Yang et al., 2021). Thus, for instance, Perea et al. (2011) stated the characteristics of Thai leading to the actual identity of the letter being more critical than letter position. Indeed, the authors observed that letter position encoding in this language is relatively flexible due to the existence of certain flexibility in the ordering of the letters (it does not necessarily correspond to the ordering of phonemes of a word) and the lack of inter-word spaces. These language features create a certain level of ambiguity in relation to the demarcation of word boundaries (see Perea et al., 2011; Winskel et al., 2012), which would explain the absence of first-letter advantage. Thus, it would be interesting to examine letter position coding in learning to read an L2, which has different characteristics from L1. For instance, the study of letter position coding during L2 word recognition with the bilinguals of Thai and English with different degrees of L2 proficiency would enable researchers to examine to what extent the characteristics of different languages as well as the degree of L2 proficiency shape the way of coding letter position. As a consequence, the properties of the visual word recognition system that are specific to a given script would be disentangled.

To summarize, the present research strongly suggests that the mechanisms underlying letter position coding are similar in case of bilinguals and monolinguals, at least when bilinguals speak alphabetic languages in which a privileged role of the first letters over the others is observed. Some modulations were, however, observed as a function of language cue in the 2AFCT as Spanish cue words led to faster and more precise responses than their Catalan counterparts, probably due to a different degree of lexical competition provided by the cues. Overall, the findings suggest that the input-coding scheme of the multilink model should be amended.

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 at: https://osf.io/mqhu5/?view_only=94cdf0d86e0b4e7e8b2757e33f6a78ce.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by The Ethics Council of the University of Minho (CEICSH 023/2014). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

MC conceived the idea and experimental design of the study and was responsible for writing and editing the manuscript overall. PF, JH, and PM contributed to the main theoretical hypotheses and interpretations. JH and PM managed the data collection. JH analyzed the data and wrote the results sections of the paper. All authors reviewed the different drafts of the manuscript and made theoretical contributions for the general discussion.

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SUPPLEMENTARY MATERIAL

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Unraveling the Mystery About the Negative Valence Bias: Does Arousal Account for Processing Differences in Unpleasant Words?

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Many studies have found that the emotional content of words affects visual word recognition. However, most of them have only considered affective valence, finding inconsistencies regarding the direction of the effects, especially in unpleasant words. Recent studies suggest that arousal might explain why not all unpleasant words elicit the same behavior. The aim of the present research was to study the role of arousal in unpleasant word recognition. To do that, we carried out an ERP experiment in which participants performed a lexical decision task that included unpleasant words which could vary across three levels of arousal (intermediate, high, and very high) and words which were neutral in valence and had an intermediate level of arousal. Results showed that, within unpleasant words, those intermediate in arousal evoked smaller LPC amplitudes than words that were high or very high in arousal, indicating that arousal affects unpleasant word recognition. Critically, arousal determined whether the effect of negative valence was found or not. When arousal was not matched between unpleasant and neutral valenced words, the effect of emotionality was weak in the behavioral data and absent in the ERP data. However, when arousal was intermediate in both unpleasant and neutral valenced words, larger EPN amplitudes were reported for the former, pointing to an early allocation of attention. Interestingly, these unpleasant words which had an intermediate level of arousal showed a subsequent inhibitory effect in that they evoked smaller LPC amplitudes and led to slower reaction times and more errors than neutral words. Our results highlight the relevance that the arousal level has for the study of negative valence effects in word recognition.

Keywords: arousal, valence, lexical decision task, visual word recognition, event-related potentials (ERPs)

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INTRODUCTION

Certain stimuli appear to capture our attention more than others, and this salience is known to be determined by several factors, such as emotional content (Schacht and Sommer, 2009b). The effect of emotional content has been studied across different stimuli, as images (e.g., Cuthbert et al., 2000), films (e.g., Bos et al., 2013), and sounds (e.g., Baumgartner et al., 2006). Likewise, emotionality has been found to play a role while processing verbal stimuli such as isolated words (e.g., Kissler and Herbert, 2013), which are the focus of the present research.

Many theories have been developed trying to understand and classify emotional stimuli and emotional responses. Based on Osgood et al.'s view[1] Osgood et al. (1957), Bradley and Lang (1999) proposed a dimensional perspective of emotion, through which emotions can be described in terms of two main dimensions: emotional valence and arousal. Emotional valence refers to the degree a stimulus is perceived as pleasant or unpleasant. On the other hand, the arousal dimension refers to the activation associated to a given stimulus, ranging between relaxing or low arousing and activating or highly arousing. These authors proposed a third dimension, dominance (that varies between under control and out of control), although this dimension is not usually manipulated in experiments due to its lack of consistency and high dependence on both emotional valence and arousal (Redondo et al., 2007). The relationship between valence and arousal has been found to be quadratic (Bradley and Lang, 1999; Redondo et al., 2007; Kousta et al., 2009; Guasch et al., 2016), meaning that the more pleasant or unpleasant a word is, the more arousing it is as well. On the contrary, words neutral in valence tend to be intermediate in arousal. This phenomenon leads to the typical boomerang-shaped graph that systematically emerges when these variables are studied (e.g., Bradley and Lang, 1999; Redondo et al., 2007; Guasch et al., 2016). Furthermore, the relation between valence and arousal is stronger in unpleasant words than in pleasant ones (Kuperman et al., 2014; Guasch et al., 2016), as pleasant words tend to have more variability in their level of arousal.

These two dimensions have been the subject of study of several investigations in the last years, and the effects of emotionality in word recognition have been studied mainly by recording the participants' response while reading emotional and neutral words. While the specificities of the task used varied depending on the study, most of them required the participants to just read the words (silent reading) or to perform a lexical decision task (LDT; i.e., answering if the stimulus presented is a real word in the given language or not[2]). There is abundant literature showing that the emotional connotation of words affects participants' performance (e.g., Siakaluk et al., 2016) as well as neural responses (e.g., Recio et al., 2014; see Hinojosa et al., 2019, for a review) during the LDT. For this reason, this task has been considered adequate to study the effects of word emotionality, and hence extensively used in previous research.

Regarding valence, the general effect found is that valenced words (either pleasant or unpleasant) are recognized faster than neutral ones (e.g., Kanske and Kotz, 2007; Schacht and Sommer, 2009b). Nonetheless, while pleasant words are consistently found to facilitate cognitive processing (see however, Bayer et al., 2012; Padrón et al., 2017b, for null results), unpleasant words have also been found to yield an inhibitory effect, meaning longer response latencies (Bayer et al., 2012; Padrón et al., 2017a). Both these facilitatory and inhibitory effects of negative valence have been reported by studies that analyzed lexical decision latencies for large corpora of words as well (see Kousta et al., 2009; Vinson et al., 2014; for facilitatory effects of negative valence; Larsen et al., 2008; Estes and Adelman, 2008; Kuperman et al., 2014; for inhibitory effects of negative valence). Some authors have tried to explain this "negative valence bias" (i.e., the inhibitory effect observed with unpleasant words). Concretely, Pratto and John (1991) proposed that humans possess a mechanism that allows for a rapid focalization of attention in unpleasant stimuli. This is known as the automatic vigilance hypothesis. According to Vogt et al. (2008), this preference for assigning attentional resources to unpleasant stimuli rather than to neutral and pleasant ones may be explained by the importance that unpleasant stimuli can have as a potential threat to the organism. These authors link the slowing down in the reaction times (RTs) to an instinctive "freezing" response elicited by dangerous stimuli, common in many animals. However, Estes and Verges (2008) defend that this inhibitory effect would be better explained by the increased difficulty that unpleasant words entail to disengage attention from them. Thus, when emotionality is not a relevant variable for the task, negative valence would be detrimental to performance. In fact, these authors found that the same set of unpleasant words elicited slower responses than pleasant words in a LDT but faster valence judgments.

All in all, the results regarding unpleasant word processing are inconsistent. As can be seen from the above, studies have found either a facilitatory effect, an inhibitory effect (the negative valence bias) or no effects of negative valence at all (for null effects of unpleasantness, see Larsen et al., 2006; Hinojosa et al., 2010; Scott et al., 2014). Hinojosa et al. (2019) argue that this inconsistency regarding the valence effect might be explained by differences in the arousal values of the words used in the different studies. Indeed, some studies have found different effects of unpleasant words depending on their level of arousal. Robinson et al. (2004) designed a 2 (valence) × 2 (arousal) experiment with pleasant and unpleasant words, and low and high arousal words. Unpleasant words were recognized faster when they were also high in arousal, compared to low arousal unpleasant words. The opposite happened with pleasant words, since low arousal facilitated performance compared to high arousal. These authors proposed that valence and arousal affect word recognition in an interactive way depending on the implicit tendencies that they elicit by nature. High arousal and unpleasantness would trigger an implicit avoidance tendency, while low arousal and pleasantness would elicit an approaching response. As a result, congruent conditions, as the combination of high arousal and negative valence (avoidance tendency + avoidance tendency) would facilitate word processing. These results have been replicated in other studies that used the same manipulation of valence and arousal (Citron et al., 2014a,b). Therefore, although the evidence supporting an effect of arousal by itself is not consistent (Kuperman et al., 2014), there is some evidence pointing toward the importance of this variable when valence effects are studied.

[1] Osgood's semantic differential scales identify three dimensions that can measure people's attitudes toward nearly anything. These three dimensions were: evaluation (e.g., good/bad); potency or power (e.g., strong/weak); and activation or movement (e.g., fast/slow).

[2] For example, "*aguacero*" (downpour) is a real word in Spanish, while "*avazgero*" is not. These "fake words" are commonly denominated pseudowords, and while they mimic the phonological and orthographic structure of a real word, they do not actually exist in the target language.

In recent years, emotionality effects have been studied using the Event-Related Potentials (ERPs) technique. In contrast with "late" measures such as RTs and errors that involve post-lexical processes, on-line measures such as ERPs are key to better provide "fine-grained" information regarding the temporal localization of emotionality effects (Kissler and Herbert, 2013). In fact, several ERP components have been reported in response to the emotional content of words, two of them being consistently found in most studies: the Early Posterior Negativity (EPN) and the Late Positive Complex (LPC).

EPN is usually reported starting approximately 200 ms after stimulus onset and it presents an occipito-temporal scalp distribution (Kissler and Herbert, 2013; Palazova, 2014). Increased amplitudes in EPN have been considered to reflect an early recognition of familiar and evolutionary relevant word forms. This facilitatory effect would be caused by an automatic and involuntary allocation of attention on intrinsically relevant stimuli (Herbert et al., 2008; Bayer et al., 2012; Palazova, 2014). Both valence and arousal have been found to be determining factors for eliciting EPN modulations (e.g., Schacht and Sommer, 2009a, for valence and Bayer et al., 2012, for arousal), so this component is usually linked to a general emotionality effect that integrates valence and arousal. However, there are some inconsistencies regarding the direction of negative valence effects in this component: While some studies have found a general facilitatory effect for emotional words, both pleasant and unpleasant, when compared to neutral ones (Herbert et al., 2008; Kissler et al., 2009; Schacht and Sommer, 2009b; Scott et al., 2009; Kissler and Herbert, 2013), others only report this facilitation for pleasant words (Schacht and Sommer, 2009a; Recio et al., 2014).

LPC, sometimes called Late Posterior Positivity (LPP), has been reported to start from 500 to 800 ms after stimulus onset and it presents a centro-parietal scalp distribution (Schacht and Sommer, 2009b; Bayer et al., 2010; Kissler and Herbert, 2013). LPC is associated with indexing a more controlled, explicit processing of emotion when compared to EPN, and it is also related with evaluation, decision making, and error detection (Citron, 2012). Increased amplitudes in LPC have thus been interpreted as a facilitatory effect of emotionality reflecting a sustained processing of evolutionary relevant stimuli (Herbert et al., 2008). However, while both valence and arousal have been found to elicit modulations in this component (e.g., Schacht and Sommer, 2009a, for valence; Bayer et al., 2012, for arousal), the direction of the effect of negative valence in LPC is, again, inconsistent. Several studies have reported an advantage for pleasant and unpleasant words over neutral ones (Fischler and Bradley, 2006; Schacht and Sommer, 2009b; Bayer et al., 2010), while others have found an advantage for pleasant words over neutral and unpleasant ones (Herbert et al., 2008; Kissler et al., 2009), or even an advantage for neutral words over pleasant and unpleasant ones (Hinojosa et al., 2009).

As can be seen from the above, it seems then that the inconsistencies regarding the direction of negative valence effects are not limited to behavioral data. Although most ERP studies point toward a facilitatory effect of positive valence in word recognition, the evidence for a general facilitatory effect (that is, for both positive and negative valence) seems to be less consistent. Note, though, that most of the above-mentioned studies have used valenced words with a high level of arousal while neutral words were intermediate or low in arousal (a table summarizing valence and arousal values and scales used in previous literature can be found as **Supplementary Material**). These results cannot then be interpreted as evidence for a genuine (or a lack of) valence effect, since both valence and arousal vary between emotional and neutral words (see for example, Kanske and Kotz, 2007; Herbert et al., 2008; Kissler et al., 2009; Scott et al., 2009). As previously suggested, and since higher levels of arousal have been associated with enhanced processing in both EPN and LPC time-windows, these differences in the arousal level between emotional and neutral words across studies may explain the inconsistencies regarding the effects of negative valence in word processing. Similar to Robinson et al.'s (2004) approach, a few studies have explored the interaction between valence and arousal in LDTs, this time not only at the behavioral level but in electrophysiological data as well (Hofmann et al., 2009; Bayer et al., 2012; Recio et al., 2014).

Hofmann et al. (2009) designed an experiment with low arousal pleasant and neutral words and unpleasant words that could be either low or high in arousal. These authors found that high arousal unpleasant words elicited faster RTs than low arousal unpleasant words. High arousal unpleasant words also showed higher amplitudes than both low arousal unpleasant and neutral words at an early time-window (N100). As regards LPC, higher amplitudes for high arousal unpleasant words were only reported when compared to neutral words with a low level of arousal. It is important to mention that, although high arousing words were actually high in arousal in this study (3.94 in a scale ranging from 1 to 5), the words included in the low arousal conditions had rather intermediate arousal values (around 3 in a scale ranging from 1 to 5).

Bayer et al. (2012) designed an experiment using pleasant, unpleasant, and neutral valenced words, half of them being low in arousal and the other half being high in arousal. These authors used a −3 to +3 scale for measuring valence and a scale ranging from 1 to 5 for measuring arousal (the mean in arousal was 3.7 for words high in arousal and 2.5 for words low in arousal). They found a negative valence effect, meaning slower RTs and more errors when responding to unpleasant words compared with neutral ones, and an interaction between valence and arousal, as low arousing unpleasant words elicited slower RTs and higher error rates than high arousing unpleasant ones. However, the ERP analysis did not show an effect of negative valence or an interaction between valence and arousal in either the EPN or LPC time-windows. They only found higher amplitudes for both pleasant words and highly arousing words separately, and the co-occurrence of valence and arousal effects was found to be limited to the LPC time-window.

Finally, Recio et al. (2014) designed an experiment using pleasant, unpleasant, and neutral valenced words with low, moderate, and high arousal. This study introduced for the first time a manipulation of arousal in three levels, in contrast with the low-high dichotomy present in previous literature. They used a scale ranging from −3 to + 3 for measuring valence and a scale ranging from 1 to 5 for measuring arousal, where words between 2.6 and 3 points were considered as "moderate" (these being similar to the "intermediate" ones used in the present study). They did not find an effect of negative valence but an overall facilitation (faster responses and higher amplitudes in EPN) for both pleasant and high arousal words separately. No effect of negative valence was found when comparing neutral and unpleasant words with moderate levels of arousal either. There was, nonetheless, an arousal effect (higher amplitudes in EPN for high arousing words and faster RTs when compared to words moderate or low in arousal) and an interaction between valence and arousal. Thus, high arousal unpleasant words speeded performance when compared to unpleasant words that were moderate or low in arousal. This interaction was also significant in the EPN time-window, high arousal unpleasant words showing higher amplitudes than unpleasant words that were moderate in arousal. Arousal affected neutral words in a similar way. However, neither the performance nor the ERP data were modulated by arousal in pleasant words.

In sum, recent data from studies that manipulated valence and arousal in single word processing provide evidence for the interaction between these two variables (see, however, Bayer et al., 2012, for null results). Both behavioral and electrophysiological results support Robinson et al.'s (2004) findings, as high arousal seems to entail an advantage in unpleasant word processing. There is also evidence supporting these interactive effects coming from fMRI studies (Citron et al., 2014a), analyses of lexical decision latencies for large corpora of words (Rodríguez-Ferreiro and Davies, 2019), and sentence processing studies (Bayer et al., 2010). All these results have important implications for the study of valence effects. First, if arousal can modulate the effect of negative valence, this variable should be controlled across negative and neutral conditions (as previously mentioned, this was not common in most studies). Second, this control should not be only limited to ensure that there are no differences in arousal between conditions, but also words with a similar level of arousal must be used. If not all unpleasant words are processed in the same way, the effect of negative valence reported when analyzing all these words on the whole would be a mix of the different effects that unpleasant words have depending on their level of arousal. Thus, these effects could vary depending on the selection of materials in each study[3].

Altogether, the evidence provided by these studies suggest that the effects of valence and arousal are deeply intertwined and difficult to disentangle. But can the interaction between valence and arousal explain the inconsistency of the results regarding negative valence effects? Although the direction of this interaction seems clear (high arousal facilitates unpleasant word processing, while low arousal inhibits unpleasant word processing), ERP results about the topic are scarce and inconsistent. Early effects (Hofmann et al., 2009), EPN effects (Recio et al., 2014), LPC effects (Hofmann et al., 2009), and no effects of this interaction (Bayer et al., 2012) have all been reported. Furthermore, most of the studies that aimed to explore the interactive effects of valence and arousal present certain limitations regarding the control of the emotional variables. Some do not include a condition of neutral valence (Robinson et al., 2004), and therefore are not able to study the effect of negative valence on its own. The studies that include words neutral in valence, often only include words low and high in arousal (Bayer et al., 2012; Citron et al., 2014a,b). This does not allow for a comparison between neutral and unpleasant words with intermediate levels of arousal to be made. Hence, the effect of negative valence reported is a result of a comparison between neutral valenced words with both high arousal unpleasant words and low arousal unpleasant ones altogether (which may have different effects on word processing). Additionally, studies that introduced the condition of intermediate arousal to explore the effects of this interaction did not find any effect of negative valence in the behavioral or electrophysiological measures when unpleasant and neutral words both intermediate in arousal were compared (Hofmann et al., 2009; Recio et al., 2014). Hence, although these studies provide evidence for an arousal effect on unpleasant word processing, further research is needed to certainly demonstrate that arousal may account for the inconsistencies regarding the negative valence effect.

We developed this study with the purpose to give an answer to the following questions: (1) Does arousal affect unpleasant word recognition? (2) Can arousal account for the inconsistencies regarding the negative valence effect? and (3) Does negative valence have an inhibitory or a facilitatory effect? To achieve these goals, we designed a LDT experiment in Spanish that included neutral words in valence with an intermediate level of arousal [e.g., *sartén* (pan)] and unpleasant words that varied in their degree of arousal [intermediate, high, and very high arousal; e.g., *ceniza* (ash), *temblor* (tremor), and *avalancha* (avalanche), respectively].

To study arousal effects in negative valence, our study introduces three different levels of arousal within unpleasant words (intermediate, high, and very high). We expect to find an arousal effect, in that responses to high and very high arousal unpleasant words will be faster in comparison to unpleasant ones intermediate in arousal. As regards ERP data, we predict larger amplitudes for unpleasant words high and very high in arousal when compared to unpleasant words intermediate in arousal in EPN or LPC time-windows. However, although arousal has been found to elicit modulations in these two components, the evidence for an interaction between valence and arousal in each of them is scarce and inconsistent. Thus, we do not know for sure if these arousal effects will be limited to one component (either EPN or LPC) or present in both time-windows. Additionally, our study introduces for the first time a differentiation between high and very high arousal in unpleasant words. This will allow us to explore whether there are incremental differences in the effect of arousal on unpleasant word recognition, or if both high and very high levels of arousal affect unpleasant word recognition in a similar way instead.

[3] For example, a mean of 5 can be obtained both with words intermediate in arousal or a compound of words with low and high arousal. In the first case, all unpleasant words would be yielding the same effect, however, in the second case the effects of low and high arousal unpleasant words will be counterbalancing each other. Additionally, the same mean can be obtained with words low, intermediate, and high in arousal, or even with many words sightly low in arousal and a few with high levels of arousal. This way, the specific selection of the materials of each study could determine the valence effect obtained.

To study the effect of negative valence in word recognition, and to further elucidate if arousal can account for the inconsistencies regarding this effect, several comparisons will be conducted. First, by comparing the neutral words and all the unpleasant ones (that is, those intermediate, high and very high in arousal altogether), we will test if there is an effect of negative valence when (a) the arousal is not matched between conditions and (b) there are words with different levels of arousal within the unpleasant words (as previously stated, this was the common manipulation of the emotional variables in most studies). Note, though, that these results cannot be interpreted as a genuine valence effect since both valence and arousal vary between the two conditions. We will then refer to this factor as Emotionality. As previously stated, we predict that high arousal will have a facilitatory effect in unpleasant word recognition, while intermediate levels of arousal will hinder recognition of unpleasant words instead. Thus, we expect that the comparison between neutral words and all the unpleasant ones (that is, those with intermediate, high, and very high levels of arousal) will result in the effect of Emotionality being weak or absent. Second, pairwise comparisons between neutral words and unpleasant words intermediate, high, and very high in arousal will be performed. This will allow us not only to further study the effect of word emotionality when arousal differs between conditions (by comparing neutral words intermediate in arousal with unpleasant words high and very high in arousal) but also to clarify if there is either a facilitatory or an inhibitory negative valence effect when arousal is controlled -and intermediate-between conditions (by comparing neutral words intermediate in arousal to unpleasant words that are intermediate in arousal as well). As for the two first comparisons, we expect to find either an absent effect of word emotionality or a facilitation for unpleasant words with high and very high arousal over neutral ones. As for the comparison between neutral and unpleasant words both with intermediate levels of arousal, we expect to find different results. Following Robinson et al.'s (2004) proposal, the combination of negative valence and intermediate arousal would be incongruent and therefore detrimental to word processing. This inhibitory effect of negative valence should be evidenced by slower RTs (as well as more errors) for unpleasant words intermediate in arousal when compared to neutral ones. Although prior evidence for an inhibitory effect of negative valence is restricted to behavioral data, we expect that our design will allow for it to show up in the ERP measures as well. Following the previous literature, this inhibitory effect should translate into smaller amplitudes for unpleasant words in EPN or LPC time-windows in comparison to neutral ones.

MATERIALS AND METHODS

Participants

Thirty-six Spanish speakers (32 women; mean age 22.3 years, *SD* = 5.42) participated in this experiment. All had either normal or corrected-to-normal vision, no language difficulties or history of neurological disease, and 30 were right-handed. All were balanced bilinguals who speak Spanish and Catalan. Prior to the experiment, participants provided informed consent. They were paid 20€ for their participation.

Materials

Two hundred forty Spanish words were selected using the emoFinder[4] tool (Fraga et al., 2018), based on the databases of Stadthagen-González et al. (2017; 204 words) and Guasch et al. (2016; 36 words). From the 240 words selected, half of them were neutral in valence and the other half were unpleasant. The scale used for valence ranged from 1 (unpleasant) to 9 (pleasant) and a 1 to 9 scale was used for arousal as well (1, low arousal; 9, high arousal). The neutral valenced words were intermediate in arousal, with values in both variables varying between 4.5 and 5.5. A subset of 40 neutral words (IN) was randomly selected using the software Match (Van Casteren and Davis, 2007), with the aim of further analyzing the differences between neutral words and the different sets of unpleasant words. The other set of 120 words were unpleasant, and they were divided in three levels of arousal: 40 unpleasant words which were intermediate in arousal (IU), with arousal values that ranged from 4.5 to 5.5 and valence values that ranged from 1.0 to 3.5; 40 unpleasant and highly arousing words (HU), with arousal values ranging from 6 to 6.9 and valence values ranging from 1.0 to 3.5; and 40 unpleasant words very high in arousal (HHU), with arousal values ranging from 7 to 8 and valence values ranging from 1.0 to 3.5. The mean values for arousal and valence for each set of words are presented in **Table 1**.

T-tests and one-way ANOVAs were carried out in order to test if there was any difference in the emotional variables for each set. The comparison between the 120 neutral words with the 120 unpleasant ones revealed differences in both valence ($p < 0.05$) and arousal ($p < 0.05$) between the two sets of words. As for the pairwise comparisons, it was assured first that the IN subset did not differ in valence or arousal to the 120 neutral words ($p_s > 0.05$). These analyses revealed no differences in valence between the three sets of unpleasant words (IU, HU, and HHU; all $p_s > 0.05$) but significant differences were found between IN words and IU, HU, and HHU words (all $p_s < 0.05$). As for arousal, the analyses revealed differences in this variable between IU, HU, and HHU words (all $p_s < 0.05$) as well as between IN words and both HU and HHU words (all $p_s < 0.05$). Importantly, IN and IU words did not differ in arousal ($p > 0.05$).

Only low-frequency words were used (frequency ≤ 15), as high frequency words are usually associated with fast RTs, and frequency can interact with emotionality, even to the point of masking emotionality effects in some experiments (Padrón et al., 2017b). The following lexical and semantic variables, known to affect word recognition, were matched across conditions and word sets (all $p_s > 0.05$): number of letters, word frequency per million, orthographic neighbours[5],

[4]EmoFinder (Fraga et al., 2018) is a web-based search engine for Spanish word properties taken from different normative databases. It includes the normative ratings in emotional dimensions (e.g., valence and arousal) and discrete emotional categories (fear, disgust, anger, happiness, and sadness) for 16,375 different words. It also provides values for lexical properties as familiarity, imageability or concreteness.

[5]Indicated by the Levenshtein Distance, neighborhood refers to the level of similarity in terms of number of deletions, insertions, or substitutions required

TABLE 1 | Mean and standard deviation values for each set of words in all controlled and manipulated variables.

Word set		Valence	Arousal	N° letters	Freq.	Orto. N.	Famil.	Imageab.	Concr.	Contex. D.	NLD
Unpleasant		2.86 (0.44)	6.34 (0.93)	7.18 (1.44)	3.81 (3.23)	2.05 (0.53)	4.77 (0.91)	4.43 (1.03)	4.56 (0.88)	1.84 (1.59)	0.64 (0.27)
	HHU	2.82 (0.37)	7.33 (0.27)	7.20 (1.38)	3.87 (2.77)	1.98 (0.43)	4.86 (0.85)	4.63 (0.91)	4.54 (0.74)	2.09 (1.71)	0.66 (0.26)
	HU	2.85 (0.46)	6.52 (0.28)	7.18 (1.55)	3.78 (3.30)	2.02 (0.57)	4.65 (1.04)	4.34 (0.96)	4.49 (0.87)	1.81 (1.55)	0.68 (0.21)
	IU	2.91 (0.48)	5.18 (0.26)	7.15 (1.41)	3.77 (3.66)	2.14 (0.56)	4.81 (0.83)	4.37 (1.18)	4.67 (1.02)	1.59 (1.50)	0.66 (0.24)
Neutral		5.06 (0.26)	5.09 (0.27)	7.14 (1.39)	3.78 (3.13)	2.04 (0.51)	4.86 (0.94)	4.40 (1.26)	4.66 (0.96)	1.65 (1.33)	0.65 (0.26)
	IN	5,13 (0.25)	5,10 (0.28)	7,25 (1.32)	3,86 (2.97)	1,98 (2.14)	4,88 (0.94)	4,31 (1.17)	4,66 (0.92)	1,70 (1.31)	0,74 (0.20)

HHU, very high arousal unpleasant words; HU, high arousal unpleasant words; IU, intermediate arousal unpleasant words; IN, subset of intermediate arousal neutral words; Freq., frequency, Orto; N., orthographic neighbors; Famil., familiarity (1–7 scale); Imageab., imageability (1–7 scale); Concr., concreteness (1–7 scale); Contex. D., contextual diversity; NDL, normalized levensthein distance.

familiarity, imageability, concreteness, contextual diversity[6] and the Normalized Levensthein Distance between Spanish and Catalan (NLD)[7]. The data for these variables was obtained using the emoFinder (Fraga et al., 2018) and EsPal (Duchon et al., 2013) tools. The mean values for these variables in each set of words are presented in **Table 1**.

Finally, for the purposes of the LDT, 240 pseudowords were created using the Wuggy software, a pseudoword generator that allows for the generation of written polysyllabic pseudowords that obey a given language's phonotactic constraints (Keuleers and Brysbaert, 2010).

Design

As we did not orthogonally manipulate valence and arousal, we used a nested repeated measures design that includes the factor Emotionality (with two levels: neutral and unpleasant). Within the unpleasant level, the factor Arousal was manipulated (with three levels: intermediate, high, and very high). As indicated, a subset of 40 neutral words was selected for pairwise comparisons with the different levels of the factor Arousal, to further study the differences between neutral and unpleasant words.

Procedure

Participants performed a LDT in a sound attenuated and dimly lit room while seated in a comfortable chair. Each trial began with an image of an eye displayed for 2,000 ms, which indicated to participants that in that moment they were allowed to blink. The image was followed by a fixation point (i.e., " + ") that appeared in the center of the screen for 500 ms. Then, the fixation point was replaced by a string of letters. The task required the participants to decide whether the string of letters was a Spanish word or not. They were instructed to press the "yes" labeled key of a keyboard with the right hand if the string of letters was a word and to press the "no" labeled key of the keyboard with the left hand if it was not a word. The string of letters remained on the screen until the participants' response or timeout (after 2,000 ms). After responding, a feedback message (i.e., "ERROR" or "CORRECT") was displayed for 750 ms. The order of the experimental trials was randomized for each participant. Prior to the experiment, a practice block consisting of 12 trials (6 words and 6 pseudowords) was presented, and there were two brief breaks during the experiment. The software used to display and record the responses was DMDX (Forster and Forster, 2003).

Once they finished the main task, participants answered a language history questionnaire, to assess that they had a native-like degree of proficiency in Spanish. The duration of each session was about 2 h.

EEG Recording

The electroencephalogram (EEG) activity was recorded from 32 Ag/AgCl electrodes attached to an elastic cap (ActiCap, Brain Products, Gilching, Germany) that was positioned according to the 10–20 system. One electrode was placed beneath the left eye to monitor blinking and vertical eye movements (VEOG), and another at the outer canthus of the right eye to monitor horizontal eye movements (HEOG). All scalp electrodes were referenced online to the right earlobe and re-referenced off-line to the average of the right and left earlobes. Electrode impedances were kept below 5 kΩ. All EEG and EOG channels were amplified using an actiCHamp amplifier (Brain Products, Gilching, Germany).

Data was processed using BrainVision Analyzer 2 (Brain Products, Gilching, Germany). EEG was refiltered offline with a bandpass of 0.1–30 Hz 12 dB/oct. zerophase shift digital filter. Average ERPs were calculated per condition per participant from -200 to 800 ms relative to the onset of the word. A 200 ms pre-target period was used as baseline. Trials were rejected if the

to transform one word into another. The metric is calculated as a mean of the 20 nearest neighbors.

[6]The term "contextual diversity" refers to the number of contexts in which a word appears.

[7]As participants were Spanish-Catalan bilinguals, we decided to control the orthographic similarity of the words used in both languages, as it is known that this variable affects word processing (Comesaña et al., 2013). With this purpose, we calculated the Normalized Levenshtein Distance, a measure of this orthographic resemblance between the languages, using the online tool NIM (Guasch et al., 2013).

amplitude on any channel exceeded ± 75 μV, and if deflections on any channel exceeded ± 150 μV. Less than 5% of trials were rejected after applying such trimming procedures. Only correct response trials were included in the averages. On average, 104 trials per participant were kept for neutral words (35 for IN) and 104 for unpleasant words (34 for IU; 35 for HU, and 35 for HHU).

RESULTS

No participants were discarded due to a high percentage of errors in the task. However, six participants were excluded from the final data due to errors while recording the behavioral or EEG activity, and another one was excluded for having a low number of valid trials in one of the experimental conditions after data trimming. Both RTs that exceeded 2 *SD* of each participant's mean and RTs lower than 250 ms or higher than 1,500 ms were treated like outliers and eliminated from the analyzed data (6.5% of the data). In addition, we excluded four words[8] from the analyses due to a high percentage of errors ($> 50\%$), so the final items were 236. Of those, 117 were neutral words (40 IN) and 119 were unpleasant words (40 IU, 39 HU and 40 HHU).

Regarding behavioral data (RTs and accuracy), the arousal effect was analyzed using repeated measures ANOVAs in which Arousal had three levels (IU, HU, and HHU). *T*-tests were performed to analyze Emotionality (comparing all the neutral words with all the unpleasant words). In addition, we conducted *t*-tests analyses to compare the subset of neutral words (IN) with each set of unpleasant ones (IU, HU, and HHU). All behavioral analyses were carried out by participants and items, and the analyzed factors were treated as within-participant factors in the former and as between-participants factors in the latter.

Event-related potential analyses were focused on the EPN and LPC components. To define EPN and LPC time-windows and scalp positions we used similar parameters as previous studies (e.g., Scott et al., 2009; Bayer et al., 2012). EPN was measured by computing mean amplitudes between 200 and 300 ms after word onset, and the analysis of this component included the data recorded by 17 electrodes (C3, T7, CP5, CP1, P3, P7, O1, OZ, O2, P4, P8, CP6, CP2, CZ, C4, and T8). This way, a 17 × 3 repeated-measures ANOVA and a 17 × 2 ANOVA were carried out for the factors Arousal and Emotionality, respectively. Three other 17 × 2 ANOVAs were performed to compare IN words with IU, HU, and HHU words. The time range for the LPC component was established between 420 and 630 ms after word onset, and the analysis of this component included the data from 10 electrodes (FC1, C3, CP1, PZ, P3, P4, CP2, CZ, C4, and FC2). This way, a 10 × 3 Repeated-Measures ANOVA was carried out for the factor Arousal, and a 10 × 2 ANOVA for the Emotionality factor. Additionally, three more 10 × 2 ANOVAs were performed to compare IN words with IU, HU, and HHU words. All ERP analyses were carried out by participants only, as it is common practice with this kind of measure. The main effect of electrode will not be discussed.

[8]The words excluded were *cinc* [zinc] (neutral), *galeón* [galleon] (neutral), *surco* [groove] (neutral), and *hedor* [stink] (HU).

Behavioral Results

The main effect of Arousal was found not to be significant in the RTs analysis [$F_1(2,56) = 2.47$, $p = 0.094$; $F_2(2,116) = 1.28$, $p = 0.282$]. However, this effect was significant in the error rates analysis [$F_1(2,56) = 5.50$, $p = 0.007$; $F_2(2,116) = 3.59$, $p = 0.031$]. Planned comparisons showed that participants committed more errors when answering to IU words than to HU ($p_1 = 0.026$; $p_2 = 0.098$) and HHU words ($p_1 = 0.023$; $p_2 = 0.048$), but no significant differences were found between HU and HHU words ($p_1 > 0.05$; $p_2 > 0.05$).

Regarding Emotionality, our analysis showed a main effect of this factor, with faster RTs in neutral words than in unpleasant words. However, this effect was only significant in the participant analysis [$t_1(28) = 3.65$, $p = 0.001$; $t_2(234) = 1.78$, $p = 0.076$]. No main effects of Emotionality were found when analyzing error rates [$t_1(28) = 1.29$, $p = 0.207$; $t_2(234) = 0.98$, $p = 0.329$].

The comparison between IN and IU words was significant in RTs [$t_1(28) = 3.78$, $p < 0.001$; $t_2(77) = 2.20$, $p = 0.031$] and errors [$t_1(28) = 4.805$, $p < 0.001$; $t_2(77) = 3.31$, $p = 0.001$], showing that participants took longer to answer (and committed more errors) when responding to IU words than to IN words. The comparison between IN and HU words also showed significant differences between these two sets of words in RTs [$t_1(28) = 2.95$, $p = 0.006$; $t_2(76) = 1.27$, $p = 0.207$] that were only marginally significant in the error rates analysis [$t_1(28) = 1.92$, $p = 0.065$; $t_2(76) = 1.90$, $p = 0.061$]. Finally, the comparison between IN words and HHU words failed to show any significant effect in both RTs [$t_1(28) = 1.48$, $p = 0.150$; $t_2(77) = 0.54$, $p = 0.591$] and error rates analyses [$t_1(28) = 1.47$, $p = 0.154$; $t_2(77) = 1.33$, $p = 0.188$]. Behavioral data are presented in **Table 2**.

Event-Related Potential Results

Early Posterior Negativity

No effects of Arousal [$F(2,56) = 0.96$, $p = 0.389$] or Emotionality [$F(1,28) = 2.77$, $p = 0.107$] were observed in this component. However, the comparison between IN and IU words was significant [$F(1,28) = 10.33$, $p = 0.003$], IU words showing larger EPN amplitudes (−1.17 μV) than IN words (−0.29 μV) (see **Figure 1**). No differences were found between IN and HU words [$F(1,28) = 3.67$, $p = 0.067$] or between IN and HHU words [$F(1,28) = 2.78$, $p = 0.107$] in this time-window.

TABLE 2 | Mean RT (in ms), and percentage of error rates (% Errors) per set of words (standard deviations in parentheses).

Word set	Mean RTs	% Errors
Unpleasant	687.88 (128.90)	4.61 (3.65)
HHU	682.47 (131.27)	3.54 (4.65)
HU	686.06 (129.68)	3.87 (4.08)
IU	695.34 (130.54)	6.48 (5.44)
Neutral	676.98 (122.25)	3.86 (3.51)
IN	674.68 (129.33)	2.30 (2.55)

HHU, very high arousal unpleasant words; HU, high arousal unpleasant words; IU, intermediate arousal unpleasant words; IN, subset of intermediate arousal neutral words.

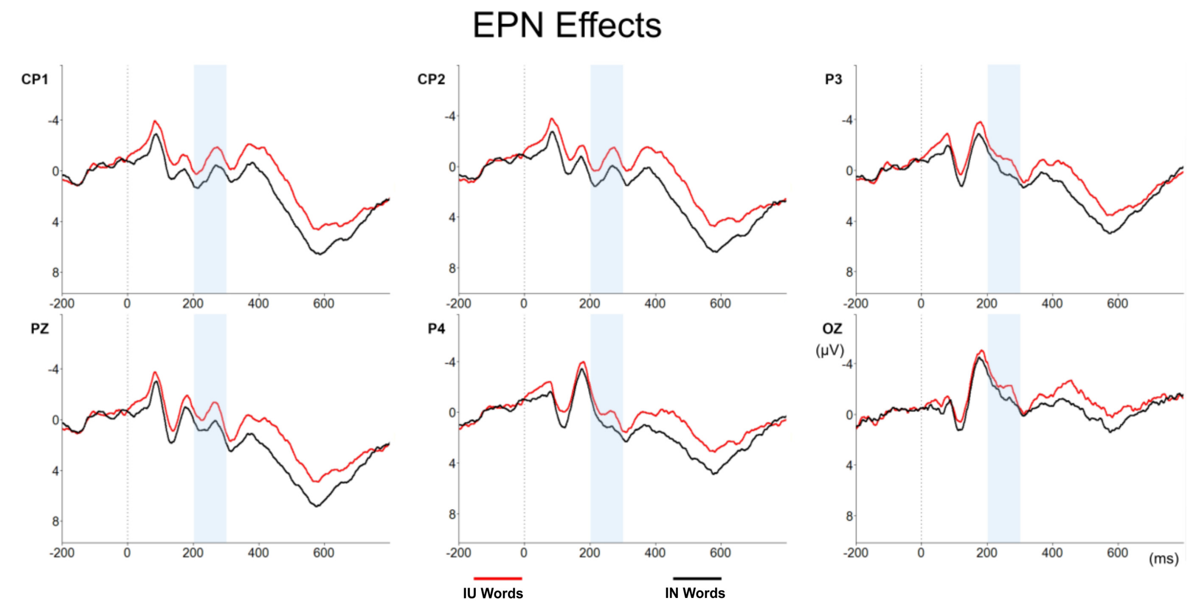

FIGURE 1 | EPN effect. EPN amplitudes for the IU (red line) and the IN words (black line). The time range of the EPN component is indicated by a blue rectangle.

Late Positive Complex

Regarding the Arousal factor, the analysis showed a significant main effect of arousal [$F(2,56) = 12.99$, $p < 0.001$]. Both HU and HHU words elicited larger LPC amplitudes (3.56 and 3.88 μV, respectively) than IU words (1.98 μV) ($p_s < 0.001$). No differences were found between HU and HHU words ($p > 0.05$) (see **Figure 2A**). The ANOVA for the Emotionality factor did not show any Emotionality effect on LPC amplitudes [$F(1,28) = 0.02$, $p = 0.893$]. Finally, the comparison between IN and IU words was significant [$F(1,28) = 48.95$; $p < 0.001$], showing that IN words elicited larger LPC amplitudes (3.91 μV) when compared to IU words (1.98 μV) (see **Figure 2B**). However, there were not differences between either IN and HU words [$F(1,28) = 0.01$, $p = 0.938$] or IN and HHU words [$F(1,28) = 0.86$, $p = 0.361$] in the LPC time-window.

DISCUSSION

The central aim of this study was to explore the possible effects of arousal on unpleasant word recognition. This way, both emotional valence and arousal were manipulated in a LDT. In addition, we carried out a series of comparisons between neutral and unpleasant words with different levels of arousal, aiming to further elucidate if these arousal effects can account for the inconsistencies reported in previous literature regarding the effect of negative valence.

First, our analyses showed that arousal did affect unpleasant word recognition. While arousal effects were not significant in the EPN time-window, unpleasant words high (HU) and very high in arousal (HHU) elicited larger LPC amplitudes in comparison to unpleasant words intermediate in arousal (IU), indicating a preferential processing of the former two when compared to the latter. Regarding behavioral data, arousal effects were significant in the error rates analysis, as participants committed less errors when responding to unpleasant words very high in arousal (HHU) than to those intermediate in arousal (IU), yet no significant differences were found in RTs. Thus, it seems that not all unpleasant words were processed in the same way. These results could be interpreted in terms of an increased difficulty to process unpleasant words intermediate in arousal (IU) when compared to unpleasant ones of high (HU) or very high arousal (HHU), or, in line with Robinson et al.'s proposal and previous findings in the matter (Robinson et al., 2004; Citron et al., 2014a,b; Recio et al., 2014), as a facilitatory effect of high arousal in unpleasant word recognition.

Regarding emotionality effects, the comparison between all the neutral words and all the unpleasant words considered together did not show significant effects in any time-window in the ERP data. Emotionality did not critically affect performance either, and, although participants were faster responding to neutral words than to unpleasant ones, this effect was only significant in the participant analysis, and no differences were found between unpleasant and neutral words in error rates. In view of these results, it could seem that there are no effects of negative valence in word processing, yet these results were obtained comparing neutral and unpleasant words that differed in arousal, and therefore cannot be interpreted in terms of valence only. Interestingly, most valence effects reported in the literature correspond to a comparison between unpleasant words high in arousal and neutral words low in arousal. These studies often report a facilitation for unpleasant words over neutral ones (e.g., Kanske and Kotz, 2007; Schacht and Sommer, 2009a) that was not replicated by our data. While unpleasant words tended to be high or very high in arousal in these studies (between 3.5 and 4 in a scale from 1 to 5), neutral words tended to be low in arousal (between 1.5 and 1.8 in a scale from 1 to 5). As the neutral words used in our study had intermediate levels of arousal, the greater

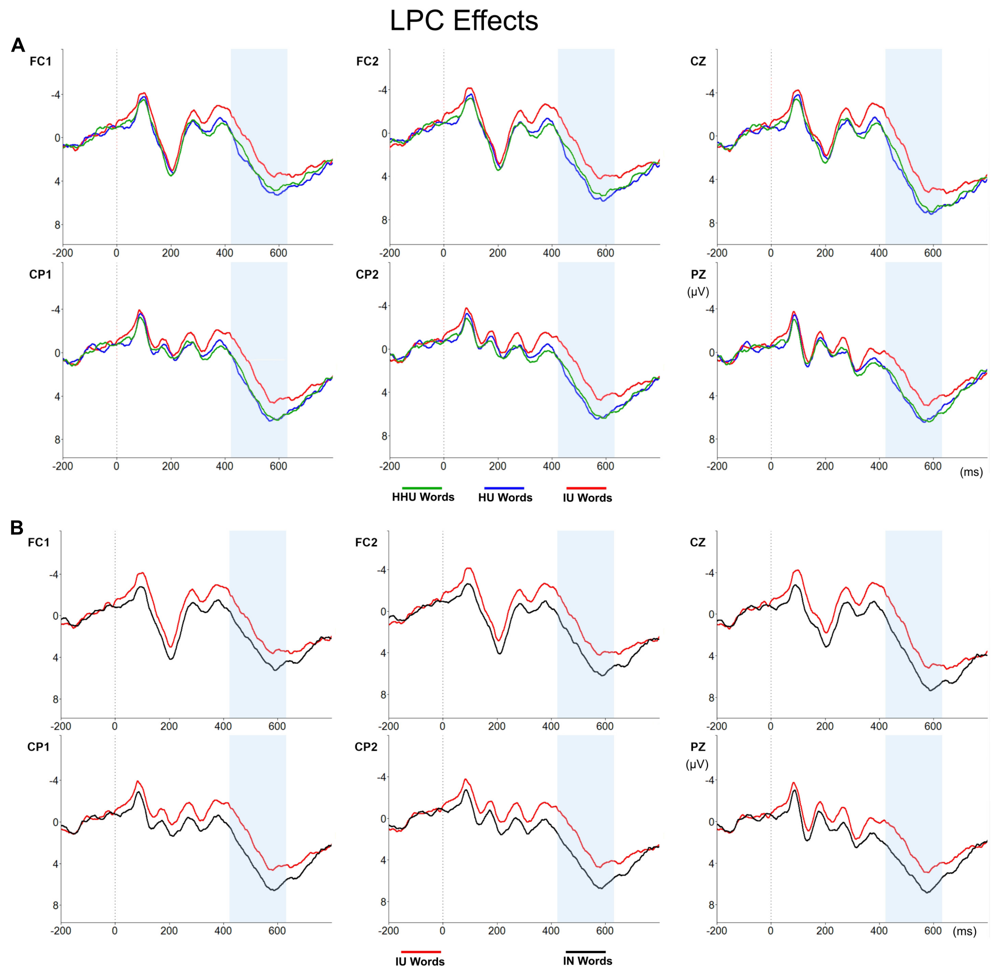

FIGURE 2 | LPC effects. **(A)** LPC amplitudes for HHU (green line), HU (blue line), and IU words (red line). The time range of the LPC component is indicated by a blue rectangle. **(B)** LPC amplitudes for the IU (red line) and the IN words (black line). The time range of the LPC component is indicated by a blue rectangle.

difference in arousal between unpleasant and neutral words in these studies in comparison to ours may account for the different results. Furthermore, as previously mentioned, this facilitatory effect of negative valence is quite inconsistent, and most of the studies that have found a facilitation for unpleasant words in comparison to neutral ones in EPN have not observed the same effects in LPC (Herbert et al., 2008; Kissler et al., 2009; Schacht and Sommer, 2009b; Kissler and Herbert, 2013). Similarly, most of the studies that have reported a facilitatory effect for unpleasant words in LPC did not find the same effect in EPN (Schacht and Sommer, 2009a) or just did not report any effects of emotionality on this component at all (Herbert et al., 2006; Kanske and Kotz, 2007). For these reasons, the absence of an effect of negative valence when arousal is not controlled between unpleasant and neutral words is not surprising.

Moreover, pairwise comparisons between the subset of neutral words (IN) and each set of unpleasant ones (IU, HU, and HHU) led to interesting results. On the one hand, both unpleasant words high (HU) and very high in arousal (HHU) seemed to be processed in a similar way to neutral ones, since none of the pairwise comparisons showed statistically significant differences between these sets of words (for HU words these differences were weak and only significant in the behavioral data, and for HHU words these differences were not significant either in the ERP or in the behavioral data). On the other hand, the comparison between unpleasant words intermediate in arousal (IU) and neutral words (IN) showed significant differences in various stages of word processing. As for EPN, IU words elicited larger amplitudes than neutral words, thus pointing toward an early allocation of attentional resources in IU words. Considering that this early effect was only significant when both unpleasant and neutral words were intermediate in arousal (but did not arise when HU and HHU words were compared to neutral ones), it seems that valence effects on EPN amplitudes were somehow related to arousal, even though no effects of arousal were significant in this time-window. One interpretation of this finding could be related to the fact that emotionality effects in EPN have been frequently associated with a general emotionality effect that does not discriminate between valence and arousal, but that is more related to the emotional relevance of the stimulus

(Citron, 2012). As was previously mentioned, there is a tendency for unpleasant words to be high in arousal as well, and for neutral words to be intermediate or low in arousal. Thus, IU words would entail a combination of valence and arousal quite uncommon in natural contexts of language, or, as in Robinson et al.'s (2004) terms, an "incongruent" combination of valence and arousal. This could explain their salience over the other sets of words and hence this early focus of attention on them. Critically, differences between IN and IU words were also significant in a later time-window. IU words exhibited smaller amplitudes than neutral words in LPC, a component that has been usually associated with evaluation, decision making, and error detection (Citron, 2012). Thus, this early allocation of attention in IU words seems to have led to a detrimental processing of these unpleasant words in later stages of word processing. Consequently, IU words elicited slower and less accurate responses than neutral words in the LDT. These results would point to an inhibitory effect of negative valence, the so called "negative valence bias." Whilst behavioral evidence for this effect was reported by other studies (e.g., Bayer et al., 2012; Padrón et al., 2017a), we present novel results regarding the inhibitory effect of negative valence in ERP data. Again, this effect seems to appear only when both neutral and unpleasant words have intermediate levels of arousal (two conditions not usually included in previous literature).

The divergences between our results on the effects of negative valence and those reported by previous studies can be related to different causes. Given that the results of this study clearly evidence that arousal affects how unpleasant words are processed, it is possible that differences in the specific manipulation of the emotional variables (and the scales used to measure them) may account for the disparate findings. Both Hofmann et al. (2009) and Recio et al. (2014) measured valence in a scale ranging from -3 to $+3$ and arousal in a scale ranging from 1 to 5, while we measured both valence and arousal in a scale ranging from 1 to 9. Furthermore, words with equivalent levels of arousal are labeled as low arousing in some studies (as in Hofmann et al., 2009) and as moderate or intermediate in arousal in others (as in Recio et al., 2014). Other methodological differences, as the source of the normative ratings for the emotional variables, might as well have affected the comparison between studies and the replicability of the results. Additionally, we find necessary to point out that we did not include pleasant words in our design, but only unpleasant and neutral ones (most previous studies used pleasant, neutral, and unpleasant words). While this allowed us to focus our study on the effects of negative valence, the absence of pleasant words may have influenced the results. Adelman and Estes (2013) state that the effects of valence can be influenced by the selection of the materials. Emotional words, especially unpleasant ones, are less common than neutral words in the natural presentation of language, so experimental conditions may create a context where the proportion of unpleasant stimuli is abnormally high, and this could cause negative valence to have an unusual relevance for the participant. According to this statement, while we included a high number of neutral words, the absence of pleasant words could have affected the naturality of our stimulus list and driven participants attention to unpleasant words. This could have happened as well in the study by Hofmann et al. (2009). Out of the four sets of words used there, three of them were low in arousal and only one had high levels of arousal. Critically, these words (high arousal unpleasant words) were the ones that participants processed differently from the others.

Finally, we find interesting to point out that, while ERP data showed that HU and HHU words were processed in a similar way and no differences between these sets of words were found at the behavioral level, only HHU words significantly affected performance. Thus, although both HU and HHU words elicited higher amplitudes than IU words in LPC, the effects of arousal in behavioral data were limited to the error rates analysis and to the comparison between HHU and IU words. Our specific manipulation of the materials might explain these results, as HU and HHU words were closer in arousal than HU and IU words. Future research should explore the linearity of arousal effects by conducting regression analyses with arousal as a continuous variable.

CONCLUSION

Although further research is needed to contrast our results and to explore the complex interaction between valence and arousal in the different stages of word processing, our data clearly evidence that not all unpleasant words are processed in the same way. Our results show an effect of arousal in unpleasant word recognition, so that unpleasant words intermediate in arousal evoked smaller LPC amplitudes than unpleasant words that were high or very high in arousal, this probably explaining the absence of an emotionality effect when all of them were compared together with neutral ones. Critically, arousal determined whether an effect of negative valence was found or not. Unpleasant words were only processed differently from neutral ones, both in EPN and LPC, when they were intermediate in arousal, proving that arousal can indeed account for previous inconsistencies regarding negative valence effects. This new evidence strongly supports the fact that both valence and arousal must be considered when studying the effect of emotional connotation in language processing.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Comitè Ètic d'Investigació en Persones, Societat i MediAmbient (CEIPSA-2021-PR-0015). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

LV, PF, and IF contributed to the conception and design of the study. LV selected the materials and wrote the first draft of the manuscript. JH programmed the experiment. LV and JH carried out the statistical analysis. IP contributed to data presentation and visualization. All authors contributed to manuscript revision, read, and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2021.748726/full#supplementary-material

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BRIEF RESEARCH REPORT
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The Omission of Accent Marks Does Not Hinder Word Recognition: Evidence From Spanish

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Recent research has found that the omission of accent marks in Spanish does not produce slower word identification times in go/no-go lexical decision and semantic categorization tasks [e.g., cárcel (prison) = carcel], thus suggesting that vowels like á and a are represented by the same orthographic units during word recognition and reading. However, there is a discrepant finding with the yes/no lexical decision task, where the words with the omitted accent mark produced longer response times than the words with the accent mark. In Experiment 1, we examined this discrepant finding by running a yes/no lexical decision experiment comparing the effects for words and non-words. Results showed slower response times for the words with omitted accent mark than for those with the accent mark present (e.g., cárcel < carcel). Critically, we found the opposite pattern for non-words: response times were longer for the non-words with accent marks (e.g., cárdil > cardil), thus suggesting a bias toward a "word" response for accented items in the yes/no lexical decision task. To test this interpretation, Experiment 2 used the same stimuli with a blocked design (i.e., accent mark present vs. omitted in all items) and a go/no-go lexical decision task (i.e., respond only to "words"). Results showed similar response times to words regardless of whether the accent mark was omitted (e.g., cárcel = carcel). This pattern strongly suggests that the longer response times to words with an omitted accent mark in yes/no lexical decision experiments are a task-dependent effect rather than a genuine reading cost.

Keywords: word recognition, lexical access, reading, lexical decision, accent marks

INTRODUCTION

One of the most characteristic features of written Spanish—together with the letter ñ—is the presence of acute accents in words. These accent marks indicate, under some rules, which one is the stressed vowel in the word [e.g., mítico (mythic); lápiz (pencil); camión (truck); see Marcet and Perea, 2021, for an overview of the rules of accentuation in Spanish; see also Real Academia Española, 2010, for a more detailed description].

Whether or not accent marks—also called diacritics—help silent reading in Spanish has been highly debated in the past decades. Indeed, many renowned writers and scholars have advocated for a much more lenient use of accent marks in a language where more than 80% of words have their stress in the last-but-one syllable (Quilis, 1993). The best example is probably the speech given by Gabriel García-Márquez at the International Conference of Spanish Language in Zacatecas in 1997. Indeed, other Romance languages such as Italian or Romanian have a much sparer role for accent marks. For instance, accent marks in Italian are mostly used for polysyllabic words with a stressed final vowel [e.g., libertà (freedom)] or to tell apart otherwise homonym words with a different accented syllable [e.g., àncora (anchor) vs. ancora (still)] (see Colombo and Sulpizio, 2021).

Besides the debates on the practical function of accent marks, the existence of accent marks in a given language raises a fundamental theoretical question: Should accented and non-accented vowels be treated as different orthographic representations? Computational models assume an English orthography in which the vowels á and a would be treated as a single orthographic unit (e.g., multiple read-out model: Grainger and Jacobs, 1996; spatial coding model: Davis, 2010). For instance, to simulate data from Spanish in the multiple read-out model, Conrad et al. (2010) removed the accent marks in diacritical words [e.g., the word ratón (mouse) was encoded as raton]. There is, however, a computational model, devised for French (Ans et al., 1998, multiple-trace model), where each diacritical vowel is represented differently (e.g., é, è, and e would be considered separate orthographic representations).

We believe that the answer to the above question is probably language-dependent (see Wells, 2000; Chetail and Boursain, 2019; Marcet et al., 2021): accent marks are probably represented as different abstract representations in languages where they indicate vowel quality (e.g., Finnish: Perea et al., 2021a; German: Perea et al., 2021b), but not in languages where accent marks only indicate lexical stress with no change in vowel quality (Spanish: Perea et al., 2020b). Concerning Spanish, which is the focus of the present study, recent empirical evidence with adult readers has shown that accent marks do not help the initial encoding of words. In a masked priming lexical decision experiment, Perea et al. (2020b) found that the response times to a word like FÁCIL (easy) were essentially the same when it was preceded by the identity prime fácil or the prime facil (i.e., with an omitted accent). In contrast, the control prime fécil was the least effective. If á and a activate different orthographic representations, one would have expected faster responses in the identity priming condition over the other two priming conditions. Likewise, in a silent sentence reading task where the participants' eye movements were recorded, Marcet and Perea (2021) found that first-pass measures on a target word [first-fixation duration, gaze duration (sum of first-pass fixations including refixations)] were remarkably similar regardless of whether the accent mark was present [e.g., cárcel (prison) or omitted (carcel)]. Furthermore, Perea et al. (2021b) found a similar pattern using a semantic categorization task ("was the word an animal name or not?"): word recognition times were extremely similar regardless of whether the accent mark was present or not [e.g., ratón (mouse) = raton; cárcel = carcel].

Notably, the empirical evidence using a single-presentation lexical decision task (i.e., a word/non-word discrimination task) in Spanish is contradictory. In a yes/no lexical decision task, Schwab (2015, Experiment 1) found faster responses to the words with the accent present than those with the accent omitted (29 ms: 761 vs. 790 ms, respectively). Although the difference was not significant (the *t*-value in the linear mixed-effects model was 1.55), this was probably due to the experiment being underpowered—the number of observations per condition was only 220 (22 participants and ten items/condition). Another interpretive issue was that the data for the non-words (e.g., the comparison of the non-words lámiz vs. lamiz) was not reported or analyzed. To reach firm conclusions, one would need to examine both word and non-word data. The logic is that, in this scenario, items without accent marks (e.g., carcel and lamiz) could have been less "wordlike" than the items with accent marks (e.g., cárcel and lámiz). If so, the omission of accent marks would produce slower response times to words but faster response times to non-words (see Perea et al., 2020a, for evidence of biases due to stimulus format in the lexical decision task). In a second experiment, Schwab (2015) employed a go/no-go lexical decision task (i.e., participants responded to "words" but not to "non-words") where the "accent present" items (e.g., words like cárcel and non-words like lámiz) and "accent omitted" items (e.g., carcel and lamiz) were shown in separate blocks. In this scenario, word response times were remarkably similar for cárcel and carcel. Schwab concluded that accent marks might not be necessary for Spanish words, at least for those with unambiguous spelling (i.e., words that do not create other words when removing the accent mark). However, there was no attempt to solve the differences between Experiments 1 and 2.

The goal of this paper was to resolve the apparent discrepancies regarding the reading cost due to the omission of accent marks in Spanish in the yes/no lexical decision task. To obtain the full picture, we examined the word and non-word data in a yes/no lexical decision task (Experiment 1) and in a go/no-go lexical decision task (Experiment 2). The rationale is that the advantage of cárcel over carcel reported by Schwab (2015, Experiment 1) in a yes/no lexical decision task could have been due to the accented items producing a "word" bias rather than a genuine task-independent advantage in word recognition. Of note, this mechanism would not be operative in Schwab (2015, Experiment 2) with the go/no-go procedure because of the blocked design (i.e., items with accent marks in one block vs. items without accent marks in the other block). We used the set of words from Marcet and Perea (2021) and Perea et al. (2021a) experiments for comparison purposes. Of note, these stimuli, which had an unambiguous spelling (i.e., the omission of the accent mark did not produce another word), only showed a negligible disadvantage of the words with the omitted accent marks.

Regarding the predictions of Experiment 1 (yes/no lexical decision task), we can envision three possible scenarios. The first scenario is that the findings with word stimuli in Schwab (2015, Experiment 1) were an empirical anomaly. If so, one would expect similar response times to cárcel and carcel. The second scenario is that, while the findings with word stimuli from Schwab (2015, Experiment 1) were reliable (i.e., faster responses to cárcel than to carcel), this apparent reading cost was due to a "word" bias for accented items in lexical decision (i.e., a task-specific effect). In this case, we would expect faster response times for the words with diacritics (cárcel faster than carcel) but slower response times for the non-words with diacritics (cárdil slower than cardil) (i.e., a "word" bias for accented items). The third scenario is to replicate the pattern of Schwab (2015, Experiment 1) word data, but with the non-words not showing an effect due to lack of diacritics (or faster responses for the non-words with diacritics). This last outcome would require rethinking the idea that the omission of diacritics in Spanish has little cost in lexical access.

EXPERIMENT 1

Materials and Methods

Participants

We recruited 40 university students, all native speakers of Castillian Spanish with normal/corrected vision and no reading problems, from the Prolific platform. This sample size guarantees 2,400 observations in each condition (40 participants × 60 items/condition), thus having enough power to detect small-sized effects (see Brysbaert and Stevens, 2018). In this and the following experiment, all participants signed an informed consent form at the beginning of the session, and the Ethics Committee of the Universitat de València approved the experiments.

Procedure

The experiment was conducted online using the Pavlovia server.[1] The program was written with PsychoPy 3 (Peirce and MacAskill, 2018). LimeSurvey[2] was also used to obtain demographic data before the experiment. Participants were instructed to do the experiment in a silent place without any interruptions. They received the usual lexical decision instructions: they had to decide whether the item on the screen was a Spanish word (if so, press M on the keyboard) or not (if so, press Z on the keyboard) as quickly and accurately as possible. A given trial started with a fixation cross that was presented for 500 ms in the center of the computer screen. Then, the item appeared in the same location as the fixation cross until the participant responded or until a deadline of 2 s. The order of trials was randomized for each participant. There was a short practice phase of sixteen trials before the experimental phase (240 trials). In the experimental phase, there were short breaks every sixty trials. The duration of the experiment was approximately 12–15 min.

Materials

The set of words was composed of the 120 accented Spanish words used by Marcet and Perea (2021). These words had a length between 5 and 10 letters (M = 6.4) and a Zipf frequency between 1.85 and 5.59 (M = 3.73) (Duchon et al., 2013). The position of the accent mark varied across words (last syllable, second-to-last syllable, third-to-last syllable; see Marcet and Perea, 2021, for further details). To create the set of 120 orthographically legal non-words of the same length as the word stimuli, we employed Wuggy (Keuleers and Brysbaert, 2010). As the output from Wuggy does not contain accent marks, we added them as in their base words [e.g., cáciro (baseword: cámara), cráror (baseword: crater), and sanión (baseword: ración)]. We created two lists of counterbalanced stimuli, each with half of the items being accented (e.g., if cráter were presented in List 1, crater would be presented in List 2). The list of stimuli (both words and non-words) is available in the same OSF link as the data (see "Data Availability" section).

[1] www.pavlovia.org

[2] www.limesurvey.org

Results and Discussion

In the analyses of the response times, we removed those latencies shorter than 250 ms and the incorrect responses. The mean correct response times and error rates (in percentage) per condition are presented in **Table 1**.

For the inferential analyses, the latency and accuracy data were fitted with Bayesian linear mixed-effects models using the brms package (Bürkner, 2016) in the R environment (R Core Team, 2021). The fixed factors in the model were Format [without diacritics (−0.5), with accent mark (0.5)] and Lexicality [word (−0.5), non-word (0.5)]. Following Barr et al. (2013), we chose the maximal random-effect structure justified by the experimental design:

$$\text{RT[accuracy]} = \text{Format}^*\text{Lexicality} + (1 + \text{Format}^*\ \text{Lexicality|subject}) + (1 + \text{Format|}\ \text{item}).$$

The latency data were fitted with the exGaussian function to capture the positive skew of the response times, and the accuracy data were fitted with the Bernoulli function due to the inherent binary responses in each trial (correct = 1; error = 0). Each model received 5,000 iterations (1,000 as a warm-up). The models converged successfully and $\hat{R}$ = 1.00 in all parameters. The output of the Bayesian models does not provide a p-value for each effect; instead, they provide a 95% Credible Interval (95% CrI), together with an estimate of the parameter and its standard error, that can be interpreted as evidence of an effect when the interval does not cross zero.

In the latency model, we found evidence of main effects of Format and Lexicality [Format: b = 22.88, SE = 2.73, 95%CrI (17.51, 28.22), Lexicality: b = 69.28, SE = 8.61, 95%CrI (52.30, 86.11)]. More importantly, we also found evidence of an interaction between the two factors [b = −37.48, SE = 4.07, 95%CrI (−45.46, −29.45)]. This interaction reflected: (1) faster responses for the words with the accent present over the words

TABLE 1 | Mean lexical decision times (in ms) and error rates (in percentages) for words and non-words with vs. without accent marks in Experiment 1.

	With accents		Without accents	
	Response time	**% Errors**	**Response time**	**% Errors**
Words	641	4.2	665	6.2
Non-words	736	4.4	710	3.6

with the accent omitted [95%CrI (−28.07, −17.4)], and (2) slower responses for the non-words with an accent present than for non-words with an accent omitted [95%CrI (8.61, 20.6)].

In the accuracy model, we did not find evidence of the effects of Format and Lexicality [Format: $b = -0.34$, SE = 0.19, 95%CrI (−0.70, 0.04), Lexicality: $b = 0.11$, SE = 0.27, 95%CrI (−0.41, 0.66)]. Notably, we found evidence of an interaction between the two factors [$b = 0.69$, SE = 0.25, 95%CrI (0.21, 1.19)], reflecting the same trend as the latency data. While the credible intervals crossed zero, we found more accurate responding for accented than non-accented words [95%CrI (−0.0401, 0.7006)] and less accurate response for the accented than for non-accented non-words [95%CrI (−0.7802, 0.0874)].

In sum, the effect of Format (accented vs. non-accented) was the opposite for words and non-words. The issue now is whether this dissociative pattern was due to a "word" bias for accented items in the yes/no lexical decision task. To examine this hypothesis, we designed an experiment parallel to Schwab (2015, Experiment 2). Participants only had to respond to words (i.e., go-no/go lexical decision) in a design composed of two blocks: one containing only accented items, and one containing only non-accented items (i.e., with an omitted accent mark for words, as in carcel). In this scenario, the presence of an accent mark would not bias participants to respond "word," hence the difference between response times to words like cárcel and carcel is expected to be minimal.

EXPERIMENT 2

Materials and Methods

Participants

We recruited an additional sample of 40 participants from the same population as in Experiment 1.

Procedure

It was the same as in Experiment 1, except for the following: (1) participants had to press the "word" key if the item was a word and refrain from responding if the item was not a word; (2) the deadline for responding was reduced from 2 to 1.5 s to speed up no-go trials; and (3) the experiment was composed of two blocks: a block in which all the items (words and non-words) were accented and a block in which all the items were not accented (i.e., with an accent omitted for words, as in carcel). The order of the blocks was counterbalanced across participants. There was a brief practice phase (8 trials) before each of the blocks.

Materials

They were the same as in Experiment 1.

Results and Discussion

The statistical analyses were parallel to those in Experiment 1. The only difference was, due to the characteristics of the go/no-go procedure, we only obtained correct response times for word trials. **Table 2** presents the mean correct response times and error rates per condition.

TABLE 2 | Mean lexical decision times (in ms) and error rates (in percentages) for words and non-words with vs. without accent marks in Experiment 2.

	With accents		Without accents	
	Response time	% Errors	Response time	% Errors
Words	608	0.7	617	1.3
Non-words	–	3.5	–	3.1

In the latency data, we found a small 7-ms disadvantage for the words with the accent omitted relative to the words with the accent present. As the 95% credible interval of this difference crossed zero [$b = 5.31$, SE = 3.88, 95%CrI (−2.34, 12.86)], we prefer to interpret this pattern as a minimal/null effect.

In the accuracy data, we found higher accuracy for word trials than for non-word trials [$b = -2.13$, SE = 0.50, 95%CrI (−3.18, −1.20)]. More importantly, we did not find evidence of an effect of Format [$b = -0.22$, SE = 0.51, 95%CrI (−1.19, 0.82)] or an interaction between two factors [$b = 0.25$, SE = 0.50, 95%CrI (−0.78, 1.20)].

The present go/no-go lexical decision experiment, using exactly the same materials of Experiment 1, only revealed a negligible reading cost for the words with the omitted accent mark, thus replicating Schwab (2015, Experiment 2).

GENERAL DISCUSSION

We designed two lexical decision experiments to examine whether the omission of an accent mark in a Spanish word could have a genuine reading cost during lexical access. Recent research on this topic has failed to reveal a reading cost of omitting the accent mark across several procedures (masked priming lexical decision: Perea et al., 2020b; semantic categorization: Perea et al., 2021b; go/no-go lexical decision: Schwab, 2015). However, in a yes/no lexical decision task, Schwab (2015, Experiment 1) found a 29-ms disadvantage for the words with the omitted accent—the non-word data were not presented. Experiment 1 successfully replicated the advantage of cárcel over carcel (a 24-ms advantage) reported by Schwab (2015, Experiment 1). Critically, the analyses of the non-word data offered fundamental clues on the nature of this effect: response times to accented pseudowords were, on average, 26 ms slower than the response times to non-accented pseudowords (e.g., cardil < cárdil). That is, the pattern of non-word data was just the opposite of the word data, thus suggesting a "word" bias for accented items in the yes/no lexical decision task. Indeed, Experiment 2, using a go/no-go lexical decision task and a blocked design, showed similar response times to words regardless of whether the accent mark was present or omitted.

Thus, the present experiments have shown that the apparent processing disadvantage of words with an omitted accent mark in the yes/no lexical decision task in the present Experiment 1 (and Schwab's Experiment 1) can be readily explained by the characteristics of the procedure. The dissociation between accented words vs. non-words fits very well with the second scenario given in the Introduction: items with an accent mark may be treated as more wordlike in a yes/no word/non-word decision. This mechanism would produce slower response times to words with the omitted accent (e.g., carcel > cárcel) and faster response times to pseudowords without an accent mark (e.g., cardil < cárdil). This type of dissociation in the yes/no lexical decision task is not new. A similar dissociation has been reported when manipulating other elements such as letter-case: in lexical decision, the word CAMINO (path) is responded faster than the mixed-case word cAmInO, whereas the pseudoword REVIDO is responded slower than the mixed-case pseudoword rEvIDo (e.g., see Perea et al., 2020a). Of note, the set of words employed in the present experiment only showed a minimal negligible reading cost when the accent mark was omitted in first-pass eye fixation measures during sentence reading (see Marcet and Perea, 2021) and in the response times in a task that requires on access to lexical-semantic memory (semantic categorization task, see Perea et al., 2021b). Therefore, the more parsimonious account of the present experiments is that the omission of accent marks in the yes/no lexical decision task does not hinder lexical access.

To sum up, our findings are consistent with the view that the omission of accent marks in Spanish—at least for words with unambiguous spelling—only conveys a negligible reading cost. This pattern has implications for the front-end of computational models of visual-word recognition in Spanish: non-accented vowels (e.g., a) can be represented at the level of abstract letter entries together with their accented counterparts (e.g., á). Nonetheless, we acknowledge that accent marks in Spanish may play some role at a phonological level—this may be more manifest in tasks that involve grapheme-to-phoneme associations (e.g., naming task), particularly for unfamiliar words. At a more applied level, the present experiment serves as another call to further simplify accentuation rules in Spanish—probably in the same line as in Italian. Finally, it is also essential to consider that the function of accent marks differs across languages, and the above conclusions may not apply to other languages (see Marcet et al., 2021, for discussion).

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 below: https://osf.io/w592x/?view_only=bb13458d70864b4ea10176be0de72bbc.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Comité de Ética de Investigación en Humanos (CEIH) of the University of Valencia. The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

AM, MF-L, ML, and MP contributed to the conception and design of the study. ML and MP performed the statistical analyses. AM, MF-L, and MP wrote the first draft of the manuscript. ML wrote some sections. All authors contributed to the article and approved the submitted version.

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The Distribution of Subjects in L2 Spanish by Greek Learners

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Our study examines the expression and position of subjects in L2 acquisition, two phenomena that are studied within the framework of the Interface Hypothesis (IH). The first version of the IH predicts that interface properties involving syntax and another cognitive domain may not be fully acquirable in a second language (Sorace and Filiaci, 2006; also Sorace, 2011). The second version of the IH predicts that formal properties involving the syntax-semantics interface are unproblematic to acquire in L2 grammars compared to the vulnerable properties integrating syntax with the higher level of pragmatics (Tsimpli and Sorace, 2006). We test these IH versions in L2 Spanish as acquired by L1 Greek speakers, a language combination understudied in the literature. Both languages share the null subject parameter, but still the IHs predict incomplete command at the syntax-pragmatics interface. Two acceptability judgment tasks were designed for Spanish: the first task tested null/overt subjects in referential contexts and the second task tested preverbal/postverbal subjects in informational contexts. Participants were L1 Greek intermediate and advanced learners of Spanish and native speakers of Spanish (15 subjects in each group). In the first task, both experimental groups showed target-like distribution of null/overt subjects in most non-contrastive and contrastive contexts, except for the advanced group in unambiguous referential contexts. In the second task, the respective groups accepted felicitous preverbal subjects with unergative verbs, but diverged from native-like distribution of postverbal subjects with unaccusative verbs in neutral contexts. The L2 groups showed a high preference for unfelicitous preverbal subjects with both intransitive verbs in informational contexts, contrary to the subject inversion patterns of the control group. The results obtained were not consistent with the IH predictions, and other factors such as the type of subject, verb class and context played a role in L2 performance.

Keywords: null subjects, preverbal subjects, postverbal subjects, syntax-pragmatics interface, syntax-semantics interface, Interface Hypothesis, L1 Greek – L2 Spanish

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INTRODUCTION

In this study, we explore the acceptance of null/overt subjects and preverbal/postverbal subjects in specific pragmatic contexts in L2 Spanish acquisition by Greek learners. Our aim is to examine both the expression and position of subjects within the framework of the Interface Hypothesis (IH), as most studies examine either the expression of null/overt subjects (see Clements and Domínguez, 2017; Lozano, 2018) or the position of preverbal/postverbal subjects (see Lozano, 2006a,b; Domínguez and Arche, 2014); scarce previous work on L2 Spanish addresses these two properties of the null subject languages. After studying the anaphora resolution of null/overt subjects, Sorace and Filiaci (2006) introduced the first version of the IH (IH-1 hereafter), which predicts that interface structures involving the mappings between syntax and other cognitive domains such as pragmatics are more complex to acquire in L2. After examining focalization and subject uses, Tsimpli and Sorace (2006) proposed a new version of the IH (IH-2 hereafter), arguing that structures involving the syntax-semantics interface are easier to acquire than structures involving the syntax-pragmatics interface. In this study, we aim at testing these versions of the IH in an understudied language combination, L1 Greek – L2 Spanish, Greek and Spanish being two languages that share the null subject value and the unergative/unaccusative universal distinction. Still, the two languages present some differences in the position of subjects in informational focus contexts. In this case, our main aim is to examine if acquiring interface phenomena remains difficult given the similar distribution of subjects in these two null subject languages.

This paper is structured as follows: section "Background" presents the IH and examines the distribution of subjects in L2 Spanish. Section "The Study" presents our study: the IH predictions and the methods of our research, including the experimental design, the procedure and the data analysis. The main results of our analysis are detailed in section "Results." The discussion of the substantial findings and the overall conclusions of our study appear in section "Discussion and Conclusions."

BACKGROUND

The Interface Hypothesis: Versions and Objections

Sorace and Filiaci (2006) proposed the first version of the Interface Hypothesis, as defined in (1).

(1) IH-1 (Sorace and Filiaci, 2006: 340)
Interface properties involving syntax and another cognitive domain may not be fully acquirable in a second language.

In their work, Sorace and Filiaci (2006) examined anaphora resolution at the syntax-pragmatics interface, concerning the use of null/overt subjects in appropriate contexts. In particular, they focused on the mastery of anaphora resolution in L2 acquisition of Italian by L1 English. In their results, the L2 learners had problems with the interpretation of overt pronouns in relation to their antecedents, but showed target-like processing of null pronouns. This asymmetry between null and overt subjects was not consistent with the IH-1, as both types of subjects were predicted to present target-deviant distribution at the syntax-pragmatics interface.

Tsimpli and Sorace (2006) also proposed a second version of the IH (IH-2 hereafter), taking into consideration the distinction between the syntax-semantics interface, involving the formal properties of grammar and the syntax-pragmatics interface, involving a higher level of language use, integrating properties of language and pragmatic processing. Their definition of the IH is stated in (2).

(2) IH-2 (after Tsimpli and Sorace, 2006: 656)
Formal properties involving the syntax-semantics interface are unproblematic to acquire in L2 grammars compared to the vulnerable properties integrating syntax with the higher level of pragmatics.

In their study, Tsimpli and Sorace (2006) examined word order in relation to focalization and the expression/omission of subjects in relation to person features (1st/2nd/3rd). The two phenomena were examined based on L1 Russian learners' performance in L2 Greek. The results showed that the L2 learners had acquired the felicitous word order with focalization, while they overused 1st/2nd against 3rd person overt pronouns, showing that person had an effect on L2 performance. The authors claimed that word order at the syntax-semantics interface was easier to acquire than subject use when the syntax-pragmatics interface was involved, in support of the IH-2. However, in their own results L2 learners had no problems with the distribution of null subjects, so that the syntactic-pragmatic constraints were not always compromised.[1]

Sorace (2011: 15) rephrased the IH as follows: "L2 learners are less efficient than monolinguals at processing structures at the syntax-pragmatics interface because their knowledge of or access to computational constraints is less detailed or less automatic than in monolinguals and they have fewer cognitive resources to deploy on the integration of different types of information in real-time language use." The syntax-pragmatics interface is claimed to be the main locus of processing difficulties and acquisition delays at the highest levels of L2 ultimate attainment. Interface problems are attributed to the fact that L2 learners need to acquire both the representational knowledge of the structure and the mapping conditions that operate within interface components, and the processing principles that apply in real-time integration of different domains. Sorace (2012: 210) explicitly states that there is "a hierarchy of computational difficulty" with structures requiring proceduralized "internal" mappings being less taxing than structures requiring the integration of contextual information.

White (2011b: 109) questioned Sorace's claim that the IH does not hold at all L2 developmental stages, since interface problems, should they occur, would not emerge out of the blue, but appear in the course of L2 language development, not only at the near-native stages. White (2011a: 588) also argues that even if L2 non-native performance reveals processing difficulties in acquiring interface phenomena, this does not imply

[1] Sorace and Serratrice (2009: 200) proposed an extension of the Interface Hypothesis (IH-3) for bilingual acquisition, in the following terms: "Processing limitations in bilingual speakers may be responsible at least for some of the difficulties attested at the interfaces, especially the ones requiring the coordination of syntactic and contextual information, while internal interfaces may be expected to be less sensitive to processing limitations because they involve mappings between formal properties of the language system alone." This is an extension of the IH to bilingual populations, which are not the focus of this manuscript.

permanent impairment at the interfaces. Slabakova (2009) and White (2011a,b) also cast doubt on what is considered "difficult" and what "easy" under the IH, as the syntax-pragmatics interface is not necessarily found to be more problematic than other linguistic domains, such as the syntax-semantics interface (see for example Serratrice et al., 2009; Sorace et al., 2009). The argument is therefore that it is inappropriate to make broad generalizations for interface domains.

Taking into consideration that not all syntax-discourse interface properties are equally problematic, Lozano (2016) formulated a more specific proposal, the Pragmatic Principles Violation Hypothesis (PPVH), which makes predictions mostly on the distribution of null/overt subjects. In his study, Lozano (2016) examined anaphora resolution in L2 Spanish by L1 English speakers. His results showed that the L2 learners presented native-like use of null subjects in topic-continuity contexts, while they avoided this type of subject in topic-shift contexts. Regarding overt pronouns, the L2 learners preferred the expression of pronominal subjects in topic-shift contexts, but also used this type of subject in topic-continuity contexts. Thus, it was easier to overuse the unfelicitous overt pronoun in topic-continuity contexts than to resort to the unfelicitous null pronoun in topic-shift contexts. These results were against the predictions of the IH of complete vulnerability at the syntax-pragmatics interface. Based on pragmatic principles related to redundancy and ambiguity, following the neo-Gricean principles of Informativeness and Manner, he proposed that overt-when-null violation to mark topic-continuity leads only to redundancy and not to informative breakdown, while null-when-overt violation to mark topic-shift leads to ambiguity that causes communicative failure in discourse. He stated his hypothesis as in (3).

(3) PPVH (after Lozano, 2016: 243)
Advanced learners will violate pragmatic principles banning redundancy more often than principles banning ambiguity, by being pragmatically more "redundant" (producing redundant overt anaphors to mark topic-continuity) than "ambiguous" (producing ambiguous null anaphors to mark a shift in topic).

This proposal follows the IH in placing the syntax-pragmatics interface as the locus of delay in L2 acquisition, but is more restrictive.

Subject Distribution in L2 Spanish

Spanish and Greek share the null subject parameter (4) (see Fernández-Soriano, 1989 for Spanish and Philippaki-Warburton, 1987, 1989 for Greek) and the unergative/unaccusative distinction affects word order (5) and (6) (see Eguren and Fernández-Soriano, 2004 for Spanish and Alexiadou and Anagnostopoulou, 2004 for Greek). However, the two languages differ with respect to subject position in informational contexts, VS in Spanish and SV in Greek (see Roussou and Tsimpli, 2006), as illustrated in (7) and (8).

(4) a. El fin de semana pro$_i$ salgo$_i$ con mis amigos.
the end of week pro go.out.1SG.PRS with my friends
"The weekend I go out with my friends."
b. To savatokirjako pro$_i$ vjeno$_i$ me tus filus mu.
the weekend pro go.out.1SG.PRS with the friends mine
"The weekend I go out with my friends."

(5) a. Juan habla con sus colegas. (unergative)
Juan speak.3SG.PRS with his colleagues
"Juan speaks with his colleagues."
b. O Janis milai me tus sinaderfus tu.
the.NOM Janis speak.3SG.PRS with the colleagues his
"Janis speaks with his colleagues."

(6) a. Ayer vino María. (unaccusative)
yesterday come.3SG.PST María
"Yesterday María came."
b. Xthes irthe i Maria.
yesterday come.3SG.PST the.NOM Maria
"Yesterday María came."

(7) *¿Quién camina/va. . .?* ("Who walks/goes. . .?")
a. Camina Juan por el parque.
walk.3SG.PRS Juan through the park
"Juan walks in the park."
b. Va Juan a la playa.
go.3SG.PRS Juan to the beach
"Juan goes to the beach."

(8) *Pjos perpatai/pijeni. . .?* ("Who walks/goes. . .?")
a. O Janis perpatai sto parko.
the.NOM Janis walk.3SG.PRS in.the park
"Janis walks in the park."
b. O Janis pijeni stin paralia.
the.NOM Janis go.3SG.PRS to.the beach
"Janis goes to the beach."

While L2 Spanish acquisition with regard to subject expression and subject position is common in the literature, the combination of L1 Greek and L2 Spanish is understudied. Lozano (2018) explored the distribution of null/overt subjects in L2 Spanish by L1 Greek learners. He focused on the development of pronominal subjects at three proficiency levels (intermediate, lower-advanced, and upper-advanced). In contrastive contexts, all L2 groups distinguished the felicitous overt pronoun from the unfelicitous null pronoun. In this case, the upper-advanced group showed convergence with native behavior, but presented some persistent deficits in topic-continuity contexts, in which they accepted redundant overt pronouns. At lower levels, L2 learners alternated between null and overt subjects, confirming a higher divergence from native-like patterns. Lozano (2009) also claimed that deficits at the syntax-pragmatics interface were selective, as the type of person played a role in the performance of learners who had problems with the anaphoric uses of 3rd person pronouns, while they presented better mastery of the deictic uses of 1st/2nd person. Lozano (2006a) examined subject-verb alternations in the data of three (upper-intermediate, lower-advanced, and upper-advanced) experimental groups of L1 Greek learners of L2 Spanish. All L2 groups showed native-like mastery of the felicitous subject position with intransitive verbs at the syntax-semantics interface. On the other hand, all L2 groups had problems with the distribution of subject-verb at the syntax-pragmatics interface, except for the upper-advanced group that showed a clear preference for the felicitous VS with unaccusative verbs in informational contexts. Lozano's (2006a) results supported again native-like command of syntactic-semantic properties, but did not confirm that all syntactic-pragmatic properties were inacquirable due to permanent vulnerability. Hertel (2003) also found that learners of higher levels performed native-like at the syntax-pragmatics interface, so that discourse-related word order was eventually acquired in L2.

Domínguez and colleagues also examined subject distribution in L2 Spanish by L1 English speakers. Clements and Domínguez (2017) found that, in contrastive contexts, L2 learners at an advanced level followed native-like intuitions with respect to the use of overt subjects, while they performed target-deviant in the case of unfelicitous null subjects. In switch referent contexts, though, advanced learners did not differ from native-like performance when the felicitous option was a null pronoun, showing command of the pragmatic constraint involving the possibility of omitting subjects in topic-shift contexts. In non-topic-shift contexts, L2 learners also approached the rates of natives, showing no problems with the use of null pronouns. However, advanced learners did not reject unfelicitous overt pronouns to the same extent as the control group. The problematic nature of the syntax-pragmatics interface was not always supported by the results. Domínguez and Arche (2014) also examined the position of subjects at three proficiency levels (beginner, intermediate, and advanced). Results indicated that beginner and intermediate groups preferred SV in all contexts, while the advanced group accepted VS over SV with unaccusative verbs in broad and narrow focus contexts, but showed optionality between the two word orders with unergative verbs in focus contexts. Subject inversion acquisition was a slow process, as systematic preference for inversion was only observed at advanced levels. Persistent SV/VS problems were caused not exclusively by the syntax-pragmatics interface, but also by the syntax-semantics interface when verb class was involved (see also Montrul, 2005).

THE STUDY

Predictions

In this study, we also examine the expression and position of subjects in various pragmatic contexts in Spanish. The novelty of our study is that we give an account of both phenomena, as in the literature most studies examine either the use of overt/null subjects (Clements and Domínguez, 2017; Lozano, 2018) or the position of preverbal/postverbal subjects (Lozano, 2006a,b; Domínguez and Arche, 2014). The combination of two null subject languages, L1 Greek and L2 Spanish, is also new, as in most studies the combination involves a non-null subject language and a null subject language, e.g., L1 English and L2 Spanish (see Hertel, 2003; Montrul, 2005; Rothman, 2009). Our main aim is to examine the extent to which Greek learners of Spanish show command of both null/overt subjects and preverbal/postverbal subjects in referential and informational contexts. These phenomena are tested under the light of the two versions of the IH as well as Lozano's (2016) PPVH. The predictions of the above hypotheses are as follows.

i According to the IH-1, L2 learners are expected to accept the unfelicitous type of subjects, null or overt, preverbal or postverbal in non-contrastive, unambiguous and contrastive referent-shift contexts as well as informational contexts in which the syntax-pragmatics interface is involved.[2]

ii According to the IH-2, L2 learners are expected to accept the felicitous subject position with intransitive verbs in neutral contexts in which the syntax-semantics interface is involved, while they will have problems with subject expression and position in referential and informational contexts in which the syntax-pragmatics interface is involved.

iii If Lozano's (2016) PPVH is accurate, L2 learners will overuse overt pronouns in referential contexts in which a null pronoun is expected, while they will perform target-like in pragmatic contexts in which an overt pronoun is expected. Pragmatic failure leading to redundancy is predicted but not leading to ambiguity.

Methods

In our study, we apply offline tasks that examine subject processing under a particular time limit in the discourse. We have chosen a written task that allows to better control subject acceptability in relation to the type of context, referent antecedent and verb class. Contextualized pragmatic felicitousness judgment tasks have been widely used in applied studies on L2 Spanish acquisition (see Hertel, 2003; Lozano, 2006a,b, 2018; Clements and Domínguez, 2017), so this is a suitable method to examine the real preferences of L2 learners.

Materials: Experimental Design

We designed two acceptability judgment tasks to examine the type of subject, null or overt, preverbal or postverbal in contextualized sentences in Spanish. These experiments include a 5-point Likert-scale from −2 (fully rejected), −1 (rejected), 0 (neither rejected/neither accepted) to 1 (accepted) and 2 (fully accepted); this allows the rating of the exact degree of

[2] Here we take into consideration White's (2011a,b) claim that the IH should hold of developmental stages and we examine not only the very advanced levels ("the near-natives" as originally proposed by the IH), but also the intermediate levels of knowledge, which are extensively studied in the literature for the interface framework (Lozano, 2006a,b, 2018; Domínguez and Arche, 2014).

acceptability of the type of subjects in various pragmatic contexts (see also Lozano, 2006a,b, 2018).

Experiment 1 consists of a total number of 21 stimuli: 16 items with two sentences each (total: 32 sentences) testing the acceptance or rejection of null/overt subjects and five distractors (total: 10 sentences). The variables checked are: (i) person (1st, 2nd, 3rd) and (ii) discourse context (referent-continuity, unambiguous referent-shift, and contrastive referent-shift). Experiment 2 consists of a total number of 25 stimuli: 20 items with two sentences each (total: 40 sentences) testing the acceptance or rejection of preverbal/postverbal subjects and five distractors (total: 10 sentences) that do not involve the phenomena examined, so that they are not further analyzed. The variables controlled for are: (i) verb class (unergative and unaccusative) and (ii) context (neutral or informational).

Experiment 1 includes three subtest conditions. Subtest 1 involves the acceptability of 1st and 2nd person null/overt subjects in non-contrastive referential contexts. This subtest contains six items: three items with 1st person subjects and three items with 2nd person subjects. Both types of person demand the production of null subjects in non-contrastive referential contexts. The variables tested are *Person* and *Subject* type in a given context, giving rise to the following conditions: (i) 1st person, null subject, non-contrastive referential context, (ii) 1st person, overt subject, non-contrastive referential context, (iii) 2nd person, null subject, non-contrastive referential context, and (iv) 2nd person, overt subject, non-contrastive referential context. Under the IH-1 and IH-2, L2ers are expected to accept unfelicitous overt pronouns of both persons due to the involvement of pragmatics; likewise, under Lozano's (2016) PPVH, L2ers will overaccept overt pronouns when null pronouns are expected.

To illustrate, in example (9) the null subject is felicitous in referent-continuity contexts in which the inflection of the verb *volver* ("return") shows the 1st person singular in (9a). In this case, the expression of the overt pronoun *yo* ("I") (9b) would be redundant. Still, an overt pronoun would be acceptable with emphatic/contrastive interpretation, but this is not the first choice in the sentence examined in Spanish. (In Greek, subject omission is also the preferred option in the equivalent contexts).

(9) Ayer, cuando *salí* del trabajo,
yesterday, when leave.1SG.PST from.the work,
__________.
____

(a) *volví* a casa para cenar con mis padres.
return.1SG.PST to house to dine.INF with my parents
−2 −1 0 1 2

(b) *yo* *volví* a casa para cenar con mis padres.
I.NOM return.1SG.PST to house to dine.INF with my parents
−2 −1 0 1 2

"Yesterday, when I left work, I went back home to have dinner with my parents."

Subtests 2 and 3 involve the acceptability of 3rd person null/overt subjects. Subtest 2 consists of five items requiring null subjects in referent-shift contexts (with one unambiguous antecedent). The variables tested are 3rd *Person* and *Subject* type in a given context, giving rise to the following conditions: (i) 3rd person, null subject, referent-shift context (with one antecedent), and (ii) 3rd person, overt subject, referent-shift context (with one antecedent). Since the distribution of null pronouns is constrained by the syntax-pragmatics interface, the IH-1 and IH-2 predict that L2ers will fail to accept the felicitous type of pronoun in unambiguous referent-shift contexts; similarly, Lozano's (2016) PPVH predicts that L2ers will be target-deviant, as in the previous subset of items.

In example (10) the inflection of the verb *decir* ("say") allows the identification of the 3rd person of the antecedent referent *el profesor* ("the teacher") so that the production of a null subject is acceptable in Spanish (10a). However, an emphatic/contrastive overt pronominal subject *él* ("he") is possible in referent-shift contexts (10b). (In Greek, a null subject is also the first choice in the equivalent contexts, but the expression of an overt pronoun is not disallowed).

(10) Cuando el profesor imparte clases de matemáticas, __________
when the teacher give.3SG.PRS classes of mathematics, __________

(a) sus alumnos no entienden ni la mitad de las cosas que *dice*
his students not understand.3PL.PRS not.even the half of the things that say.3SG.PRS
−2 −1 0 1 2

(b) sus alumnos no entienden ni la mitad de las cosas que *él* *dice*.
his students not understand.3PL.PRS not.even the half of the things that he.NOM say.3SG.PRS
−2 −1 0 1 2

"When the teacher gives mathematics class, his students do not understand even half of the things that he says."

Subtest 3 involves five items that require the expression of 3rd person subjects. The variables tested are 3rd *Person* and *Subject* type in a given context, giving rise to the following conditions: (i) 3rd person, overt subject, contrastive referent-shift context (with two antecedents), and (ii) 3rd person, null subject, contrastive referent-shift context (with two antecedents). Under the IH-1 and IH-2, L2ers will fail with the felicitous overt pronoun, due to difficulties in acquiring referential properties. On the other hand, Lozano's (2016) PPVH predicts that L2ers will perform target-like.

In example (11), the inflection of the verb *hablar* ("speak") shows the 3rd person singular in Spanish, but it does not distinguish the antecedent referents *Manolo* or *Sofía*, so the expression of the pronoun *él* ("he") is obligatory in (11a) to refer to the antecedent (*Manolo*). A null subject would generally refer to the closest singular antecedent (*Sofía*) in the discourse (11b). (In Greek, the felicitous option is also an overt pronoun in the equivalent contexts).

(11) Manolo y Sofía trabajan en una empresa multinacional.
Manolo and Sofía work.3PL.PRS in a company multinational.

(a) Sus colegas dicen que *él* no *habla* muy bien inglés.
their colleagues say.3PL.PRS that he.NOM not speak.3SG.PRS very well English
−2 −1 0 1 2

(b) Sus colegas dicen que no *habla* muy bien inglés.
their colleagues say.3PL.PRS that not speak.3SG.PRS very well English
−2 −1 0 1 2

"Manolo and Sofía are working in a multinational company. Their colleagues say that he does not speak English very well."

In Experiment 2, we examine the position of subjects with intransitive verbs in various contexts. Two subtest conditions are included. Each subtest contains five items with unergatives and five with unaccusatives. Subtest 1 involves the unergative/unaccusative distinction that allows the anteposition of unergative subjects and the postposition of unaccusative subjects (see also Lozano, 2006a,b). This distinction is examined in direct question-answer pairs in which the informational focus is neutral, so the syntactic-lexical-semantic properties of verbs constrain the position of their subjects. The variables tested are *Word Order* and *Verb Class* in a given context, giving rise to the following conditions: (i) SV, unergative verb, neutral context, (ii) VS, unergative verb, neutral context, (iii) SV, unaccusative verb, neutral context, and (iv) VS, unaccusative verb, neutral context. Under the IH-2, L2 learners will accept the felicitous subject position with both verb classes at the syntax-semantics interface.

In the contextualized examples (12) and (13), the broad focus questions *¿Qué sucede?* ("What happens?") and *¿Qué sucedió en el banco?* ("What happened in the bank?") trigger as new information the entire answer, allowing SV with the unergative *caminar* ("walk") in (12a) and VS with the unaccusative *entrar* ("enter") in (13a). On the other hand, the second word order option is not acceptable in Spanish neutral contexts in (12b) and (13b). (In Greek, unergative verbs also accept the SV order, while unaccusative verbs allow the VS order in neutral contexts).

(12) Estás en casa y oyes las voces de la gente que está en la calle. Luego, tu madre vuelve de su trabajo y le preguntas: ¿Qué sucede? Y ella responde:
be.2SG.PRS in house and listen.2SG.PRS the voices of the people that be.3SG.PRS in the road. then, your mother return.3SG.PRS from her work and her.ACC ask.2SG.PRS: what happen.3SG.PRS? and she.NOM answer.3SG.PRS:

(a) *Mucha gente camina* por la calle.
many people walk.3SG.PRS around the road
−2 −1 0 1 2

(b) *Camina mucha gente* por la calle.
walk.3SG.PRS many people around the road
−2 −1 0 1 2

"You are at home and listen to the voices of the people being in the road. Then, your mother comes back from her work and you ask her: What is happening? And she answers to you: A lot of people are walking in the road."

(13) Ayer, mientras estabas en el banco, viste a un ladrón. Hoy tu amiga Juana te pregunta: ¿Qué sucedió en el banco? Y tú contestas:
yesterday, while be.2SG.PST.CONT in the bank, see.2SG.PST to a thief. today your friend Juana you.ACC ask.3SG.PRS: what happen.3SG.PST in the bank? and you.NOM answer.2SG.PRS:

(a) *Entró un ladrón*.
enter.3SG.PST a thief
−2 −1 0 1 2

(b) *Un ladrón entró*.
a thief enter.3SG.PST
−2 −1 0 1 2

"Yesterday, while you were at the bank, you saw a thief. Today your friend Juana asks you: What happened in the bank? And you answer: A thief walked in."

Subtest 2 examines the distribution of subjects in informational focus contexts. In this case, the syntactic-pragmatic properties of focus determine word order, so the felicitous word order is VS with both unergative/unaccusative verbs. The examined contexts contain direct question-answer pairs, as in Subtest 1, but, in this case, the question is with *¿Quién...?* ("Who.?"), triggering a focalized subject that introduces new information into the discourse. The variables tested are also *Word Order* and *Verb Class* in a given context, giving rise to the following conditions: (i) SV, unergative verb, informational context, (ii) VS, unergative verb, informational context, (iii) SV, unaccusative verb, informational context, and (iv) VS, unaccusative verb, informational context. Under both the IH-1 and IH-2, L2ers will accept the unfelicitous option of preverbal subjects as the syntax-pragmatics interface is involved in the contexts examined. Lozano's (2016) PPVH does not make predictions for this subset of cases.

In the contextualized examples (14) and (15), the narrow focus question with *¿Quién.?* ("Who. . .?") receives as answer the VS order with the unergative *reírse* ("laugh") in (14a) and the unaccusative *venir* ("come") in (15a). The anteposition of subjects is unacceptable in (14b) and (15b) contexts in Spanish. (In Greek, though, the felicitous option is the SV order with both intransitive verbs in informational focus contexts).

(14) Estás en una clase de física. Todo el mundo
be.2SG.PRS in a class of physics. all the world
está callado
be.3SG.PRS silent
mientras el profesor explica
while the teacher explain.3SG.PRS
la lección, pero un
the lesson, but a
chico se ríe. El
boy REFL laugh.3SG.PRS. the
profesor no ve quién
teacher not see who
se ríe, así que
REFL laugh.3SG.PRS, so that
te pregunta: ¿Quién se
you.ACC ask.3SG.PRS: who REFL
ríe? Tú responde s:
laugh.3SG.PRS? you.NOM answer.2SG.PRS:

(a) *Se ríe un chico.*
REFL laugh.3SG.PRS a boy
−2 −1 0 1 2

(b) *Un chico se ríe.*
a boy REFL laugh.3SG.PRS
−2 −1 0 1 2

"You are in the physics class. All people are silent while the teacher explains the lesson, but a boy is laughing. The teacher does not see who is laughing, so that he asks you: Who is laughing? You answer: A boy is laughing."

(15) María sale de la librería un momento y
María leave.3SG.PRS from the library a moment and
al minuto
in.a minute
aparece una chica a la que no conoces.
appear.3SG.PRS a girl to the whom not know.2SG.PRS.
Cuando
when
regresa María, te pregunta: ¿Quién
return.3SG.PRS María, you.ACC ask.3SG.PRS: who
ha
have.AUX
venido? Tú responde s:
come.3SG.PRS.PRF? you.NOM answer.2SG.PRS:

(a) *Ha venido una chica.*
have.AUX come.3SG.PRS.PRF a girl
−2 −1 0 1 2

(b) *Una chica ha venido.*
a girl have.AUX come.3SG.PRS.PRF
−2 −1 0 1 2

"María leaves the library for a moment and in a minute a girl appears that you do not know. When María comes back, she asks you: Who has come? You answer: A girl has come."

All test items were fully randomized.[3]

Participants

Participants of both experiments were two groups of L1 Greek learners of L2 Spanish and a group of native Spanish speakers. The non-native groups consisted of intermediate and advanced students who were learning Spanish as an L2 at the Instituto Cervantes de Atenas. At the time of the experiments, intermediate and advanced learners were attending the respective third and fifth Spanish courses for 4 hours a week. Both groups had passed the Examination for the Diploma of Spanish as a Foreign Language (*DELE)*. Intermediate learners had obtained an average rate of 86% in the B1 Exam, while advanced learners had attained a mean of 89% in the C1 Exam, according to the European Framework for Foreign Languages. Spanish native speakers were living in Madrid and were students at the Universidad Autónoma de Madrid. This third group served as a control group and established the rate of acceptability of the various types of subjects in Spanish. **Table 1** shows the essential information for the three groups.

TABLE 1 | Participants.

Groups	Intermediate	Advanced	Control
First language	Greek	Greek	Spanish
Number	15 (3 males and 12 females)	15 (2 males and 13 females)	15 (5 males and 10 females)
Age range (SD)	30-60 (9.27)	34-62 (8.24)	30-50 (7.07)
Studies in L2 Spanish	3rd L2 course	5th L2 course	——
Duration	3 years	5 years	——
Proficiency level	B1	C1	Native
Average score in *DELE* exams	86%	89%	——

[3] A reviewer suggests that a between-subjects design would have been more appropriate, with several lists and the distribution of the experimental items per list following the Latin Square procedure, and would have allowed for more distractors, something to take into account for future research.

Procedure

Both Experiments 1 and 2 were administered in the Instituto Cervantes de Atenas, where the classes of L2 Spanish were taught and in the Universidad Autónoma de Madrid, where the native speakers were studying. All participants provided written informed consent to participate in the tasks of our study. Participants also answered a language questionnaire about their L1 (Greek being the only L1 examined in this study), and their knowledge of L2 Spanish, to distinguish between two competence levels for L2 learners, which determined the factor of Group in the statistical analysis. Then all groups were instructed as to how to complete the acceptability judgment tasks and how to rate the two-sentence items. The five points of the scale were explained, as follows: −2 (fully rejected), −1 (rejected), 0 (neither rejected nor accepted), 1 (accepted), and 2 (fully accepted). The participants were also given a distractor example that indicated how to rate the felicitous and unfelicitous options. All questions and doubts were answered to avoid misunderstandings. The duration of each task was 45 min, but participants were given extra time if necessary.

Coding of Data and Statistical Analysis

In Experiments 1 and 2, the ratings of subject types (null/overt or preverbal/postverbal) on the five-point scale were classified as follows: the accepted (1, 2) and rejected (−1, −2) values were grouped together, while the neither accepted/rejected (0) value was also noted as third category. Subjects were coded in accordance with the context of each given condition. For each condition, a Generalized Linear Model (GLM) was used to compare percentages of accepted items (1, 2) across different levels, using the binomial distribution (see Dobson and Barnett, 2018). Also we examined the interaction of *Person* (1st and 2nd) and *Group* (intermediate, advanced, and control) in Experiment 1 and *Verb Class* (unergative and unaccusative) and *Group* in Experiment 2 applying a Generalized Linear Mixed Model (GLMM) of accepted items (1, 2) with the binomial distribution (see Moscatelli et al., 2012). The GLMM has a high statistical power as it estimates the variability of fixed and random effects. *P*-values were adjusted according to Tukey correction for multiple comparisons. The statistical analysis was performed using the software SAS v9.4, SAS Institute Inc., Cary, NC, United States. The statistical decisions were made taking as significance level the value 0.05.

RESULTS

Experiment 1 yielded a total of 1,440 responses (480 from each group), while Experiment 2 yielded a total of 1,800 responses (600 from each group). The responses to the distractors were not included in the analysis because they did not involve the phenomena examined. Prior to analysis, the responses were categorized following the grouping of accepted and rejected values, while the zero value was not selected by any of the participants.

Regarding Experiment 1, the number and percentage of accepted values (1, 2) by *Context* (non-contrastive, unambiguous referential, and contrastive) and *Subject* (null/overt) are presented in **Table 2**. In the three subtest conditions, the L2 intermediate and advanced groups showed a higher rate of felicitous than unfelicitous type of subjects, following the patterns of the control group, except for the advanced group in the overt subject condition in 1st person non-contrastive and unambiguous referential contexts.

In the GLM, no significant differences between groups for both null/overt subject conditions in non-contrastive and contrastive contexts were found. On the other hand, in unambiguous referential contexts there were significant differences in the overt subject condition ($F = 5.23$, p-value = 0.0093). The statistical differences were detected in the comparison between advanced and control groups ($t = 3.23$, adj p-value = 0.0066, according to Tukey correction).

To examine the interaction of *Person* (1st and 2nd) and *Group* (intermediate, advanced, and control) in non-contrastive contexts, a GLMM was applied. In the null subject condition, there were no significant differences detected. In the overt subject condition there were significant differences with respect to *Person* ($F = 9.54$, p-value = 0.0036), but no interaction of *Person* and *Group*. In the *post hoc* test, there were significant differences between 1st and 2nd person ($t = -3.09$, adj p-value = 0.0036 according to Tukey correction). See **Figure 1** for the 1st vs. 2nd person comparison.

Regarding Experiment 2, the number and percentage of acceptance values (1, 2) by *Context* (neutral and informational), *Verb Class* (unergative and unaccusative), and *Subject* (preverbal/postverbal) appear in **Table 3**. In the first subtest condition, the L2 intermediate and advanced groups showed a native-like rate of the felicitous preverbal subjects with unergatives in neutral contexts, while both groups showed variability between SV and VS with unaccusatives, diverging from target patterns. In the second subtest condition, both L2 groups showed a higher preference for the unfelicitous subject position in informational contexts, and the intermediate group presented full variability in the case of unaccusatives, against native intuitions for postverbal subjects.

In the GLM there were no significant differences between groups in the case of unergatives in the first subtest condition, while the statistical differences were significant in both preverbal ($F = 4.37$, p-value = 0.0189) and postverbal subject conditions ($F = 4.44$, p-value = 0.0179) with unaccusatives. In the preverbal subject condition, the significant differences were detected in the comparison between advanced and control groups ($t = 2.58$, adj p-value = 0.0353, according to Tukey correction). In the postverbal subject condition, the differences were found in both intermediate-control ($t = 2.48$, adj p-value = 0.0449, according to Tukey correction) and advanced-control group comparisons ($t = -2.98$, adj p-value = 0.0131, according to Tukey correction).

In order to examine the interaction of *Verb Class* (unergative and unaccusative) and *Group* (intermediate, advanced, and control) in neutral contexts, a GLMM was applied. In both SV ($F = 40.87$, p-value < 0.0001) and VS conditions ($F = 75.7$, p-value < 0.0001), there were significant differences regarding *Verb Class*, but no interaction of *Verb Class* and *Group*. In

TABLE 2 | Overall means and Standard Deviation in the contexts of Experiment 1.

		Acceptance percentage								
		INTERM			ADVAN			CONTR		
		N	Mean	Std	N	Mean	Std	N	Mean	Std
Non-contrastive context	Null	15	97%	9%	15	99%	4%	15	100%	
	#Overt	15	28%	26%	15	42%	33%	15	36%	34%
1st person	Null	15	98%	9%	15	100%		15	100%	
	#Overt	15	18%	25%	15	42%	41%	15	22%	37%
2nd person	Null	15	96%	12%	15	98%	9%	15	100%	
	#Overt	15	38%	35%	15	42%	37%	15	49%	40%
Unambiguous referential context	Null	15	92%	17%	15	88%	13%	15	97%	7%
	#Overt	15	48%	42%	15	60%	28%	15	33%	40%
Contrastive context	#Null	15	11%	15%	15	15%	26%	15	5%	9%
	Overt	15	89%	21%	15	91%	21%	15	97%	7%

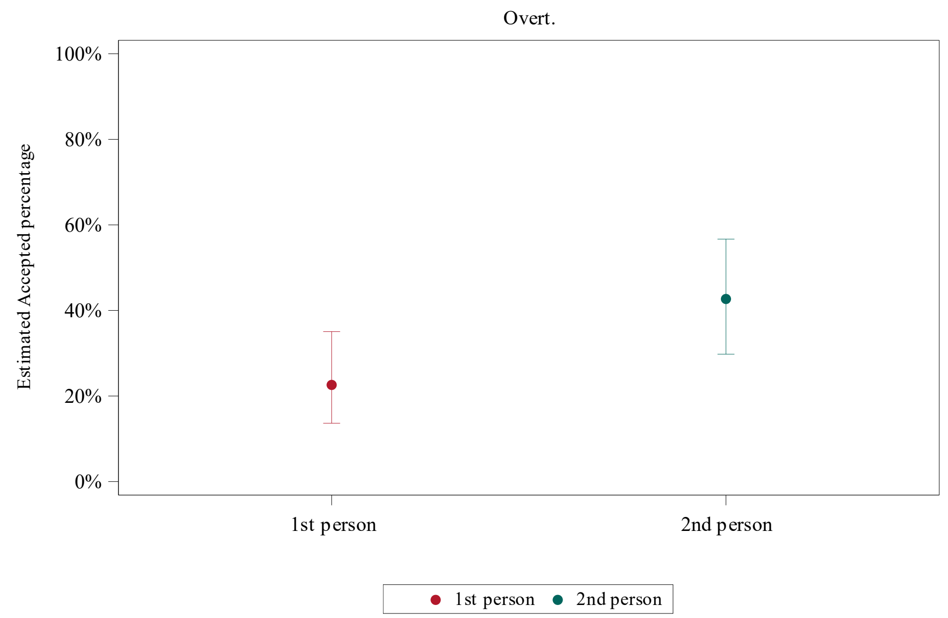

FIGURE 1 | Estimated acceptance percentage according to Person in the overt subject condition.

the *post hoc* test, there were significant differences between unergatives and unaccusatives in both SV (intermediate: $t = -3.37$, adj p-value = 0.019; control: $t = -4.64$, adj p-value = 0.0005, according to Tukey correction) and VS conditions (intermediate: $t = 5.69$, adj p-value < 0.0001; advanced: $t = 5.58$, adj p-value < 0.0001; control: $t = 4.85$, adj p-value = 0.0002, according to Tukey correction). See **Figures 2**, **3** for unergative and unaccusative comparison in SV and VS conditions.

In the second subtest condition, the GLM showed that there were significant differences between groups with preverbal ($F = 17.80$, p-value < 0.0001) and postverbal subject options ($F = 11.45$, p-value = 0.0001) with unergatives in informational contexts. The significant differences were detected in both intermediate-control (preverbal: t: −4.6, adj p-value = 0.0001; postverbal: $t = 4.16$, adj p-value = 0.0004, according to Tukey correction) and advanced-control group comparisons (preverbal: $t = 5.02$, adj p-value < 0.0001; postverbal: $t = -4.77$, adj p-value < 0.0001, according to Tukey correction). Regarding unaccusatives, statistical differences between groups were also found in both preverbal ($F = 26.27$, p-value < 0.0001) and postverbal subject conditions ($F = 8.18$, p-value = 0.0010). The significant differences were detected in both intermediate-control (preverbal: $t = -5.76$, adj p-value < 0.0001; postverbal: $t = 2.98$, adj p-value = 0.0131, according to Tukey correction) and advanced-control comparisons (preverbal: $t = 6.25$, adj p-value < 0.0001; postverbal: $t = -3.92$, adj p-value = 0.0009, according to Tukey correction).

To examine the interaction of *Verb Class* (unergative and unaccusative) and *Group* (intermediate, advanced, and control)

TABLE 3 | Overall means and Standard Deviation in the contexts of Experiment 2.

			Acceptance percentage								
			INTERM			ADVAN			CONTR		
			N	Mean	Std	N	Mean	Std	N	Mean	Std
Neutral context	Unergative	SV	15	97%	7%	15	95%	21%	15	97%	7%
		#VS	15	37%	28%	15	33%	31%	15	51%	20%
	Unaccusative	#SV	15	76%	31%	15	77%	26%	15	57%	33%
		VS	15	84%	20%	15	79%	22%	15	97%	10%
Informational context	Unergative	#SV	15	85%	18%	15	89%	17%	15	48%	36%
		VS	15	63%	34%	15	55%	33%	15	95%	12%
	Unaccusative	#SV	15	81%	32%	15	87%	25%	15	32%	38%
		VS	15	79%	34%	15	65%	37%	15	97%	10%

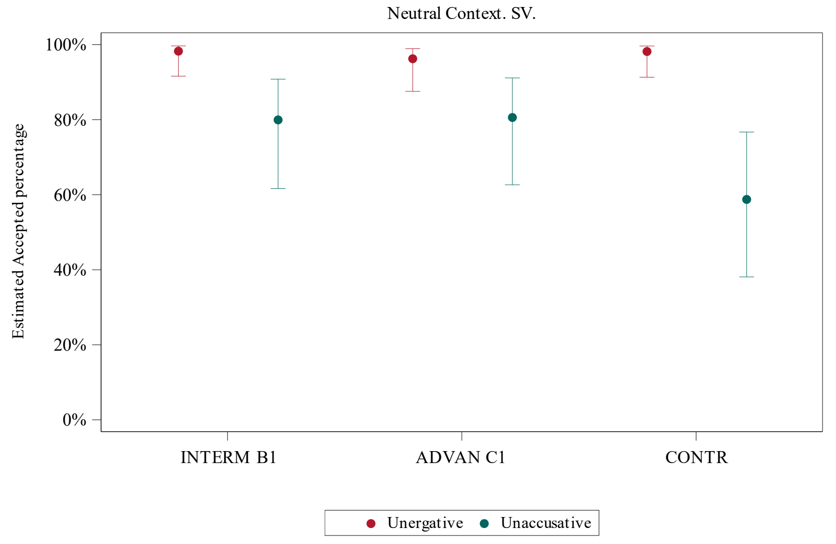

FIGURE 2 | Estimated acceptance percentage for the SV condition in neutral contexts according to Verb Class.

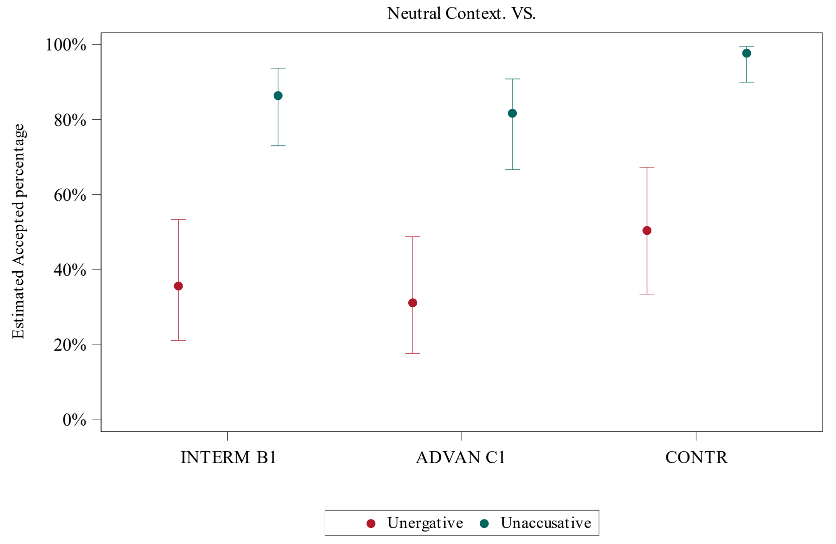

FIGURE 3 | Estimated acceptance percentage for the VS condition in neutral contexts according to Verb Class.

in informational contexts, a GLMM was applied. In the SV condition, there were no significant differences regarding *Verb Class* and there was no interaction of *Verb Class* and *Group* in the acceptance values. In the VS condition, the differences were significant with respect to *Verb Class* (F = 5.45, p-value = 0.0244), and there was no interaction of *Verb Class* and *Group*. In the *post hoc* test, there were no significant differences between unergatives and unaccusatives in neither condition for the three groups.

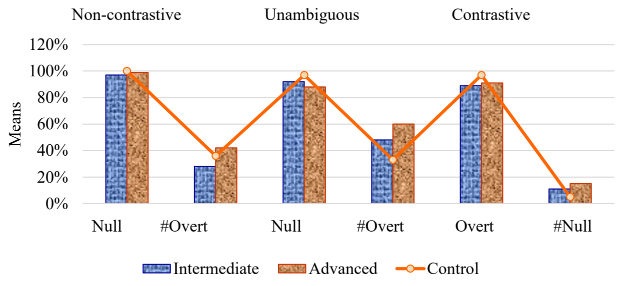

FIGURE 4 | Subject uses in referential contexts.

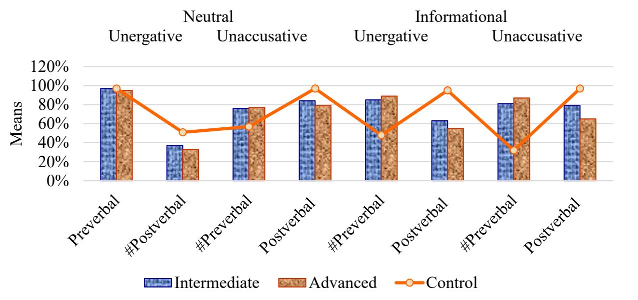

FIGURE 5 | Subject positions in pragmatic contexts.

DISCUSSION AND CONCLUSIONS

In this study, we have examined the distribution of subjects in the judgments of L1 Greek intermediate and advanced learners of L2 Spanish in two contextualized acceptability tasks.

In Experiment 1, both intermediate and advanced learners showed native-like acceptance of the felicitous null subjects against the unfelicitous overt subjects in non-contrastive referential contexts (Subtest 1). Their performance was independent of the type of person, 1st or 2nd in the null subject condition. However, in the overt subject condition, person had an effect on subject expression, but this was not related to the factor of group, as both L2 groups did not significantly diverge from native patterns. In unambiguous referent-shift contexts (Subtest 2), the L2 groups also showed a higher acceptance of 3rd person null subjects than overt subjects, though they did not reach the ceiling rates of 1st/2nd person in the previous contexts. The intermediate group showed a tendency toward target-like patterns with both null and overt subjects, while the advanced group presented significant divergence from native rates in the case of the unfelicitous overt subjects. In contrastive referent-shift contexts (Subtest 3), the L2 groups followed native-like judgments with both felicitous overt subjects and unfelicitous null subjects of 3rd person. In this case, all groups clearly rejected null pronouns in favor of expressing overt pronouns with contrastive interpretation. The tendencies of the intermediate and advanced groups with respect to the control group are shown in **Figure 4** for the three contexts examined in Experiment 1.

In Experiment 2, the intermediate and advanced groups showed target-like acceptance of felicitous preverbal subjects with unergative verbs in neutral contexts, but diverged from native-like subject inversion with unaccusative verbs in neutral contexts (Subtest 1). Thus, verb class played a significant role in the judgments of L2 learners with respect to subject position. In informational contexts (Subtest 2), both L2 groups showed divergence from native-like distribution of subjects with unergative and unaccusative verbs. Both groups accepted unfelicitous preverbal subjects, compared to the control group that showed a clear preference for the discursive VS order. In this case, context type had a higher effect on learners' performance than verb type. See **Figure 5** for the word order patterns of the L2 groups with respect to the control group in neutral and informational contexts in Experiment 2.

If we examine the overall results of the two experiments against the predictions formulated in section "Predictions," we observe that the intermediate and advanced learners of Spanish had no persistent problems with the distribution of null/overt subjects in non-contrastive and contrastive referent-shift contexts in Experiment 1, so that their performance runs against the predictions of the IH-1 (Sorace and Filiaci, 2006) and the IH-2 (Tsimpli and Sorace, 2006). Lozano's (2016) PPVH can also be rejected in non-contrastive contexts, as the L2 groups did not show significant differences from natives with overt pronouns. However, the advanced group diverged from native rejection of overt subjects in unambiguous referent-shift contexts, showing optionality in their judgments along the predictions of the IH-1/IH-2 and the PPVH.

Regarding Experiment 2, the results run against the IH-2 (Tsimpli and Sorace, 2006), as both L2 groups had difficulties with the distribution of postverbal subjects-unaccusative verbs at the syntax-semantics interface. The syntactic-lexical/semantic properties were not always acquired, and verb class played a role in neutral contexts, as the position of subjects with unergative verbs was acquired earlier by L2 learners. In informational contexts, the non-target performance of both L2 groups showed that they had not yet acquired the syntactic-pragmatic properties of subject distribution. Here the influence of the L1 Greek that allows SV in informational contexts against VS in Spanish (Roussou and Tsimpli, 2006) might be the source of non-target performance, so that the L2 learners overgeneralized the L1 felicitous option.

The results showed that both L2 groups performed better than expected under the IH-1 and IH-2 in non-contrastive and contrastive contexts in Experiment 1. The involvement of pragmatics did not necessarily lead to unacceptable use of subjects in referential contexts. The predictions of Lozano's (2016) PPVH were not correct in contexts where a null subject was the felicitous option, and the distribution of redundant overt pronouns was variable because they were accepted in unambiguous referent-shift contexts, but rejected in non-contrastive contexts, while ambiguous null subjects were correctly highly avoided in contrastive contexts. Regarding Experiment 2, the predictions of the IH-2 were not fulfilled in the performance of L2 groups. The syntax-semantics interface was not necessarily acquired earlier than the syntax-pragmatics interface. The L2 groups showed a better performance in the case of referential null/overt subjects than in the case of informational preverbal/postverbal subjects, to the effect that not all syntactic-pragmatic properties were equally acquirable or inacquirable in L2, against both versions of the IH.

Overall, the IH-1 and IH-2 failed to account for the results of the two experimental tasks. The PPVH was not fulfilled either in Experiment 1 (the only experiment here for which it made any predictions). The IH-1 did not capture the performance of the intermediate and advanced learners of Spanish in the case of null/overt subjects, but only for the advanced group in unambiguous referent-shift contexts, and for both L2 groups in informational subject-focused contexts. The IH-2 fared well for both L2 groups only in the case of the unergative word order (not for unaccusatives) –not in the case of referential uses of null/overt subjects. The PPVH fared better than the IH in the case of contrastive contexts, but not for non-contrastive contexts. Thus, none of the hypotheses considered captured the performance of L2 learners in all cases examined. Our interpretation would be that the performance of L2ers was affected by grammatical factors, such as the type of subject, verb class and context, and best accounted for in terms of transfer effects. The involvement of interfaces was orthogonal to performance in L2 Spanish by L1 Greek speakers, a result that questions the empirical adequacy of the IH.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Comissió d'Ètica en l'Experimentació Animal i Humana (CEEAH), Universitat Autònoma de Barcelona. The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

PM and AG designed this study. PM conducted the experiments and statistical analysis. Both authors are responsible for interpreting the results, and writing the manuscript.

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DATA REPORT
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The VIDAS Data Set: A Spoken Corpus of Migrant and Refugee Spanish Learners

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The VIDAS data set (Verbal Interaction Dataset of Acquired Spanish) presents data from 200 participants from different countries and language backgrounds (50 Philippines with L1 Tagalog; 50 Ukrainians with L1 Ukrainian; 50 Moroccans with L1Arabic; 50 Romanians with L1 Romanian). They completed an oral expression and interaction test in the context of a Spanish certification exam for adult migrants. The aim of the VIDAS data set is to provide researchers in psycholinguistics and second language acquisition with a Spanish spoken corpus of traditionally marginalized and underrepresented learners, providing a compelling data set of oral interactions by migrants and refugees. The corpus contains more than 29 h of recordings of the oral interactions of the participants with trained interviewers, as well as background information about the participants (age, gender, maximum education level, years of residence, and language background). It furthermore contains the scores obtained by the participants in the oral expression and interaction exam. The VIDAS corpus allows for the development of studies on L2 spoken language comprehension and processing, as well as for comparative analyses of language acquisition between different L1 groups at different linguistic levels.

Keywords: language learning, migrants, refugees and asylum seekers, underrepresented learners, language minorities

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INTRODUCTION

Language data sets and corpora have proven to be crucial in the understanding, modeling and conceptualization of first and second or additional language speech processes, such as acquisition, development, or comprehension (Meurers, 2015; MacWhinney, 2017). Second language acquisition (SLA) research has benefited from data gathered from natural language use in its aim to gain a better understanding of non-native language acquisition and development processes at different linguistic levels (Granger et al., 2015; Myles, 2015). Additionally, spoken data sets of non-native speech are key to training and improving automatic speech recognition (ASR) technologies in the particularly challenging aim of recognizing non-native speech, especially in spontaneous conversational contexts including a diversity of native language backgrounds (Yoon et al., 2010).

In recent decades, the growing interest in the analysis of natural language use both in the field of psycholinguistics and SLA and in the development of ASR has led to the creation of different repositories that collect data by second or additional language learners. While most of them were initially based on written texts, an increasing number of spoken learners' corpora and data sets are being generated in last years (see Fernández and Davis, 2021, for an overview). Although the dominance of English as the target language is still overwhelming in the field, the growing interest on these resources has led to the development of a growing number of Spanish learners' speech data sets (see SLABank by MacWhinney, 2017; CORELE by Campillos Llanos, 2014, or SPLLOC by Mitchell et al., 2008). Nevertheless, the samples of speakers mostly comprised by university students and their L1 backgrounds are still rather limited (see McEnery et al., 2019), as well as the speaking tasks that have been used to collect the data. The availability of spontaneously generated samples in conversational contexts of interaction is markedly limited. Consequently, current data sets neglect the representation of a variety of learner profiles with various cultural, academic and language backgrounds, from different learning contexts, and in different task types.

In the current study we aim at providing the community with the VIDAS data set (acronym for Verbal Interaction Dataset of Acquired Spanish). The VIDAS data set presents a database of 200 speech samples of migrant and refugee learners of Spanish in an oral expression and interaction task. The speakers are divided in four groups based on their native languages (L1), thus allowing for comparative analysis of the productions of learners from different linguistic and cultural origins set in the same communicative situation. The VIDAS data set opens an important space for comparative analysis from different perspectives and processes, such as language comprehension and production, and at different levels (phonological, grammatical, lexical, pragmatic, and discursive). Importantly, the VIDAS data set provides speech data of migrants and refugees, representing an opportunity to analyze these processes in traditionally marginalized and underrepresented samples and in conversational settings. Although transcribed and annotated corpora are, undoubtedly, a highly valuable tool for research in SLA,[1] we believe that access to raw data allows for researchers to approach their analysis from their own paradigms and perspectives, avoiding underlying assumptions in transcription processes that may influence and modify the interpretation of the data depending on the purposes of the study (e.g., Leclercq, 2020).

Applied linguistics, psycholinguistics, and SLA researchers have largely studied the factors involved in the acquisition of an additional language from different perspectives. Nevertheless, non-native language learning in migrants and refugees has not received that much attention, and these populations are still understudied and often ignored or disregarded. After the proposal of a sampling bias in the field of psychology, with research mainly focusing on a very limited participant profile – namely, WEIRD participants; Western, Educated, Industrialized, Rich, and Democratic (Henrich et al., 2010), different researchers in applied linguistics and SLA have raised concerns on the existence of a similar bias also affecting their area of expertise (Bigelow and Tarone, 2004; Ortega, 2005, 2019; Andringa and Godfroid, 2019, 2020). This has led to a call for researchers in this field to go beyond this apparent comfort zone and "demonstrate and make a case for the impact of their work beyond the walls of the academy, in a society that faces many real linguistic needs and questions" (Andringa and Godfroid, 2020, p. 140). After estimation of Plonsky (2016) of 67% of samples in SLA being comprised of university students, Andringa and Godfroid (2020, p. 138) concluded from their recent metadata analysis that participants in applied linguistics research "are truly WEIRD." This only yields underrepresentation of certain groups in the understanding of language acquisition posing a clear scientific problem, but also presents an ethical dilemma (see Ortega, 2005, 2019; Andringa and Godfroid, 2019, 2020). Our partial aim with the VIDAS data set is to partially compensate this reality and provide an inclusive corpus from underrepresented samples.

For migrants who have just arrived in a country, the challenge of acquiring at least a basic competence in the host language becomes a pressing need to minimally accommodate to their new environment (Doughty and Long, 2008). Migration policies often include specific levels of language proficiency as a legal requirement to acquire citizenship or work access (Hope, 2011). Basic proficiency in the host language has overarching effects on integration at economic, social, and personal levels, and it is a catalyst of economic opportunities and employability (Majhanovich and Deyrich, 2017), of access to social resources, education, and health care, and of social and political participation (Hou and Beiser, 2006; Albarracin et al., 2019). Furthermore, host language proficiency has been shown to have a deep impact beyond economic and social integration, impacting general well-being (Yates, 2011).

Data and reports on international migration [McAuliffe and Khadria, 2019; European Border and Coast Guard Agency (Frontex), 2020] show that migration is a growing phenomenon. Consequently, the acquisition of a language in a migration context, far from being an exceptional or marginal phenomenon, is nowadays conceived as an extended reality to which the society in general, and the scientific community in particular, must respond consciously and with commitment. In this context, research on the acquisition of a second language in migration and refugee contexts is gaining social and scientific interest. The analysis of SLA processes in these contexts undoubtedly poses a series of specific challenges to SLA researchers, given the conditions and peculiarities of the samples (Nieuwboer and van't Rood, 2016). In a committed and explicit effort to account for language processing of traditionally marginalized and underrepresented learners, the VIDAS data set provides a compelling repository of Spanish oral interaction by migrants and refugees. Specifically, 200 oral interaction samples have been selected, edited, and published divided into 4 speakers groups split by their nationality, which in turn represent different linguistic backgrounds: Philippines (50), Ukrainians (50), Moroccans (50), and Romanians (50).

First and previously known languages have proven to be core factors affecting the acquisition and development of an additional language (see Odlin, 2003; Ringbom, 2007; Jarvis and Pavlenko, 2008 for a review). In this sense, the typological distance

[1]Some of the samples from this data set have already been transcribed and made available as part of a different corpus with more limited purposes (see Nebrija-Inmigra corpus, in SLA-Talkbank, available at https://slabank.talkbank.org/access/Spanish/Nebrija-INMIGRA.html).

between languages and their formal similarity has been widely recognized as influencing factors for the acquisition of additional languages (Cenoz, 2001; Ringbom, 2001). For instance, acquiring the morphosyntactic system and the grammatical and pragmatic uses of articles in Spanish can be especially complex for learners speaking a Slavic language, such as Ukrainian, who do not use articles. This will not, however, pose the same degree of difficulty for speakers of Romanian, a Romance language with many similarities to Spanish. An Arabic speaker, on the other hand, will very likely struggle to recognize and produce minimal phonetic pairs, such as p/b, e/I or o/u, whereas a Filipino speaker will easily perceive, and most likely produce, these contrasts. Hence, the peculiarities, similarities and differences, and the proximity between the linguistic and sociocultural systems of each language call for a case-by-case analysis, attending to each combination of languages individually and specifically. Such an approach will allow us to deepen our understanding of the phenomena involved in the acquisition of an additional language from a scientific perspective. But importantly, this will allow us as a community to accurately define adequate pedagogical approaches based on scientific evidence, especially in the face of the increasing interest in learning Spanish worldwide, and in the face of migratory phenomena.

In addition to L1, length of residence (LOR) in the country of immigration is a main factor traditionally associated with the proficiency level attained by additional language learners (Chiswick and Miller, 2001; van Tubergen and Wierenga, 2011). Similarly, the level of education of the speaker has also been proposed as a predictive factor of L2 attainment, specifically in migration contexts (Chiswick and Miller, 2001; Yilmaz and Schmid, 2015; but see Pérez-Vidal and Juan-Garau, 2011, for a discussion on its potential influence in oral skills development). With this in mind, and in addition to the oral productions, the VIDAS data set also incorporates data for LOR, level of education, as well as the scores obtained in the oral interaction task from the exam that the participants completed. This will be useful for further analysis on the influence of one or a combination of these factors.

The VIDAS data set will allow for the development of studies exploring intercultural competence and the acquisition of pragmatics, interlanguage development at different phonological, lexical, morphological, or syntactic levels, or discourse analysis, among others. VIDAS focuses on Spanish as a continuously growing language and its combinations with different L1 that have been traditionally disregarded and underrepresented in the field of SLA (Ortega, 2019). Thus, the VIDAS data set here presented stands as a significant contribution to and progress for this field, by representing the first corpus of Spanish as a migration language of a similar magnitude and scope.

PARTICIPANTS

The VIDAS data set compiles a selection of oral interaction samples from 200 Spanish learners in the context of migration.

TABLE 1 | Characteristics of the samples.

	Morocco	Philippines	Romania	Ukraine
Participants	50 (25)	50 (49)	50 (42)	50 (42)
Age	34.3 (6.32)	34.3 (6.22)	31.3 (7.29)	29.6 (6.33)
LOR	7.91 (5.47)	4.65 (4.21)	5.47 (4.49)	2.12 (2.09)
Level of education	4.2 (1.95)	4.25 (1.96)	4.26 (1.97)	4.26 (1.98)
Score	8.82 (1.59)	7.68 (1.64)	9.35 (1.09)	8.69 (1.48)

Number of participants (and number of females), age, length of residence in years (LOR), level of education and mean score in the oral expression and interaction test (with SD).

All participants completed a semi-structured oral interview with a trained interviewer in the context of the specific linguistic certification test for immigrant workers in the Community of Madrid, Diploma LETRA[2] (Baralo Ottonello et al., 2016). All the participants included in the final data set passed the examination with a score of at least five out of 10 (see **Table 1** for details). Their ages ranged from 19 to 49 years ($M = 32.35$; SD = 6.8), and their length of regular or irregular residence in Spain ranged from 0 (less than 1 year) to 24 years ($M = 4.99$; SD = 4.68). The participants were divided into four groups according to their nationalities and mother tongues (50 Philippines with L1 Tagalog; 50 Ukrainians with L1 Ukrainian; 50 Moroccans with L1 Arabic; and 50 Romanians with L1 Romanian).

DATA COLLECTION

The data were collected in the context of a linguistic certification test for immigrant workers from the Community of Madrid[3] between the years 2011 and 2016. All the participants first completed a short questionnaire that collected information about their personal data and linguistic history. They then participated in an individual interview with an expert interlocutor structured in three blocks or tasks.[4] Participants were interviewed individually in a room with two examiners: one of them acted as the main interlocutor, while the other only observed and took notes on the linguistic productions of the interviewees. All interviewers received specific training (a 100-h training course). The interviews were recorded with SONY ICD-PX312 recorders. Informed consent of the participants was collected orally, given the high variability in their levels of reading competence, especially in relation to their level of literacy.[5]

[2]http://www.diplomaletra.com/

[3]The test certifies a level of competence in Spanish that exceeds level A1, but with specific content which does not correspond to the A2 level, taking into account the concept of partial competence in a language, and assuming that the development of the different skills in immigrant workers is irregular (see Baralo Ottonello et al., 2016).

[4]https://figshare.com/articles/dataset/THE_VIDAS_DATASET/16578686

[5]At the beginning of the recording, the participants were asked for their express consent for the audio recording of the test, and it was explained to them that the data would be used for research purposes. Interviewers were instructed to adapt their discourse to the level of competence in the language of each participant.

DATA CURATION

The edition process of the raw recordings had two steps. First, we deleted the first minutes of the conversations where explicit consent was given by each participant and basic personal information was collected. And second, we silenced all the bits where any specific piece of personal information was given in the middle of the conversation (e.g., family name or address details). This preprocessing of the audios was conducted in Audacity. Following this process, the original raw data consisting of 32 h 53 min 28 s was edited and converted into a data set of 29 h 37 min 43 s. The segments deleted were similar in length for all participants and the correlation between the length of the original and edited audio clips was very high ($r = 0.96$, $p = <0.001$).

DATA SET OVERVIEW AND DESCRIPTION

The VIDAS full data set can be found in https://figshare.com/articles/dataset/THE_VIDAS_DATASET/16578686. It includes, on the one hand, the 200 recordings of the oral interviews of all participants. The audio clips presented in the data set include the whole recording of the interviews. All the slots containing personal information and those bits that could violate the anonymity of the participants were silenced. On the other hand, the data set includes a summary Microsoft Excel® spreadsheet with the linguistic and sociodemographic data corresponding to each participant. The audio files are conveniently labeled with the same code that is presented in the spreadsheet where we provide background information on the participants' age at the time of data collection (in years), gender, nationality, reported L1(s), and level of education. Level of education was coded as follows: no formal education = 1, primary school = 2, secondary school = 3, high school = 4, professional training = 5, and university = 6. Along with these data, the spreadsheet also presents the score obtained by each of the participants in the oral interaction test. The distributions of the results in the oral examination split by the country of origin of the participants are also presented in **Figure 1**.

We also present a first approach to the general analysis of the data in which the possible relationship between the scores obtained in the test and the time of residence in the country (LOR) is analyzed, as well as possible differences as a function of the country of origin, being this factor directly associated with participants' different L1s. Years of residence in the host country and scores obtained in the oral interaction test were found to be moderately positively correlated ($r = 0.36$, $p < 0.001$). In line with other preceding studies, the longer the residence in the country, the higher the level of exposure to Spanish would be, consequently improving the competence in such language. In order to analyze the influence of the country of origin (and therefore their L1) in the scores, we conducted a Kruskal-Wallis test, given that the data were not normally distributed. The results showed a significant difference between the groups ($p = <0.001$). A Dwass-Steel-Critchlow-Fligner test revealed that the Philippine group obtained the lowest scores in the test, and their results differed significantly from those from every other group (all ws > 4 and ps < 0.004). The Romanian group obtained the highest scores, being similar to those obtained by the Moroccan group but significantly larger than

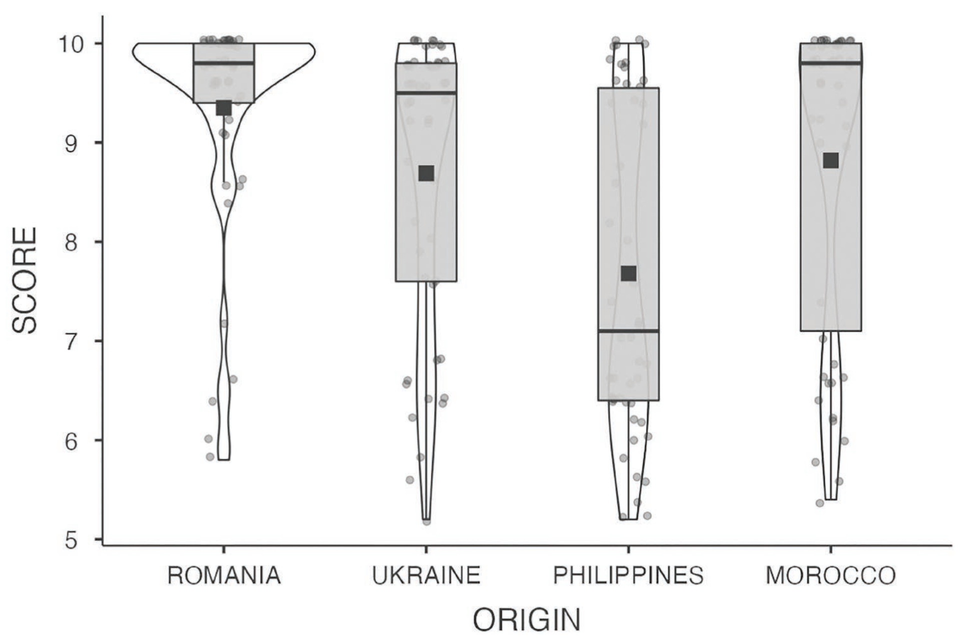

FIGURE 1 | Box plots of the scores obtained by each group of participants in the oral expression and interaction test. The horizontal black lines represent the median score per group, and the black squares correspond to the means.

those obtained by the Ukrainian participants ($w > 3.5$ and $p < 0.01$). There were no other significant differences between the scores.

CONCLUSION

The VIDAS data set is presented as the first repository of its kind for Spanish as a migration language. It includes a series of edited recordings corresponding to a conversation in the context of an oral interaction test that is part of an official examination (Diploma LETRA). Four groups of 50 persons each are presented, corresponding to 4 different countries of origin and 4 different mother tongues, thus providing an inclusive data set. We believe that this data set will open new avenues of research and analysis in the areas of applied linguistics, SLA and psycholinguistics. The samples and data presented allow for different analysis from various perspectives. Researchers can use this data set, among other things, to explore the influence of different sociodemographic factors on lexical sophistication, interlanguage and development of different grammatical, phonetic, sociopragmatic, or discursive aspects. The recordings obtained in the same contextual situation from different samples representative of four groups with different languages of origin could result in a valuable tool for the development of contrastive analysis with different combinations of native languages that have been traditionally underrepresented in this field. Additionally, access to real L2 speech samples may serve equally the L2 Spanish teaching community – both learners and teachers – in the development of different kind of educational strategies and resources (see, for instance, Fono.ele corpus – reported in Blanco Canales, 2011).[6]

Finally, it is worth noting that the VIDAS data set constitutes a realistic snapshot of Spanish migrant situation. In the data set, one can find from a recent graduate in Medicine from Romania awaiting the validation of her degree to be able to work in Spain after only 8 months of residence in the country (i.e., participant 5_090) to a domestic worker who left her entire family in Philippines and has been living in Spain for 2 years (i.e., participant 5_056); this nicely exemplifies the plethora of individual realities that constitute the regular and irregular immigration reality in Spain, pointing also to different paths in the acquisition of Spanish as an additional language in migration contexts.

[6]Available at: http://www3.uah.es/fonoele/

DATA AVAILABILITY STATEMENT

The data sets 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

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

MP and JD developed the idea together, analyzed the data, and drafted the manuscript. AD coordinated the data acquisition. All authors approved the final version after discussing the intellectual content and authors agreed to be accountable for all aspects of the work.

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BRIEF RESEARCH REPORT
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Gamma Oscillations in the Temporal Pole Reflect the Contribution of Approach and Avoidance Motivational Systems to the Processing of Fear and Anger Words

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Prior reports suggest that affective effects in visual word processing cannot be fully explained by a dimensional perspective of emotions based on valence and arousal. In the current study, we focused on the contribution of approach and avoidance motivational systems that are related to different action components to the processing of emotional words. To this aim, we compared frontal alpha asymmetries and brain oscillations elicited by anger words associated with approach (fighting) motivational tendencies, and fear words that may trigger either avoidance (escaping), approach (fighting) or no (freezing) action tendencies. The participants' task was to make decisions about approaching or distancing from the concepts represented by words. The results of cluster-based and beamforming analyses revealed increased gamma power band synchronization for fear words relative to anger words between 725 and 750 ms, with an estimated neural origin in the temporal pole. These findings were interpreted to reflect a conflict between different action tendencies underlying the representation of fear words in semantic and emotional memories, when trying to achieve task requirements. These results are in line with the predictions made by the *fear-hinders-action* hypothesis. Additionally, current data highlights the contribution of motivational features to the representation and processing of emotional words.

Keywords: approach, avoidance, EEG, gamma band, beamforming, temporal pole

INTRODUCTION

Language plays a pivotal role in communicating feelings and regulating social interactions. In the last few years, several event-related potentials and functional magnetic resonance imaging studies have investigated the neural underpinnings of emotional language, showing interactions between language and emotion at several processing stages during word, sentence and discourse comprehension (see Citron, 2012; Hinojosa et al., 2020, for reviews). Of note, research on the oscillatory neural activations associated with the processing of emotional words is very scarce, and has mainly relied on the assumptions of dimensional models of emotion (Russell, 2003). According to this view, valence (ranging from feeling unpleasant/negative to pleasant/positive) and arousal (ranging from feeling quiet to active) are the fundamental dimensions of affect. Thus, the emotional word *massage* refers to a positive and relaxing concept, whereas *shoot* denotes a negative and activating concept. In the study by Hirata et al. (2007), the authors observed a power decrease in the beta and gamma bands for both positive and negative words compared to neutral words that were associated with facilitated language processing during emotional word reading. Also, Wang and Bastiaansen (2014) reported an alpha power decrease for emotional words relative to neutral words that was interpreted in terms of attentional engagement during the processing of negative and positive high-arousing words.

Despite of the prevalence of dimensional models in behavioral and neurobiological research about the interplay between language and emotion, there is evidence indicating that approach and avoidance motivational directions (Davidson, 1993, 1995; Harmon-Jones et al., 2017) might also play a role in the processing of emotional words. In this sense, the valence-arousal conflict theory (Robinson et al., 2004) predicts that positive valence and low arousal are associated with approach-related action tendencies, while negative valence and high arousal are linked to avoidance behaviors. In line with this proposal, prior studies have shown that motivationally incongruent words (e.g., positive high arousing and negative low arousing words) are responded to more slowly than motivationally congruent ones (positive low arousing and negative high arousing words), although these effects were restricted to tasks that explicitly demanded approach-avoidance judgments from participants (Citron et al., 2014, 2016; Wang et al., 2018). Of note, in these studies the contribution of motivational directions to the processing of emotional words is subsidiary of the two affective dimensions of valence and arousal. To circumvent this limitation, a recent study compared the processing of fear and anger words that were matched in valence and arousal, but gave rise to different approach and avoidance motivational action tendencies (Huete-Pérez et al., 2019). In this sense, anger typically elicits approach-related behaviors (fight). In contrast, the dominant tendency evoked by fear is avoidance (flight), although this emotion may also prompt both approach (fight) or passive (freeze) action tendencies (Canon, 1929; Valk et al., 2015; LaBar, 2016). The results showed small size effects that consisted of delayed responses to fear words relative to anger words, which were again restricted to an approach-avoidance task (Exp. 3). The authors speculated that two possible explanations could account for their data. According to the *anger-fosters-action* hypothesis, approach motivational tendencies associated with anger would speed responses to these words relative to fear words. Alternatively, the *fear-hinders-action* hypothesis assumes that slower RTs to fear words reflect internal cognitive conflict and interference between avoidance (i.e., escaping), passive (i.e., freezing) and approach (i.e., fight) action tendencies, and/or the inhibition of incongruent motivational directions.

Together, evidence from these studies illustrate the need to consider motivational direction as separate from affective valence or arousal dimensions. However, neurobiological studies on the interplay between language and emotion have neglected the contribution of avoidance and approach action tendencies to the processing of affective language. To fill this gap, in the current study we analyzed brain oscillatory responses to anger and fear words matched in valence and arousal in an "approach-distancing" task to further test the predictions made by the *anger-fosters-action* and *fear-hinders-action* hypotheses regarding the processing of the motivational component of emotional words. To this aim, we assessed frontal alpha asymmetry (FAA), a difference score computed by subtracting the natural log of frontal left hemisphere alpha power from the natural log of frontal right hemisphere alpha power. Alpha band activity is inversely related to underlying cortical processing, since decreases in alpha power tend to be observed when underlying cortical systems engage in active processing. Therefore, higher FAA scores indicate relatively greater left frontal activity whereas lower scores suggest relatively greater right frontal activity (Coan and Allen, 2004; Briesemeister et al., 2013; Kelley et al., 2017). Of note, prior research has shown that FAA is a reliable correlate of motivational action directions, with increased left frontal activity indicating tendencies toward approach motivation (Davidson, 1993; Adolph et al., 2017; Harmon-Jones and Gable, 2018). Also, we analyzed oscillations in the beta-frequency and the gamma-frequency bands. Increased power in these bands have been proposed as a neural correlate of cognitive and response conflict, interference and inhibition (Sánchez-Carmona et al., 2019; Wiesman and Wilson, 2020; Wiesman et al., 2020; Schaum et al., 2021).

Predictions could be made as follows. If an *anger-fosters-action* mechanism drives motivational effects during the processing of fear and anger words, anger words associated with approach action tendencies should elicit higher right alpha activity (e.g., greater relative left vs. right frontal activation) relative to fear words. Alternatively, if prior motivational effects reflect conflict, interference and/or inhibition of incongruent action tendencies related to a *fear-hinders-action* mechanism, we would expect increased beta and/or gamma oscillatory power to fear words relative to angry words.

MATERIALS AND METHODS

Participants

Our sample size was determined based on an *a priori* power analysis using G*Power (Faul et al., 2007). Assuming a $\alpha = 0.05$ significance level, we estimated that a total sample size of 27 participants would provide 80% power to detect effects (medium size effect $d = 0.5$). Considering potential drop-outs, we recruited 33 Spanish native participants to exceed the criterion. Of the 33 recruited participants, 7 were excluded from further the analyses due to low overall task accuracy (out from 1.5 times the interquartile range). The remaining sample consisted of 20 females and 6 males aged 18–36 years (*M* = 20.42 years, *SD* = 3.45). All participants reported normal or corrected-to-normal vision and, with the exception of 3 left-handed participants, were right-handed according to the Edinburgh Handedness Inventory (Oldfield, 1971). They did not report any history of neurological disorders. Participants signed an informed consent before the experiment. The study was approved by the ethics committee at Instituto Pluridisciplinar.

Stimuli

There were 35 anger words and 35 fear words. Since prior findings have shown that a "distancing" response should be expected for both fear and anger words (Huete-Pérez et al., 2019), we also selected 70 positive happiness-related words as fillers to match the number of "approach" responses in the task. Words were selected from several normative studies (Ferré et al., 2012, 2017; Guasch et al., 2016; Hinojosa et al., 2016a; Stadthagen-Gonzalez et al., 2017; Stadthagen-González et al., 2018) using the EmoFinder (Fraga et al., 2018). Both dimensional (valence, from *negative* to *positive*, and arousal, from *calmed* to *activated*, both in 9-points scale), and discrete (fear, anger, disgust, sadness and happiness, from *nothing at all* to *extremely*, all in a 5-points scale) affective ratings were considered. Fear and anger words had valences ratings < 4, and arousal scores ≥ 5. Fear words scored ≥ 3 in fear and ≤ 2.8 in anger, sadness, disgust and happiness. Similarly, anger words scored ≥ 3 in anger and ≤ 2.8 in other discrete emotions. Independent *t*-tests showed that fear words and anger words were matched in valence ($p = 0.587$), arousal ($p = 0.129$), happiness ($p = 0.956$), sadness ($p = 0.455$), disgust ($p = 0.106$), the target emotion (i.e., the average fear score of fear words vs. the average anger score for anger words; $p = 0.129$), and the contrast emotion (i.e., the average anger value for fear words vs. the average fear value for anger words; $p = 0.305$). Also, as illustrated in **Table 1**, stimuli were statistically matched (all $p \geq 0.096$) in age of acquisition (Alonso et al., 2015; Huete-Pérez et al., 2019), concreteness and familiarity (Ferré et al., 2012; Duchon et al., 2013; Guasch et al., 2016; Hinojosa et al., 2016b; Huete-Pérez et al., 2019), number of higher frequency lexical neighbors, number of lexical neighbors, logarithm of contextual diversity, logarithm of lemma frequency, logarithm of word frequency, mean Levenshtein distance of the 20 closets words, number of syllables, and word length (Duchon et al., 2013). We used the K-means clustering procedure for this matching (Guasch et al., 2017). To avoid effects of grammatical category (Palazova et al., 2011), the number of nouns and words that could be considered both nouns and adjectives (Diccionario de la Lengua Española, RAE, 2014)[1] was similar across conditions (fear words: 31 nouns and 4 nouns-adjectives; anger words: 30 nouns and 5 noun-adjectives). Finally, positive (filler) words were matched to both fear and anger words in these affective, sublexical, lexical and semantic variables with the exception of valence, discrete emotions, as well as the logarithm of lemma frequency, word frequency, and contextual diversity.

[1]https://dle.rae.es

Procedure

The whole set of 140 words were randomly presented to each participants in a single block. A 10 trials practice block was allowed before the beginning of the experimental block. Each trial began with a fixation cross with a random duration from 500 to 1,000 ms. Thereafter, a word was presented until participants' response or after a time limit of 3,500 ms. Participants performed an "approaching-distancing" task (Huete-Pérez et al., 2019). They were asked to think about the word's referent and decide whether they would approach (e.g., *premio*/prize), or distance (e.g., *dinamita*/dynamite, *combate*/combat) themselves from it by pressing one of two different buttons (response buttons were counterbalanced). Participants performed the experimental task seated comfortably in an electrically shielded and sound-attenuated room. Task stimuli were presented on a computer monitor that was positioned at eye level about 65 cm in front of the participant. The task was designed and implemented in MATLAB, using Psychtoolbox.[2]

EEG Recording

EEG activity was recorded from 62 Ag/AgCl electrodes mounted in an electrode cap (Electro-Cap International), arranged according to the International 10–10

[2]www.psychtoolbox.org

TABLE 1 | Lexical, semantic and affective features of the experimental stimuli and the filler stimuli (standard deviations in parentheses).

	Fear words	Anger words	Positive-happiness words
Valence	3.07 (0.54)	3.01 (0.45)	7.06 (0.58)
Arousal	6.89 (0.56)	6.69 (0.54)	6.67 (0.61)
Happiness	1.29 (0.28)	1.29 (0.23)	3.71 (0.53)
Sadness	2.26 (0.32)	2.32 (0.35)	1.27 (0.20)
Fear	3.43 (0.38)	2.34 (0.33)	1.53 (0.40)
Anger	2.24 (0.48)	3.30 (0.30)	1.31 (0.23)
Disgust	1.96 (0.49)	2.15 (0.45)	1.26 (0.21)
Concreteness	4.89 (1.01)	4.55 (0.76)	4.67 (0.88)
Familiarity	5.07 (0.81)	5.21 (0.89)	5.34 (0.81)
Age of acquisition	7.72 (1.62)	7.70 (1.94)	7.77 (1.69)
Logarithm of word frequency	0.86 (0.54)	0.64 (0.56)	0.94 (0.49)
Logarithm of lemma frequency	3.51 (0.77)	3.18 (0.93)	3.68 (0.61)
Number of letters	8.00 (2.31)	8.17 (2.50)	7.74 (2.49)
Number of syllables	3.40 (0.95)	3.31 (0.80)	3.16 (0.96)
Number of lexical neighbors	2.80 (4.91)	3.14 (4.77)	3.00 (5.83)
Number of HF lexical neighbors	0.40 (1.44)	0.63 (1.59)	0.31 (0.81)
OLD20	2.27 (0.79)	2.25 (0.80)	2.18 (0.64)
Logarithm of contextual diversity	0.57 (0.42)	0.45 (0.42)	0.65 (0.38)

The value indicated is the mean of all the words in that condition, and the standard deviations are in parentheses.
HF, higher frequency; OLD20, mean Levenshtein distance of the 20 closest words.

System (American Electroencephalographic Society, 1991). All electrodes were referenced to the average of mastoids and their impedances were kept below 10 KΩ. In addition, the electrooculographic activity was recorded using vertical and horizontal bipolar electrodes. These electrodes were placed at supra-infraorbital level of the left eye and on the outer canthus of both eyes, respectively. Recordings were amplified using BrainAmp amplifiers (BrainProducts, Munich, Germany), continuously digitized at a sample rate of 1,000 Hz, and filtered online with a frequency band-pass of 0.01–100 Hz.

Data Analysis

All statistical analyses involved a single factor with two levels (fear words, anger words). To test evidence against the null hypothesis, we conducted Bayesian analyses whenever the results from paired-samples *t*-test showed null findings. Positive words were not analyzed as they were filler stimuli.

Behavioral Analysis

We first removed the responses out of 2 standard deviations (SD) from the mean values of correct trials for each subject and condition. Thereafter, reactions times (RTs) outside the time range from + 300 to + 3,500 ms were also discarded. Both response speed and accuracy were analyzed with a paired-samples *t*-test analysis comparing fear words and anger words.

Time-Frequency Analysis

EEG data were analyzed with the Fieldtrip software package (Oostenveld et al., 2011),[3] a toolbox implemented in the MATLAB environment (The MathWorks, Natick, MA). Only correct trials were included in the analysis. First, the continuous sets of raw data were re-referenced to the averaged mastoids and segmented into −1500 to 2000 ms epochs. Subsequently, an independent components analysis (Makeig et al., 1997) was performed to eliminate the blink artifacts (Jung et al., 2000). Finally, epochs with artifacts were individually rejected with a visual inspection criterion. Following this procedure, we retained, on average 29.58 (*SD* = 2.53) trials to anger words and 29.54 (*SD* = 2.42) trials to fear words. Time-frequency data were computed by convolving single trial data with a complex Morlet wavelet w (t, fo) having a Gaussian shape in time (δt) and a frequency (δf) around the center frequency (fo). This transformation allows an easy adaptation to balance the trade-off between temporal and frequency precision as function of frequency and produces smooth time-frequency plots easy to interpret (Cohen, 2014). Overlapping wavelets were centered at all frequencies comprised between 2 and 80 Hz, linearly spaced by two Hz steps. In order to adjust the balance between temporal and frequency precision as a function of frequency, the width of the wavelet increased from 3 to 7 cycles from low to high frequencies (Cohen, 2014). Finally, to normalize the resulted power, a decibel transformation was taken relative to baseline, defined from −500 to −300 ms before emotional words ($dB_{tf} = 10\log10[activity_{tf}\text{-}mean(baseline_f)]$).

To test the *anger-fosters-action*, we calculated total frontal alpha power (8–13 Hz) for each participant and experimental condition before baseline normalization (e.g., Harmon-Jones, 2006). Thereafter, we normalized these distributions by log-transforming the power values for all electrodes. Finally, a FAA index was computed by subtracting the natural log of left alpha power from the natural log of the right alpha power. This measure was computed for F3/F4 electrodes comprising the whole epoch, starting from target stimuli onset. To statistically compare the relative frontal alpha activity between FFA indexes for fear and anger words, we conducted a paired-samples *t*-test.

To test the *fear-hinders-action* hypothesis examined the full spectrum of neural oscillations elicited by anger and fear words: theta (4–7.5 Hz), alpha (8–13 Hz), beta (14–30 Hz) and gamma bands (30–50 Hz). In each of these frequency bands, we followed a non-parametric randomization test with a clusters analysis approach (Maris and Oostenveld, 2007). This procedure controls for Type I error rate over electrodes and time. The spatial threshold to determine significant clusters was set at 2 channels. Differences between anger and fear words were explored with a parametric *t*-test, conducted for each time and electrode point. Spatio-temporal clusters were consequently identified as contiguous time points and electrodes groups with a *p*-value below.05. Cluster *p*–values were summed to obtain a cluster level test statistic. Only the cluster with the maximum statistical-level was considered. The significance of the test statistic was assessed by constructing a reference distribution of the cluster statistic. A cluster statistic histogram was obtained by calculating the cluster test statistic after randomly reassigning the data to each condition. After repeating this step over 1,000 times, *p*-values were then computed as the proportion of permutations that resulted in a larger observed cluster level statistic. Statistical analyses were performed for each frequency band. All permutation statistics were done using Fieldtrip.

Source Reconstruction

To estimate the neural origin of significant effects at the surface level, we followed a time domain linearly constrained minimum variance (LCMV) beamformer approach (Van Veen et al., 1997; Gross et al., 2001). This method tests for the likelihood of activity in every brain location using an optimized spatial filter that allows the maximization of the activity at the location of interest and the suppression of the external interfering activity. First, we computed a forward model to enhance the source specificity, based on a standardized realistic head. The volume conductor was distributed in a regular 3-D grid of 12 mm, and the leadfield matrix was calculated individually for each voxel. Subsequently, we computed the inverse model to obtain a spatial filter. Time segments were concatenated and re-referenced to the common average. Thereafter, the covariance matrix was calculated. Following this procedure, we obtained a common spatial filter. This filter was multiplied for the data of each experimental condition to estimate the source strength at grid points. Finally, data from the time-frequency decompositions were bandpass filtered around the target frequency band and the absolute value of the Hilbert transform computed from −500 to 800 ms for each condition and subject. To control against

[3] http://www.fieldtriptoolbox.org

the power bias toward the center of the head, a baseline transform was performed before submitting source estimations to statistical analysis. At each grid location and for each subject and experimental condition, absolute power changes relative to baseline was calculated (post-stimulus power—pre-stimulus power).

Oscillatory power projections into the cortical source space for anger and fear-related words were compared using the non-parametric cluster-based permutations approach described above. Since time-windows were already defined by the results of time-frequency analyses, clusters were created relying only in the spatial dimension.

RESULTS

Behavioral Results

On average 4% of trials were outliers. Similar RTs we found for fear words (M = 891 ms; SD = 0.152) and anger words (M = 889 ms; SD = 0.163) [$t(25) = 0.341$, $p = 0.736$, $d = 0.018$,

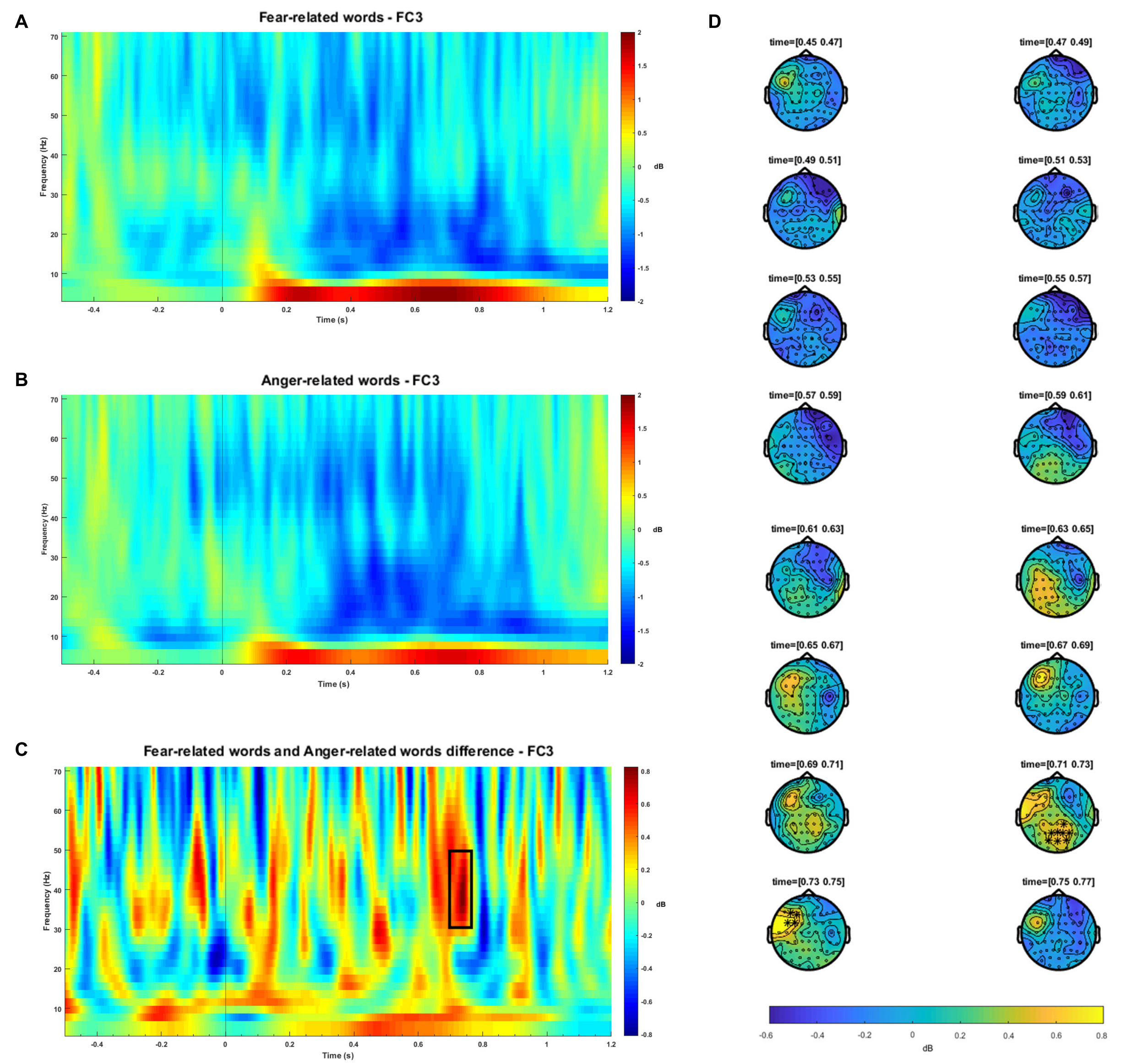

FIGURE 1 | Time-frequency plots for the fear-related words **(A)** and anger-related words conditions **(B)**, for 4–70 Hz at a representative electrode location (FC3). To avoid artifact contamination, a -300 to -500 baseline prior stimulus target onset was used. Total power is expressed as decibel transformation relative to baseline. The black vertical line indicates the stimulus onset. **(C)** Time-frequency plot for the difference between fear-related words and anger-related words at a representative electrode (FC3). The black box highlights both the frequencies and the time range in which significant results were observed. The black vertical line indicates the stimulus onset. **(D)** Topographic distribution along the time course of the significant clusters observed in the gamma band (30–50 Hz) between fear-related words and anger-related words. Significant electrodes ($p < 0.05$) are highlighted with a black star. Color bar represents power difference between conditions, measured in decibels.

BF_{01} = 4.574)]. Also, fear (*M* = 2.692, *SD* = 1.619) and anger words (*M* = 3.039, *SD* = 1.949) did not differ in accuracy [$t(25) = -0.768$, $p = 0.449$, $d = 0.043$, $BF_{01} = 3.689$).

Time-Frequency Results

No significant differences were observed between fear and anger FAA indexes [$t(25) = -0.614$, $p = 0.545$, $d = 0.119$, $BF_{01} = 4.062$]. The results of time frequency analysis revealed increased activity in gamma power (cluster-based permutation test, $p < 0.05$) during the processing of fear words relative to anger words. These differences were observed at left fronto-central locations between 714 and 753 ms. A second significant effect was observed at right parieto-occipital sensors, starting from 690 up to 740 ms.[4] These findings are illustrated in **Figure 1**. No differences were observed in theta, alpha or beta bands. **Table 2** shows the results of the statistical analyses.

Source Localization Results

Beamforming analysis to estimate the neural origin of gamma band effects for fear words relative to anger words in the significant clusters yielded a peak maximum in the left temporal pole (BA 38; MNI coordinates x = −42, y = 17, z = −34). **Figure 2** illustrates significant clusters ($p < 0.05$) from cluster-based permutation test.

DISCUSSION

In this study we further investigated the contribution of approach and avoidance motivational directions to the processing of emotional words. To this aim, we compared FFA and brain oscillations elicited by words denoting concepts associated with approach responses (i.e., anger words) with those evoked by words with conceptual referents related to conflicting action tendencies such as escape, fight of freeze (i.e., fear words). In line with prior reports, our data suggest a contribution of motivational systems to the processing of emotion words (Citron et al., 2014, 2016; Wang et al., 2018). As expected, participants gave distancing responses in the "approaching-distancing" task to both fear and anger negative words, whereas approaching responses were mainly restricted to positive words. Of note, RT differences between fear and anger words were not statistically significant, which contrasts with our prior findings (Huete-Pérez et al., 2019). This finding was unexpected since we only introduced slight changes in the current design (e.g., number of target stimuli). However, RT differences between fear and anger words in Huete-Pérez et al. study only emerged in the analyses by participants and they did not reach statistical significance in the analysis by items. All in all, these observations indicate that behavioral effects indexing the contribution of approach and avoidance systems to the processing of fear and anger words are rather weak. In contrast, our novel finding of increased gamma power to fear words compared to anger words suggests that brain activity might be a reliable index of the activation of approach and avoidance motivational systems in word processing.

Our study was designed to specifically test predictions made by two alternative explanations for prior results showing an influence of motivational systems in the processing of fear and anger words (Huete-Pérez et al., 2019). According to the *anger-fosters-action* view, a processing advantage for anger words could be expected in "approaching-distancing" tasks since these words are unequivocally associated with approaching, fight-related responses. In contrast, the *fear-hinders-action* hypothesis emphasizes the role of cognitive interference and the need to inhibit incongruent motivational directions associated with conflicting action tendencies underlying the representation of fear words, such as escaping, freezing or fighting.

The lack of FAA differences and the observation of increased activity in the gamma band for fear words relative to anger words favors an interpretation within the framework of the *fear-hinders-action* proposal since gamma oscillations have been related to conflict detection, interference and inhibition (Wiesman and Wilson, 2020; Wiesman et al., 2020), as well as the formation of memory for emotional experiences (Headley and Paré, 2013) amongst other functions. Interestingly, the results of our source analyses revealed that differences in gamma activity between fear words and anger words had an estimated neural origin in the left temporal lobe. This brain region is part of the associative limbic cortex or paralimbic cortex, and projects to other brain regions with a key role in emotional processing, such as the amygdala, the insula or the orbital prefrontal cortex (Chabardès et al., 2002; Olson et al., 2007; Herlin et al., 2021). The temporal pole has mnemonic functions related to the representation of conceptual knowledge in both semantic (Patterson et al., 2007; Ardila et al., 2014; Chadwick et al., 2016) and emotional (Dolan et al., 2000; Olson et al., 2007; Herlin et al., 2021) memories. Also, a critical role in binding highly processed linguistic and emotional information during the representation of semantic knowledge has been acknowledged (Olson et al., 2007). Thus, gamma activations in the temporal pole might reflect efforts to link different types of information about conflicting approaching, avoidance and freezing motivational action tendencies distributed in semantic and emotional memories underlying the conceptual representation of fear words. Of note, the timing of these EEG effects in relation to the RTs suggests that they seem to index the resolution of the task (i.e., competition between

[4]There is some prior evidence showing handedness and gender effects in relation with approach-avoidance motivation and emotion (Brookshire and Casasanto, 2012; Kret and De Gelder, 2012; Hardie and Wright, 2014). To explore these potential interactions, we conducted additional analyses in the gamma band with handedness and sex. We failed to observe statistical differences in the gamma band between left-handed and right handed-participants (four non-significant negative clusters, all *p*s > 0.19), or between females and males (four non-statistically significant clusters, all *p*s > 0.59), for the processing of fear and anger words.

TABLE 2 | *P*-values for the clusters in each frequency band analyzed.

Frequency-band	Cluster-based permutation test
Theta (4–7.5 Hz)	p = 0.0889 (positive cluster)
Alpha (8–13 Hz)	Unobserved positive/negative clusters
Beta (14–30 Hz)	p = 0.3337 (negative cluster)
Gamma (30–50 Hz)	p = 0.042 (positive cluster)

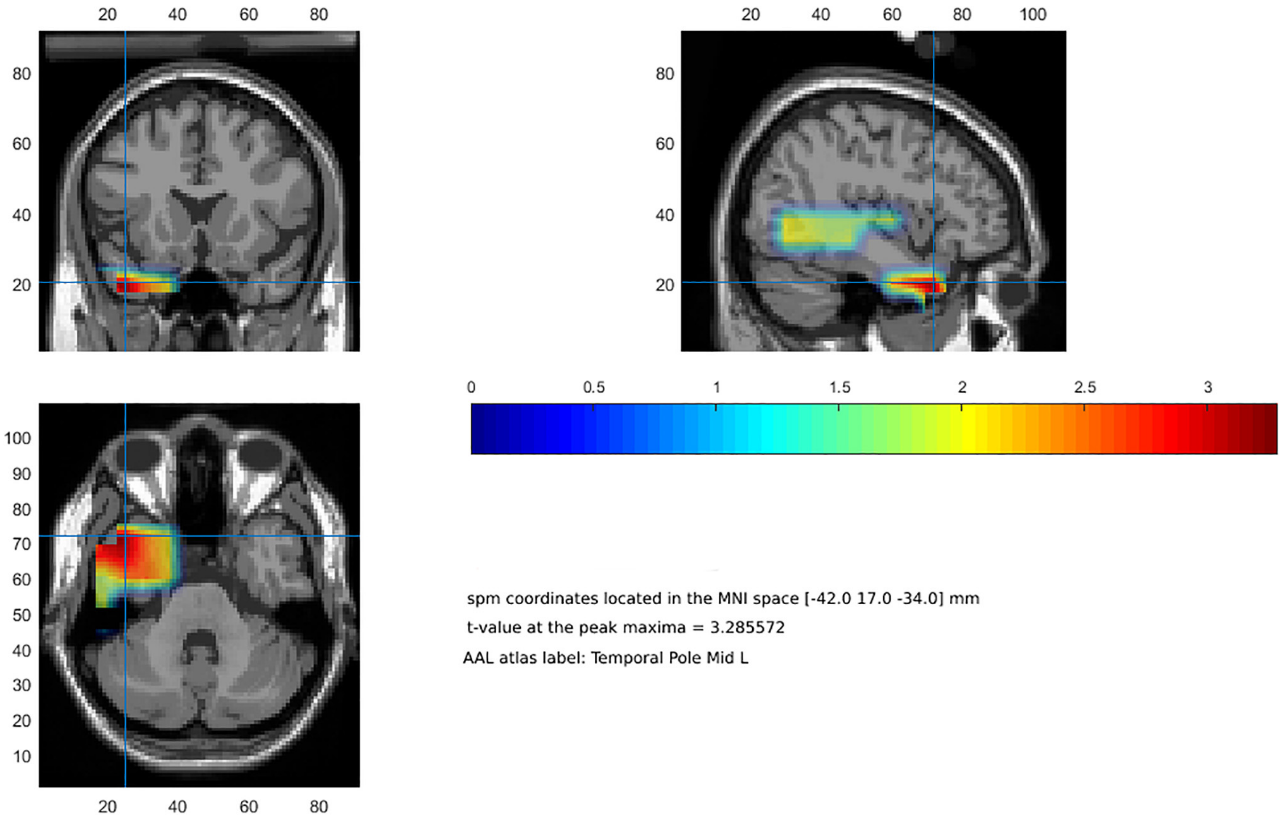

FIGURE 2 | Beamforming reconstruction of the neural sources of gamma activity observed at the scalp level (fear-related words > anger-related words). Color bar represents *t*-values.

incompatible actions) rather than an automatic processing of word meanings.

To sum up, it has been widely established that the affective dimensions of valence and arousal influence the processing of emotion words (e.g., Kissler et al., 2007; Herbert et al., 2008; Méndez-Bértolo et al., 2011; Hinojosa et al., 2014). In contrast, with few exceptions, evidence regarding the contribution of approach and avoidance motivational systems to word processing is rather scarce (e.g., Citron et al., 2014, 2016; Huete-Pérez et al., 2019). Here we report a different pattern of brain activation for fear and anger words that were matched in arousal and valence, but were related to different motivational directions. Importantly, gamma band modulations in the temporal pole extend prior findings by showing that approach-withdrawn effects possibly arise from the conflict generated by the integration of difference sources of information about incongruent action tendencies involved in the conceptual representation of fear words, which is in line with the predictions made by the *fear-hinder-actions* hypothesis.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The study was reviewed and approved by the Comité de Ética del Instituto Pluridisciplinar. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

GS, PF, DH-P, and JH contributed to the conception and design of the study. GS, AS-C, and JA performed the statistical analyses. GS and JH wrote the first draft of the manuscript. PF, AS-C, DH-P, and JA reviewed and edited the manuscript. All authors contributed to the article and approved the submitted version.

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Effects of COVID-19 on Multilingual Communication

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The paper presents the results of a study on the analysis of the perception of coronavirus disease 2019 (COVID-19) by Spanish-, German- and Russian-speaking social media actors after the emergence of vaccines and attitudes toward vaccination. The empirical base of the study was corpus data, materials from online media, social networks, microblogging, blogs, instant messengers, forums, reviews, and video hosting data. The Spanish-language database included 6,640,912 tokens and 43,251,900 characters; the German-language database included 16,322,042 tokens and 109,139,405 characters; and the Russian-language database included 16,310,307 tokens and 109,060,935 characters. With a neural network approach, a multilingual analysis was performed, which made it possible to analyze the topic structure and the semantic network with the allocation of the semantic core and the associative network. Differential and integral features of the identified structures based on the material of these three databases made it possible to determine the general and different characteristics of the perception by Spanish-, German-, and Russian-speaking users of the development of the pandemic, a number of social problems, attitudes toward various types of vaccines, observance of preventive measures, and readiness for vaccination.

Keywords: speech perception, social media, COVID-19, neural network technologies, multilingual communication, vaccination

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INTRODUCTION

Perception of decease: The cognitive representation of a disease present in both patients and healthy individuals largely determines the emotional and behavioral responses of members of society. The specificity of the disease perception is one of the important factors in decision-making within the system of preventive measures, transformation of the health care system, as well as social, political, and economic spheres, especially during a pandemic.

A note should be made of the coronavirus disease 2019 (COVID-19) IMPACT project[1], which is an international online survey conducted in 78 countries/regions of the world aimed at studying behavioral and psychological consequences of COVID-19. Based on the project data, a study was conducted in 16 European countries in the early period of the pandemic, which showed that Europeans reacted in a similar way to information about the COVID-19 spread in other countries; national differences were of no importance, but age, gender, and educational background affected the perception of COVID-19 under certain conditions. In addition, perceptions of this decease were

[1] https://ucy.ac.cy/acthealthy/en/covid-19-impact-survey

more consistent in explaining overall stress than taking preventive measures against COVID-19 (Dias Neto et al., 2021). The perception of COVID-19, the reaction of society to the introduced anti-COVID-19 measures, the need for protective measures (the requirement to observe social distancing, wear masks, wash hands, etc.) largely determines the behavior of people and, as a result, the effectiveness of the fight against the pandemic (Bilgili et al., 2021).

In the absence of a vaccine or treatment for COVID-19, all measures to contain and limit the spread of the infection depend on the behavior of the people. Meanwhile, since the beginning of the pandemic, 2 types of responses to the infection spread have been formed: one part of society perceived the new infection with anxiety and even fear and was actively engaged in preventive protection; the other part, on the contrary, ignored the danger of the disease and protested sharply against all introduced preventive measures (Bump, 2020; Burnett, 2020; Dave et al., 2020; Malone and Bourassa, 2020; Niemi et al., 2021; Tagini et al., 2021).

During the COVID-19 pandemic, the World Health Organization introduced the concept of "Infodemia" to show the danger to global society, in the age of social networks, the distortion of reality in the rumble of echoes and comments of the global community on real or often invented facts. Thorough studies have already been carried out on how the coronavirus situation is described from journalistic communication (Papapicco, 2020).

For example, COVID-19 threat assessment, trust in information sources, and fear of the infection are important predictors of COVID-19 preventive behavior in Latvian citizens. Beliefs of a COVID-19 conspiracy significantly reduce the threat assessment of the new disease and the credibility of relevant information, and the fear of COVID-19 is determined by threat assessment, which is the most important factor associated with COVID-19 preventive behavior (Šuriņa et al., 2021).

Research has also shown that Americans perceive the COVID-19 threat as significantly greater than other causes of death to which it has recently been compared, including seasonal flu and car accidents. It is important to note that citizens were less apt to help victims of COVID-19, as they consider such assistance to be dangerous for themselves, and patients with COVID-19 to be more infectious and more responsible for their condition (Niemi et al., 2021). Similar conclusions are drawn by other researchers who have found that many people, such as health care providers and citizens living in high-risk areas, may experience negative attitudes caused by COVID-19 (Adja et al., 2020; Singh and Subedi, 2020). Patients with COVID-19 have experienced various types of discrimination, such as isolation, denial of service, harassment, and bullying (Turner-Musa et al., 2020). As a result, people who become infected or only suspect they have symptoms of COVID-19 postpone seeking medical help or even hide the disease. Such behavior seriously threatens the safety of others, makes it extremely difficult to take anti-COVID-19 measures, and contributes to the spread of the infection (Dubey et al., 2020). Discrimination against patients with COVID-19, according to experts, is widespread throughout the world, for example, in America, Nepal, Jordan, India, Italy, and China (Aacharya and Shah, 2020; Chopra and Arora, 2020; Khasawneh et al., 2020; Sahoo et al., 2020; Singh and Subedi, 2020; Turner-Musa et al., 2020; Zhao et al., 2021a).

The psychological problems caused by COVID-19 have also received coverage from various countries (Al-Omiri et al., 2021; Zhao et al., 2021b).

The emergence of vaccines marked a new stage in the pandemic; the focus on the analysis of COVID-19 perception was naturally changed to the analysis of society's readiness to get vaccinated actively. Since COVID-19 vaccination is voluntary, everyone's willingness to participate in vaccination campaigns is the key factor in the success of pandemic control (Lu et al., 2021).

Attitudes toward COVID-19 vaccines have begun to be actively studied in various populations in various countries, since it is obvious that, for effective vaccination of the population, it is important to increase public confidence and awareness of the efficacy and safety of COVID-19 vaccines. Simulations have shown that vaccination of older people reduces deaths, while vaccination of younger and more socially active people minimizes infections (Wang et al., 2021). For example, researchers found that Chinese teenagers have a positive attitude toward COVID-19 vaccines (Cai et al., 2021). Analysis of the intention to receive a vaccine against COVID-19, as well as predictors of such intentions in the Norwegian population, showed that the majority (61.6%) of participants intend to get vaccinated, 24.8% of the population are not sure, and 13.8% are not going to receive the vaccine (Wolff, 2021). It is important to analyze the motivation of citizens of various countries when making a decision on vaccination. Researchers found that, among Americans, older Asian men with higher levels of education correlated with vaccination (Malik et al., 2020). Predictors of a positive vaccination decision for British adults are positive beliefs, less fear of side effects, willingness and positive attitude toward obtaining the necessary information to make a reasonable decision to get vaccinated against COVID-19, an increased perception of the COVID-19 risk to others (but not to themselves), old age, and participation in the influenza vaccination in winter 2019/20 (Sherman et al., 2020). For Australians, refusal to get vaccinated is determined by the belief that the COVID-19 threat is exaggerated by inadequate medical literacy and under education (Dodd et al., 2021). North American respondents prefer to rely on natural immunity; the lack of confidence in the benefits of the vaccine is determined by fears of unintended consequences in the future and unwillingness to contribute to the commercial profit of pharmaceutical companies (Rosman et al., 2021). Results of German studies show that, since April 2020, when the intention to get vaccinated was estimated at about 79%, a steady decline has been observed throughout 2020. The lowest rates were recorded in early and mid-December, when only about 48% of the population were ready to get the vaccine against COVID-19. Following this drop, support for vaccination has risen again to 68% by early March 2021 (Betsch et al., 2021).

Significantly, public opinion about experience and credibility is critical to the success of a vaccination campaign. Trusting scientists and public health experts who make informed claims about COVID-19 and about the safety and efficacy of vaccines is essential to a successful vaccination campaign.

If the public no longer believes the official expertise, then it becomes impossible to control the pandemic. Vaccinations, testing, masking requirements, non-drug interventions are compromised. In such a situation, the importance of effective crisis communication increases (Rosman et al., 2021).

Yanni Zhang, Naveed Akhtar, Qamar Farooq, Yiwei Yuan, and Irfan Ullah Khan conducted a critical discourse analysis aimed at exploring the dialectical relationship between discourse and ideology to reveal hidden psychological messages and ideology in the informational coverage of the pandemic. Psycholinguistic techniques, news reports, and comments from Chinese and American media about COVID-19 were analyzed, and the authors used Wang Zhenhua's Appraisal Theory and Halliday's Systemic Functional Grammar as tools to make a comparative analysis of the corpus (Zhang et al., 2021).

The purpose of this study was to identify the characteristics of the perception of the COVID-19 pandemic by Spanish-, German-, and Russian-speaking social media participants after the emergence of vaccines and the attitude toward vaccination itself.

Germany, Russia, and Spain are among the countries most severely affected by the coronavirus; however, all three countries belong to different types of cultures (Hofstede, 2015), which makes a comparative study of the response of society to the crisis situation caused by the pandemic especially interesting.

The COVID-19 pandemic has transformed almost all spheres of society, transferred communication processes to the virtual space, which enhances the importance of studying digital data.

Studies that were previously conducted in various countries to analyze the perception of the coronavirus infection and readiness for vaccination were mainly based on survey data; however, social media materials using psycholinguistic methods and neural network technologies have not yet been applied.

MATERIALS AND METHODS

Data Collection

To collect data, Sketch Engine[2] systems were used.

In accordance with the specifics of the program, the data were collected according to several lists. After the selection of the material, all data were combined into one database for each language:

- Covid, vaccine, vaccination, EpiVacCorona, CoviVac, Sputnik, Sputnik V, Sputnik Light, Moderna, AstraZeneca, Pfizer, and Biontech.
- Risk group, immunity, covid dissidents, vaccination, covidiots, placebo, injections, side effect, antibodies, contraindications, Gamaleya Center, Chumakov Center, and Vector.
- Vaccinated, anti-masker, certificate of a vaccinated person, certificate of vaccination, anti-vaxers, anti-vaccinators.
- Collective immunity, agitation, those who had recovered, come through, infection, infect, and prevent.
- Protection, freedom, choice, quarantine, wave, strain, and variant.

Data

The empirical base of the study was corpus data, materials from online media, social networks, microblogging, blogs, instant messengers, forums, reviews, and video hosting data.

Quantitative characteristics of the data:

The Spanish-language database included 6,640,912 tokens and 43,251,900 characters.

The German-language database included 16,322,042 tokens and 109,139,405 characters.

The Russian-language database included 16,310,307 tokens and 109,060,935 characters.

Methods

To analyze the content of social media, a multimodal approach was used using neural network technologies, text analysis, content analysis, sentiment analysis, and analysis of lexical associations.

The research used experience of content analysis technologies, including Sketch Engine and other quantitative automated systems and qualitative manuals presented in Papapicco and Mininni (2020).

With a neural network approach, a multilingual analysis was performed, which made it possible to identify the topic structure and the semantic network with the identification and analysis of its semantic core and associative network.

NLP topic modeling and clustering techniques are used to catalog, analyze, and automatically extract topics from datasets, such as survey responses. For example, topic modeling can use the identification of groups of words that often occur together (Lossio-Ventura et al., 2021), and clustering methods help group texts based on their similarity. The advantages of the neural network approach for topic modeling became apparent after the appearance of the BERT language model (Google) (Zhou et al., 2019; Liu et al., 2020; Zhao et al., 2021a,b). In particular, BERT enhances the semantic representation of texts with its feature extraction and fine-tuning transfer learning capabilities (Vaswani et al., 2017; Devlin et al., 2019; Lossio-Ventura et al., 2021).

In this study, the neural network technology TextAnalyst 2.3 was used for multilingual analysis of user perception. This model allows for automatic semantic ranking of the textual database using several algorithms: an algorithm for forming a homogeneous frequency network of text using an artificial neural network based on neural-like elements with time summation of signals, and an iterative Hopfield-like algorithm for ranking network vertices on a scale of 0–100%. In addition, the n-gram representation of the network is formed by iterative re-weighting at a given number of steps, or based on the convergence criterion of the ranking process. Thus, lexemes are analyzed in the context of syntagmas of a given (n) length on a semantic network formed on the basis of text analysis. The frequency network of the text is built as a set of pairs of words that are found in the sentences of

[2]https://www.sketchengine.eu/

the text. The network vertices are weighted by their frequency of occurrence in the text. The connection weight of a pair of vertices in the network corresponds to the frequency of occurrence of word pairs in text sentences (Kharlamov and Pilgun, 2020).

After identification of a topic structure, a semantic network was formed, in which semantic clusters were identified and analyzed.

Of particular importance for the analysis of the actors' perception is the analysis of lexical associations. An associative search was performed, associative networks were built, and reactions to similar stimuli in the three analyzed language bases were analyzed.

Word Association (WA) paradigms are applied across various types of research (Brooks et al., 2014; Vivas et al., 2019). With the help of Implicit Association Tests (IATs), implicit social cognition, subconscious motivations, attitudes toward the presented stimulus, as well as automatic associations for subjects that hide at a conscious level (see, for example, Project Implicit)[3] are studied. The potential of associations in the analysis of various types of network data has also already shown its effectiveness (File et al., 2019). In this study, a multilingual associative search was used, which allowed building relevant associative networks for similar stimuli in different language databases (Kharlamov and Pilgun, 2020). Thus, based on the material of the Spanish, German, and Russian datasets, the reactions of actors were identified and analyzed, which made it possible to draw conclusions about the preferential perception of users, to highlight and analyze the most frequent associations, peculiarities of perception of the COVID-19 pandemic by Spanish-, German-, and Russian-speaking social media participants after the emergence of vaccines. Also, a comparative analysis was performed, and ways of conducting predictive analytics were outlined.

Tools

To collect data, Sketch Engine (see text footnote 2) systems were used.

The verbal content was analyzed using the neural network technology TextAnalyst 2.3[4].

Content analysis was performed using the AutoMap text mining tool[5].

For visual analytics, the Tableau platform was used[6].

RESULTS

Spanish-Speaking Actors

Topic Structure

Explicitly expressed information that makes up the topic structure of the Spanish database makes it possible to identify the following topics that were of greatest interest for users when they discussed the problems of COVID-19 after the emergence of vaccines:

- Effect of the vaccine on the **population** (*población*/connection weight—80):

En el caso de México, la tasa de letalidad bruta derivada de una infección por la COVID-19 ha alcanzado cifrascercanas al 11%, para situarse entre uno de los países cuya población, una vez contagiada por esta enfermedad, tiene unamayor probabilidad de fallecer.

- Features of various vaccines and their efficacy (**Pfizer:** connection weight—82, AstraZeneca—81):

La mayoría de los inmunizados ha recibido el preparado de Pfizer (17.956.122), seguido de Moderna (2.176.152), AstraZeneca (4.503.479) y la monodosis de Janssen (1.784.344).

- Vaccination duration (**week/*semana*–** Вес связи–85; **hours/*horas***: connection weight—89; frequency—19, 02; **month/*mes***—74, **day/*día***: connection weight—89):

En cuanto a grupos de edad, casi el 90% de los españoles de 60 a 69 años tienen la pauta completa de la vacuna, en su mayoría de AstraZeneca, que requiere más tiempo de intervalo entre dosis, entre 12 y 14 semanas, motivo por el que varias comunidades adelantaron la segunda dosis para hacer frente a la expansión de la variante delta.

- Significance and features of **vaccination (*vacunación***: connection weight—86):

Carolina Darias, ministra de Sanidad: "España se convierte en el segundo país de la Unión Europea con el porcentaje de vacunación completa más alta."

- Effect of vaccination on the spread of **COVID-19** (connection weight—92):

El número de muertes por COVID-19 ha sido 15, lo que supone un descenso con respecto a ayer, cuando se registraron 24.

- Factor for priority vaccination—age (años/years—69):

En cuanto al plan de vacunación, la Comunidad de Madrid ha administrado 7.564.441 dosis, sobre un total de 7.903.484 recibidas y el 52,5% de la población general ha recibido la pauta completa, cifra que alcanza al 63,4% de la población diana (mayores de 16 años).

- New cases, spread of the infection and fear of the disease (***contagio*/contagion**—81, enfermedad/disease—82):

La Comunidad de Madrid ha notificado 5.167 nuevos contagios, de los que 3.523 se diagnosticaron en las últimas 24 horas, y siete fallecidos (uno más que ayer), al igual que sigue aumentando la presión hospitalaria.

Semantic Network

The identification of the semantic network and the analysis of the semantic core make it possible to study the semantic accents that users focus on when discussing

[3]https://www.projectimplicit.net/
[4]http://www.analyst.ru/index.php?lang=eng&dir=content/products/&id=ta
[5]http://www.casos.cs.cmu.edu/projects/automap/
[6]https://www.tableau.com/

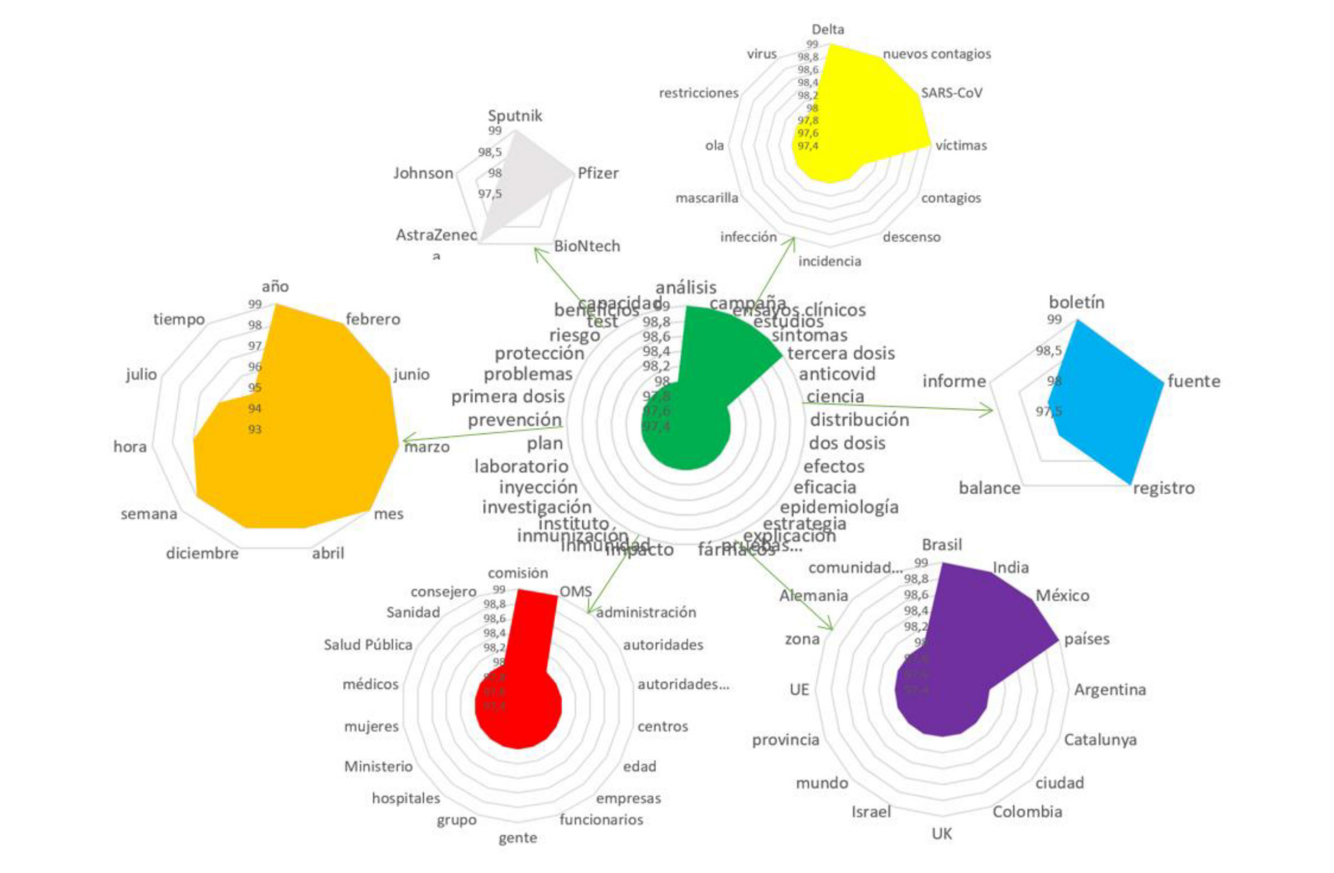

FIGURE 1 | Features of vaccine production and specificity of vaccination.

the analyzed problem; semantic clusters with implicit information are indicative of the users' opinions and assessments (**Figure 1**):

Significant nominations of the semantic network with connection weights of (99): analysis, vaccination campaign, science, clinical trials, symptoms, third dose, anti-COVID-19 measures, 98 vaccine distributions, first dose, two doses, effect, efficacy, tests, risk, strategy, explanations, pharmaceutical research, result, immunity, safety, laboratory, plan, prevention, problems, protection, benefits, intensity, and distribution.

Contexts are as follows:

Insiste el inmunólogo español en este mensaje. «Aunque los anticuerpos disminuyan, gracias la memoria inmunológica, cuando entremos en contacto con el virus, se van a activar y van a generar una respuesta».Entonces, ¿hace falta una tercera dosis de refuerzo?

1. Discussion of various types of vaccines.

Significant nominations of the semantic network with connection weights of (99): Pfizer, BioNtech (98), AstraZeneca, Johnson, Jansson, and Sputnik.

Contexts are as follows:

> *"Según criterio del especialista, pueden recibir cualquiera de las dosis disponibles ya sea a virus inactivado, de vector viral, o ARN mensajero. Entonces, cualquiera de las autorizadas en el país como Sputnik, Sinopharm o AstraZeneca pueden ser administradas en este tipo de huéspedes," indica.*

2. Spread of infection.

Significant nominations of the semantic network with connection weights of 99: delta variant, SARS-CoV, new infections, victims; 98—infection, recession, incidence, infection, masks, wave, restrictions, and virus.

Contexts are as follows:

Los datos sobre la situación epidemiológica en España y gran parte del mundo no son demasiado alentadores. En nuestro país ayer la incidencia alcanzó los 644 casos por 100.000 habitantes, más de 30.500 contagios en 24 horas y todavía se espera al pico de la quinta ola, que en Catalunya parece que ya alcanzó recientemente, dando pie al descenso.

3. Territorial features of the infection spread and vaccination:

Significant nominations of the semantic network with connection weights of 99: Brazil, India, Mexico, countries, Europe, EU, region, 98—Argentina, Catalonia, city, Colombia, Israel, world, province, zone, Germany, Great Britain, and autonomous communities.

Contexts are as follows:

Laboratorios de Biológicos y Reactivos de México (Birmex) anunció el 7 de mayo que a partir de finales de junio iniciaría con el proceso para envasar la vacuna rusa Sputnik V en México. Sin embargo, los reactivos para envasar llegaron a México apenas este miércoles.

4. Subjects of vaccination, persons responsible for vaccination.

Significant nominations of the semantic network with connection weights of 99: commission, WHO, 98—administration, government entities, medical institutions, medical centers, age groups, companies, public sector employees, people, groups, hospitals, ministry, women, doctors, health care, and advisers.

Contexts are as follows:

El lunes 12 de julio arranca en España la fase III del estudio multicéntrico mundial que Pfizer y BioNTech está llevando a cabo para evaluar la seguridad y eficacia de su vacuna en mujeres embarazadas.

5. Time characteristics of vaccination.

Significant nominations of the semantic network with connection weights of 99: year, February, June, month, 98—April, December, week, hour, day, time, etc.

Contexts are as follows:

Los enfermos de covid persistente llevan muchos meses, algunos incluso más de un año, sufriendo la sintomatología covid prácticamente a diario. Por edad—el perfil medio de estos pacientes es el de una mujer de 43 años, aunque también los hombres sufren esta patologí a-, muchos de ellos han añadido recientemente una preocupación más a su dura cotidianidad: los posibles efectos de la vacuna.

6. Information support of vaccination.

Significant nominations of the semantic network with connection weights of 99: record, source, register, and report.

Contexts are as follows:

La vacuna es segura. Todas las vacunas aprobadas son sometidas a pruebas rigurosas a lo largo de las diferentes fases de los ensayos clínicos, y siguen siendo evaluadas regularmente una vez comercializadas. Los científicos también siguen constantemente la información procedente de diferentes fuentes en busca de indicios de que una vacuna pueda tener efectos adversos.

The analysis of the Spanish semantic network enables identification of semantic accents that are of particular importance for actors, characterize the perception of the vaccination process, its protection and risks, as well as the principle of its distribution, which in itself already implies agreement with vaccination, even considering the necessity of the third dose. When discussing the specifics of the vaccine production and the vaccination process, actors focus on issues of vaccine knowledge, number of doses, immune response, explanatory process and vaccination strategies. After the emergence of several types of vaccines, actors began to actively discuss the merits of specific vaccines. Pfizer/BioNtech, AstraZeneka, Janssen, and Sputnik received the most attention in the discussion. All vaccines are of foreign origin. Despite the fact that the vaccination process has begun, Spanish users continue to worry about the spread of the infection, its new variants, and waves of infections; at the same time, actors emphasize the decline in the spread of the infection. In addition, other anti-infection measures such as masks and other restrictions are still in place. In the segment of the semantic network dedicated to persons responsible for vaccination, doctors, communities, risk groups, government entities, women, and public sector employees take pride of place. In the vaccination process, Spain aligns itself with the WHO, as well as with the experience of various EU countries and other Latin American countries because of the language proximity, and organizes the process on a territorial basis, while participation in vaccination differs in different cities and autonomous communities.

The actors are actively discussing the time characteristics of vaccination, age factors, as well as the timing required to test a new vaccine and identify *side effects*.

Information support for vaccination, according to Spanish-speaking actors, as confirmed by the semantic network data, is very scarce and limited to records and reports.

Associative Network

The analysis of lexical associations based on the results of the associative search and the associative network built made it possible to identify implicatures, subtextual information characterizing the attitude of actors to vaccination, peculiarities of actors' perceptions of the COVID-19 pandemic after the commencement of vaccination, of various processes associated with the creation of vaccines, and the organization of the vaccination process.

Stimulus Pfizer

Contexts with responses:

La vacuna de Pfizer utiliza ácido ribonucleico mensajero; es una tecnología nueva para vacunas pero tenemos muchos años investigándolo -desde hace 30 años- como candidatos a medicinas. Es una vacuna muy eficaz que empieza a proteger desde la primera dosis y protege muy alto luego de la segunda dosis (**Figure 2**).

As part of the fight against the pandemic and the arrangement for batch manufacturing of the Pfizer vaccine, Spanish-speaking actors pinned their great hopes on improving the health of their fellow citizens, on reducing the number of infected with each dose received (*pandemia, enfermedad, salud, contagios, población, vacunación, corona virus, millones, dosis*). The effect stretched for weeks; users began to compare the efficacy of the Pfizer vaccine with other vaccines used in Spain, such as AstraZeneca.

Stimulus Risk Group/Grupo de Riesgo

Contexts with responses:

En este grupo, hay muchas dudas sobre la inmunización. Las respuestas de los especialistas a las preguntas clave. Los pacientes oncológicos están en el grupo de riesgo para recibir la vacuna (**Figure 3**).

The analysis of the associative network also made it possible to conclude that the Spanish-speaking actors trust their healthcare

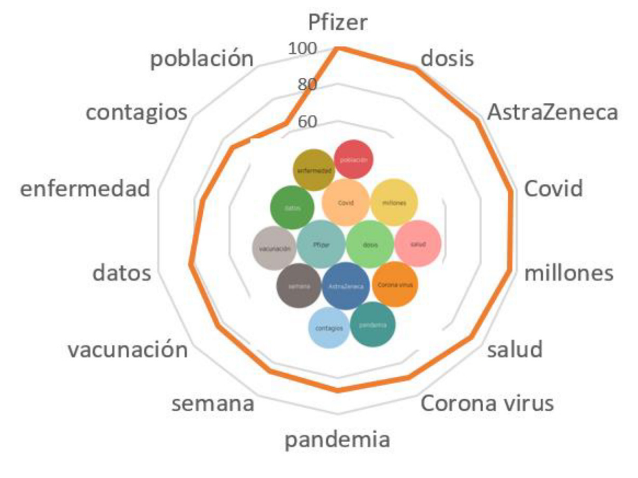

FIGURE 2 | Associative network of the stimulus *Pfizer.*

FIGURE 3 | Associative network of the stimulus risk group/*Grupo de riesgo.*

community (*Sanidad, Ministerio*). In addition, the Spanish actively discussed and worried about the situation with risk groups during the pandemic (*grupo de riesgo, pandemia*). The vaccination campaign in Spain implies the use of *AstraZeneca* and *Pfizer* vaccines, which are supposed to prevent the spread of diseases caused by the coronavirus infection (*enfermedad, coronavirus, población, compaña*). Actors believe that the existing data make it possible to organize mass vaccination of risk groups as well, provided that the protocol is strictly adhered to (*datos, semanas*).

German-Speaking Actors

Topic Structure

Explicitly expressed information that makes up the topic structure of the German database makes it possible to identify the following topics that are of greatest interest for users discussing the problems of COVID-19 after the commencement of the vaccination campaign:

- Effect of the vaccine on the **population** (*Menschen*/connection weight—74, persons/*Personen*—64):

Obwohl ein milder Verlauf der Krankheitinsbesondere bei jungen Menschen häufig ist und die meisten Erkrankten vollständig genesen, sind schwere Verläufe mitLungenentzündung, die über ein Lungenversagen zum Tod führen können, möglich.

- Features of various vaccines and their efficacy (**vaccine/*Impfstoff***: connection weight—74):

Der hier besprochene Vektor-Impfstoff (COVID-19 VACCINE Janssen) ist ein gentechnisch hergestellter Impfstoff.

- Significance and features of **vaccination (*Impfung***: connection weight—72):

Es gibt keine spezifische Therapie. Neben dem Vermeiden einerInfektion durch Beachtung der AHA + A + L-Regeln (Abstand halten, Hygiene beachten, Alltagsmaske tragen, Corona-Warn-Appherunterladen, regelmäßig lüften) bietet die Impfung den bestmöglichen Schutz vor einer Erkrankung.

- Effect of vaccination on the spread of **COVID-19** (connection weight—75, *Corona*—76):

Die Genspeed Biotech GmbH in Rainbach im Mühlkreis (Bezirk Freistadt) stellt einen weltweit einzigartigen COVID-19-Schnelltest her, der Antikörper gegen das Virus nach einer Erkrankung nachweist und in einer weiteren Ausbaustufe sogar eine aktuelle Infektion belegen soll.

- Pronounced territorial factor of vaccination—Germany (*Deutschland*—69):

Mittlerweile wird auch in Deutschland eine sogenannte "Kreuzimpfung," also eine Corona-Impfung aus zwei Impfstoffen, angeboten.

Semantic Network

Significant nominations of the semantic network with connection weights of (99): *antibodies, doctor (98), examination, vaccine, development, result, experience, production, immune system, vaccination, dose, vaccination center, protection, side effects, problems, rules, reaction, safety, symptoms, action, access, research, vaccination commission, laboratory, and immune response* (**Figure 4**).

Contexts are as follows:

Doch ab 14 Tagen nach der zweiten Dosis waren die T-Zell-Antworten in beiden Gruppen vergleichbar. Allerdings ist ebenfalls noch nicht klar, ob die Antikörper- oder die T-Zell-Antwort wichtiger für den Schutz gegen COVID-19 sind—oder ob beide gleichermaβen eine Rolle spielen.

7. Discussion of various types of vaccines.

Significant nominations of the semantic network with connection weights of (99): *Moderna, Pfizer, BioNtech, AstraZeneca*, and *Johnson*.

Contexts are as follows:

Biontech, Moderna, and AstraZeneca: Wie es gegen Mutanten helfen könnte, Impfstoffe zu kombinieren.

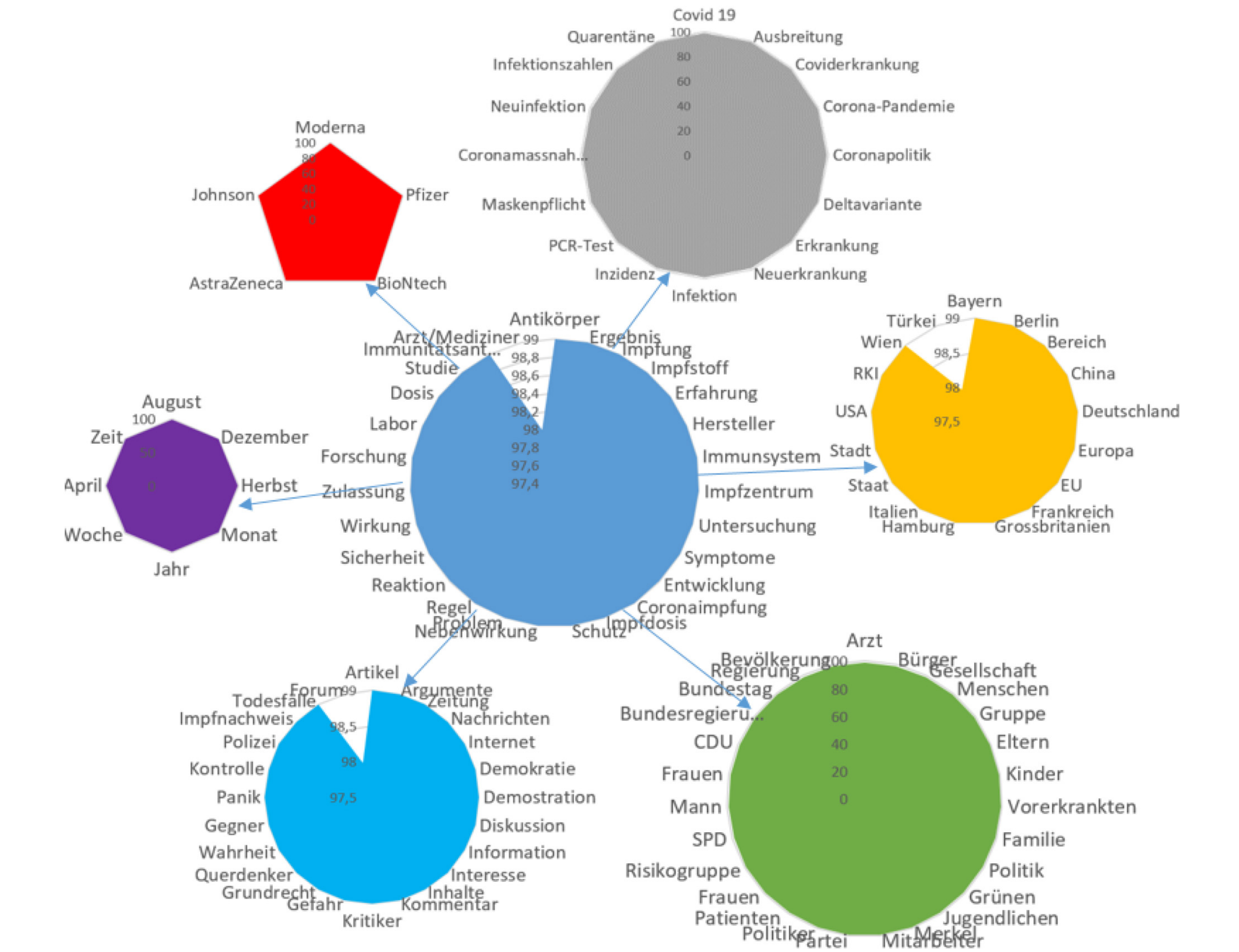

FIGURE 4 | Features of vaccine production and specificity of vaccination.

8. Spread of infection.

Significant nominations of the semantic network with connection weights of 99: *covid, spread, pandemic, covid policy, delta strain, disease, new infections, infection, inditions, masks, PCR test, number of cases, and quarantine.*

Contexts are as follows:

Studien aus Israel und Grossbritannien legen auch nahe, dass vor allem Biontech Ansteckungen deutlich vermindert.

9. Territorial features of the infection spread and vaccination.

Significant nominations of the semantic network with connection weights of 99: *Bavaria, Berlin, China, Germany, Europe, EU, France, United Kingdom, Hamburg, Italy, Switzerland, state, city, United States, Vienna, and Turkey* (98).

Contexts are as follows:

Darüber hinaus haben drei Impfstoffe aus China eine Notfallzulassung im eigenen Land erhalten, obwohl die Phase-3-Studien noch nicht abgeschlossen waren.

10. Subjects of vaccination, persons responsible for vaccination.

Significant nominations of the semantic network with connection weights of 99: *doctor, citizens, society, people, group, parents, children, people with pathologies, family, party, Green Party, youth, Merkel, employees, patients, women, politicians, risk groups, Socialist Party of Germany, man, federal government, Bundestag, government, population, and CDU party.*

Contexts are as follows:

12.45 Uhr: SPD-Gesundheitsexperte Karl Lauterbach hält die Delta-Variante für deutlich gefährlicher als bisherige Mutanten des Coronavirus.

11. Time characteristics of vaccination.

Significant nominations of the semantic network with connection weights of 99: *year, time, day, week, month, autumn, August, December*, etc.

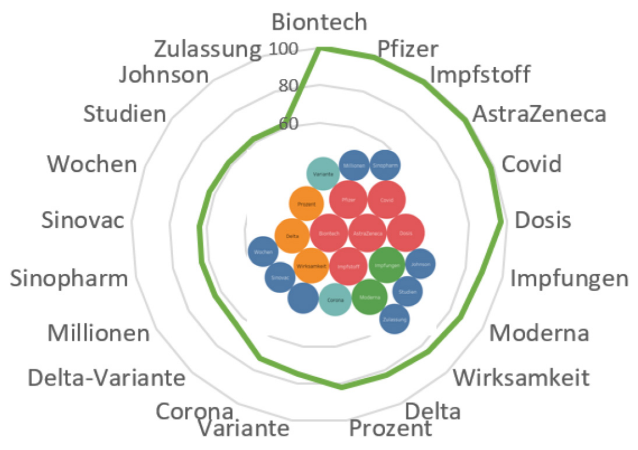

FIGURE 5 | Associative network of the stimulus *BioNTech.*

Contexts are as follows:

Demnach ist der Impfstoff von Pfizer/Biontech zwei Wochen nach der zweiten Dosis zu 88 Prozent wirksam gegen eine durch die Delta-Variante ausgelöste COVID-19-Erkrankung, bei der Alpha-Variante sind es 93 Prozent.

12. Information support of vaccination.

An information campaign to support vaccination faced criticism and protests from German-speaking actors, who, focusing on their rights, insisted on their right to choose. Significant nominations of the semantic network with connection weights of 99: *article, forum, newspaper, arguments, YouTube, news, internet, democracy, demonstration of protest, panic, control, police, discussion, information, interest, content, comment, critic, danger, constitutionally eligible, negacionists, truth, freedom, and anti-vaccination*.

Contexts are as follows:

PIMS ist für mich dazu kein Argument, vor allem weil man es—wie viele andere Dinge zu Corona—einfach als etwas völlig neues in den Raum geschmissen hat, obwohl dieses sehr seltene Phänomen auch schon vor Corona vorhanden war, oft dann aber im Zusammenhang mit dem Kawasaki-Syndrom in Zusammenhang gebracht.

The analysis of the German semantic network makes it possible to identify semantic accents that are of particular importance for actors and characterize the perception of the vaccination process and the motivation for making a decision whether to get vaccinated. When discussing the specifics of the vaccine production and the vaccination process, the actors highlight the issues of vaccine knowledge, vaccination rules, immune system response, and number of doses. After the emergence of several types of vaccines, the actors began to actively discuss the merits of specific vaccines. Moderna, Pfizer/BioNtech, AstraZeneka, and Johnson received the most attention in the discussion, and Germany also participated in the production of some of them. Despite the vaccination, people in Germany are worried about the spread of infection, its new variants, serious consequences, and deaths from the coronavirus infection. Moreover, other protective measures against infection are still in place, such as tests, quarantine, self-isolation, and wearing masks. In the semantic web, a segment is distinguished associated with those responsible for administering vaccinations, along with communities, population groups, with different gender and professional characteristics. The actors are actively discussing the actions of the authorities, politicians, and leading political parties in Germany on the eve of the elections. In the vaccination process, Germany is guided by its own research institute RKI, the experience of various EU countries and other countries, and also organizes vaccination on a territorial basis, and the organization of vaccination differs in individual cities and provinces.

The actors are actively discussing the timing of vaccination, age factors, as well as the time required to test a new vaccine and identify *side effects*.

The informational support of vaccination according to the semantic network has a pronounced critical connotation. There is a clear protest against compulsory vaccination; demands are made to provide truthful information about the risks of vaccines, respect for democratic foundations, freedom of choice and demonstration of will, and protection against discrimination against vaccine opponents.

Associative Network

Stimulus BioNTech

Contexts are as follows:

Bei Biontech berichten Geimpfte das Gegenteil: Hier fallen die Impf-Nebenwirkungen nach der zweiten Impfung stärker aus als nach der ersten (**Figure 5**).

The BioNTech/Pfizer vaccine jointly developed by Germany and United States is actively discussed by German actors who compare it with other vaccines: AstraZeneca, Johnson, and Moderna. Users are concerned about its efficacy (*Wirksamkeit, Prozent*) against the coronavirus, as well as against the new Delta strain (*Variante Delta*). Along with familiarization with the protocol of its administration (*Wochen*), the reliability of research (*Studien*) and the availability of official permission for mass production (*Millionen, Zulassung*), its alternatives are also being considered, namely Sinopharm and Sinovac. Evidence shows that German-speaking citizens are taking vaccinations thoroughly by studying the situation and weighing other options.

Stimulus Risk Group (Risikogruppe)

Contexts with responses:

Die Infektionskrankheit COVID-19 kann einigen Menschen sehr gefährlich werden. Besonders riskant ist eine Corona-Infektion für Ältere, chronisch Kranke und Menschen mit einem geschwächten Immunsystem. Zu dieser Risikogruppe zählen auch Krebskranke, etwa Männer mit Prostatakrebs (**Figure 6**).

For German-speaking actors, the risk group includes primarily elderly people (*Jahre, Teilnehmer*), who are given priority in the vaccination process (*Corona-Impfung, Dosis, Priorisierung*). The actors believe it is necessary in such cases to carefully study the dose of the vaccine and the reasons for including

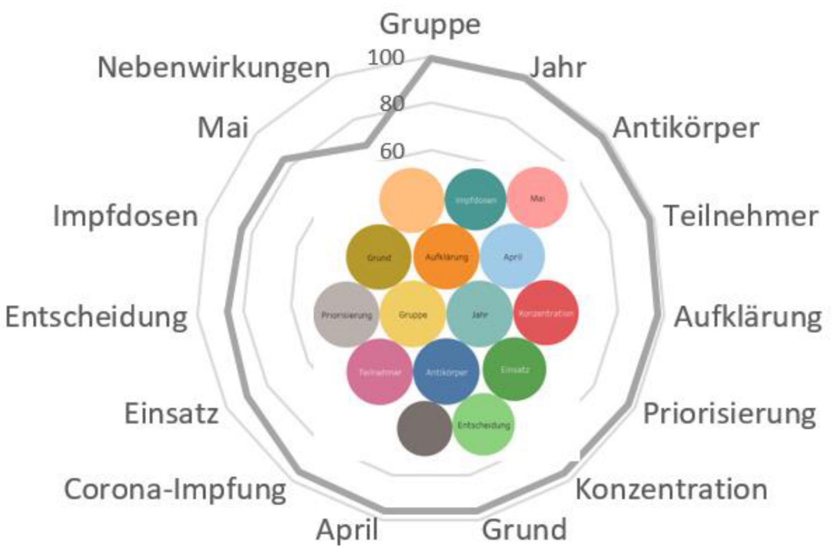

FIGURE 6 | Associative network of the stimulus *risk group (Risikogruppe).*

citizens into the risk group, to calculate the concentration of antibodies, and to prevent side effects. German users place great emphasis on the need for outreach to ensure that vaccination decisions are well-thought-out and the use of vaccines is reasonable (*Konzentration, Grund, Einsatz, Entscheidung, Aufklärung, Nebenwirkungen*).

Russian-Speaking Actors

Topic Structure

Explicitly expressed information, which makes up the topic structure of the Russian-language database, makes it possible to identify the following topics that are of greatest interest for users discussing the problems of COVID-19 after the commencement of the vaccination campaign:

- Effect of the vaccine in **humans** (*люди*- connection weight of 96; frequency of 36,332):

Vector vaccines use viruses that are safe for humans and cannot reproduce in the human body (vectors).

This is the world's first registered vector vaccine based on a new technological platform that involves human adenoviruses Ad26 and Ad5, which carry the S gene of the coronavirus protein. The vaccine is developed at the N. F. Gamaleya Center, Russia.

- Features of various vaccines and their efficacy (**vaccine/*вакцина*, *вакцинация*, *прививка***: connection weight of 82; frequency of 201,188; **vaccination:** connection weight of 75; frequency of 37,208):

The efficacy of the Sputnik V vaccine of 91.4% was confirmed by the analysis of data at the final checkpoint of clinical trials.

Kryuchkov noted that cases of body temperature rise after vaccination against the coronavirus are not the only possible early post-vaccination manifestation—these can also include "injection site masses, as well as body temperature rise, general weakness, and malaise, that is, the classic manifestations of ARVI," Sputnik radio reports.

- Vaccination duration (**year/год** - connection weight of 79; frequency of 66,711; **time/время**: connection weight of 75; frequency of 19,702; **day/день**: connection weight of 71; frequency of 17,506):

Vaccination against coronavirus at the level of 70% of the population in each country by the middle of next year will stop the pandemic and restart the global economy.

But such medieval obscurantists like you ensure the presence of COVID that already has a chance to achieve such mutations against which vaccines will show increasingly lower efficacy. Time and anti-vaxers work for COVID.

- Significance and features of **vaccination** (connection weight of 76; frequency of 12,702):

"If a person's vaccination was, as they say, without a hitch, that is, without fever and so on, this doesn't mean this person will not have immunity. On the other hand, it cannot be said that if a person has been in bed with a high temperature of 39 degrees for three days after their vaccination, then their immune response will definitely be higher," Kryuchkov explained.

- Efficacy and distribution of the vaccine **"SputnikV"** (connection weight of 73; frequency of 26,167):

Curiously, this new situation provides arguments for both proponents and opponents of vaccinations. The first are convinced that vaccination should be even more massive (60% of those vaccinated, which were mentioned at first, are no longer enough), and that it is necessary to strengthen immunity with additional or repeated doses, since the common use of Sputnik V may not work.

- Effect of vaccination on the spread of **COVID-19** (connection weight of 80; frequency of 30,533):

In addition, it is noted that there is, currently, a global inequality in terms of access to vaccines against COVID-19, and, in poorer countries, far fewer people are fully vaccinated or received at least one dose than in richer countries, where vaccines are produced and governments have begun to talk about revaccination.

- Public discussions of various issues related to vaccination, the formation of immunity, protection against the coronavirus infection (**question:** connection weight of 68; frequency of 18,403):

My whole family was ill with this COVID; we've come through it easily, without pneumonia and side effects, only temperature was sometimes higher, and some of did not even notice that they had been ill; but the essential point about which everyone is silent is that: how long does the immunity last after the illness?

- New cases, spread of the infection (**new:** connection weight of 68; frequency of 4,548; **cases:** Вес связи–68; frequency of 2,204):

As of June 24, 2021, in Moscow, the situation with the new coronavirus COVID-19 remains tense. New cases of the coronavirus infection were recorded in various districts and cities of the region. The total number of cases in Moscow was 1,315,841 people.

- Discussion of measures being taken to combat the pandemic, **work** on vaccination (**work:** connection weight of 70; frequency of 59,468):

Then work began on obtaining virus isolates, and whole-genome sequencing was performed, as a result of which a vaccine strain was obtained and another strain that is used for quality control.

Semantic Network

Significant nominations of the semantic network with the following connection weights: vaccination (99), campaign (94), research (88), efficacy (87), doses (90), medication (96), result (86), vaccinations (86), center (86), trials (84), production (82), use (79), work (74), doctors (73), MOH (73), development (73), solution (73), antibodies (72), quantity (72), system (72), opportunity (71), end (71), organization (71), situation (71), basis (70), protection (69), immunity (69), millions (69), problems (69), response (68), means (68), effect (68), Vector (67), and development (67) (**Figure 7**).

Contexts are as follows:

Why are Russians afraid of vaccination? Expert opinion. At the moment, Russia ranks number one among countries the population of which is skeptical about vaccination.

We already heard about it. Places for people with the right skin color, or a sign in the form of a yellow star on clothes, so that one can immediately see who is in front of them. Get injected and you will have more rights than those not injected.

1. Discussion of various types of vaccines.

Significant nominations of the semantic network with the following connection weights: vaccines (100), AstraZeneka (99), Sputnik (99), Pfizer (81), EpiVacCorona (69), and CoviVac (67).

Contexts are as follows:

As for this point, you need to be vaccinated, with a foreign vaccine, in an ideal scenario. But this is almost impossible. Of the Russian vaccines, the best of three evils is, obviously, CoviVac. A good thing cannot be called "Sputnik" in the 21st century.

2. Spread of infection.

Significant nominations of the semantic network with the following connection weights: COVID (19), cases (85), new (84), healthcare (82), infection (80), virus (79), disease (78), level (77), safety (76), COVID (72), coronavirus infection (69), and pandemic (68).

Contexts are as follows:

Stop talking nonsense. It is disgusting to read. If you want to be vaccinated—get vaccinated, if you do not, whatever, stop blaming people for deaths.

3. Territorial features of the infection spread and vaccination.

Significant nominations of the semantic network with the following connection weights: country (95), Russia (94), United States (83), world (81), Moscow (73), region (72), chapter (71), RF (71), regions (69), and place (67).

Contexts are as follows:

The chart shows that Russia and Australia are the most worrisome because of the number of such doubters. I do not know what is wrong on the smallest continent. But the Russian phenomenon seems to be clear. One thing distinguishes our country from all the global powers listed in the study—that is the lack of choice.

4. Subjects of vaccination, persons responsible for vaccination.

   Significant nominations of the semantic network with the following connection weights: human (96), groups (77), population (77), authorities (72), citizens (71), patient (71), President (71), government (69), and experts (69).

Contexts are as follows:

And as for anti-vaccinators for ideological reasons, it is something of "artificially created natural selection." Word up. If a person does not care about himself or herself, then we must not let him or her be careless about others. For instance, antimaskers do not want to understand that a mask is not their protection from others. On the contrary, the mask is the protection of others from a possible carrier.

5. Time characteristics of vaccination.

Significant nominations of the semantic network with the following connection weights: year (96), time (87), day (86), years (83), week (76), month (74), July (72), and moment (70).

Contexts are as follows:

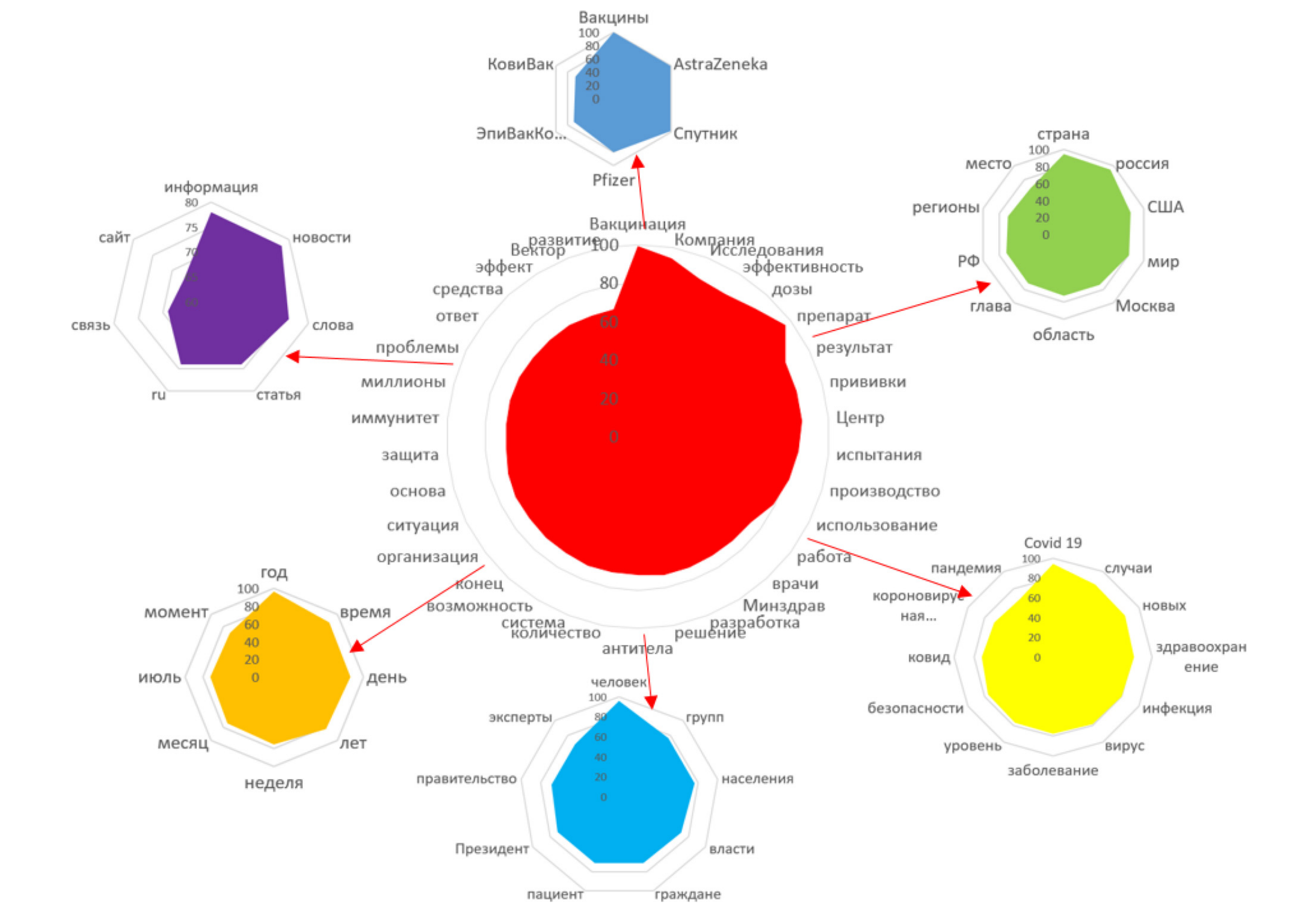

FIGURE 7 | Features of vaccine production and specificity of vaccination.

Russian statistics cannot be trusted, at all. It will show as many as is necessary at the current moment. And much time has passed. The vaccine is usually tested for 5–7 years. Are there any data on side effects in 5–7 years? Or in 3 years? That is a rhetorical question.

6. Information support of vaccination.

Significant nominations of the semantic network with the following connection weights: information (78), news (78), words (76), article (74), ru (74), link (69), and website (67).

Contexts are as follows:

Coronavirus is a poorly understood disease, and the effect of vaccines under development is, accordingly, the same. Experts do not yet have answers to many questions, hence the wariness of people. We are doing all the testing during the pandemic; that is, all information is being collected today. Our task was to obtain such a dose, and a vaccination schedule that ensures the body's immune response is as quick as possible.

The semantic network analysis allows identification of semantic focuses that are of particular importance for actors and characterize the perception of the vaccination process and motivation when making a decision about vaccination. When discussing the specifics of vaccine production and the vaccination process, the actors highlight the issues of vaccine efficacy, the number of doses that will be delivered to various regions, as well as social problems, the possible infringement of the rights of people who reject vaccination. After the emergence of several types of vaccines, the actors began to actively discuss the merits of specific vaccines. AstraZeneka and Sputnik received the most attention in the discussion. Of the three Russian vaccines: Sputnik, EpiVacCorona, and CoviVac, the last one is recognized as the safest. The actors argued about the causes of the spread of the infection, severe consequences and deaths from the coronavirus infection, as well as by the state of modern healthcare in Russia. The persons responsible for the vaccination are criticized by both supporters of vaccination and opponents alike. The attention of users is attracted by the peculiarities of vaccination in different countries and in different regions of Russia, the readiness, and desire of the population to get vaccinated against the coronavirus infection. The actors are actively discussing the time characteristics of vaccination, as well as the time required to test a new vaccine and identify side effects. According to the analysis of the core of the semantic web, the actors negatively assessed the informational support of vaccination.

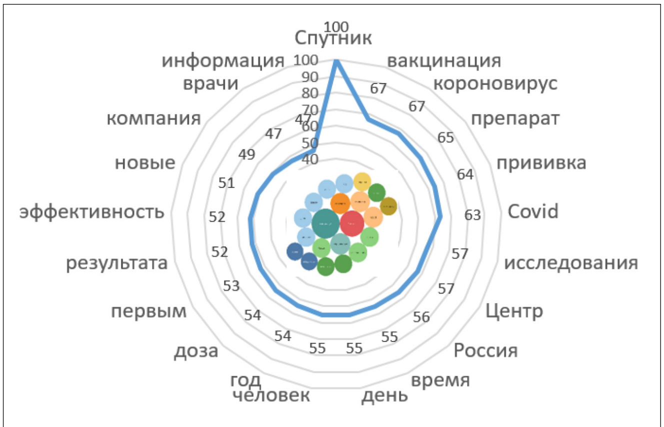

FIGURE 8 | Associative network of the stimulus *Sputnik.*

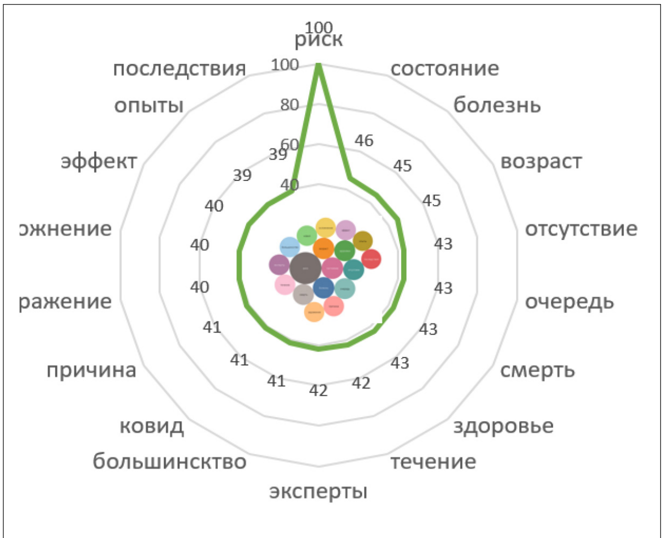

FIGURE 9 | Associative network of the stimulus *Risk group.*

Associative Network

Stimulus Sputnik (10/108246)

Contexts with responses:

Russia was the first country in the world to register a vaccine against COVID-19; it was Sputnik V, the medication developed by the N. F. Gamaleya Research Center for Epidemiology and Microbiology in cooperation with the Russian Direct Investment Fund (**Figure 8**).

The vaccine is being produced; it arrives in the regions in batches, which is even good. The fact is that the Sputnik V vaccine requires special storage conditions.

Stimulus Risk Group (10/7163)

Contexts with responses:

The risk groups include elderly people. In age groups over 70, vaccination reduces the risk of death among those affected by 31–52% (and the risk of getting affected by more than 90%) (**Figure 9**).

After the emergence of the vaccine, Russian-speaking actors began to actively discuss the organization of vaccine production and vaccination campaigns, the consequences of the vaccine for various groups of the population, etc. Since the first vaccine was Sputnik V, this particular vaccine was in the spotlight. After the emergence of other vaccines, discussions began on the merits and demerits of each type, as well as the efficacy of vaccines against new strains.

The mandatory requirement for vaccination (at work or in educational institutions), the suspension from work of those who have not been vaccinated, the introduction of QR codes to visit public events, cafes, and restaurants, have caused significant criticism on social networks. Ironic stories about the inconsistency of the actions of the authorities and the conflicting statements have become widespread.

The Russian-speaking actors perceive sharply negatively the lack of choice of vaccines, since other Russian vaccines EpiVacCorona (10/13266) and CoviVac (10/11554) were not produced in the required quantities during this period, which formed a shortage and limited the choice of vaccines.

Data from associative networks also show that it is CoviVac that receives the most trust from users as the safest for health. Despite the publication of studies on the effectiveness and safety of the first Russian vaccine in official resources, the actors expressed opinions about the lack of sufficient time for testing, a list of contraindications, and fear of long-term consequences. The actors also believe that the developers of Russian vaccines have not found out whether a protective antibody titer is formed in the subjects, i.e., these vaccines may not be effective in preventing the coronavirus infection. In addition, mistrust is caused by information of posted instructions and on specialized resources.

The level of confidence in vaccines and the understanding of the need for vaccination are significantly undermined by the conflicting opinions of medical experts. The Internet interviews and statements of doctors who are skeptical about vaccination and declare the uselessness of vaccinations have become actively spread. These opinions are popular because they allow people who have doubts or are afraid of vaccination to receive external "authoritative" confirmation of their fears and justify their reluctance to get vaccinated.

The actors are convinced that foreign vaccines are more effective and safe in view of historically established and well-established stereotypes in public opinion about the advantages of imported products and drugs. The most actively discussed are AstraZeneca (10/4053) and Pfizer (10/4896). Moderna gets an index of (0/0) during associative search.

The actors express dissatisfaction with the lack of awareness of the consequences of vaccination for human health and think the issue is too politicized.

Particularly dangerous consequences of vaccination are recognized for people with poor health and chronic diseases, which are at risk (included in the risk group). Accordingly, people of elderly age groups automatically fall into risk groups.

The heightened emotional background of the vaccination discussion has led to the formation of digital conflictogenic zones. Vaccination supporters (including some actors who were forced to get vaccinated) sharply attack vaccination opponents ("COVID dissidents," "covidiots"), accusing them of a threat to the life of society: *"anti-vaccine idiots get sick, infect others, die themselves, and threaten death to others, thereby causing damage not only to strangers but also to the state."* Vaccination opponents insist on the right of choice, voluntariness of any medical procedures, on the right to be masters of their bodies and health.

DISCUSSION

Previous research on the perception and behavioral and psychological impact of COVID-19 was based on surveys; this study focuses on the analysis of content generated by social media users. The materials include both the opinions of actors who purposefully express their points of view and reasoning and messages that are related to various spheres of the actors' lives, which indirectly relate to the pandemic and vaccination. The use of neural network technologies makes it possible to analyze not only implicit information but also explicit information to evaluate hidden reactions and assess actors that form the perception of the analyzed issues.

There is a large project COVID-19 IMPACT (see text footnote 1), which is an international online survey conducted in 78 countries/regions of the world studying the behavioral and psychological impact of COVID-19.

In particular, based on data from the COVID-19 IMPACT project, a study was conducted on the perception of COVID-19 in Europe at the early stage of the pandemic. Perception of a disease is an important predictor of emotional and behavioral responses in many diseases. The results of a large-scale study of IP addresses associated with COVID-19 across Europe have been published. The authors analyzed the temporal development, identified predictors (within demographics and contact with COVID-19), and examined the impacts of IP on perceived stress and preventive behaviors (Dias Neto et al., 2021).

This study analyzes the perception of the COVID-19 pandemic by Spanish-, German-, and Russian-speaking social media participants after the commencement of vaccination campaigns in the later stages of the pandemic using neural network technologies and psycholinguistic techniques, which made it possible to identify the implicit information and semantic focuses that are most important for the actors in Spanish-, German-, and Russian-speaking digital environment.

While before the emergence of any vaccine or treatment for COVID-19, all measures to contain and limit the spread of the infection depended on people's behavior, after the commencement of the vaccination process, it became important to ensure that citizens positively perceive national vaccines, their safety, efficacy, and the power to stop the spread of the disease.

The results of this study are consistent with the findings of the study by Rosman et al. (2021) that the credibility of public health experts, scientists, and doctors who confirm the safety and efficacy of vaccines greatly contribute to the success of vaccination.

The results of our study also confirmed the conclusions by Rosman et al. (2021) that, for European countries, doubts about the safety of a vaccine expressed by official authorities significantly reduce the willingness of the population to get vaccinated. Thus, in March 2021, the safety of the AstraZeneca vaccine was questioned; several countries suspended its use. At the same time, politicians and public health experts were quick to reassure the public that all COVID-19 vaccines are safe and effective (Goldstein et al., 2020). Meanwhile, this no longer helped in terms of changing the attitude of the population, which began to increasingly lose faith in state institutions; a similar trend is intensifying, for example, in Germany since the beginning of 2021 (Betsch et al., 2021; Rosman et al., 2021).

This study correlates with the results of a comparative analysis of Chinese and American media reports on COVID-19 (Zhang et al., 2021), which reveal a close relationship of publicity coverage of the pandemic with political and ideological motives, and also confirm the importance of adhering to the principles of social responsibility.

Researchers have already noted the inconsistency of cultural comparisons of the disease perception (Bean et al., 2007; Kaptein et al., 2013). In the present study, a comparison was made with the inclusion of two European countries and a country outside Europe, thus changing the level of analysis from individual countries to European and non-European regions (north vs. south; west vs. east). Consideration of differences in the cultures and the severity of the pandemic in these countries, to some extent, contributed to the identification of differences.

The study of the peculiarities of the perception of the COVID-19 pandemic by Spanish-, German-, and Russian-speaking social media actors made it possible to identify differential and integral features of the topic structure, semantic, and associative networks built on the material of the three databases, which made it possible to determine the common and different characteristics of user perception after the commencement of the vaccination process and their attitude toward the vaccination itself.

Despite the coincidence of the topics identified in the topic structure that characterizes explicit knowledge of vaccination, the Russian-language topic network is more diverse. Russian-speaking users, as well as Spanish- and German-speaking ones, were concerned about such topics as the effect of the vaccine on people, the peculiarities of vaccination, the efficacy of the vaccines, and their influence on the further spread of COVID-19. The Russian- and Spanish-language databases show anxiety of the actors caused by the time characteristics of vaccination and new cases of the disease, which are less represented in the topics of the German-language discussions. Russian-speaking users are more actively discussing measures to combat the pandemic, work on organizing the vaccination process, immune development, and protection against the coronavirus infection. On the other hand, German-speaking users pay more attention to the territorial and age-related factors of vaccination, while Spanish-speaking users express a stronger fear of the disease.

Implicit knowledge revealed during the analysis of semantic networks made it possible to identify a large number of differential features characteristic of the perception of vaccination by speakers of the three analyzed languages. For German- and Russian-speaking users, it is important to have a well-adjusted production, efficiency, and response of the immune system to the vaccine, while Spanish users discuss rather the protective mechanism of the vaccine and the required number of doses, thereby confirming their absolute readiness for vaccination. The core of the semantic network reveals a strong concern of German users about the vaccine efficacy. The semantic emphasis highlighted in the German- and Russian-language materials shows that users are more concerned about the immune system's response to the vaccine and its side effects on the body, while Spanish actors have a greater fear of the disease and death from COVID-19, and therefore ignore the possible consequences of vaccination.

Of key importance in the semantic network built on the material of all analyzed languages is the content on vaccines used in the respective country. Germany was a co-manufacturer of certain vaccines, while Spain did not have its own brand, and Spanish actors actively discussed all types of vaccines, including the Russian Sputnik, the possibility of which was not considered in Germany. The Russian actors discussed both Russian and foreign vaccines.

The further development of the pandemic and measures to prevent the spread of the infection are of concern to all users, but only German- and Spanish-speaking actors attach great importance to preventive measures complementary to vaccination. It should be noted that information about "complementary" measures was used in the official media in Germany and Spain as a means of pressure on vaccination opponents, since vaccinated citizens were exempted from their observance.

All three databases reflected the territorial strategy for combating COVID-19. For example, Germany and Spain align with EU countries, neighboring countries, and vaccine-producing countries; also, the competences on the national territory are differentiated, taking into account their specificity. The Spanish-language corpus also reflected data from Latin America, which can be explained by a linguistic proximity, and the Russian-language material often included discussions of the anti-COVID strategy of the United States considered a strong manufacturer and a long-term rival.

The content on vaccination subjects and those responsible for this process takes significant portions in all three databases. The main administrative structures and institutions involved in the organization of vaccination were also actively discussed. German-speaking users discussed groups of vaccinated persons in more detail, dividing them by age, gender, and the presence of pathologies. The upcoming elections in Germany have strongly influenced the vaccination debate, as comparisons of the anti-COVID policies of various leading parties have given the discussion a strong political dimension. The politicization of the topic of vaccination is also found in the Russian-speaking corpus.

The time factors of vaccination mostly coincided in all three language corpora and were associated with the chronology of the process organization in the respective countries.

The greatest differences were found in implicit knowledge devoted to information support. Open dissatisfaction with the anti-COVID policy in Germany was observed in the discussions of German-speaking users, who demanded respect for the foundations of democracy and respect for the opinions and choices of citizens during vaccination. The actions of vaccination opponents that were suppressed with the involvement of the police were actively discussed; and this caused an increase in protests and indignation. The study demonstrated the big availability and easy access to the big number of varied sources of information for the German users. The German-speaking actors also demanded to provide objective and truthful information about vaccination and its effectiveness and criticized the control and discrimination against vaccination opponents. The data show that the actors negatively perceive information support for vaccination, believe that there is a lack of convincing information in Germany, and doubt the advisability of vaccination. Negative perception is also noted among Russian-speaking users, who received a significant amount of conflicting information from various sources. Spanish-speaking actors mainly relied on official reports and data, without questioning the competence of the authorities in organizing vaccination campaigns. Thus, it can be concluded that the data indicate a high degree of loyalty of the Spanish actors to vaccination supported by trust in the government; therefore, the feasibility of vaccination was practically not discussed by the Spanish actors.

The German-speaking actors had wide access to information; an excess of information was perceived as a counterproductive factor in the vaccination campaign, as it led to increased doubts among residents about the need for a vaccine and the reliability of the information received, which, in the light of the upcoming elections to the Bundestag, acquired a political connotation and resulted in waves of protests.

The Russian-speaking users received information from various sources, but despite this, they demonstrate low readiness for vaccination. A rather common tactic in Russia is a "wait and see" attitude. Even the actors who believe vaccination is necessary to end the pandemic choose to delay vaccination for themselves and their family members out of fear of the consequences. The decisive factor in obtaining the vaccine is the requirements of employers and the administration of higher and secondary educational institutions, as well as the imposed bans on visiting cafes and restaurants without a QR code confirming vaccination.

Grave doubts of both the Russian and German actors are caused by fear of infringement of the rights of people who refuse to get vaccinated.

The Russian-speaking actors perceive negatively the mandatory requirement to get vaccinated (at work or to have the right to study) and the lack of choice of vaccines. Data show that it is CoviVac that receives the most trust from users as the safest for health. Despite the fact that the effect of the first Sputnik V vaccine has been studied in much more detail than the others, it causes a negative attitude among the actors.

The analysis of the content with responses to the stimuli vaccine and risk group in the three language datasets showed that the Russian actors trust foreign vaccines more than the Russian-made ones. A similar perception is characteristic for Spanish users. Meanwhile, the German actors doubt the high efficacy of the vaccine, especially against new virus variant; they are concerned about possible side effects and prefer to receive extensive information in advance and the opportunity to compare various types of vaccines and make a deliberate decision.

While people from risk groups in Spain and Germany have a reasonable priority in vaccination, Russian users consider the consequences of vaccination for people with poor health, chronic diseases, and those who are at risk, especially dangerous. It should be noted that, in Spain, teachers and medical workers were the first who were vaccinated as those included into the risk group.

In the Russian-speaking media space, strong emotions during the discussion of vaccination have led to the formation of digital conflictogenic zones. Vaccination supporters sharply attack vaccination opponents ("covid dissidents," "covidiots"), accusing them of posing a threat to the life of society. Vaccination opponents insist on the right to be masters of their bodies and health. Similar opposition was observed among the German-speaking actors. The irreconcilability of positions has led to the emergence of a new conflictogenic digital zone also in the German-speaking cyber environment.

The most striking differential features of vaccination perception can be traced in the readiness to receive the vaccine: The Spanish-speaking actors show a positive attitude; they get vaccinated obediently and readily; the German-speaking actors perceive vaccination with suspicion and study the information thoroughly; the Russian-speaking users are characterized by "wait and see" attitude and fear of the consequences.

The results of the study confirm the official data on vaccinations (as of September 30): Spain—78%[7]; Germany—64%[8]; Russia—33%.[9]

CONCLUSION

This study showed that, despite the similarity of the topic structures expressing explicit knowledge, the analysis of implicit knowledge revealed significant differences in the perception of the COVID-19 pandemic by Spanish-, German-, and Russian-speaking social media participants after the emergence of vaccines and the attitude toward vaccination itself. Different cultural features, the development of the pandemic, and social foundations in Germany, Spain, and Russia have led to a larger or lesser degree of readiness for vaccination in the population. With active campaigning to vaccinate in all countries, the Spanish-speaking users perceived vaccination as a salvation from COVID-19, protection from the infection, and a chance to overcome the fear of death; they trusted official sources of information and did not seek confirmation of the efficacy and safety of the vaccine in alternative sources. The German-speaking users thoroughly and critically studied the extensive amount of available information, were suspicious of new vaccines, and defended their right to choose, the foundations of democracy and freedom of opinion, which they also actively defended in offline actions and demonstrations. The Russian-speaking users received contradictory information from various sources; they demonstrate low readiness for vaccination and the fear of the consequences. A rather common tactic in Russia is a "wait and see" attitude.

The cognitive representation of the disease formed among the actors in the Spanish-, German-, and Russian-speaking media space, largely depended on the emotional and behavioral response of members of society. The peculiarities of perception of COVID-19 became one of the important factors in making a decision on vaccination and taking preventive measures for all three types of actors.

In addition, the results of the study confirmed the effectiveness of using multimodal neural network analysis to study speech perception in various discourses.

[7]https://www.mscbs.gob.es/profesionales/saludPublica/ccayes/alertasActual/nCov/documentos/Informe_GIV_comunicacion_20211001.pdf

[8]https://ourworldindata.org/covid-vaccinations?country=DEU

[9]https://gam-kovid-vak.ru/skolko-privito-ot-koronavirusa-v-rossii-na-4-oktyabrya/

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Cyprus National Bioethics Committee (ref.: EEBK EΠ 2020.01.60). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

MP, AR, and OK performed the material preparation, data collection, analysis, and wrote the first draft of the manuscript. All authors commented on previous versions of the manuscript, read and approved the final manuscript, and contributed to the study conception and design.

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Grammatical Gender in Spoken Word Recognition in School-Age Spanish-English Bilingual Children

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This study investigated grammatical gender processing in school-age Spanish-English bilingual children using a visual world paradigm with a 4-picture display where the target noun was heard with a gendered article that was either in a context where all distractor images were the same gender as the target noun (same gender; uninformative) or in a context where all distractor images were the opposite gender than the target noun (different gender; informative). We investigated 32 bilingual children (ages 5;6–8;6) who were exposed to Spanish since infancy and began learning English by school entry. Along with the eye-tracking experiment, all children participated in a standardized language assessment and told narratives in English and Spanish, and parents reported on their child's current Spanish language use. The differential proportion fixations to target (target – averaged distractor fixations) were analyzed in two time regions with linear mixed-effects models (LME). Results show that prior to the target word being spoken, these bilingual children did not use the gendered articles to actively anticipate upcoming nouns. In the subsequent time region (during the noun), it was shown that there are differences in the way they use feminine and masculine articles, with a lack of use of the masculine article and a potential facilitatory use of the feminine article for children who currently use more Spanish than English. This asymmetry in the use of gendered articles in processing is modulated by current Spanish language use and trends with results found for bilingual and second-language learning adults.

Keywords: grammatical gender, bilingual (Spanish/English), eye-tracking (ET), visual world paradigm (VWP), typically developing child

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INTRODUCTION

Both children and adults process speech incrementally, making use of what they have heard to anticipate the endings of words and sentences (e.g., Marslen-Wilson, 1987; Bates et al., 1996; Friederici and Jacobsen, 1999; Fernald et al., 2001). Even 2-year-olds can identify referents of familiar words with only partial word information (Fernald et al., 2001; Fernald and Hurtado, 2006). The present study examines incremental comprehension of spoken language in Spanish-English bilingual school-age children.

In many languages such as Spanish, nouns are assigned grammatical gender. For example, *the tomato* in French (*la tomate*) is feminine while in Spanish (*el tomate*) and Italian (*il pomodoro*) it is masculine. Learners use phonological, semantic, and morphological cues to assign nouns to gender classes (Karmiloff-Smith, 1979; Pérez-Pereira, 1991). In Spanish, definite articles are two of the most frequent words in Spanish. The log frequency for *el* is 4.50 and for *la* is 4.63 (with a maximum log frequency of 4.85 in EsPal, a Spanish Lexical Database; Duchon et al., 2013). Articles are almost always compulsory in a noun phrase, but as unstressed monosyllables, they have low saliency (Mariscal, 2009).

Monolingual children around 1;4–1;5 years of age produce bare nouns in Dutch, English, and German while those children learning Spanish and Italian tend to precede nouns with a "filler syllable" to hold the place for an article, or proto-article (Bottari et al., 1993; Peters and Menn, 1993; Lleó, 1998). Around 1;10, children acquiring a Romance language such as Spanish, produce a high percentage of articles and proto-articles and by 2;3 produce articles in an adult-like manner regardless of language. Thus, monolingual children make use of articles in spoken language comprehension from an early age. For example, Lew-Williams and Fernald (2007) found that 2- and 3-year-old's learning Spanish as their first language (L1) identified visual referents earlier in the context of different-gender articles (informative) than same-gender articles (uninformative). Specifically, children saw two pictures of objects with names of either the same [e.g., *la* pelota (fem.ball), *la* galleta (fem.cookie)], or different grammatical gender [*la* pelota, *el* zapato (masc.shoe)], as they heard a Spanish sentence referring to one of the objects. Children looked to the correct referent earlier on different-gender trials, when the article was potentially informative, than on same-gender trials, when the article could precede the name of either object. This study provided the first evidence that young Spanish-learning children with only 500 words in their expressive vocabularies already utilize morphosyntactic information in the process of establishing reference, exhibiting an anticipatory effect. Similarly, other researchers have shown children who speak other gendered languages also show sensitivity to gender early in development. By 25 months, French-learning children fixate referents earlier when preceded by informative gender-marked articles (van Heugten and Shi, 2009). However, at 24 months, Dutch-learning children are not yet sensitive to grammatical gender (van Heugten and Johnson, 2011), which may be due to the fact that they have yet to acquire the gender-marking system in Dutch, and articles are more obligatory in Spanish and French than Dutch. Additionally, there may be a difference in Romance language article acquisition vs. Dutch as Spanish has a more transparent gender system (typically -o ending for masculine nouns and -a ending for feminine nouns) (see for e.g., Pérez-Pereira, 1991; Sá-Leite et al., 2020). Although there are exceptions to the endings of masculine and feminine nouns, and there are opaque endings as well (-e ending), overall, gender acquisition and processing is facilitated by these regularities (Sá-Leite et al., 2019). Dutch, on the other hand, has an opaque gender system where grammatical gender values are either "common" or "neuter" (Sá-Leite et al., 2019). For example, in Dutch, "de fiets [the bicycle]" is common and "het huis [the house]" is neuter. Therefore, due to the lack of transparency and regularity in Dutch, children may take longer to acquire the grammatical gender system.

While the development of the use of gendered articles in children is under investigation, it has been shown repeatedly that adult monolingual speakers can make use of such cues to facilitate processing. Lew-Williams and Fernald (2007) for example, tested children in the study described earlier, and also included a group of monolingual Spanish-speaking adults. Their results showed that these adults were able to identify the correct referent faster when gender was informative compared to when it was not. They were also able to do so faster than the children in the study. This result of monolingual adult speakers using informative gender to facilitate online processing has been replicated several times in multiple L1s, including Italian, French, and Russian (e.g., Bates et al., 1996; Akhutina et al., 1999; Dahan et al., 2000; Dussias et al., 2013).

Although monolingual speakers have been overwhelmingly shown to be able to use gender-marked articles to identify familiar referents, adults learning a second language (L2) with gender-marking show varied success in using gender-marked articles in online processing. Grammatical gender appears to be one of the more difficult aspects of language for L2 learners to master (Carroll, 1989). Replicating their earlier work with monolingual adults and children, Lew-Williams and Fernald (2010) tested adult L2 learners of Spanish with about 5 years of Spanish classroom learning. The learners attended to the correct referent with equal speed, regardless of whether the articles were informative or not, suggesting that they were unable to use gender as a cue to facilitate online processing. Even when frequency of exposure to article-noun pairs was controlled by training adults on novel nouns, native Spanish speakers fixated referents earlier when grammatical gender was informative whereas L2 learners did not (Lew-Williams and Fernald, 2010). Counter to these results, Dussias et al. (2013) found that English-speaking learners of Spanish were able to use gender to facilitate the processing of an upcoming word, but this ability was modulated by proficiency. So, while it remains unclear if L2 learners are reliably able to use gender as a cue to facilitate processing, it seems that proficiency may likely play an important role (Dussias et al., 2013; Hopp, 2016; Hopp and Lemmerth, 2018).

For more balanced bilinguals, several studies have shown that, like their monolingual counterparts, they are able to use grammatical gender to facilitate processing in different-gender contexts (informative) compared to same-gender contexts (uninformative), however, an asymmetry arises in the use of the masculine and feminine articles. Many researchers have discussed and explained masculine default accounts. Harris (1991) posited that the masculine gender in Spanish is the unmarked or default gender as there are numerous Spanish examples that corroborate this argument. He further claims that the masculine gender is the "absence of any information about gender in lexical entries" (p. 44). Others have also proposed the masculine default gender in French (Hulk and Tellier, 1999), in Italian (Riente, 2003), in Greek (Tsimpli and Hulk, 2013), among others. Hur et al. (2020) also noted that agreement in the feminine gender appears to be more salient or more recognizable in both online and offline receptive tasks when compared to the "unmarked default status" of the masculine gender (Domínguez et al., 1999; Smith et al., 2003; Alemán Bañón and Rothman, 2016; Beatty-Martínez and Dussias, 2019). As there is a consensus that masculine appears to be the default, feminine thus seems to be the marked option.

Spanish-English speaking adults have been shown to use the feminine article to facilitate processing but show no use of the masculine article. This gender asymmetry has been shown for Spanish-English bilinguals from Latin-America (Valdés Kroff et al., 2017) as well as Italian-Spanish learners from Italy (Dussias et al., 2013). Valdés Kroff et al. (2017) explain this effect by saying since *el*, the masculine article, is used extensively as the default article in code-switching, this may lead bilinguals to ignore it as a cue when preceding a noun during comprehension. Additionally, De la Cruz Cabanillas et al. (2007), found that 82% of gendered loanwords in their corpus were masculine, further giving rise to the default status of the masculine gender. If the masculine gender is indeed the default or unmarked gender, then it stands to reason that it is ignored in terms of facilitatory processing, and the non-default (or marked) feminine article is therefore informative enough to cue facilitatory processing. Thus, there appears to be an underlying difference in the representation and processing of masculine and feminine gender in Spanish due to distributional asymmetries between them, which leads to biases in gender assignment (Beatty-Martínez and Dussias, 2019).

This account of the gender asymmetry effect is strengthened by complementary results outside the realm of gender. Connell et al. (2021) tested L1-Spanish L2-English learners for their ability to anticipate an upcoming word based on the form of the indefinite article in English, with "a" being used before consonant initial words and "an" before vowel initial words. Their results showed that L2-English learners were able to use the phonological form of an article to anticipate the upcoming word, but that they only did so when the article was "an" and did not use the "a" article to cue anticipatory processing. In this case, "anticipatory" processing is used as opposed to "facilitatory" since the effects were found before the onset of the target noun. For the remainder of the paper, "anticipatory" will be used to denote processing that occurs strictly before a target word is spoken, and "facilitatory" will be used to refer to processing advantages including, but not limited to, the target word itself.

This ability to use the feminine article was further modulated by proficiency, with high-proficiency learners using the "an" to anticipate to a greater degree than the low-proficiency learners. While not a gender distinction, the alternating forms of the English indefinite article do exhibit a similar status asymmetry, with the "a" form arguably serving as the default form, and this asymmetry is reflected in online processing as is with grammatical gender.

In summary, monolingual toddlers and adults can use gender-marked articles to facilitate spoken word recognition. Bilinguals can also use gender-marked articles to facilitate spoken word recognition, however, proficiency appears to play a role for late learners and there seems to be a difference in the way masculine and feminine genders are processed.

Behaviorally, we know that children with language disorders are less accurate in producing gender-marked articles than their typically-developing peers (e.g., Morgan et al., 2013). This suggests that they might also be less likely to comprehend articles compared to their peers. Initially, we planned to test whether bilingual children with language disorders were less likely to use different gender-marked articles (informative) to speed word recognition than bilingual typically-developing children (the control group) were. Like Lew-Williams and Fernald's (2007) younger native Spanish-speaking monolinguals, we expected older bilingual children to fixate referents more rapidly in contexts where articles were informative rather than uninformative. However, preliminary tests for gender sensitivity in our sample of typically-developing bilingual children showed no difference, despite the fact that they were enrolled in dual language (English-Spanish) schools. Rather than continue to recruit children with language disorders, the focus of the study turned to typically-developing bilingual children to evaluate the factors leading to their different gender processing from that of younger monolinguals. Here we report the analyses from this deviation from our planned study and discuss implications for understanding neurotypical bilingual language development.

In order to investigate how typically-developing Spanish-English bilingual children comprehend and attend to gender-marked articles in Spanish, a visual world paradigm was used to examine gender-marked articles in informative and uninformative contexts. Children also completed a narrative task to elicit spontaneous production of gender-marked articles.

The following research questions were addressed:

1. Do Spanish-English bilingual children take advantage of informative grammatical gender marking on articles in Spanish in anticipatory or facilitatory processing?
2. Do bilingual children show a differential use of the gendered articles by masculine or feminine like that shown by bilingual adults?
3. Does current Spanish use (input/output) influence bilingual children's ability to use gendered articles in an anticipatory or facilitatory manner?

MATERIALS AND METHODS

Participants

Fifty-one children between the ages of 5;6-8;6 were recruited from 4 dual language elementary schools in Austin, Texas. All parents and children gave informed consent/assent to participate in the study and were compensated for their participation. This study was approved by the Institutional Review Board at the University of Texas at Austin. Three participants were excluded due to language impairment, 5 due to frequent track loss and inability to complete a 9-point validation, 3 due to lack of fixations in either condition in the analysis time window (which can arise from using peripheral vision, looking off screen, etc.), 1 due to computer error, 4 due to English as a first language, and

TABLE 1 | Participant characteristics presented in means and standard deviations.

Characteristic	M	SD
Age (months)	86.60	(10.20)
SES/Mother's Hollingshead Index	3.50	(1.84)
Age of first exposure to English (years)	2.82	(1.98)
Age of first exposure to Spanish (years)	0	(0)
Spanish input and output (percent)	60.40	(21.90)

3 due to no Spanish behavioral data. Thus, analyses are based on data from 32 children (14 F).

Children were categorized as typically-developing if they scored within normal limits on the Bilingual English Spanish Assessment (BESA; Peña et al., 2018; ages 3–6;11) or the Middle Extension (BESA-ME; Peña et al., 2008; ages 7–9;11) and no parent or clinician concern was noted (Gutiérrez-Clellen and Simón-Cereijido, 2007). These tests are used to assess language ability in bilingual children in both English and Spanish. A certified bilingual speech-language pathologist (first author) administered and scored all tests.

Parents completed the Bilingual Input Output Survey (BIOS; Peña et al., 2018) in which they provide information on the child's language use since birth and their child's current language input (how much they hear) and output (how much they speak) on an hourly day-to-day basis at home. Teachers reported spending equal amounts of classroom time speaking English and Spanish. As the correlation between input and output within languages was 0.91, input and output data within each language were averaged for all analyses. This variable is called Spanish Use. **Table 1** shows participant means for age, age of first exposure to English and Spanish, mother education based on Hollingshead (1975) index (a proxy for socioeconomic status), and Spanish Use at the time of testing. All children were exposed to Spanish from birth and, on average, heard and spoke more Spanish than English at the time of testing.

Materials

Thirty familiar objects were selected to be targets on experimental trials. Half of the target names had masculine grammatical gender and half feminine. Twenty-two of the thirty nouns (73%) had a transparent gender (words ended in -o or -a) while eight had an opaque gender (words ended in -n, -j, -z, -e, -r). Of the eight opaque words, 7 were masculine and 1 was feminine. Each target was combined with three unrelated distractors with the same gender as the target in the same-gender condition and 3 unrelated distractors of the opposite gender as the target object in the different-gender condition. Using EsPal (Duchon et al., 2013), target objects were found to be of equal log frequency by gender ($p = 0.88$[1]). Distractors were not phonological competitors of the target in that they did not match in consonant-vowel onset and did not rhyme. The distractor objects did not differ from target objects in log frequency ($p = 0.81$; see Footnote 1), in word length ($p = 0.63$), familiarity ($p = 0.94$[2]), imageability ($p = 0.80$[3]), or concreteness ($p = 0.48$[4]). Stimuli were colored Snodgrass and Vanderwart line drawings (Rossion and Pourtois, 2004) depicting animals, body parts, clothes, household items, foods, vehicles, instruments, toys, and other objects young children are familiar with. The Snodgrass and Vanderwart pictures were standardized for Spanish (Sanfeliu and Fernandez, 1996) and distractor objects did not differ from target objects in familiarity ($p = 0.78$), visual complexity ($p = 0.06$), or naming agreement ($p = 0.87$; see Footnote 1). The target objects were slightly less visually complex than the distractors, although the difference was not significant. Each object occupied a distinct quadrant of the display screen (example display **Figure 1**). Target objects occurred in each quadrant equally[5] often to discourage anticipation of their positions. The pictures were edited to fit within 250 × 250 pixels.

FIGURE 1 | An example of a same-gender condition display, including el brazo [masc.arm], el piano [masc.piano], el anillo [masc.ring], and el mono [masc.monkey].

A female Spanish-English bilingual speaker was recorded saying "*enséñame [show me]*" and the appropriate definite article with each target noun[6]. She spoke slowly to minimize co-articulation in order to make grammatical gender the only potentially useful source of information about the upcoming noun and to have consistent timing for the onset of information. Recordings were edited to extract one token each of *enséñame,* the masculine article *el,* and the feminine article *la.* Similarly, target nouns were spliced out of the recordings and saved as their

[1]One target object was excluded from this, as no frequency data was available in the database.

[2]Eight target objects and 19 distractors were excluded as no familiarity data was available in the database.

[3]Eleven target objects and 22 distractors were excluded as no imageability data was available in the database.

[4]Eight target objects and 18 distractors were excluded as no concreteness data was available in the database.

[5]Target objects occurred in one quadrant one additional time compared to the rest of the three quadrants.

[6]When a masculine noun follows *mira a [look at]*, the definite article *el* combines with *a* and becomes the contraction *al*. This does not occur with feminine nouns. Thus, *enséñame* was used instead.

TABLE 2 | Language measures presented in means and standard deviations.

Language measure	English		Spanish	
	M	**SD**	**M**	**SD**
Mean Length of Utterance in Words	8.47	(2.28)	6.85	(1.59)
Number of Different Words	88.70	(30.20)	86.10	(21.6)
Percentage of Grammatical Utterances	53.02	(20.90)	72.20	(22.90)

own sound files. The mean target noun duration was 669 ms (SD = 128 ms).

Design and Procedure

All participants were presented with the same three practice trials initially (2 same-gender and 1 different-gender contexts). Then thirty experimental trials were presented in a pseudo-random order with the constraint that the same condition did not appear more than three times in a row. Two lists of stimuli were constructed so that each participant saw every target object once, half in each condition, with the assignment of target to condition counterbalanced across lists and thereby participants. Seventy-five of the ninety distractors (83%) appeared in both conditions across the two lists, so their properties were roughly counterbalanced.

Eye movements were tracked with an SR Research EyeLink 1000, sampling at 1,000 Hz. Eye-tracking began with a 9-point calibration and validation routine. Participants were instructed to listen carefully and look at what each sentence described. Each trial began with a central validation point followed by a 200 ms preview of the objects. A central fixation cross appeared for the duration of the sound file *enséñame*. Approximately 550 ms later, an article sound file began, *el* (365 ms) or *la* (300 ms), and finally after a pause of ∼370 ms, the target noun began. As the youngest children in the study were 5;6, a positive non-verbal reinforcement was added (experimenter offered a thumbs up or quiet clapping) to motivate them to continue. After participants fixated on the target object for 500 ms, a red square appeared around the target for 300 ms, and the trial ended.

After the eye-tracking task, participants were introduced to a wordless picture book and were asked to tell a story in each language: *Frog Goes to Dinner* (Mayer, 1974) and *Frog On His Own* (Mayer, 1973). When comparing groups of children who told these two stories, negligible differences have been observed in language measures (Heilmann et al., 2016). Both the book and language order were counterbalanced across participants. Stories were transcribed and coded for mean length of utterance in words (MLUw), number of different words (NDW), and percentage of grammatical sentences based on the procedures described by Miller and Iglesias (2008) using Systematic Analysis of Language Transcripts (SALT) software. Inter-scorer reliability was 96.2% at the word level and 88.7% for the grammaticality of the sentence.

RESULTS

Language measures (MLUw, NDW, and grammaticality) mean values for English and Spanish are shown in **Table 2**. MLUw was slightly higher in English while NDW was similar across both languages and grammaticality was higher in Spanish. Pearson correlations between children's ages, language history, and measures of language skills are shown in **Table 3**.

Spanish-dominant bilingual children in the US typically acquire articles between 5;0 and 6;10, which is later than most monolinguals (e.g., Pérez-Pereira, 1989; Gutiérrez-Clellen et al., 2006; Morgan et al., 2013). At this age, monolingual children are 100% accurate when using grammatical morphemes in everyday conversations. Our sample of children produced gender-marked articles with 85.4% (SD = 25) accuracy in the elicited production portion of the BESA/BESAME (3–4 items). When telling stories, children produced articles with 89.2% (SD = 21.4) accuracy. A grammatical morpheme is typically considered "acquired" when a child uses the structure accurately at least 80% of the time in obligatory contexts (i.e., Bloom and Lahey, 1978). These accuracy levels suggest that most of the children have acquired gender-marked articles and that their accuracy is typical of Spanish-dominant bilinguals of the same age.

The eye-tracking data was exported using SR Research Data Viewer software. An interest period was set from the beginning of the article until the participant fixated the correct target for 500 ms or more. A Time Course (Binning) report was used to export the data. This report binned time into 20 ms bins and excluded samples that fell outside of four pre-defined interest areas around the images and samples during blinks or saccades. Trials for which the target object had never been correctly fixated were excluded from the eye movement analyses (5.1%). All further analyses were conducted in *R* (R Core Team, 2013). Further data cleaning in R included excluding trials for which the target object had not been correctly fixated on within 5,000 ms (11.4%). The fixations were time locked to the onset of the article preceding the target noun and included a 200 ms baseline (for the time it takes to plan and launch a saccade; Hallett, 1986). Differential proportions of fixations to target (DPFT) were then calculated for use in the analysis by subtracting the averaged proportions of distractor fixations from the proportions of target fixations. The DPFT are presented in **Figure 2** below.

In **Figure 2**, data points below 0 reflect that participants were looking at the distractors more than the target; points at 0 reflect equal proportion fixations to target and distractors; and points above 0 reflect that participants were looking more at the target than the distractors. **Figure 2** illustrates fixations on the target object in the context of same- (black dashed) and different-gender (red solid) conditions with masculine-target trials presented on the left and feminine-target trials presented on the right. **Figure 3** shows these same results separated by a split of the participants' reported combined Spanish Use (language input and output) with high Spanish use being those with over 50% use of Spanish and low being <50% use of Spanish.

Lexical Anticipation

To investigate effects of lexical anticipation, the DPFT were analyzed with a linear mixed-effects model (LME) using the Buildmer (Voeten, 2020) package in R on a window from 530 to 900 ms, which includes fixations in the pause region after the article had been heard, but before the onset of the target

TABLE 3 | Pearson correlations between participant age, language history, and measures of language skills.

	Spanish Input/Output	English 1st exposure	Spanish MLUw	Spanish NDW	Spanish GRAM	Article accuracy
Age	−0.21	−0.09	0.56***	0.40*	−0.18	−0.08
Spanish input/output		0.040*	0.41*	0.01	0.47**	0.39*
Eng 1st exp			−0.02	0.05	−0.05	0.11
Spanish MLUw				0.045**	−0.19	0.13
Spanish NDW					−0.23	0.0
Spanish GRAM						0.61***

*MLUw, Mean length of utterance in words; NDW, Number of different words; GRAM, grammaticality. *p < 0.05; **p < 0.01; ***p < 0.001.*

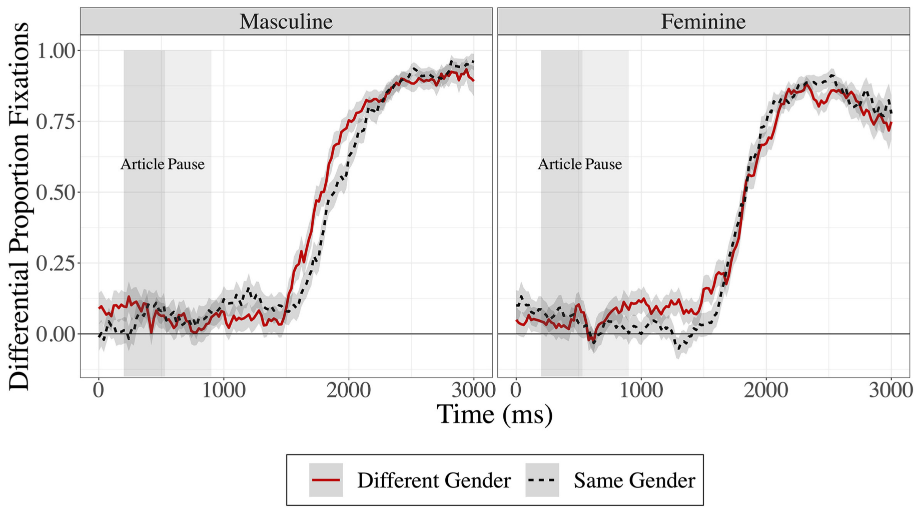

FIGURE 2 | Differential proportion fixations to target, with fixations in the different-gender condition in solid red lines and fixations in the same-gender condition in dashed black lines. Masculine targets are presented in the left panel and feminine targets are presented in the right panel. Time in milliseconds is presented on the x-axis and differential proportion of fixations to target is presented on the y-axis. The shaded regions represent ±1 standard error of the mean.

noun. The Buildmer function in the Buildmer is provided with a maximal model including all interactions and random effects justified by the design and performs a stepwise and elimination of effects with forward and backward effect-selection based on the change in log-likelihood ratio tests of compared models. The model given to the Buildmer function for this analysis included fixed effects of condition (same vs. different article), target gender (feminine vs. masculine) and Spanish Use (input/output) (high vs. low Spanish Use). The model also included random intercepts of participant and item, random slopes of condition and target gender for participant, and random slopes of Spanish Use for item. The same-article masculine condition served as the baseline to which all comparisons were made. The model output by the Buildmer function as the maximal model included fixed effects of condition, target gender, and Spanish Use and the interaction of target gender and Spanish Use as well as all random effects. The low Spanish Use, masculine trials across both conditions serve as the baseline to which all comparisons are made.

Table 4 summarizes the results of the maximal model. The significant effect of target gender [ß $= -0.27$, $t_{(62.9)} = -2.80$, $p = 0.008$] indicates that for low Spanish Use participants, there were significantly fewer looks to the feminine items compared to masculine items, regardless of condition. The significant interaction between target gender and Spanish Use [ß $= -0.26$, $t_{(59.30)} = -2.22$, $p = 0.030$] indicates that the effect of gender seen for the low Spanish Use participants reverses directionality, with high Spanish Use participants looking at the feminine items more than the masculine items. It is important to note here that the effect of condition was not significant, and no interaction with this effect significantly improved the fit of the model (as it was not included by the Buildmer function in the final model), indicating that the condition of the trial (same- or different-gender) did not significantly improve the model.

Lexical Facilitation

The results just presented speak to processing during the pause after the article has been spoken, but before the noun, and can thus reflect anticipatory processing. Inspection of **Figure 3** reveals that looks to the correct target do not begin to drastically increase until well into the word in all conditions, at least 500 ms after the end of the article. In order to look at the effects of gender on the processing of the spoken word itself, here, we might expect to find carry-over effects or effects of facilitation during the processing of the word itself. To investigate these effects,

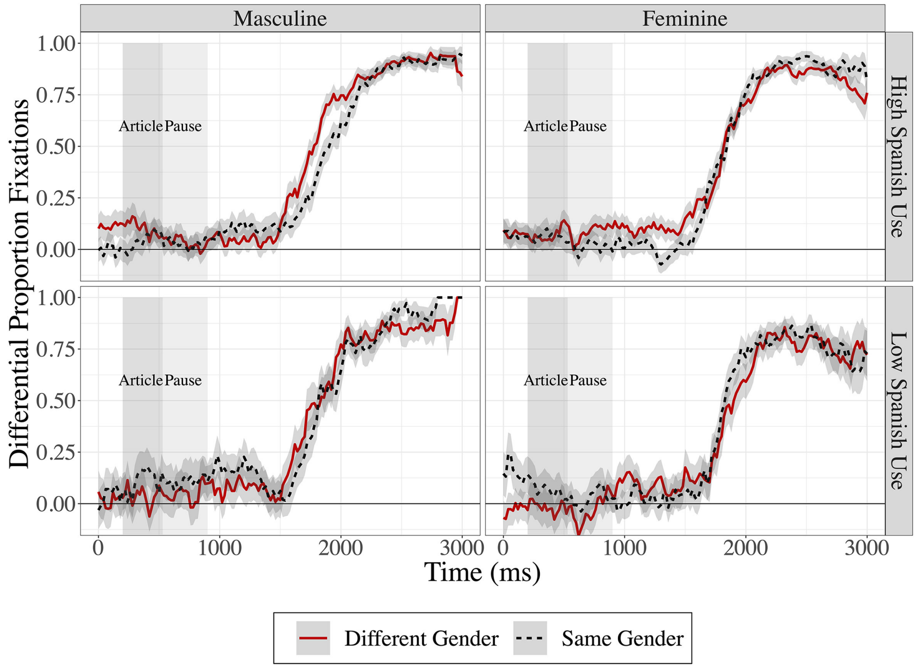

FIGURE 3 | Differential proportion fixations to target, with fixations in the different-gender condition in solid red lines and fixations in the same-gender condition in dashed black lines. Masculine targets are presented in the left panel and feminine targets are presented in the right panel. Participants with ≥50% Spanish Use are shown in the top row, and participants with <50% Spanish Use are presented in the bottom row. Time in milliseconds is presented on the x-axis and differential proportion of fixations to target is presented on the y-axis. The shaded regions represent ±1 standard error of the mean.

TABLE 4 | Results of LME on DFPT by target gender, condition, and Spanish use in the pause region.

	Estimate	Std. error	df	*t*-value	Pr(>|t|)
Intercept	0.15	0.08	78.13	1.84	0.069
Condition	0.02	0.06	71.24	0.38	0.704
Gender	−0.28	0.10	62.85	−2.76	0.008
Spanish use	−0.10	0.09	60.19	−1.16	0.252
Spanish use: Gender	0.26	0.12	59.30	2.22	0.030

TABLE 5 | Results of LME on DFPT by target gender, condition, and Spanish use in the post-pause region.

	Estimate	Std. error	df	*t*-value	Pr(>|t|)
Intercept	0.08	0.10	73.07	0.83	0.407
Gender	−0.06	0.14	73.92	−0.42	0.679
Condition	0.08	0.12	75.41	0.67	0.502
Spanish use	0.02	0.10	70.24	0.15	0.878
Gender: Condition	−0.3	0.14	72.10	−2.27	0.026
Gender: Spanish use	−0.05	0.14	71.33	−0.33	0.742
Condition: Spanish use	−0.06	0.13	74.24	−0.46	0.645
Gender: Condition: Spanish use	0.34	0.14	66.30	2.35	0.022

the same analysis described above was conducted on the period of time after the pause during the spoken word. This window began at the end of the pause (i.e., the beginning of the target word) and extended to 1,500 ms. All details of the model were identical to the main model with the only change being the time window of the analysis. The maximal model included all fixed effects and all possible interactions. The low Spanish Use, same-gender, masculine target trials serve as the baseline to which all comparisons are made.

Table 5 summarizes the results of the post-pause analysis window. The significant interaction between target gender and condition [ß $= -0.30$, $t_{(72.1)} = -2.7$, $p = 0.03$] indicates that the (non-significant, negative) effect of gender becomes more negative from same- to different-article trials. In other words, there was a greater reduction in looks to the feminine items from same gender trials to different gender trials in low Spanish Use participants compared to the reduction in looks in the masculine items. The significant 3-way interaction [ß $= 0.34$, $t_{(66.29)} = 2.35$, $p = 0.022$] indicates that the previously described effect of target gender and condition reverses direction from low Spanish Use to high Spanish Use. This means that what was a reduction in looks to the feminine article items between same- and different-gender trials is reduced (and in fact reverses directionality, from low to high Spanish Use), and this reversal indicates that high Spanish Use participants show a greater positive increase in looks to target in the different gender items for feminine targets compared to masculine targets.

DISCUSSION

The purpose of this study was to investigate grammatical gender processing in school-age Spanish-English bilingual children. Past work has focused on toddlers and adults who are monolingual, bilingual, or second language (L2) learners. Here, however, we hone in on early school-aged bilingual children who have been exposed to Spanish since infancy and have had varied experiences with English.

The first question posited was whether or not Spanish-English bilingual children can take advantage of grammatical gender marking on articles in online processing. The second question asked was if these bilingual children would show a similar gender asymmetry effect as seen in bilingual adults. Lastly, the third question asked was if current Spanish use (input/output) influences bilingual children's ability to use gendered articles in an anticipatory or facilitatory manner. We addressed these three questions in anticipatory and facilitatory processing by looking at two separate time regions (pause between article and noun and during the word).

The results of the present study showed that this group of bilingual children do not take advantage of informative gender marking on articles to actively anticipate an upcoming word. During the pause region, these bilingual children did not look at the correct target item more when the target item differed in gender from the distractors (informative) compared to when the gender of the target matched that of the surrounding distractors (uninformative). This demonstrates that these bilingual children did not use grammatical gender of the article to anticipate upcoming information in the speech signal.

The second analysis looked at effects of lexical facilitation and was conducted on the period of time while the target word was being spoken,. The three-way interaction of target gender, condition, and Spanish Use (as shown in **Table 5**) indicates that the use of feminine and masculine gender as cues for processing is different depending on children's current Spanish Use. Children who currently use Spanish less than English, appear not to be using the gendered article as a cue at all. Even more so, in the feminine target trials, they seem to use the masculine default as a preference (Otheguy and Lapidus, 2003; Balam, 2016) and look at the three masculine distractors more than the feminine target since as discussed previously, masculine is considered the default gender (see for example: Harris, 1991; Valdés Kroff et al., 2017; Balam et al., 2021). As the masculine is the default or unmarked gender, it may thus be easier to acquire and use (Pérez-Pereira, 1991). In other words, in the absence of using an article cue, these children seem to be anticipating the more frequent gender, which is masculine. On the other hand, children who use Spanish more than English showed a significant increase in looks to the feminine objects compared to those children who use Spanish less. These bilingual children who speak Spanish more than English, do not show the same masculine preference and in fact, may even use the feminine article to facilitate processing.

Furthermore, it was shown that bilingual children do not use the feminine and masculine articles in the same way in processing. This lack of use of the masculine article and potential use of the feminine article by bilingual children who speak more Spanish demonstrates an asymmetry. This asymmetry in the use of the masculine and feminine genders in processing is trending with results found with bilingual and second-language learning adults (Dussias et al., 2013; Valdés Kroff et al., 2017) and is discussed extensively in regards to a masculine gender default (see for example Harris, 1991; Hur et al., 2020). Collectively, this gender asymmetry in processing has been found for Spanish-English adult bilinguals, adult Italian learners of Spanish, and now the present work suggests that these findings may be relevant to school-aged Spanish-English bilingual children. Adding in the evidence for a parallel asymmetry shown for English learners in the use of "a" vs. "an," these results may suggest that the root of this asymmetry is not only restricted to simply code-switching or attrition accounts as previously posited and may indeed be more related to bilingualism and current language use in general (De la Cruz Cabanillas et al., 2007; Valdés Kroff et al., 2017).

Limitations

In looking-while-listening and visual world paradigms, participants are often asked to name stimulus objects prior to the experiment, or they hear a label for each object (Dahan et al., 2000; Lew-Williams and Fernald, 2007, 2010). Thus, the objects, their target names, and grammatical gender are typically primed prior to experiments. In this study, we did not pre-expose participants to objects or their names. As a result, we cannot be certain that the children would have consistently provided the same label as we used.

The majority of the target nouns had transparent gender while 26% had opaque gender (87% of which were masculine gender). It is possible that bilingual children had to spend more cognitive resources processing these opaque, masculine nouns, resulting in the lack of anticipatory online processing. This is in line with previous literature which has shown that opaque nouns in Spanish require more effortful processing than transparent nouns (Hernandez et al., 2004). The percentage of opaque gender nouns is slightly higher than Dussias et al. (2013), who also noted that cognitive processing may be more effortful for opaque nouns which potentially led to a lack of an anticipatory effect for low-proficiency Italian-Spanish adult learners in the masculine different-gender trials. However, in this study, no anticipatory effect was noted in either masculine or feminine articles even though there was only one feminine opaque gender noun. An additional potential limitation is that accuracy was calculated based on eye movements rather than a verbal response or overtly clicking the image of their choice. Lastly, given the variability inherent in data collected with children, the small sample size may have influenced our ability to detect anticipatory processing in these bilingual children.

Conclusion and Future Directions

In sum, these school-aged Spanish-English bilingual children did not demonstrate the ability to use grammatical gender in Spanish anticipatory online processing. However, an asymmetry between the use of masculine and feminine articles was seen while children were hearing the noun and indicates that the amount of current Spanish use may differentially influence how gendered articles are used to facilitate processing. This result is similar to bilingual adults asymmetrical use of gender. Other factors may modulate the ability for school-age children to utilize this gender cue in a facilitatory or anticipatory way. Additionally, to the authors' knowledge, this is the first grammatical gender eye-tracking study focusing on school-aged children. As this is an important age for language development, acquisition, and/or attrition, further research on grammatical language processing is needed for this age group. Future work may want to directly compare bilingual and monolingual children with bilingual and monolingual adults to further clarify the nature of the gender asymmetry in these groups.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University of Texas at Austin Institutional Review Board. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

AB and ZG contributed to the conception and design of the study. AB collected all of the participant data, wrote the first draft of the manuscript, and wrote sections of the final manuscript. KC performed the statistical analyses and wrote sections of the final manuscript. All authors contributed to manuscript revision.

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Emotional Attractors in Subject-Verb Number Agreement

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Considering the crosstalk between brain networks that contain linguistic and emotional information and that no studies have examined the impact of semantic information of affective nature on subject-verb number agreement, the present Event Related Potential (ERP) study investigated the extent to which emotional local nouns whose number mismatched that of subject head nouns might be considered by the parser during comprehension of grammatically correct sentences. To this end, twenty-eight Spanish native speakers were tested on a self-paced reading task while their brain activity was recorded. The experimental materials consisted of 120 sentences where the valence (negative vs. neutral) and number (singular vs. plural) of the local noun of the singular subject noun-phrase (NP) were manipulated; *El gorro de aquel/aquellos cazador(es)/mecánico(s) era*... [The hat of that/those hunter(s)/mechanic(s) was...]. ERP results measured in the local noun position showed that valence and number interacted in the 300–500 ms (negative component) and 780–880 ms (late positivity) time windows. In the (target) verb position, the two factors only interacted in the late 780–880 ms time window, revealing an "ungrammatical illusion" for plural marked neutral words. Our findings suggest that number agreement is sensitive to affective meaning but that the emotional information of an attractor is considered in different operations and at different stages during grammatical sentence processing; it can affect lexical and syntactic representation retrieval of a subject-NP and impact agreement encoding only at late stages of processing, during verb agreement and feature integration.

Keywords: number agreement, comprehension, attraction effect, emotional word processing, ERPs

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INTRODUCTION

Subject-verb number agreement in Spanish, as in many other languages, conforms to the rule of having the number morphological features of the verb agreeing with those of the subject noun-phrase (NP) (see Acuña-Fariña, 2009 for a review). However, findings from the psycholinguistic literature have shown that agreement is not susceptible to influences coming neither only from the head noun nor only from syntax. For example, number agreement can be affected by factors, such as the difference between the morphological singular number of the head nouns and the morphological plural number of the closest-to-the-verb (local) noun (Bock and Miller, 1991; Haskell and MacDonald, 2003; Bock and Middleton, 2011) or the distance between a mismatching feature embedded in a prepositional phrase (PP) and the subject head noun (e.g., Franck et al., 2002). Evidence showing that agreement does not come entirely from a syntactic source and that it is sensitive to the role of semantics comes from studies showing that plural local nouns elicit more plural agreement attraction errors when the noun phrases have a notional distributive reading (e.g., *The label on the bottles*) than when they do not (e.g., The house of my cousins; Vigliocco et al., 1995, 1996). These findings suggest that grammatical information of a subject can be overridden by the number specification of the conceptual representation of the subject phrase and that conceptual factors may impact grammatical encoding. In all the above cases, the observed result is that the verb seems to be "attracted" to the plural number of the preceding noun when it mismatches the number of the head noun. This may happen mainly for three reasons: (i) the plural feature of the local noun may override the default assignment by being mistakenly detected by the verb-agreement mechanism (*feature percolation account*; Bock and Eberhard, 1993); (ii) singular number (being morphologically unmarked) is more vulnerable to the influence of plural number (Eberhard, 1997); or (iii) due to unsuccessful number reconciliation of the number features of the subject noun when agreement features are transmitted to the target verb (*marking and morphing account*; Bock et al., 2001).

In comprehension studies, attraction effects have been demonstrated mainly in the form of "grammatical illusions." Thus, sentences, such as "*The key to the cabinets* *are . . .," seem to be processed faster, as shown in reaction time (e.g., Wagers et al., 2009) and as if they are grammatically correct, as demonstrated in the reduced negative left anterior negativity (LAN/N400) or positive (P600) components of agreement violation detection as compared to other ungrammatical sentences, such as "*The key to the cabinet *are*..." (e.g., Tanner and Van Hell, 2014). Such illusions have also been explained by a feature percolation account that assumes erroneous percolation into a subject noun position when syntactic constituents are hierarchically integrated into a processing structure (e.g., Bock and Cutting, 1992). In addition, they have been accounted for by a cue-based retrieval failure during syntactic integration caused by feature slippage or misidentification of the correct controller of agreement (e.g., Wagers et al., 2009).

However, there are findings to suggest that even in grammatical sentences, effects of attraction can be shown in the form of "ungrammatical illusions." Nicol et al. (1997) found slower reading times and less accurate responses when a singular head noun was followed by a plural than a singular attractor, as in "The author of the speeches is..." vs. "The author of the speech is..." in a Maze task where participants had to decide which of the two words was a better continuation for a sentence. Laurinavichyute and von-der-Malsburg (2019) found that a plural noun that mismatched the number of a subject noun in grammatical sentences, such as "The admirer of the singers supposedly thinks that..." slowed down processing on the verb. Processing difficulty in correct sentences of NP-mismatch conditions with a singular head (Experiment 3: *The key to the cabinets was*...), as displayed in slower reading times, was also reported by Pearlmutter et al. (1999). Similarly, Franck et al. (2015) showed that plural object interveners slowed down the grammaticality judgment of subject-verb dependencies. In an Event Related Potential (ERP) study, Kaan (2002) found that the grammatical condition of a singular subject and a plural object in German yielded an enhanced early positivity at the critical verb. In another ERP study, Martin et al. (2012) found evidence of processing costs during comprehension of elliptical sentences, such as "*Marta se compró la camiseta que estaba al lado del vestido y Miren cogió otra*..." (Marta bought the t-shirt$_{[FEM]}$ that was next to the dress$_{[MASC]}$ and Miren took another$_{[FEM]}$...): the gender of a mismatching attractor emitted larger negativity and larger late positivity in the condition where the attractor had a different gender from the antecedent. In other words, when the attractor did not match the retrieval cue, this had an impact on the processing of grammatical sentences as well. Finally, in a sentence completion study in Basque, the only study where the number of attraction effects have been examined in grammatical sentences at an electrophysiological level, Santesteban et al. (2020) found slower subject-verb production when the subject and object mismatched in number than when they matched. Mismatching objects elicited an early production P2 followed by a negative component, showing the difficulty of number feature retrieval and monitoring during correct subject-verb agreement production.

Recent studies that have looked at the impact of semantic factors on agreement processing have considered the case of emotional meaning. This is not surprising as emotional content due to its salience, with affective information being prioritized over non-affective information and capturing attention resources (e.g., Zajonc, 1980, 2001; Delaney-Busch and Kuperberg, 2013), has been found to affect lexical processing and shows its signature in neural implementation as well. More enhanced effects are reported for emotional than non-emotional words (e.g., knife vs. sink) whether they are processed in isolation or embedded in sentences and interact with other semantic or morphosyntactic information (see Kissler et al., 2006; Citron, 2012 and Hinojosa et al., 2020 for reviews). The majority of ERP studies at the sentential level that have examined the influence of emotional valence on the agreement have considered the case of gender agreement in Spanish (e.g., Hinojosa et al., 2014; Díaz-Lago et al., 2015; Fraga et al., 2017; Jiménez-Ortega et al., 2017). Some have found that the detection of gender agreement violations between adjectives and nouns can be affected at the early stages of morphosyntactic processing by whether the content of the agreeing element is emotional, as reflected by the interaction between grammaticality and valence in the LAN/N400 time window (Hinojosa et al., 2014; Jiménez-Ortega et al., 2017; Fraga et al., 2021). With regard to number agreement and sentence comprehension with ERPs, which is the focus of the present study, to our knowledge, there are only two studies that have investigated the role of emotional words (Martín-Loeches et al., 2012; Jiménez-Ortega et al., 2017 where the manipulation of emotional information involved a subliminal presentation of adjectives as the question of interest was centered on the automaticity of syntactic processing). Here, we focus on the study by Martín-Loeches et al. (2012) because in their experimental procedure the variables of valence and number were manipulated supraliminally, as in our study. The researchers used Spanish sentences of determiner-noun-adjective-verb structure for syntactic processing (Experiment 1) and manipulated emotional valence (positive, negative, neutral adjectives) and grammaticality (syntactically correct vs.

incorrect). Thus, the adjective, which was the critical word, either matched or mismatched the number of the noun it modified and in the latter case resulted in the creation of syntactic violations: e.g., *La hermana querida acude* (The loved$_{[SG]}$ sister arrives) vs. **La hermana queridas acude* (The loved$_{[PL]}$ sister arrives); *La chica fea baila* (The ugly$_{[SG]}$ girl dances) vs. **La chica feas baila* (The ugly$_{[PL]}$ girl dances); and *El espejo ovalado refleja* (The oval$_{[SG]}$ mirror reflects) vs. **El espejo ovalados*$_{[PL]}$ *refleja*.

Event-Related Potentials elicited during the performance of a grammaticality judgment task revealed a larger LAN (350–450 ms) component for incorrect than correct sentences only when the adjective was negative rather than neutral. Thus, morphosyntactic processes were found to be sensitive to the emotional information carried by the syntactically anomalous emotional words and affect the detection of number agreement of violations between the adjective and its noun. A late positive component (P600; 600–700 ms) was elicited by ungrammatical sentences and was not modulated by valence, suggesting that emotional information modulated grammatical processing only at the early stages of agreement computation (reflected in the LAN component).

Despite the merits of the study of Martín-Loeches et al. (2012), some aspects of the materials and the design may not have offered the best condition for clear evidence of valence and morphosyntactic effects on number agreement (for a review of methodological and procedural issues that may have contributed to discrepancies in studies of emotional impact on gender and number agreement see Fraga, 2020). Apart from emotionality, animacy was different between the conditions of interest, as the subject noun in the emotional conditions (positive/negative) was animate, whereas in the neutral condition it was inanimate. Importantly, the critical word (the adjective) was the element that bore both the valence and agreement manipulations making rather difficult the attribution of effects. Finally, language use is predominantly based on computation and processing of well-formed utterances both in comprehension and in production, and given that the existing relevant literature has mainly considered syntactic violations, more research is needed to address number agreement processing in grammatically correct contexts.

Thus, in the present study, we sought to investigate the interplay between morphosyntactic and semantic information in number agreement not examined so far. Specifically, we investigated the extent to which the emotional content of a local noun, i.e., of an element not directly relevant to the computation of subject-verb number agreement but of reported salience, might be considered by the parser along with its morphosyntactic features and affect the application of syntactic rules for the comprehension of grammatical sentences. That is, we tested the effect of emotion under the most stringent agreement conditions. Our focus was on two ERP components because they are the most relevant ones for current purposes: a negative component/N400 between 300 and 500 ms that when yielded is associated with initial emotional analysis (e.g., Delaney-Busch and Kuperberg, 2013) and a late posterior positive component/late posterior positivity (LPP)/late positive component (LPC)/P600 (after 500 ms) that is typically associated with sustained attention to emotional input and elaborate processing (e.g., Bayer et al., 2010; see Hinojosa et al., 2020 for a review). Regarding syntactic computations of ERP components in the same time windows, a (left anterior) negativity has been suggested to index the processing of dependency relations and is emitted when morphosyntactic violations or mismatches are detected. A late (centroparietal) positivity is associated with effects of reanalysis of syntactic violations or of expectations (present study) of agreement relations, which are not consistent with the syntactic analysis taking place (e.g., Osterhout and Mobley, 1995; Kutas and Federmeier, 2011; see Kuperberg, 2007 and Molinaro et al., 2011 for reviews.) Importantly, to obtain a clear picture of the effect of emotional attractors as emotionally loaded words (on a purely semantic level) and as syntactic interfering elements (on a syntactic level), we performed separate analyses in the position of the attractor (local noun) and of the target (verb), respectively.

METHOD

Participants

In total, 28 Spanish native speakers (5 men, age M = 20.6; SD = 1.8), undergraduate students at the University of the Basque Country (UPV/EHU) received monetary compensation for their participation. The experiment was approved by the University ethics committee and all participants provided a signed consent prior to the experiment.

Materials and Procedure

Experimental materials consisted of 120 grammatical sentences involving singular subjects with a PP modifier. Each sentence was presented in four experimental conditions (30 sentences per condition), as a result of crossing the manipulation of Valence (negative vs. neutral) and Number (singular vs. plural) of the attractor nouns inside the PP modifying the singular subject: *El gorro de aquel/aquellos cazador(es)/mecánico(s) era de gran colorido por seguridad* [The hat of that/those hunter(s)/mechanic(s) was very colorful for safety]. Half of the sentences had negative attractors and half neutral ones (taken from Davis and Perea, 2005; Redondo et al., 2007). All sentences were 11 words long and had an inanimate neutral subject noun and an animate attractor (in position 5). The verb (in position 6) was singular, as was the subject noun, since all sentences were grammatical. Negative and neutral attractors were controlled for frequency (M = 9.3 vs. M = 9.4 per million); length (M = 7.3 vs. M = 7.4); number of syllables (M = 3.2 vs. M = 3.2); and concreteness (M = 6.8 vs. M = 7.1; 1–7 scale); [all ts(118) < 1.98]. They only differed between them with regard to valence [M = 2.6 vs. M = 5.3; $t(118)$ = 23.05, p < 0.001] and arousal [M = 5.8 vs. M = 4.5; $t(118)$ = 8.34, p < 0.001; 1–9 scale]. An additional set of 120 filler sentences of subject and relative clauses were also included in the stimuli.

The experiment was performed using Presentation software (version 16.0[1]). Prior to the experiment, participants were instructed about the electroencephalogram (EEG) procedure and were seated comfortably in a quiet room in front of a 17-inch monitor. Sentences were displayed in the middle of the screen word-by-word for 350 ms interstimulus interval (ISI = 250 ms) in a serial visual presentation paradigm. Participants were asked to read the sentences silently for comprehension and answer YES/NO questions in 33% of the trials by pressing one of two keys on a keyboard placed on their lap [e.g., sentence: *La cita de la camarera era a las ocho y media* (The appointment of the waitress was at half past 8). Question: *¿La cita era a las doce y media?* (Was the appointment at half past 12?)]. A fixation cross (+) was presented for 1,000 ms prior to each trial. Materials were pseudo-randomized so that no two sentences of the same condition were displayed one after the other and each experimental sentence was followed by a filler sentence. All 240 sentences were distributed over four blocks, allowing breaks in between. A short practice session of six trials preceded the experiment. Each session that included the easy-cap application and removal lasted about 1 h.

Electroencephalogram Recording

The ERPs were recorded from 32 scalp electrodes mounted in an ActiCAP International (Inc.; 10–20 system). The electrodes were placed as follows: Fp1, Fp2, F7, F3, Fz, F4, F8, FC5, FC1, FC2, FC6, T7, C3, Cz, C4, T8, CP5, CP1, CP2, CP6, P7, P3, Pz, P4, P8, O1, Oz, and O2. All electrodes were referenced to the right mastoid and re-referenced offline to the left mastoid electrode. The vertical and horizontal electro-oculograms (VEOG and HEOG) were recorded from electrodes located below (VEOG) and at the outer canthus (HEOG) of the right eye. Electrode impedance was kept below 10 kΩ at all scalp and mastoid sites and at the eye electrodes. Gratton and Coles' ocular correction was applied and the electrical signals were digitalized online at a rate of 250 Hz and filtered offline with a bandpass of 0.1–35 Hz (half-amplitude cutoffs). Head movements and other artifacts were manually removed.

RESULTS

Scoring and Data Analysis

Average ERPs were computed for the emotional attractor (local noun), the verb (target) position, and each electrode. Segments were constructed from 200 ms before and 1,000 ms after the onset of the word that was the focus of analysis.[2] The trials associated with each sentence were averaged for each participant. The 200 ms prior to the onset was also used as a baseline for all sentence-type comparisons. After the baseline correction, epochs with artifacts were rejected. Based on the literature and visual inspection of the data, 300–500 and 780–880 ms time windows were considered during the statistical analysis. After the stimuli were recorded and averaged, repeated-measures ANOVAs were carried out in three regions of interest (ROI) that were computed out of the 28 electrodes: frontocentral (Fp1, Fp2, F7, F3, Fz, F4, F8, FC5, FC1, FC2, and FC6), centroparietal (T7, C3, Cz, C4, T8, CP5, CP1, CP2, and CP6), and parieto-occipital (P7, P3, Pz, P4, P8, O1, Oz, and O2). Initial analyses that also included hemisphere (left vs. right) did not yield significant interactions with the manipulated variables of valence and number either in the attractor or in the verb position. Thus, repeated-measures ANOVAs were performed over the experimental manipulations, using three within-participant factors: valence (negative vs. neutral), number (singular vs. plural), and region (frontocentral vs. centroparietal vs. parieto-occipital). Effects of the Region factor were reported only when they interact with the experimental manipulations.

Attractor (Local Noun) Position

300–500 ms Time Window (Negativity/N400)

The analysis within 300 and 500 ms after participants had read the attractor yielded a significant main effect of valence, $F(1, 27) = 7.21$, $p = 0.012$, $\eta^2 p = 0.211$, with an increased amplitude for negative than for neutral attractors ($M = -0.49$ vs. $M = 0.28$); a significant main effect of number $F(1, 27) = 7.01$, $p = 0.013$, $\eta^2 p = 0.206$, with an increased amplitude for singular than for plural attractors ($M = -0.40$ vs. $M = 0.19$); and a significant region by valence interaction $F(2, 54) = 4.12$, $p = 0.022$, $\eta^2 p = 0.132$. Because the three-way interaction approached significance, $F(2, 54) = 2.96$, $p = 0.060$, $\eta^2 p = 0.099$, we followed up with analyses of the interaction between valence and number in each region and found that it was significant in the frontocentral region, with an increased amplitude for negative than for neutral attractors when they were singular, $t(27) = 2.70$, $p = 0.012$ and for singular versus plural when they were negative, $t(27) = 2.81$, $p = 0.009$.

780–880 ms Time Window [Late Positivity/Late Posterior Positivity (Late Positive Component)/P600]

Analyses for the late positive component neither yielded a significant main effect of valence, $F(1, 27) = 0.79$, $p = 0.380$, $\eta^2 p = 0.029$, nor of number, $F(1, 27) = 0.26$, $p = 0.613$, $\eta^2 p = 0.010$. The interaction between region and number was significant, $F(2, 54) = 5.51$, $p = 0.007$, $\eta^2 p = 0.169$, as was the three way interaction between region, valence, and number, $F(2, 54) = 3.56$, $p = 0.035$, $\eta^2 p = 0.117$. Followed up analyses showed that the interaction between valence and number was significant in the frontal region, where there was a marginally significant attractor number effect for neutral attractors, $t(27) = 1.84$, $p = 0.076$, with an increased amplitude for singular than for plural attractors

[1]www.neurobs.com

[2]As the purpose of the comprehension task that was used in our study was simply to ensure that participants were actually processing the displayed sentences, in the main text we focus on the analyses of the electrophysiological data. The accuracy (in%) of the participants was overall very high in all conditions: Negative-singular = 92.5 (8.4); Negative-plural = 93.2 (7.7); Neutral-singular = 91.4 (SD = 9.7); Neutral-plural = 90.7 (10.1). Repeated-measures ANOVA analyses did not show any significant effect (all Fs < 1). The response times of correctly answered questions were the following per condition: Negative-singular = 2,472 (441); Negative-plural = 2,575 (602); Neutral-singular = 2,477 (549); and Neutral-plural = 2,396 (452). The analyses only showed a marginally significant valence effect [$F(1, 27) = 4.121$, $p = 0.052$], $\eta^2 p = 0.132$, with a tendency for slower responses to questions about sentences containing negative (2,544 ms) than neutral (2,437 ms) attractor nouns.

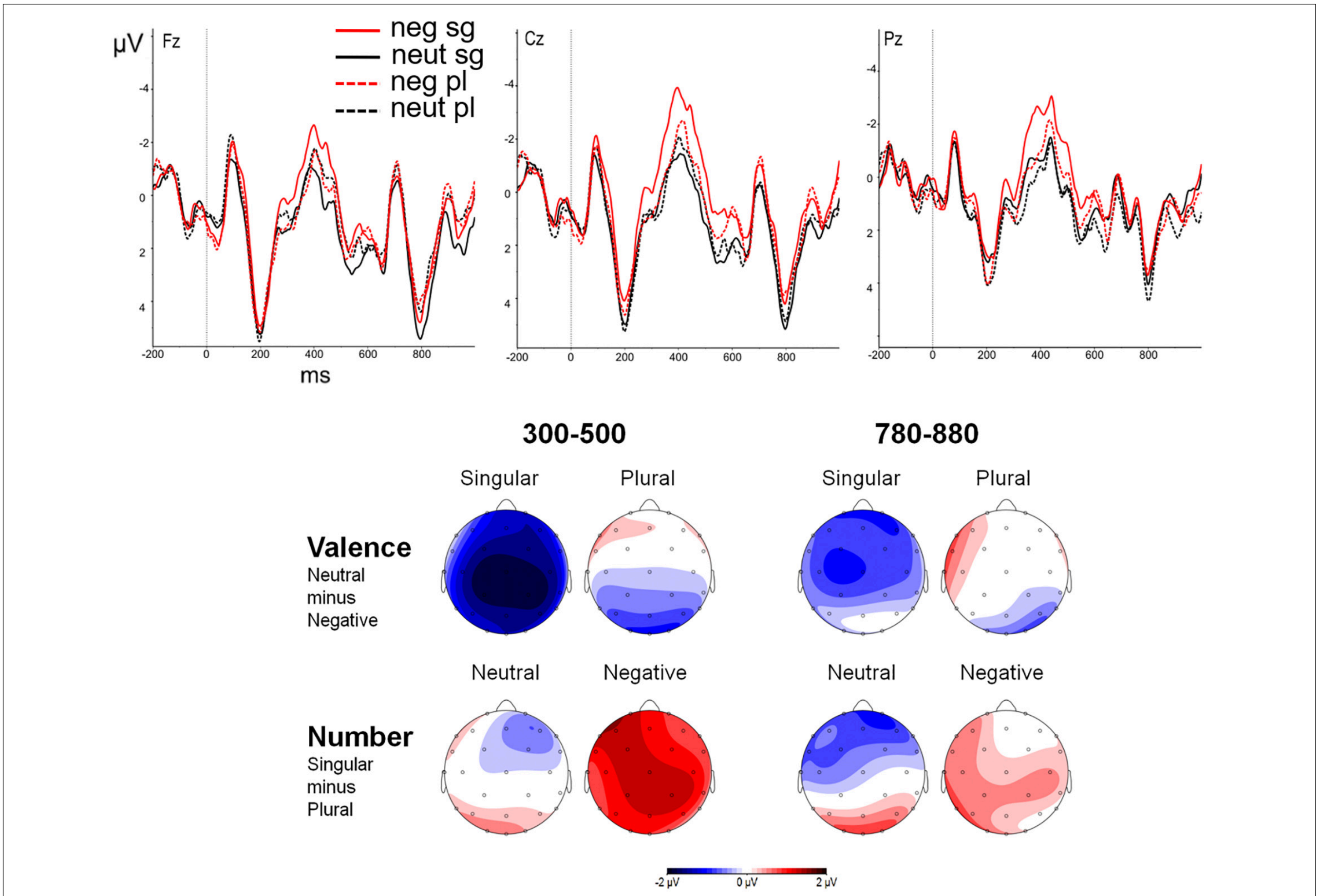

FIGURE 1 | Event-Related Potentials (ERPs) to valence and number manipulations at the three midline electrodes (Fz, Cz, and Pz) and topographic maps in the attractor (local noun) position in 300–500 and 780–880 ms windows.

and a marginally significant valence effect in singular attractors, $t(27) = 1.93$, $p = 0.064$, with an increased amplitude for neutral than for negative attractors. [**Figure 1** shows effects of valence and number of the attractor in the attractor (local noun) position in 300–500 and 780–880 ms windows, respectively.]

Verb (Target) Position

300–500 ms Time Window (Negativity/N400)

The analysis in the agreement position (of the verb) showed that the main effect of valence was not significant, $F(1, 27) = 2.10$, $p = 0.159$, $\eta^2p = 0.072$, nor was the effect of number, $F(1, 27) = 0.16$, $p = 0.691$, $\eta^2p = 0.006$. The interaction between region and valence was significant, $F(2, 54) = 6.26$, $p = 0.004$, $\eta^2p = 0.188$, showing an increased amplitude for neutral than for negative attractors in the parieto-occipital region; $t(27) = 2.09$, $p = 0.047$.

780–880 ms Time Window [Late Positivity/Late Posterior Positivity (Late Positive Component)/P600]

In the late time window, the analysis in the verb position did not show a significant main effect of valence, $F(1, 27) = 0.72$, $p = 0.403$, $\eta^2p = 0.026$, nor of number, $F(1, 27) = 2.49$, $p = 0.126$, $\eta^2p = 0.084$. The interaction between region and number approached significance, $F(1, 27) = 2.62$, $p = 0.082$, $\eta^2p = 0.089$ and further analyses yielded a marginally significant difference between plural and singular attractors in the centroparietal region, $t(27) = 1.94$, $p = 0.063$, and a significant difference in the parieto-occipital region, $t(27) = 2.32$, $p = 0.028$, with plural attractors showing an increased amplitude when compared to singular attractors. The interaction between valence and number was marginally significant, $F(1, 27) = 3.77$, $p = 0.063$, $\eta^2p = 0.123$, showing that valence effects were only present for singular attractors, with larger positivity for negative than for neutral attractors, $t(27) = 2.08$, $p = 0.047$. In addition, attractor number effects were only significant for neutral attractors, with larger positivity for plural than singular attractors, $t(27) = 2.94$, $p = 0.007$. (**Figure 2** shows effects of valence and number of the attractor in the verb position in 300–500 and 780–880 ms windows, respectively.)

DISCUSSION

Considering the crosstalk between brain networks that contain linguistic and emotional information (Pulvermüller, 1999;

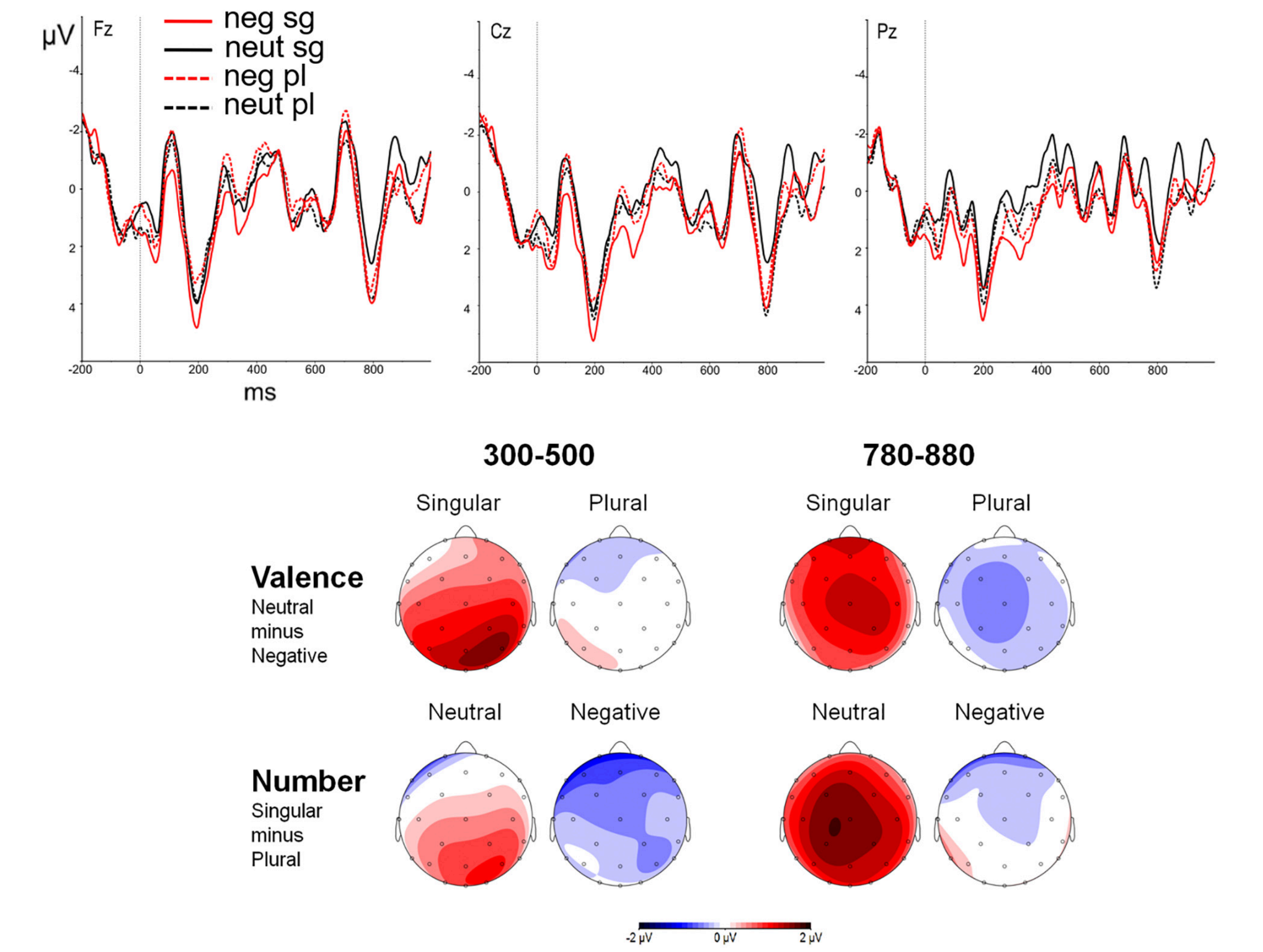

FIGURE 2 | Event-Related Potential (ERPs) to valence and number manipulations at the three midline electrodes (Fz, Cz, and Pz) and topographic maps in the verb (target) position in 300–500 and 780–880 ms windows.

Palazova, 2014; see Hinojosa et al., 2020 for a recent review) and the attention-grabbing effects that affective meaning appears to have on lexical processing (e.g., Delaney-Busch and Kuperberg, 2013), in the present ERP study, we explored the extent to which semantic information of affective nature may impact access to syntactic representations during subject-verb number agreement. Thus, we investigated the attraction effect of emotional local nouns, i.e., interference of structurally irrelevant items, on grammatical sentences during sentence comprehension.

Unlike previous studies on agreement dependencies, where the influence of emotional content was considered in tandem with morphosyntactic violations (Martín-Loeches et al., 2012; Hinojosa et al., 2014; Fraga et al., 2017), the design of the present study allowed us to tease apart semantic from syntactic effects and provide a clearer picture of the impact valence that may have on number agreement processing. The manipulation of valence (negative vs. neutral) and number (singular vs. plural) of the attractor showed different effects on the processing of the attractor as a lexical item (local noun) and on the way, the retrieval of the features of the attractor affected subject-verb agreement computation.

With regard to the former, as reflected in the negative ERP component that was yielded (300–500 ms), we found a strong valence effect only for singular attractors. The fact that the valence effect was absent for plural attractors may be due to the costlier processing of morphologically and semantically richer plural nouns, which might have canceled out the larger saliency of nouns with negative vs. neutral emotional valence. Thus, if plurality and valence effects were of similar size, they might have canceled each other out. Additionally, the fact that attractor nouns that matched in both number and valence with the (singular and neutral) subject noun tended to elicit a larger late positive ERP component (780–880 ms) suggests that the parser had more difficulty identifying the subject and discarding the attractor noun as a possible candidate to be assigned the subject role.

The effects shown on the agreeing verb are particularly interesting, as in verb position, one would expect to find the attraction effect in the form of an ungrammatical illusion and the impact of valence (if there was). The negative ERP component showed that subjecthood feature checking was costlier when the attractor had the same valence as the subject noun that was neutral. This suggests that head and attractor noun features were retrieved for agreement computation. Importantly, the late ERP positive component showed sensitivity to the emotional content of the local noun during feature integration and reanalysis. The fact that "ungrammatical illusions" caused by attraction on grammatical sentences (e.g., Franck et al., 2015) only showed with neutral attractors suggests that the saliency of emotionally negative attractors facilitated discarding the features of the attractor as the agreement source.

Despite being an underinvestigated topic, studying emotional effects in agreement, especially attraction effects in grammatical sentences, can have important implications. It can provide information about what is considered by the parser during online the processing of agreement relations and offer explanations about whether "ungrammatical illusions" can be attributed to the faulty mental encoding of linguistic representations or difficulty in accessing the right morphosyntactic information due to factors, such as the emotional value of an attractor. It can also shed light on the debate between strongly modular models that assume distinct sequential processes between syntactic and semantic representations (e.g., Ferreira and Clifton, 1986; Friederici and Weissenborn, 2007) and fully interactive models that assume that syntactic and semantic constraints interact simultaneously at the message-level representation (e.g., Hagoort, 2003) or intermediate accounts (e.g., Kim and Osterhout, 2005). Our findings suggest that number agreement is not insensitive to affective meaning but that emotional information of an attractor is considered in different operations and at different stages during grammatical sentence processing: for the retrieval of lexical and syntactic representations of the subject-NP and during subject-verb number agreement. Regarding number agreement processing, valence seems to be considered at an early stage of feature checking, where it acts as a cue for the selection of agreeing elements (a local noun with the same valence as the subject noun triggered similarity-based interference). At a late stage of reanalysis, both valence and number features of the attractor are checked to confirm grammaticality.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The study was reviewed and approved by the Ethics Committee of the UPV/EHU (Comité de Ética para las Investigaciones relacionadas con Seres Humanos, CEISH; Project code: M10_2019_167). Participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

AH and MS conceived and designed the study, collected the data, performed the statistical analyses, and drafted the manuscript. Both authors agreed on the final content prior to submission.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2022.880755/full#supplementary-material

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