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Carrot or parrot? An eye-tracking study on spoken word recognition in a language attrition context

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ABSTRACT
Despite the extensive research on bilingual development, our understanding of how lexical competition unfolds in the bilingual mind remains limited. Previous studies have predominantly focused on crosslinguistic competition, neglecting the examination of the competition process within each language and the influence of diverse bilingual experiences, such as first language attriters, heritage speakers, or sequential bilinguals. Consequently, there is a critical gap in our knowledge regarding how bilinguals navigate and resolve competition dynamics during spoken word recognition in the context of language attrition. We compare the within-L1 and within-L2 competition mechanisms of Spanish-English attriters ($N = 65$) with two monolingual control groups (Spanish and English speakers). Participants completed two visual world tasks with manipulation of onset/rhyme overlap. Results indicate a contrast between the competition mechanisms exhibited by the L1 monolingual group and the Spanish attriters during L1 spoken word recognition. Our findings highlight the role of bilingual experiences in modulating L1 competition dynamics, shedding light on the complex relationship between bilingualism and lexical competition.

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Language attrition; spoken word recognition; visual world paradigm; lexical competition; grammatical gender

Introduction

Upon the onset of speech, listeners engage in the processing of incoming acoustic information by activating multiple candidate words that bear partial resemblance to the speech input (Weber and Scharenborg 2012). These competing candidates must be promptly activated and discarded in order to effectively resolve the temporal ambiguity arising from the unfolding speech input and to achieve successful word recognition.

The role of phonological information in the disambiguation process of lexical competition has been a subject of debate among researchers. Early models, such as the COHORT model (Marslen-Wilson 1987), suggested that competition was solely influenced by the phonological onset of the auditory signal. In contrast, the TRACE model (McClelland and Elman 1986) proposed that later-accessed phonological information within the word also played a crucial role. Research on lexical competition indicates that lexical competitors sharing the onset of the target word (cohort competitors) exhibit a greater tendency to compete for recognition compared to competitors matching the word's ending (rhyme competitors) (Allopenna, Magnuson, and Tanenhaus 1998; Magnuson et al. 2003). However, the competition process is dynamic and influenced not only by the evolving

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acoustic match of the input but also by the structure of the lexicon from which candidate words are activated (e.g. neighbourhood density, word frequency) (Magnuson et al. 2007; Shook and Marian 2013).

Despite substantial research in spoken word recognition (SWR), the effects of lexicon structure, the nature of acquisition (first versus second language), and the role of additional languages in bilingual speakers have not been extensively investigated from a bilingualism perspective.

Since Spivey and Marian's (1999) landmark eye-tracking study on crosslinguistic activation in Russian-English bilinguals, research on bilingual lexical processing has focused primarily on investigating lexical activation and competition from a crosslinguistic perspective through eye-tracking in the Visual World Paradigm (VWP) (Blumenfeld and Marian 2007; Canseco-Gonzalez et al. 2010; Tanenhaus et al. 1995). This experimental task has been widely employed to examine both monolingual and bilingual lexical processing due to its high sensitivity to transient effects, such as lexical access (Huettig, Rommers, and Meyer 2011).

One of the major advantages of the VWP is its ability to investigate the time-course of spoken word recognition in real-time. Participants listen to a spoken utterance while simultaneously observing a visual scene comprising various objects, including items (images or written words) that may be mentioned in the speech input (targets, e.g. carrot), items that partially overlap with the target (competitors, e.g. carriage and parrot), and unrelated distractors (e.g. ladle). By tracking participants' eye movements on the display, researchers gain insights into the considered visual items, the timing of consideration, and the duration of consideration. This information is crucial for understanding how speakers achieve lexical access and evaluating the adequacy of previous theoretical approaches in spoken word recognition (Berends, Brouwer, and Sprenger 2015).

While research using the VWP has addressed lexical competition in monolinguals and crosslinguistic interactions (CLI) in bilinguals, the lexical competition process along the bilingual development spectrum remains poorly understood.

The bilingual experience varies considerably depending on factors such as age of acquisition, linguistic proficiency, and language use and exposure (e.g. de Bruin 2019; Grosjean 1989). Although bilingualism is used as an umbrella term to describe all communities that speak more than one language, existing research has documented this inter-variability among bilingual populations by exploring how differences within this heterogeneous group affect various linguistic processes (Dussias and Sagarra 2007; Karayayla and Schmid 2019; Miller and Rothman 2020). Given the above, if bilinguals with diverse degrees of proficiency or language use can exhibit perception and production discrepancies along the continuum, it makes sense to investigate whether there are also differences in lexical access and competition mechanisms.

Recent studies have highlighted competition differences in lexical processing among bilinguals considering proficiency, age of acquisition, linguistic environment, and linguistic experience (Bruggeman and Cutler 2019; Sarrett, Shea, and McMurray 2022; Shin et al. 2015). However, further investigation is needed to understand how first language (L1) and second language (L2) lexical competition processes compare in bilinguals with diverse linguistic and extralinguistic factors (e.g. L2 learners, sequential bilinguals, heritage speakers, language attriters). Investigating these issues will allow us to better understand the complex dynamics of this process as well as to take into account the heterogeneity within the bilingual continuum.

This study aims to examine spoken word recognition at the word level in the context of L1 attrition. From an L1 attrition perspective, the bilingual's native language can be subject to a myriad of changes as a result of the co-activation of languages, crosslinguistic competition and reduced L1 input and use due to long-term L2 exposure (Schmid and Köpke 2017). By investigating potential changes in an attrited linguistic system during L1 spoken word recognition, we can uncover novel processes in bilingual lexical processing and enhance our understanding of the bilingual development spectrum.

Although previous research on L1 attrition has demonstrated how the L2 influences L1 lexical access during visual word recognition (Segalowitz 1991), no studies have explored L1 attrition in the context of spoken word recognition by examining bilinguals' L1 and L2 lexical processing using online measures.

The study

This study examines lexical competition dynamics in Spanish-English attriters,[1] Spanish and English monolingual speakers (control groups) during two visual world eye-tracking experiments. We manipulate onset/rhyme overlap within each language to investigate within-L1 and within-L2 lexical competition. Additionally, we explore the role of external factors from the language attrition literature, such as language proficiency, language aptitude, length of residence, L1 and L2 use and exposure, age, sex, and educational level (Schmid and Dusseldorp 2010), in the competition process.

We predict that English monolinguals will demonstrate a 'cohort effect', a stronger and earlier tendency to attend to cohort competitors over rhyme and unrelated candidates before selecting the target referent image (Allopenna, Magnuson, and Tanenhaus 1998). While no prior research has investigated onset/rhyme competition among Spanish monolinguals, we anticipate a similar disambiguation process in Spanish and English. However, the specific properties of Spanish may impact the competition process.

Grammatical gender serves as a morphosyntactic cue during word recognition facilitating lexical disambiguation. Evidence from studies on SWR suggests that grammatical gender, particularly, the gender-marked information encoded in the article preceding the noun (e.g. *l**a** [f.] cas**a** [f.] – the house*), modulates lexical activation by constraining phonological cohort competitors that mismatch the gender of the target spoken word in monolingual (Dahan et al. 2000; Lew-Williams and Fernald 2007) and bilingual domains (Dussias et al. 2013; Morales et al. 2015).

Spanish grammatical gender is primarily conveyed through transparent nominal suffixes (-o for masculine and -a for feminine, Corbett 1991; Franceschina 2005; Harris 1991). Spanish natives seem to exhibit a heightened sensitivity to these canonical endings as these cues can help learners classify nouns into gender categories and facilitate gender processing and retrieval in language comprehension via a form-based route (Caffarra and Barber 2015; Gollan and Frost 2001; Hernández et al. 2004; Pérez-Pereira 1991). Considering this, Spanish grammatical gender, as a system that manifests at the rhyme of the noun and contributes to lexical ambiguity resolution, may influence the competition mechanisms of L1 monolinguals. This influence could be attributed to the interplay between phonological similarity and gender overlap at the rhyme of the word, which may lead to increased rhyme competition effects.

Regarding bilingual-attriters, only one study has explored within-L1 competition with onset/rhyme phonological overlap in bilinguals who emigrated to an L2 environment with reduced L1 use (Bruggeman and Cutler 2019). Interestingly, Dutch-English bilinguals in that study exhibited different competition dynamics compared to their L1 Dutch monolingual counterparts, showing lower rhyme competition during L1 SWR. The authors suggested that the participants' extensive length of residence and L2 exposure in the L2 environment could account for these differences. However, they did not specifically address L1 attrition. This study aims to investigate whether attriters' within-L1 competition is affected by L1 attrition, potentially replicating reduced activation of rhyme competitors seen in previous research (Bruggeman and Cutler 2019).

Materials and methods

Participants

Sixty-five Spanish-English attriters (43 female; 32 from Mexico and 33 from Spain), 50 Castilian-Spanish monolingual speakers[2] (48 female) and 63 British-English monolingual speakers (42 female) with normal or corrected-to-normal vision and hearing were paid for their participation and included in the analyses (see Table 1 for more information on the participants' characteristics).

Table 1. Participant characteristics by group.

	Spanish-English bilinguals			Spanish monolinguals			English monolinguals		
Variable	*M*	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range
Age	28.7	9	19–51	25	8.5	18–56	26.11	10.65	18–60
Age at onset of bilingualism (AoO)	6.67	3.54	3–16		–			–	
Age of arrival (AoA)	24	6.32	17–43		–			–	
Length of residence (LoR)	5	6	2–32		–			–	
Length of L2 instruction (L2Inst)	11.38	5.16	2–35		–			–	
Education level	10 PhD degree 28 Master's degree 23 Bachelor's degree 4 Voc. training			– 5 Master's degree 35 Bachelor's degree 10 Voc. training			2 PhD degree 11 Master's degree 47 Bachelor's degree 3 Voc. training		

Linguistic and extralinguistic factors

Sociolinguistic and personal background questionnaire (SPBQ)

General information about the participants' personal background and language use was gathered online through the Schmid and Dusseldorp's (2010) sociolinguistic and personal background questionnaire (SPBQ) (see the Appendix for the full version of the task). A principal component analysis (PCA) with Varimax rotation (30) was performed on the Likert scale questions relevant to the participants' linguistic identification, language exposure and language use (see Table 2 below).

Aptitude test. Language aptitude was assessed using the LLAMA Language Aptitude tests (Meara 2005). This computer-based battery includes four subtests for vocabulary acquisition (LLAMA B), sound recognition (LLAMA D), sound-symbol correspondence (LLAMA E), and grammatical inferencing (LLAMA F). The participants' score percentages from the four subtests were averaged and a compound variable was calculated.

Proficiency tasks. Language proficiency in both L1 and/or L2 was evaluated online using a C-test (Grotjahn 1987; Keijzer 2007; Mehotcheva 2010) and a Can-Do scale (ALTE 1998), sourced from Schmid's Language Attrition webpage (Schmid n.d.). To analyse the data, accurate responses from the C-tests were aggregated for each test, and the total percentage of accurate responses was calculated. The participants' responses from the Can-Do scales were classified and then averaged per main linguistic skill (i.e. listening, speaking, reading, and writing). Then, a total variable was calculated for each version of the test (see Table 3 for a summary on the participants' language aptitude and proficiency scores).

Table 2. Summary of the predictor variables extracted from the PCA.

Composite predictor variables	Items	Cronbach's *α*	Variance	KMO	Bartlett's test
L2 exposure	L2 receptive exposure and use	.720	15.9%	.5	<.001
BIMOD_FAM	L1 use with family and cultural attitudes	.725	13.7%	.5	<.001
L1 exposure	L1 receptive exposure	.759	7.9%	.5	<.001
BIMOD_PART	L1 use with partner	.978	6.9%	.5	<.001

Table 3. Language aptitude and language proficiency scores across groups.

	Spanish-English bilinguals			Spanish monolinguals			English monolinguals		
Variable	*M*	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range
Language aptitude	50.50	12.30	22.5–75/100	43.43	13.5	16–78/100	46.23	14.15	10–73.7/100
Spanish C-test	61	3.46	45–66/66	62.14	3.49	51–66/66		–	
English C-test	8.28	0.93	6–9.5/10		–		8.34	0.88	6.70–9.25/10
Spanish Cando	4.78	0.30	3–5/5	4.85	0.17	4–5/5		–	
English Cando	4.34	0.72	3–5/5		–		4.39	0.55	3–5/5

Flanker task. The Flanker Task (Eriksen and Eriksen 1974) assesses participants' inhibitory control and selective attention (i.e. the capacity to attend to a specific input while simultaneously inhibiting irrelevant information triggered by a stimulus). The task consists of 3 conditions (congruent, incongruent, and mixed). In each condition, 5 black chevrons (Font size 18, Courier New) appear in the centre of the screen, pointing in different directions (left or right), while participants indicate the direction of the target chevron situated in the centre by clicking on one of the two keys selected from the keyboard.

The task was administered in-person on a computer screen with E-Prime 2.0 (Schneider, Eschman, and Zuccolotto 2002). The participants' accuracy and response times were recorded. Inhibitory control was assessed by measuring the response time (RT) interference scores.

The visual world tasks: design and materials

Two visual world eye-tracking experiments were designed for this study, one for each of the languages under investigation. Each experimental set included a visual display containing four line-drawings (target, cohort competitor, rhyme competitor, and unrelated item) and a question mark sign (see Figure 1 below). Both versions of the task consisted of 15 practice trials. Five practice trials presented an auditory word that was not represented visually on the display. This design aimed to encourage participants to select the question mark response option when the spoken word did not match any of the other items on the screen, thus discouraging guessing (Botezatu et al. 2022). Forty experimental trials were included in the Spanish version and 33 experimental trials in the English version due to word selection constraints specified below. All stimuli were black and white pictures of inanimate and animate items to avoid colour bias.

Most of the stimuli[3] were selected from the On-line Resource for Psycholinguistic Studies (Szekely et al. 2004) and Snodgrass and Vanderwart's (1980) set of pictures (see Tables 4 and 5, Appendix), as all items were normed for name agreement, image agreement, familiarity, and visual complexity (Berends, Brouwer, and Sprenger 2015). All the items were also normed for stress, frequency, and number of syllables in each language. To control for Spanish and English stress patterns, all lexical items were selected to have two syllables and were stressed on the initial syllable (Domínguez Martínez and Cuetos Vega 2018; Fudge 1984).

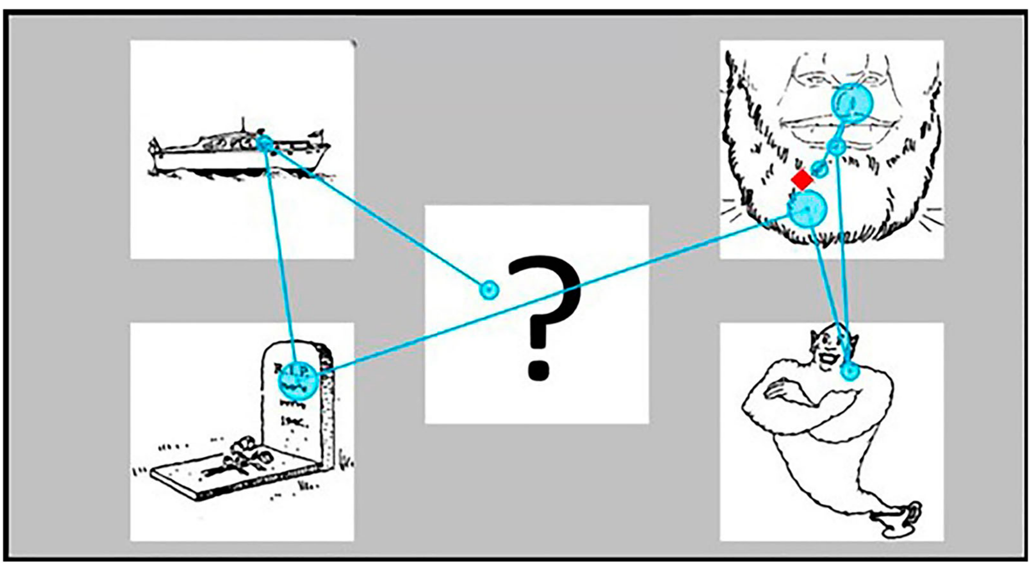

Figure 1. Scan path data view. Sample experimental trial from the VWP task with items from Snodgrass and Vanderwart's (1980) dataset. Clockwise order of components from upper left corner: cohort competitor (*barco-ship*), target item (*barba-beard*), unrelated item (*genio-genie*), rhyme competitor (*tumba-grave*), and central picture question mark.

All auditory stimuli were recorded separately by a female native speaker of Castilian Spanish and a female native speaker of British English in a quiet room. The recordings were then adjusted to a standardised intensity level of 60 dB. White noise (62 dB) was added using PRAAT software (Boersma and Weenink 2017) to challenge word recognition (resulting in a speech-to-noise ratio of −2 dB). Phonological overlap was manipulated by selecting cohort and rhyme competitors that overlapped with the first or last two phonemes of the spoken target word (e.g. button (target), bucket (cohort competitor) and onion (rhyme competitor)).

Procedure

The eye movements of the experimental and English control groups were tracked with an SMI RED 250 desktop mounted eye-tracker and the E-Prime 2.0 software at the at the University of Essex. Data from the Spanish control group were obtained from two populations in Spain: at the University of Zaragoza using a portable SMI RED 250 eye-tracking device and at the University of Murcia using a portable Tobii Pro X3-120 eye-tracking device.

Participants were seated at a comfortable distance of 60 centimetres from the screen. Instructions were given in the participant's L1. Following Botezatu and associates (2022), bilinguals were tested in their L1-Spanish prior to being tested in their L2-English to avoid L1 inhibition following L2 performance.

After a 9-point calibration, participants viewed a trial preparation screen on a computer display (1680 × 1050) for 2000 ms. Then, each trial was presented to the participants. Auditory stimuli were presented 200 ms after picture display onset, and participants selected the corresponding word using a mouse. Pictures were pseudo-randomised to ensure even presentation.

The order of the in-person tasks (Flanker, visual world, and language aptitude) was counterbalanced within each participant group. Data collection included one in-person session and one online session via the Moodle X platform, with an estimated duration of approximately 1 hour (30 minutes per session).

Data analysis

To assess within-L1 and within-L2 lexical competition, we conducted two sets of analyses on the eye-tracking data: one on total looking time to each competitor (cohort/rhyme), and one on the time course of the visual world task as the participants' eye-movements were launched towards the two types of competitors in question. Specifically, we compared Spanish attriters' and Spanish monolinguals' eye-movements towards L1 phonological competitors (cohort and rhyme), and Spanish attriters' and English monolinguals' fixations towards English competitors.

For both analyses, blinks and saccades were discarded. Total duration of looks at rhyme and cohort phonological competitors per trial were analysed using linear mixed-effects models (LMM) with the lme4 package (Version 1.1.26; Bates et al. 2015) in R (Version 4.0.3; R Core Team 2022). To analyse competitor fixations over time, we employed generalised linear mixed-effects models (GLMM) with a logistic link function via the lme4 package.

Following Godfroid's (2020) approach, data points were collapsed into time bins (40 msec) to calculate the aggregate measures via the eyetrackingR package (Version 0.2.0; Forbes, Dink, and Ferguson 2021) and were entered as a continuous covariate in the analysis. The dependent variable, odds of fixating on the rhyme or cohort competitor versus other looks, was computed by taking the ratio of fixations to non-fixations and then applying a logarithmic transformation (logit) (Barr 2008).

Results

Accuracy and reaction time

All analyses in this study are restricted to the time window from the onset of the spoken word until the participants clicked on the referent picture (target item) (Magnuson et al. 2007). The cut-off point for each group was selected by excluding any reaction time data of the mouse click-response two standard deviations above the grand mean, the point by which fixation proportions tended to asymptote for the three groups. The main analyses were performed on the first second of task duration, beginning from the first 200 ms.

Trials with over 25% trackloss were excluded. Equipment malfunctions and trackloss led to 17.7% of missing values. Only correct responses, meaning participants accurately matched the spoken word with the corresponding picture, were included in the analyses. Participants who selected the incorrect item in over half of the total trials per language were excluded from further analyses (10 participants: 6 Spanish monolinguals, 3 Spanish bilingual-attriters, 1 English monolingual).

Reaction times averaged as follows: bilingual group (Spanish version): 1476.15 ms ($SD = 553.58$ ms); (English version): 1809.14 ms ($SD = 705.23$ ms); Spanish monolingual group: 1582.67 ms ($SD = 464.79$ ms); English monolingual group: 1655.44 ms ($SD = 579.27$ ms). The bilingual group correctly identified 90% (Spanish) and 76% (English) of the target items on average. The Spanish monolinguals identified 70% on average and the English monolinguals identified 87.8% on average.

Given the lower accuracy of Spanish monolinguals in the visual world task, we conducted a follow-up experiment with a group of 15 Spanish monolingual participants, manipulating background noise presence. By controlling for background noise, we aimed to address potential noise-related effects observed in the study (e.g. lower accuracy rates for Spanish monolinguals) without influencing the reliability of the results. The analyses performed across both conditions will be discussed in the following section.

Within-L1 lexical competition

Separate mixed-effects models were built for each competitor to analyse participants' gaze behaviour towards L1 competitors. We employed a forward model selection approach (Barr et al. 2013) to determine the random and fixed-effects structure based on model comparisons. The final models included a two-way interaction (Time Bin x Group) with a quadratic term (orthogonalised to remove collinearity) to better capture the data (see Figure 2), along with random intercepts for participant and item.

Covariates encompassed external variables potentially impacting both Spanish L1 groups, such as gender, age, L1 proficiency, education level, language aptitude, and Flanker task interference scores.

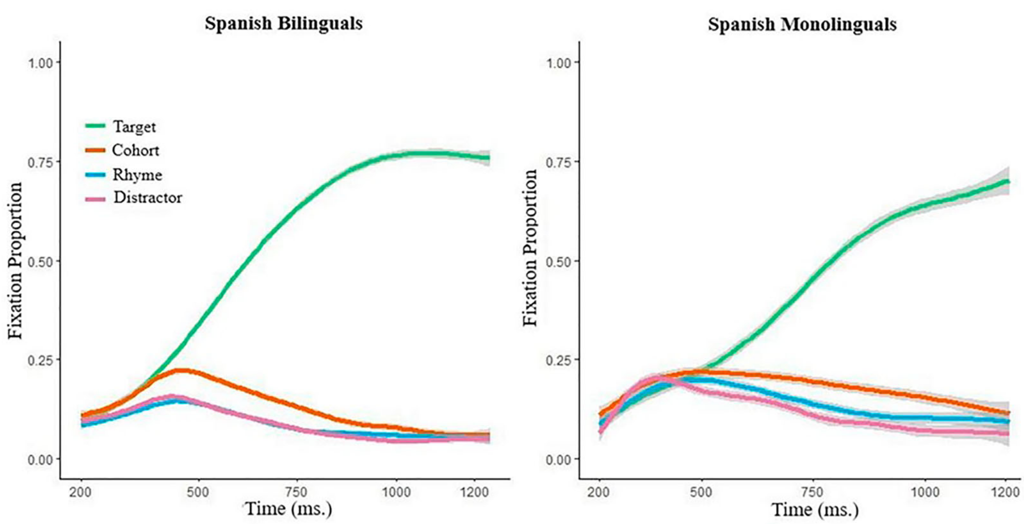

Figure 2. Average fixation proportions towards the Spanish L1 candidates across time. Comparison between the Spanish bilinguals and the Spanish monolinguals.

Additionally, specific external factors affecting the experimental group were included, including age of arrival (AoA), age at onset of bilingualism (AaO), L2 proficiency, L1 and L2 exposure, length of residence (LoR), and length of L2 instruction (LoIns).

Figure 2 below shows the average proportion of fixations to the Spanish items over time. From word onset, the bilingual group seems to fixate for longer on the cohort competitor and on the target word than on the rhyme competitor or the distractor before returning to baseline levels. The Spanish monolinguals present a very different looking behaviour, as they seem to pay more attention to the rhyme competitor from earlier.

Looks to the L1 rhyme competitor

The GLMM used to assess the odds of looking at the rhyme over time by group (Spanish attriters vs L1 monolinguals) indicated that the bilingual-attriter group was less likely to look at the rhyme competitors (estimate = −0.48, SE = 0.08, z(49370) = −5.990, $p < .001$) than L1 monolinguals. This model accounted for 44% of the variance. Further within-group GLMMs on the first four 200 ms time windows from the spoken word's onset confirmed a rhyme effect in both groups, with participants fixating more on the rhyme competitors compared to the distractor items. However, the timing of this effect differed between both groups. The Spanish monolinguals exhibited early competition from the rhyme candidates starting around 450 ms (estimate = −0.18, SE = 0.02, z(7882) = −6.285, $p < .001$), whereas the Spanish bilinguals did not show rhyme competition until later at 700 ms (estimate = −0.18, SE = 0.02, z(20968) = −7.07, $p < .001$).

A linear mixed-effect model on total duration fixations to the L1 rhyme competitor, containing *group* (experimental vs control) as the predictor, also indicated that the experimental group looked less to the rhyme competitors than the monolingual control group (estimate = −0.51, SE = 0.08, t(71) = −6.073, $p < .001$).

Additional LMMs were fitted to account for the external factors that could affect the attriters' total duration of looks to the rhyme competitors. One model, incorporating *length of residence* and *L2 proficiency* and accounting for 9% of the variance, showed that the Spanish attriters who had spent more time in the L2 context (UK) (estimate = −0.069, SE = 0.02, t(65) = −2.541, $p < .05$; effect size = −0.63), and highly L2-proficient bilinguals (estimate = −0.079, SE = 0.03, t(67) = −2.501, $p < .05$; effect size = −0.61) looked less at rhyme competitors (see Figure 3).

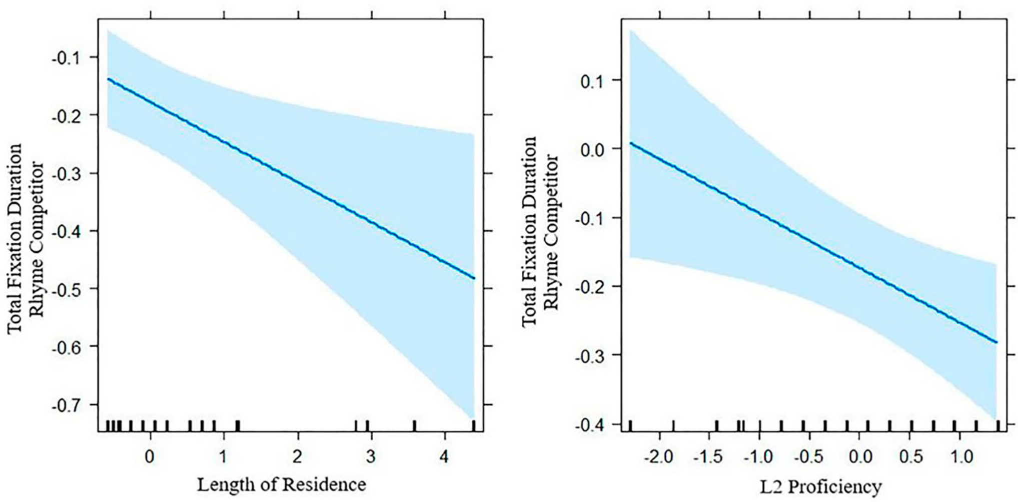

Figure 3. Length of residence and L2 proficiency predictor effects for the L1 rhyme candidates among the Spanish bilingual group.

Looks to the L1 cohort competitor

The GLMM assessing the odds of looking at the L1 cohort competitor by group over time showed no significant difference between groups (estimate = −0.27, SE = 0.18, z(50042) = −1.486, *p* = 0.137), explaining 56% of the variance. Further within-group models on the first four time windows confirmed a cohort effect (i.e. stronger competition from the cohort competitors than the rhyme or distractor items) for both groups, starting during the 200 to 400-ms interval (Spanish bilinguals: estimate = −0.32, SE = 0.01, z(56626) = −34.871, *p* < .001; Spanish monolinguals: estimate = −0.13, SE = 0.02, z(14478) = −5.923, *p* < .001). However, the duration of this effect differed between the two groups. The Spanish bilinguals' cohort effect remained significant until the 800 ms (estimate = −0.56, SE = 0.02, z(31687) = −23.064, *p* < .001), while the Spanish monolinguals' cohort effect persisted beyond the first 1000 ms time window (estimate = −0.68, SE = 0.04, z(8163) = −15.391, *p* < .001).

The LMM for total duration of fixations towards the cohort L1 competitors across groups revealed no significant distinctions between the Spanish monolingual and attriter groups (estimate = 0.06, SE = 0.08, *t*(113) = 0.746, *p* = 0.457). However, higher *language aptitude*, particularly higher scores in the sound-symbol correspondence LLAMA subtest, led to longer fixations at the cohort competitor (estimate = 0.12, SE = 0.03, *t*(120) = 3.390, *p* < .001; effect size = 0.62) (see Figure 4).

A separate LMM performed only on the attriters' L1 showed that *length of residence* and *self-perceived L2 proficiency* influenced their looking patterns towards the L1 cohort competitors. Attriters who spent more time in the L2 context (estimate = 0.13, SE = 0.04, t(64) = 2.840, *p* < .01; effect size = 0.70), and those with higher self-rated L2 proficiency (estimate = 0.09, SE = 0.04, *t*(65) = −2.099, *p* < .05; effect size = 0.51) looked at cohort competitors for longer (see Figure 5).

Follow-up analyses: absence of noise

To control for the background noise of the experimental tasks and to ensure the reliability of the results from the current study, we conducted additional GLMMs on the Spanish monolinguals' odds of fixating on the rhyme and cohort competitors during the visual world task in the absence of noise. The analyses in the quiet condition replicated the cohort (estimate = −0.40,

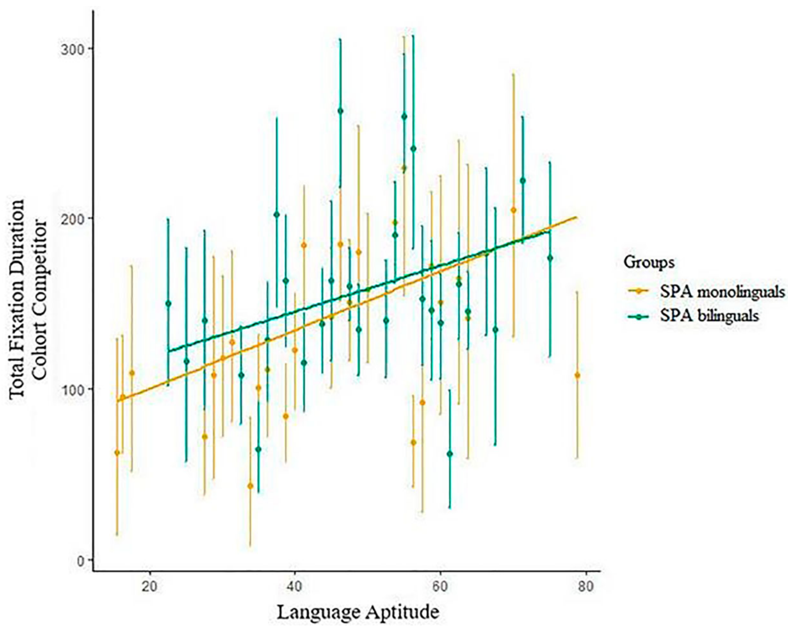

Figure 4. Total fixation duration towards the L1 cohort competitor by language aptitude across groups (Spanish bilinguals and Spanish monolinguals).

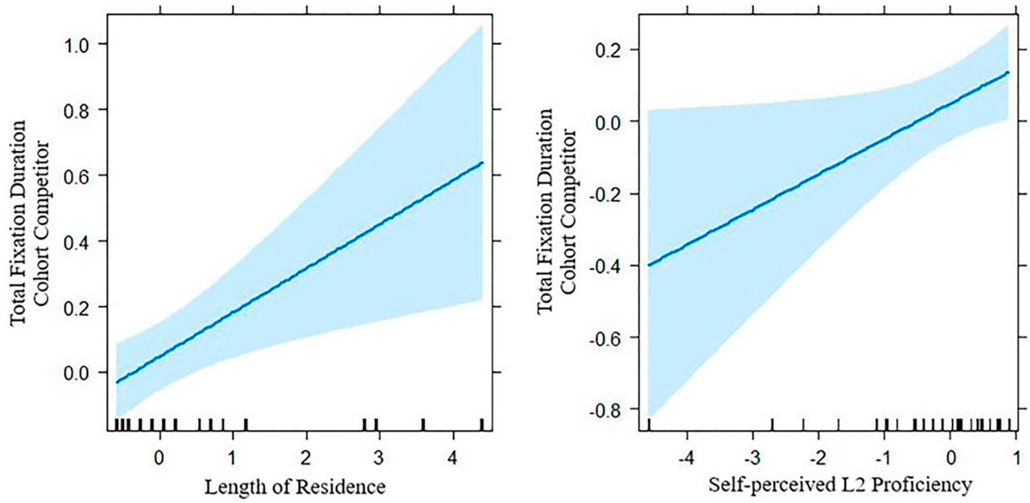

Figure 5. Length of residence and self-perceived L2 proficiency predictor effects for the L1 cohort candidates among the Spanish bilingual group.

SE = 0.03, z(20106) = −13.110, $p < .001$) and rhyme effects (estimate = −0.29, SE = 0.03, z(20106) = −8.545, $p < .001$) observed in the noisy condition, supporting the previous findings. Notably, accuracy rates increased during the quiet condition (92%), whereas reaction times remained consistent (M = 1565.53 ms, SD = 419.86).

Within-L2 lexical competition

To compare the attriters' and English monolinguals' looking behaviour towards the rhyme and cohort English candidates, we followed the same statistical approaches we employed earlier to analyse the L1 candidates, including the same covariates. These models included random intercepts for participant and item and random slopes for group across items.

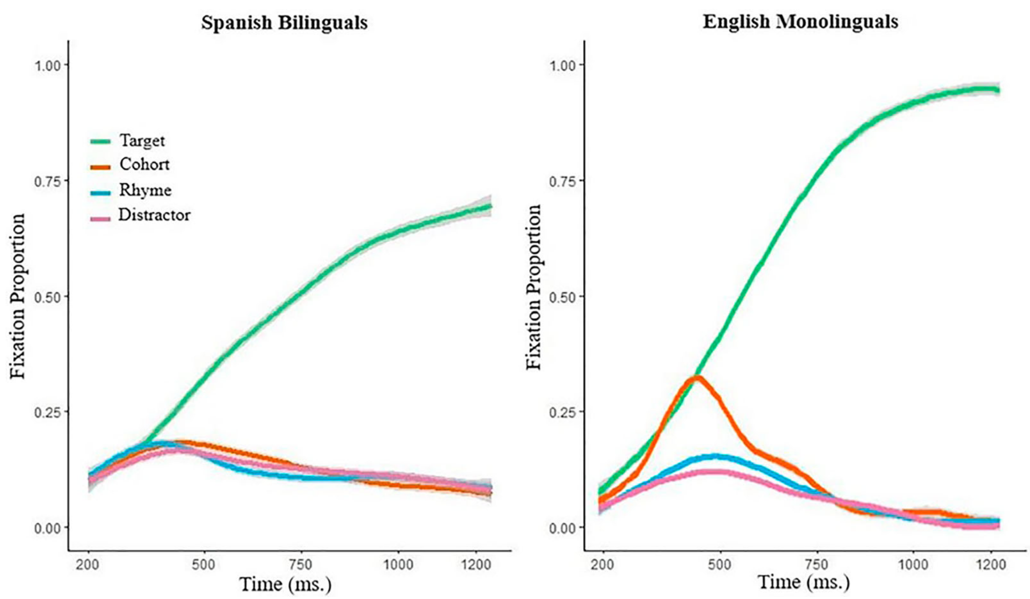

Figure 6. Average fixation proportions towards the English candidates across time. Comparison between the Spanish bilinguals and the English monolinguals.

In the figure above, it is evident that English monolinguals exhibited stronger cohort competition compared to their looks towards the rhyme, which were almost indistinguishable from looks towards the unrelated item. The Spanish attriters seemed to prioritise the cohort competitor briefly before inhibiting both competitors and the distractor simultaneously.

Looks to the L2 rhyme competitor

The GLMM examining the odds of looking at L2 rhyme candidates by group (Spanish attriters vs English monolinguals) across time, accounting for 46% of the variance, indicated that the bilingual group was more likely to look at the rhyme competitor (estimate = 0.38, SE = 0.10, z(73478) = 3.584, $p < .001$) than the English monolingual group. However, the within-group GLMMs revealed that the Spanish bilingual group did not show significant rhyme competition during the visual world task in English, as the odds of looking at the rhyme competitors did not differ from those of the distractor items (estimate = −0.03, SE = 0.01, z(91446) = −2.779, $p = .06$). Conversely, English monolinguals presented a rhyme effect during the 400–800 ms interval (estimate = −0.17, SE = 0.01, z(21484) = −9.811, $p < .001$).

The linear mixed-effects model assessing total fixation duration on English rhyme competitors across groups revealed that *group* and *L2 proficiency* influenced participants' looking behaviour. The experimental group paid more attention to the English rhyme competitors than the English monolinguals (estimate = 0.17, SE = 0.06, t(70) = 2.665, $p < .01$), and highly proficient speakers of English paid less attention to the rhyme candidates (estimate = −0.09, SE = 0.03, t(108) = −3.219, $p < .01$; effect size = −0.73) (see Figure 7).

Looks to the L2 cohort competitor

The GLMM assessing the odds of looking at the English cohort competitors by group across time indicated no significant difference between the attriter and English monolingual groups (estimate = 0.11, SE = 0.09, z(73478) = 1.276, $p = 0.202$). This model explained 48% of the variance. According to the within-group GLMMs, both groups presented a cohort effect. In the case of English monolinguals, this effect began at the 200–400 ms interval (estimate = −0.43, SE = 0.01, z(32238) = −21.872, $p < .001$), while for Spanish bilinguals, it initiated at the 400–600 ms interval (estimate = −0.12, SE = 0.02, z(14034) = −6.138, $p < .001$). Additionally, a linear mixed-effects model on total fixation duration of English cohort competitors across groups showed no significant

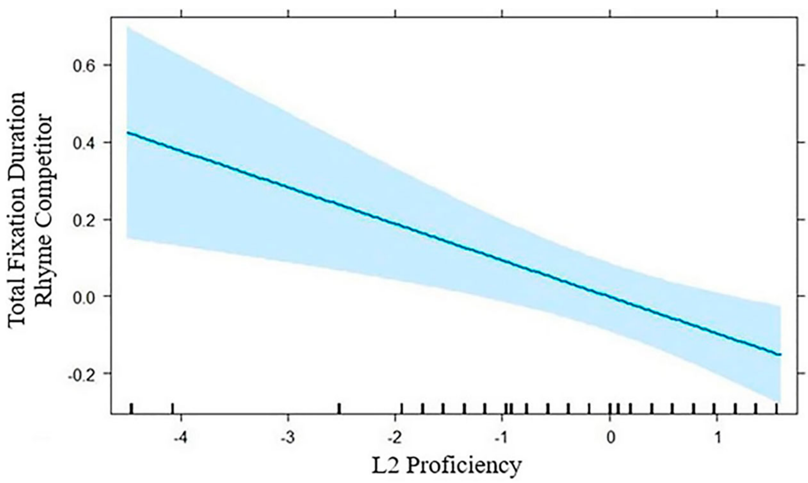

Figure 7. English proficiency predictor effects for the L2 rhyme candidates across groups (Spanish bilinguals and English monolinguals).

distinction between the attriter and English control groups (estimate = −0.06, SE = 0.07, $t(60) = -0.978$, $p = 0.332$).

Discussion

To better understand how lexical competition influences lexical processing in bilinguals' first and second languages from a language attrition context, this study sought to explore within-L1 and within-L2 lexical competition dynamics in Spanish-English bilingual-attriters during SWR. The results revealed that the bilingual-attriters' L1 competition dynamics differed from their monolingual counterparts during the Spanish visual world task. Specifically, they exhibited delayed activation and reduced competition from L1 rhyme competitors compared to the Spanish monolingual group. Additionally, the Spanish-English bilinguals did not employ similar competition dynamics to disambiguate both L1 and L2 processes, rapidly inhibiting both English competitors prior to recognising the spoken target word.

Given that spoken word recognition can be influenced by bilingual experience (e.g. Shook and Marian 2013), we hypothesised that certain features of lexical items, particularly those relevant for lexical access, may be interpreted differently. In Spanish, the rhyme of a word holds important information such as gender distinctions, which facilitate gender retrieval (Corbett 1991; Gollan and Frost 2001), contributing to the disambiguation of the competition process (Lew-Williams and Fernald 2007). Conversely, in English, the rhyme of a word does not carry similar weight and is less likely to serve as a cue for lexical access.

Our findings confirm these assumptions, particularly underscoring the Spanish monolinguals' language-specific sensitivity to transparent endings. As illustrated in Figure 2, Spanish monolinguals retained information from the rhyme competitor longer, suggesting reliance on the rhyme for competition resolution. In contrast, as shown in Figure 6, the English monolinguals suppressed the rhyme competitor earlier, retaining only the target and cohort as the two 'viable' candidates. We argue that, unlike in English, Spanish rhyme candidates matched the target's gender and phonologically overlap with the target's word ending, heightening their activation levels, thereby leading to increased rhyme competition during the SWR process. Interactive approaches like TRACE (McClelland and Elman 1986) propose that lexical information can influence pre-lexical representations to enhance speech perception (McClelland, Mirman, and Holt 2006). Therefore, it is plausible that Spanish monolinguals used this gender-marked information as a cue for lexical access, facilitating word recognition when the gender cue is presented sequentially (Dahan et al. 2000) but increasing rhyme competition when presented simultaneously in both rhyme and target items.

Interestingly, the Spanish attriters exhibited very different L1 competition dynamics from the Spanish monolinguals, as they relied less on L1 rhyme information, resembling the patterns observed in English monolinguals. This difference may indicate that their process of lexical access and lexical selection has been influenced by their L2 experience, where word endings contribute less to disambiguation.

According to the Competition model (Bates and MacWhinney 1987; MacWhinney 2019), the availability and reliability of a cue are crucial factors during language learning. Spanish monolinguals might rely on the cues at the end of the word as they have learned through frequent L1 use and exposure that important information is stored at the rhyme of the word (e.g. gender). The model contends that these cues become more dependent on their reliability over time and that entrenchment, the repeated use of that cue, is central to L1 maintenance. Nevertheless, prolonged influence from the L2, particularly in an L2-dominant context, together with L1 disuse, can affect how this protective factor operates in the L1.

Although the susceptibility of a particular linguistic feature to L2 transfer seems to depend on their L1–L2 similarities (MacWhinney 2019), previous research has demonstrated how the L2 can impact L1 patterns even in very distinct languages (Malt et al. 2015). Moreover, while the lexical competition process in SWR is not language-specific, previous studies have highlighted how the competition dynamics can be modulated by the bilingual development experience (e.g. Bruggeman and Cutler 2019; Sarrett, Shea, and McMurray 2022; Shin et al. 2015), or individual differences (e.g. McMurray et al. 2010), regardless of the similarity between the bilinguals' L1 and L2. Thus, it is possible that transfer from L2 to L1 lexical competition dynamics can occur, as evidenced by the weakened effects of L1-Spanish rhyme competitors observed in this study. Consequently, we posit that the changes in the L1 competition dynamics exhibited by the Spanish attriters align with the Competition model and should be considered as a consequence of L1 attrition.

Further support for this interpretation comes from the analyses of the predictor variables related to bilingual experience. The shift in L1 looking patterns, which prioritises information contained in the onset rather than the rhyme, becomes more pronounced over time and with an increase in L2 proficiency. These results corroborate previous findings linking these two factors to L1 attrition effects (e.g. Dussias and Sagarra 2007; Segalowitz 1991).

Language aptitude, particularly its phonetic/phonemic coding component, also modulated cohort competition effects for both attriters and Spanish monolinguals. Participants who were more skilled at identifying speech sounds and establishing sound-symbol associations presented longer fixations on cohort competitors. This outcome finds support in the extensive evidence on SWR where a more robust cohort competition prevails over rhyme candidates due to their initial advantage at the activation stage (Allopenna, Magnuson, and Tanenhaus 1998; Magnuson et al. 2003). We propose that participants with enhanced phonetic/phonemic coding abilities could have experienced heightened sensitivity to the word's onset information due to its initial phonetic similarity to the target, resulting in a greater reliance on rapidly activated cohort competitors over rhyme-aligned ones (Figure 7).

In terms of L2 competition dynamics, the Spanish attriters swiftly activated and suppressed both cohort and rhyme candidates. However, distractor candidates received comparable attention, indicating a lack of strong bias towards either type of competitor. This suggests they did not rely on them to resolve temporal ambiguity during within-L2 competition. The absence of significant effects from cohort and rhyme competitors can be attributed to the participants' high levels of L2 proficiency. More experienced L2 users, particularly older and more proficient L2 speakers, exhibited quicker suppression of L2 competitors, aligning with existing literature (e.g. Blumenfeld and Marian 2013; Botezatu et al. 2022; Sarrett, Shea, and McMurray 2022).

Conclusion

The present study provides evidence that Spanish-English attriters employ distinct competition dynamics from the ones presented by their L1 monolingual counterparts when disambiguating auditory input during L1 spoken word recognition. In terms of L1 processing, the attriters rely less on the rhyme, which is typically more informative for disambiguation processes in their L1, but they exhibit performance driven by their L2. Additionally, the Spanish attriters with higher English proficiency are able to disambiguate the L2-English spoken word more quickly, relying less on competitors. Two external factors linked to L1 attrition – L2 proficiency and length of residence – influenced the participants' performance. Highly proficient bilinguals with longer exposure in the L2 environment adjust their competition dynamics to align more closely with monolingual L2 users. Based on the Competition model, we argue that the observed changes in the bilinguals' L1 competition resolution dynamics provide evidence of L1 attrition, as the prolonged transfer from the L2 has likely influenced the protective factors that typically safeguard the L1, such as entrenchment. Consequently, the attriters in our study demonstrated a shift in their L1 competition mechanisms, aligning more closely with their L2, where the rhyme of the word contributes less to the competition resolution.

The study's demonstration of contrasting lexical processing between the attriter and monolingual systems contributes to a better understanding of the fine-grained changes occurring during spoken word recognition across the bilingual development spectrum. Particularly, it addresses how bilingual attriters, an understudied population, manage the lexical competition process and how their competition resolution mechanisms are modulated by individual differences and specific bilingual experience. However, many questions remain unanswered regarding how other bilingual populations with different levels of proficiency and exposure navigate this complex competition process. Additional research should investigate how the linguistic attriter system differs from other bilingual systems, such as heritage speakers and sequential bilinguals, in order to explore the extent to which bilingual variability impacts lexical competition in both first and second languages.

The data that support the findings of this study are available on request from the corresponding author, C.S.

Notes

1. In keeping with the terminology proposed by Schmid and Köpke (2017), we will refer to the experimental group under investigation as attriters. By using this name, we do not presuppose that any changes have, in fact, taken place in their L1.
2. The monolingual speakers under investigation were classified as such due to their restricted exposure to a second language, primary limited to their educational curriculum in their respective home countries until the age of 16. Although they had encountered a second language during their schooling, their understanding was either non-existent or extremely limited, as indicated by their responses to the personal background questionnaire.
3. Out of the 292 pictures used, 33 were created by a professional graphic designer. These images were also controlled for name and image agreement, stress, frequency, and number of syllables. Prior to application in the study, all the visual stimuli were piloted.

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Appendix

Sociolinguistic and Personal Background Questionnaire (SPBQ)

1. Please, write your name and surname
2. What is your date of birth?
3. What is your gender?
4. Where were you born? Please give the name of the village/town/city and country.
5. What is (are) your mother tongue?
6. What is the highest level of education you have completed?
7. If you have done a university degree, in which year are you?
8. If you have done a university degree, what degree have you studied?
9. What do you do for a living?
10. When did you come to the UK?
11. Have you ever lived in another country, other than the UK and your country of birth?
12. If you've indicated that you have lived in another country, please say here which country that was.
13. What language(s) did you acquire before starting school?
14. If you marked 'other', please specify the language(s) here.
15. Did you attend any English classes before coming to the UK?
16. What language or languages did you learn professionally or at school?
17. What language or languages did you learn outside of an educational environment?
18. Have you ever been back to your home country since leaving for the UK?
19. In general, how would you rate your English language proficiency before you came to the UK?
20. In general, how would you rate your English language proficiency at present?
21. In general, how would you rate your Spanish language proficiency before you came to the UK?
22. In general, how would you rate your Spanish language proficiency at present?
23. How often do you speak Spanish?
24. Do you consider it important to maintain your Spanish?
25. In general, do you have more Spanish-or English-speaking friends in the UK?
26. Do you feel more at home with British or with your home culture?
27. Are you in frequent contact with relatives and friends from your country?
28. Do you ever watch Spanish television programmes?
29. Do you ever read Spanish newspapers, books or magazines?
30. Do you feel more comfortable speaking Spanish or English?
31. Could you, please, indicate to what extent you use Spanish in the domains provided? You may simply tick the box:
    - At work; With friends; With your relatives; With your flatmates
    - all the time; frequently; sometimes; rarely; very rarely
32. Could you, please, indicate to what extent you use English in the domains provided? You may simply tick the box:
    - At work; With friends; With your relatives; With your flatmates
    - all the time; frequently; sometimes; rarely; very rarely
33. You have come to the end of this questionnaire. Is there anything you would like to add? This can be anything from language-related comments to remarks about the questionnaire.

Experimental item lists from the visual world tasks in Spanish and English

Table 4. Experimental items used in the visual world task in Spanish.

Target item	Cohort competitor	Rhyme competitor	Unrelated item
Paja (Hay)	Pavo (Peacock)	Hoja (Leaf)	Reina (Queen)
Barba (Beard)	Barco (Boat)	Tumba (Grave)	Genio (Genie)
Rama (Branch)	Ramo (Bouquet)	Cama (Bed)	Bolso (Purse)
Tabla (Wood)	Taza (Cup)	Jaula (Cage)	Pierna (Leg)
Beso (Kiss)	Vela (Candle)	Hueso (Bone)	Libro (Book)
Novia (Bride)	Nota (Musical note)	Lluvia (Rain)	Cuadro (Picture)
Bota (Boot)	Bola (Ball)	Gota (Drop)	Cisne (Swan)
Lata (Can)	Labios (Lips)	Puerta (Fence)	Hongo (Mushroom)
Perro (Dog)	Pera (Pear)	Gorro (Hat)	Hilo (Thread)
Puente (Bridge)	Puerta (Door)	Guante (Glove)	Bolsa (Bag)
Burro (Donkey)	Bucle (Loop)	Carro (Wagon)	Percha (Hanger)
Pato (Duck)	Pata (Paw)	Gato (Jack)	Olla (Pot)
Rana (Frog)	Radio (Radio)	Luna (Moon)	Ducha (Shower)
Gancho (Hook)	Ganso (Goose)	Corcho (Cork)	Búho (Owl)
Casa (House)	Cabra (Goat)	Rosa (Rose)	Yunque (Anvil)
Cuna (Crib)	Cubo (Block)	Trona (Highchair)	Bomba (Bomb)
Placa (Badge)	Playa (Beach)	Vaca (Cow)	Pistola (Gun)
Rayo (Lightning)	Raya (Ray)	Tallo (Stem)	Vino (Wine)
Humo (Smoke)	Hucha (Piggybank)	Termo (Thermos)	Pulpo (Octopus)
Regla (Ruler)	Remo (Oar)	Jungla (Jungle)	Bruja (Witch)
Llave (Key)	Llama (Llama)	Nube (Cloud)	Tipi (Tepee)
Garra (Claw)	Gafas (Glasses)	Sierra (Saw)	Concha (Shell)
Copa (Wineglass)	Coma (Comma)	Capa (Cape)	Pinzas (Tweezers)
Lobo (Wolf)	Loro (Parrot)	Globo (Balloon)	Roca (Rock)
Pecho (Chest)	Pelo (Hair)	Techo (Roof)	Tigre (Tiger)
Mapa (Map)	Mazo (Hammer)	Arpa (Harp)	Mosca (Fly)
Arma (Gun)	Árbol (Tree)	Goma (Rubber)	Piña (Pinecone)
Cuerda (Rope)	Cuernos (Antlers)	Hada (Fairy)	Cactus (Cactus)
Ancla (Anchor)	Anca (Frog leg)	Chancla (Flip flop)	Casco (Helmet)
Moño (Bow)	Lápiz (Pencil)	Pozo (Well)	Peine (Comb)
Metro (Subway)	Media (Stocking)	Potro (Foal)	Tanque (Tank)
Mono (Monkey)	Moto (Motorcycle)	Cono (Ice cream cone)	Nudo (Knot)
Planta (Plant)	Plancha (Iron)	Llanta (Tire)	Morsa (Walrus)
Pala (Shovel)	Palo (Stick)	Ala (Wing)	Coche (Car)
Peso (Weight)	Pesca (Fishing)	Queso (Cheese)	Alce (Moose)
Clavo (Nail)	Clase (Class)	Pavo (Turkey)	Mujer (Woman)
Lima (Lime)	Libra (Pound)	Pluma (Feather)	Dedo (Finger)
Vaso (Glass)	Baño (Toilet)	Oso (Bear)	Huevo (Egg)
Niña (Girl)	Niño (Boy)	Piña (Pineapple)	Ojo (Eye)
Tronco (Log)	Trono (Throne)	Banco (Bench)	Piano (Piano)

Table 5. Experimental items used in the visual world task in English.

Target item	Cohort competitor	Rhyme competitor	Unrelated item
Barrel	Barrow	Camel	Necklace
Apron	Acorn	Onion	Palm tree
Button	Bucket	Onion	Present
Candle	Cannon	Needle	Bathtub
Monkey	Money	Donkey	Tweezers
Medal	Meadow	Bottle	Drawer
Iron	Eyebrow	Wagon	Dentist
Hammer	Hammock	Pitcher	Dustpan
Hanger	Handcuffs	Burger	Hippo
Rooster	Ruler	Toaster	Trumpet
Lemon	Lettuce	Bacon	Rocket
Letter	Leopard	Lobster	Cookie
Lightning	Lightbulb	Earring	Mushroom
Lion	Lighthouse	Dragon	Closet
Lighter	Light switch	Beaver	Ashtray
Magnet	Magpie	Helmet	Thermos
Mirror	Mixer	Anchor	Table
Lipstick	Lizard	Music	Cowboy
Carrot	Carriage	Parrot	Ladle
Teapot	Tepee	Robot	Ladder
Jacket	Jack-knife	Rabbit	Pizza
Paper	Paintbrush	Diaper	Ostrich
Pencil	Penguin	Apple	Toilet
Pillow	Pillar	Arrow	Windmill
Pumpkin	Puzzle	Dolphin	Airplane
Rainbow	Raincoat	Window	Glasses
Razor	Raincoat	Tractor	Panda
Radish	Racket	Jellyfish	Mailbox
Tire	Tiger	Dresser	Pirate
Toothbrush	Toothpaste	Paintbrush	Curtain
Turtle	Turkey	Whistle	Eagle
Wallet	Waffle	Biscuit	Trophy
Butter	Bucket	Waiter	Package