THE DYNAMICS OF LEXICAL ACTIVATION AND COMPETITION IN BILINGUALS' FIRST VERSUS SECOND LANGUAGE

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ABSTRACT

Speech input causes listeners to activate multiple candidate words which then compete with one another. These include onset competitors, that share a beginning (*bumper*, *butter*), but also, counter-intuitively, rhyme competitors, sharing an ending (*bumper*, *jumper*). In L1, competition is typically stronger for onset than for rhyme. In L2, onset competition has been attested but rhyme competition has heretofore remained largely unexamined. We assessed L1 (Dutch) and L2 (English) word recognition by the same late-bilingual individuals. In each language, eye gaze was recorded as listeners heard sentences and viewed sets of drawings: three unrelated, one depicting an onset or rhyme competitor of a word in the input. Activation patterns revealed substantial onset competition but no significant rhyme competition in either L1 or L2. Rhyme competition may thus be a "luxury" feature of maximally efficient listening, to be abandoned when resources are scarcer, as in listening by late bilinguals, in either language.

Keywords: spoken-word recognition, bilingualism, lexical competition, eyetracking

1. INTRODUCTION

To understand spoken language, listeners have to segment separate words out of a continuous stream of incoming speech that does not typically contain clear word boundaries. Listeners do not wait until the end of an utterance, but start processing as soon as they hear the first phoneme. Words that match the incoming speech are activated in the listener's mind and as the speech continues, and more information about the intended words becomes available, most of the activated words are no longer supported by the speech input and are hence discarded. A word is recognised when only one lexical candidate remains and 'wins' this lexical competition (see [14] for a review), a process that can be successfully captured by eye-tracking studies [1, 30], in which participants' eye gaze is recorded as they listen to speech while viewing displays of images or written words on a computer screen. The strength of lexical activation of the words or the images depicting them is reflected by the number and duration of looks to them. Typically, words that overlap with the onset of a spoken word ("onset competitors") compete both earlier in time and more strongly for recognition than words that overlap with the offset [i.e., rhyme competitors; 1, 25].

Second language (L2) listeners face many spoken-word recognition problems that do not trouble native (L1) listeners, as when phonetic misperception [e.g., 5, 15, 17] leads to the activation of spurious lexical candidates [8, 13] and failure to de-activate words that no longer match the speech input [12]. These problems make L2 listening harder than L1 listening [e.g., 11, 16]. As yet, however, it is not known how L1 and L2 lexical processing compare in one and the same listener. If the activation and competition of word candidates occurs in the same way in L2 as in L1 listening, then L2 listeners will show L1-like onset-rhyme effects. We here address this question in a population of Dutch-English bilingual emigrants living in an L2 immersion environment (Australia). This population allows us to ask further whether listeners who predominantly use, and are highly proficient in, their L2, still show the typical lexical competition processes in their L1. In equivalent experiments in each of their languages, we compare the processes of lexical activation and competition in L1 and L2 listening as revealed by the patterns of eye gaze to drawings representing competitor words that overlap with the onset or rhyme of a heard word.

2. METHOD

2.1. Participants

Eighteen Dutch emigrants from Sydney, Australia, (aged 27 – 73 years, M = 50.1, SD = 15.4; 11 females) participated in two experiment sessions in exchange for a small reimbursement. Data from two further participants were discarded due to calibration problems in both sessions. All participants were native speakers of Dutch, who had migrated to Australia as adults (mean age at migration = 29.3 years, SD = 8.5). Their mean length of residence in Australia was 21.3 years (SD = 16.1). Participants were highly proficient in both Dutch and English, with mean scores of 92.2% (SD = 5.8) on the Dutch and 94.1% (SD = 5.2) on the English version of LexTALE [21]. Written informed consent was obtained from all participants.

2.2. Design and materials

Two versions of the experiment were constructed in parallel. The materials in the L1 version were in Dutch, in the L2 version in English. Three sets of 40 sentences – one set each for Onset and the Rhyme conditions, and one filler set – were recorded with neutral intonation by a female native speaker of Dutch (L1 version) or Australian English (L2 version). Recordings were made with Adobe Audition in a sound-attenuated booth at a 44.1 kHz sampling frequency. Each sentence contained a critical word that was not easily predictable from the preceding context (e.g., *The box did not contain the butter that the customer had ordered*) and was paired with a visual display of four black-and-white line drawings. Three drawings were distractors (neither semantically nor phonologically related). In filler trials only, the fourth drawing depicted the critical word itself, while in Onset and Rhyme conditions, the fourth drawing depicted a competitor that shared respectively its onset or rhyme with the critical word (e.g., *button* as onset competitor for *butter*, *jumper* as rhyme competitor for *bumper*). Thus a "target" drawing matching the critical spoken word was absent from the competitor conditions, as in the standard predecessor studies with this paradigm [18, 24]. Competitor/target and distractor images were counterbalanced across four fixed positions on the screen. Mean overlap for the onset competitors was 3.8 phonemes in the L1 and 3.5 phonemes in the L2 materials; mean rhyme overlap was 3.2 and 3.5 phonemes in the L1 and L2 materials respectively.

As bilinguals may activate lexical candidates from both languages during spoken-word recognition [29, 31], all distractors in each trial were phonologically unrelated to the critical word they occurred with, both in L1 and L2. Since cognates are particularly affected by cross-language co-activation [6], any competitors that were cognates in Dutch and English were always paired with distractors that were cognates in both languages as well. This was the case in 17 Onset and 13 Rhyme trials in the L1 experiment, and in 18 Onset and 14 Rhyme trials in the L2 experiment.

2.3. Procedure

All participants completed L1 and L2 experiment sessions, approximately three weeks apart (M = 18.3 days, SD = 4.7, range 12 – 29 days). Session order was counterbalanced across participants. The experimenter (the first author) is a native speaker of Dutch who is fluent in English and the language that was spoken during each session depended on the participant's preference. For the majority of participants, this was Dutch. The same experimental procedure was followed for both sessions.

Participants were tested individually in a sound-attenuated booth, while seated in front of a computer screen at a comfortable viewing distance. Participants' eye movements were recorded at a sampling rate of 1000 Hz (monocular) using an Eyelink 1000 Tower Mount system with chin and forehead rest (SR Research, Ltd.). Auditory stimuli were presented over Beyerdynamic DT770 pro headphones at a loud but comfortable level that was kept constant for all participants. Written instructions were presented on the screen in the language of the experimental session and were subsequently repeated orally by the experimenter and clarified if needed. Participants were instructed only to listen to the sentences and to not take their eyes off the screen. Before the start of the experiment, the eyetracker was calibrated and validated using a 9-point calibration grid. An automatic drift check was conducted after every five trials and calibration was subsequently repeated if required. Each trial began with a fixation cross appearing in screen centre; participants were instructed to look at this cross until it disappeared. At this point the visual display was shown for 1s. After this preview period the sentence started playing while the display remained on the screen.

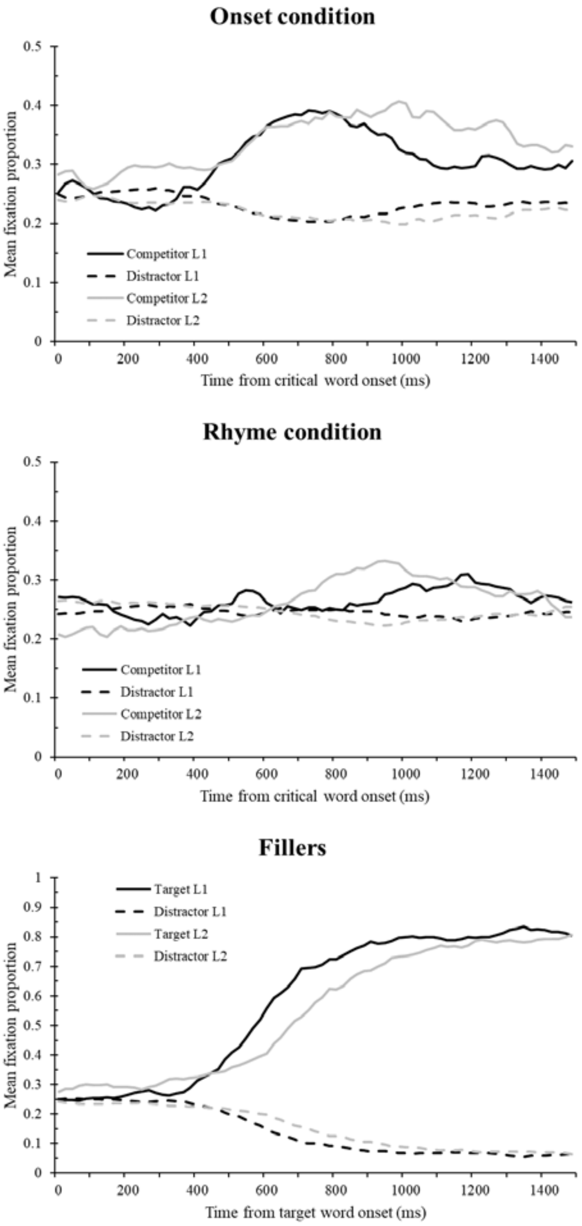
The experiment presented here formed part one of a larger eyetracking study with several listening conditions. Within each session, participants were presented with only 60 of the 120 available sentence-display pairs (20 Onset, 20 Rhyme and 20 filler trials). One set of 60 pairs was used with half the participants, the remaining pairs with the other half, in a different randomisation per participant.

3. RESULTS

Data for one participant in the L1 experiment and two other participants in the L2 experiment were excluded from analysis due to calibration difficulties. Data from 17 L1 listeners and 16 L2 listeners (18 unique participants) were thus included in the reported comparisons. (N.B.: Analysis of data from only those 15 participants who completed both experiments yielded the same significant effects and interactions as reported here.) To maintain integrity of the eyetracking data, trials with a track loss percentage above 30% were excluded from analysis. This was the case for 10 of 1020 trials for the L1 experiment and 29 of 960 trials for the L2 experiment. Fig. 1 shows, for both experiments, the mean fixation proportions to competitors and distractors from the onset of the critical word for the Onset (top panel) and the Rhyme condition (middle), and the mean fixation proportions to target and distractors for the filler trials (bottom). Proportions were calculated over 20 ms time bins and distractor proportions averaged over three distractors.

For a comparison of the lexical competition listeners experienced in L1 and L2, the looking behaviours of the L1 and L2 experiments were analysed within over a 1s time interval starting at 400 ms after critical word onset. The start of this window was chosen as the time point at which the lines representing the proportion of looks to the target and to the distractors start to diverge in the filler trials.

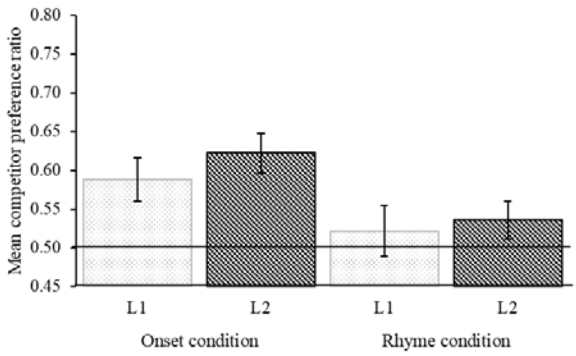
Figure 1: Fixation proportions from target word onset in L1 and L2.



3.1 Competitor preference ratios

First, we calculated competitor preference ratios for each type of competitor in both languages to assess the strength of lexical competition. A competitor preference ratio above 0.5 indicates that of all looks to competitors and distractors, over half were directed to the competitor picture, and thus that the competitor did compete for recognition. Ratios were computed by dividing the total number of competitor fixations in the analysis window by the sum of all competitor and distractor fixations in the same window. (N.B. as each display contained three distractors and only one competitor picture, distractor fixation totals were divided by three.) Fig. 2 shows L1 and L2 competitor preference ratios per condition. For each experiment, competitor preference ratios were compared to 0.5 in a one-sample two-tailed t-test by participants (1) and by items (2). Onset competitors were fixated significantly more than distractors, both in L1 ($M_1 = 0.60$, $t_1(16) = 4.21$, $p < .001$; $M_2 = 0.57$, $t_2(39) = 2.86$, $p = .007$) and L2 ($M_1 = 0.60$, $t_1(15) = 3.62$, $p = .003$; $M_2 = 0.57$, $t_2(39) = 2.49$, $p = .017$). Rhyme competitors did not attract more looks than distractors, however, either in L1 ($M_1 = 0.50$, $t_1(16) = 0.20$, $p = .842$; $M_2 = 0.48$, $t_2(39) = 0.71$, $p = .480$) or L2 ($M_1 = 0.54$, $t_1(15) = 1.15$, $p = .268$; $M_2 = 0.51$, $t_2(39) = 0.24$, $p = .814$). This suggests that in both L1 and L2 listeners experienced competition from onset competitors, but not from rhyme competitors. Paired t-tests showed that competition strength did not significantly differ for L1 and L2 either for onset ($t(14) = 1.25$, $p = .231$) or for rhyme competitors ($t(14) = 0.72$, $p = .483$).

Figure 2: Mean competitor preference ratios for L1 and L2. (Error bars: standard errors of the means.)



3.2 Time course analysis

To compare listeners' looking patterns in L1 and L2 (Fig. 1), a time-course analysis was performed on competitor fixation proportions across competitor conditions and languages using weighted empirical logits [3] with linear mixed-effects regression models [LMER; 2] in R [26], using the packages lme4 [4] and lmerTest [19]. As the inclusion of participants and items as crossed effects is typically not possible for eye-tracking experiments due to the strong correlation between individual fixations, separate by-participants and by-items analyses are usually carried out for these experiments. Here, only a by-participants analysis was conducted, as items differed across languages. Competitor fixations were aggregated into 50 ms time bins across items and transformed to empirical logits

[3], including in the total number of fixations for each time bin only fixations on competitors or distractors. Competitor (onset competitors coded as -0.5, rhyme competitors as 0.5) and Language (L1 coded as -0.5, L2 as 0.5) were added as fixed categorical predictors. Time was added as a continuous fixed predictor, as well as random intercepts and slopes for participants and for aggregated fixations nested within participants. Table 1 shows the results of this analysis.

Table 1: LMER: competitor fixations in L1 and L2.

Effect	Est.	SE	*t*-value
(Intercept)	-0.84	0.07	-12.26*
Time	0.16	0.11	1.50
Competitor	-0.50	0.14	-3.70*
Language	0.01	0.05	0.28
Time * Competitor	0.31	0.20	1.53
Time * Language	0.19	0.09	2.19*
Competitor * Language	0.14	0.10	1.38
Time * Competitor * Language	-0.44	0.18	-2.50*

* $p < .05$

The analysis shows a main effect of Competitor type, with a β-value of -0.50, indicating that across both languages, onset competitors attracted more looks than rhyme competitors. The analysis also reveals a significant two-way interaction between Time and Language, whereby over time, fixation proportions are maintained longer in L2 than in L1. Finally, the significant three-way interaction of Time, Competitor and Language, suggests that the maintained fixations affect the competitor types at different time points.

4. DISCUSSION

This investigation of bilinguals' L1 and L2 listening dynamics has found largely similar processes in both languages, with some difference in the time course of lexical activation (start of word form processing) but none in the presence of lexical competition (relative activation of competitors' versus distractors' word forms). The Dutch-English bilinguals experienced longer-lasting activation of onset competitors, and earlier activation of rhyme competitors, in L2 than in L1. This suggests greater difficulty of suppressing lexical candidates in L2, as per previous findings [e.g., 9, 31]. But although they experienced substantial onset competition, there was no indication of significant rhyme competition in either language.

The lack of rhyme competition here contrasts with the rhyme-competitor effects that are typically found for L1 listeners, including for control groups of L1 listeners of Dutch and English with the very materials used in this study [10]. It also disagrees with findings for L2 listening by [28], who found robust onset and rhyme competition for Korean L2 listeners of English that was no different from that experienced by the American L1 participants. Those Korean L2 listeners, however, were only 9.4 years old on average when they moved to the United States (i.e., considerably younger than our participants, who were all at least 18 years of age at emigration), so it is unsurprising that they would show more native-like listening behaviour than the present participant group.

We hypothesize that working memory (WM) may explain the lack of rhyme competition demonstrated in L1 as well as L2 listening. First, listeners may have lower WM span in L2 than L1 listening [27]. Second, spoken-word recognition is not language-selective. Lexical candidates from the L1 are activated during L2 listening, and vice versa, at least in proficient, immersed listeners [e.g., 7, 20, 23, 31]. This may lead bilinguals to activate more competitors – and thus use more WM resources – in both L1 and L2 listening than monolingual listeners of either language.

Note that readers with larger WM capacities (as measured by a reading-span task) resolve temporary syntactic ambiguities more slowly than readers with lower WM capacities [22]. This is held to imply that readers with more WM entertain alternative meanings of an ambiguity longer than those with less WM, who quickly accept a probable interpretation. Drawing a parallel with spoken-word recognition, this may suggest that monolingual listeners – whose WM need only store competitors from a single language – have sufficient WM capacity available to consider both onset and rhyme competitors. Bilinguals, whose WM juggles competitors from multiple languages, may not have such capacity. Due to the temporal nature of speech, onset competition typically occurs earlier than rhyme competition. Thus, by the time rhyme competitors start overlapping with the incoming speech signal, a large part of bilingual listeners' WM resources is already in use by activated onset competitors from the L1 and L2. Following a reasoning parallel to that of [22], this may mean that bilinguals are quicker to discard rhyme competitors – which are less likely lexical candidates than onset competitors – than monolingual listeners and thus do not show the levels of rhyme competition in L1 and L2 listening that are typical for L1 listeners of either language. The fact that the WM capacity span appears to be smaller in L2 listening may itself further contribute to a reduction of rhyme competition.

We conclude that (a) rhyme competition effects in L1 listening seem to weaken or disappear for listeners who live in an L2 immersion environment where they predominantly use the L2, (b) even highly proficient L2 listeners do not appear to exhibit the rhyme competition pattern typically found in L1 listeners, and (c) rhyme competition may thus be a "luxury" feature of maximally efficient listening, to be abandoned when resources are scarcer.

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