FOLLOWING THE PATH OF LEXICAL ACCESS IN BILINGUALS (SPANISH-ENGLISH) THROUGH EYE-TRACKING

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ABSTRACT

Lexical access has been suggested by Huettig and McQueen [4] to show cascade processing when auditory and visual information are presented to native speakers. The aim of this study was to determine whether cascade processing in Spanish-English bilinguals in a Mexican university is similar to that observed in native speakers.

Two groups of participants were formed according to their level of English: high and low proficiency. No differences were found between groups. Although visual preference for three competitors was different in four time windows, supporting the existence of lexical processing in cascade, a significant preference for the semantic competitor was found, in contrast to the route found in native speakers [4]. These results support the notion of lexical processing in cascade, revealing a different retrieval of lexical information when auditory and visual input is presented in a second language.

Keywords: lexical access, bilinguals, eye-tracking

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1. INTRODUCTION

Research on lexical access has suggested the use of cascade processing when auditory and visual information are presented to native speakers [4]. That is, retrieval of phonological and semantic knowledge besides visual-shape information, stored previously in memory, plays an important role in word recognition.

Thus, the acquisition of a second language (L2) modify how a person interacts with words. Some cognitive models argue that lexical access in bilinguals depends on L2 proficiency [5]. That is, during the first stages when learning a L2, bilinguals need to translate L2 words to their first language (L1) in order to access to L2 word's meaning. Consequently, high proficiency bilinguals access directly to the meaning of the L2 words without translation. This evidence may suggest that bilinguals perform a lexical cascade processing since lexical access depends on the sensorial information that is being perceived.

However, some factors can modify the lexical access path reported by Huettig and McQueen [4]. For example, Huettig, Singh, and Mishra [2] demonstrated that literacy affects the path of lexical activation when phonological and semantic competitors are presented simultaneously. That is, less literate participants showed a preference for the semantic over the phonological competitor, while more literate ones showed an equal preference for both. The authors suggested that higher literacy supports a broader activation of linguistic elements stored previously in one language.

Therefore, the aim of the present research is to examine whether L2 students of English follow the same path of lexical access as native speakers when presented simultaneous auditory and visual information in the L2. As in the previous studies, lexical access was measured by an eye-tracking task which is a method of assessing the attention to images that represent elements of an object of interest. According to Huettig, Olivers, and Hartsuiker [3], eye-tracking can show the cognitive processes embedded in lexical access and previously stored information about a word. We hypothesized that high proficiency (HP) English's students will exhibit more marked eye-fixation in response to phonological referents from a critical auditory word than low proficiency (LP) English's students.

2. METHOD

2.1. Participants

Forty Mexican college students enrolled in English as L2 were recruited (mean age = 23.53 years, *SD* = 5.4, range = 19-43). Twenty-three were male and 17 were female.

Two groups, High Proficiency (HP) and Low Proficiency (LP), were formed according to their L2 scores measured by three subtests of the TOEFL test, as described in the Instruments section. Participants' characteristics and the results of all tests are provided in Table 1. Ten additional participants were excluded due to low scores on the Listening Comprehension, Grammar-Structure, and Grammar-Written Expression subtests.

Table 1: Demographic Data and Proficiency Scores in L2.

	High proficiency	Low proficiency	*t*-test
	M (*SD*)	*M* (*SD*)	
Age	21.95 (3.15)	25.26 (6.72)	p = n.s.
Gender (male/female)	10/10	13/7	n.a.
Listening Comprehension	18.10 (3.14)	7.30 (2.55)	$p < .001$
Grammar-Structure	9.05 (1.05)	6.45 (1.46)	$p < .001$
Grammar -Written Expression	13.75 (3.24)	8.65 (2.99)	$p < .001$
Total Proficiency in L2	58.54 (6.92)	31.04 (4.66)	$p < .001$

2.2. Instruments

L2 proficiency was determined using three sections of the Test of English As a Foreign Language (TOEFL): Listening Comprehension (30 questions); Grammar-Structure (15 items), and Grammar-Written Expression (25 items). The maximum total score was 100 points. Participants who scored 50 points or higher formed the HP group, and those who scored less than 50 points formed the LP group.

2.3. Stimulus Selection

The stimuli consisted of 150 English concrete nouns that were familiar to participants, according to the language curriculum at this institution.

Thirty experimental trials were designed; each included an auditory critical word and four competitor words represented with images: a phonological competitor, a semantic competitor, a shape competitor, and a distractor. Images were collected from the Snodgrass and Vanderwart [7] object pictorial set as well as the image database from the Psycholinguistics Lab of the Faculty of Psychology, UNAM. Visual stimuli were presented in black and white pictures (315 x 280 pixels). The selection of the auditory critical word was defined by word frequency in Spanish, according to the COLMEX database [1], and then associated with the American English word frequency, according to the SUBTLEXus database [8]. Each auditory critical word, such as "cherry", was embedded in a neutral phrase (e.g. "Yesterday he saw the *cherry*"). The phrases were recorded by a female speaker of American English in neutral intonation (48,000 Hz and 16 bits).

The phonological competitors overlapped with the critical word as follows: in 5 words the phonological competitor and the critical word overlapped in the first phoneme; in 17 words the overlap occurred in the first two phonemes (e.g. cherry-chair); in 7 words it occurred in the first three phonemes, and in one word it occurred in the first four phonemes. The phonological competitor was unrelated to the critical word, both semantically and with respect to its shape.

Semantic competitors were delimited by semantic association according to the University of South Florida Free Association Norms [6] and were associatively related to the critical word (e.g., cherry-apple). Semantic competitors were unrelated to the critical word both phonologically and with respect to shape.

Shape competitors shared visual properties with the auditory critical word (e.g., cherry-bomb) but were associatively and phonologically unrelated. Distractors were unrelated to the critical word, semantically, phonologically, or with respect to shape.

2.4. Experimental Design

Thirty experimental trials were presented to each participant. Each started with the presentation of a fixation point for 500 ms. At the offset of the fixation point a blank screen was presented for 600 ms, followed by the presentation of four pictures (three competitors and one distractor). The onset of the critical word occurred 2300 ms after the onset of the four pictures, which were visible for 3600 ms. Each experimental trial lasted 4700 ms. The onset of the critical word was the time zero for statistical analysis. The analysis window started 100 ms before the critical word and ended 1000 ms after it (Figure 1). The experimental trials were counterbalanced in two sequences; each competitor and distractor was presented in different locations of the four quadrants.

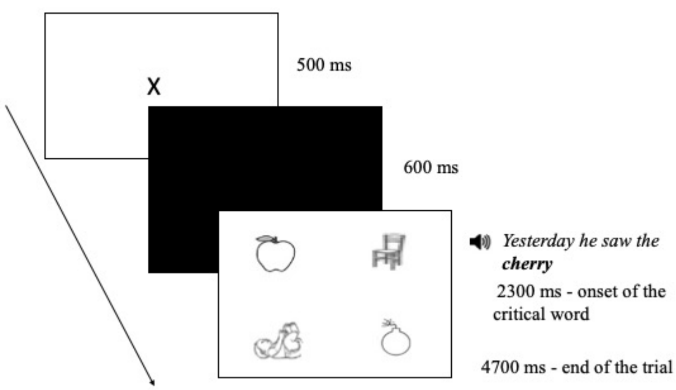
2.5. Procedure

Participants attended to two experimental sessions: in the first they took the proficiency test, and in the second they performed the visual world task. The task was conducted using the Tobii X2-30 eye-tracker, located immediately below a 24-inch screen. This eye-tracker records gaze data at 30 Hz with an average accuracy of 0.5° visual angle. The Tobii Studio package was used to present the trials. Participants sat centrally, 60 cm from the screen.

Prior to the experimental trials, their gaze was calibrated using a five-point procedure in which an attention-getter appeared in every position of a 3 x 3 grid of calibration points. The experiment initiated after four or more points were successfully calibrated for both eyes. Auditory stimuli were presented through a single loudspeaker located behind the screen.

Participants did not perform any explicit task. That is, they were instructed to listen to the sentences carefully and to look to whatever they wanted to as long as they kept their eyes on the screen throughout the experiment.

Figure 1: Example of the trial sequence in the experiment.



2.6. Scoring

Areas of interest were defined according to the size of the individual stimulus (315 x 280 pixels). For statistical analysis we computed the proportion of looks for the three competitors and the distractor every 100 ms, as in Equation 1:

(1)

$$\frac{P}{\sum_{i=1}^{n} P_i}$$

where P is each picture showed to participants (competitor or distractor) and *n is the number of pictures*. The proportion of fixation time is the dependent variable in the analysis reported below. In order to obtain eye fixation based on the auditory critical word, we conducted a baseline correction, as in Equation 2:

(2)

$$x_i - BL$$

where *x* is the ith fixation sample from -100 ms to 1000 ms, with respect to the critical word, and *BL* is the mean of fixation samples in baseline from -100 ms to 0 ms. After baseline correction the chance level was zero.

3. RESULTS

A 4 x 12 x 2 analysis of variance (ANOVA) was performed with within-subjects factor Competitor (phonological, semantic, shape, and distractor) and Bin (baseline and the following eleven bins), and two inter-subjects factors, Proficiency in L2 (HP and LP). Greenhouse-Geisser correction was used in order to avoid Type I Error. The analysis of proportion of looks revealed a main effect of Competitor (F(3,114)=7.73, p<.001, η^2_P = 0.16) and two-way interaction of Competitor and Bin (F(33,389)=8.69, p<.001, η^2_P = 0.18). It is important to note that the main three-way interaction was not statistically significant (F(3,114)=.92, p= n.s., η^2_P= 0.02).

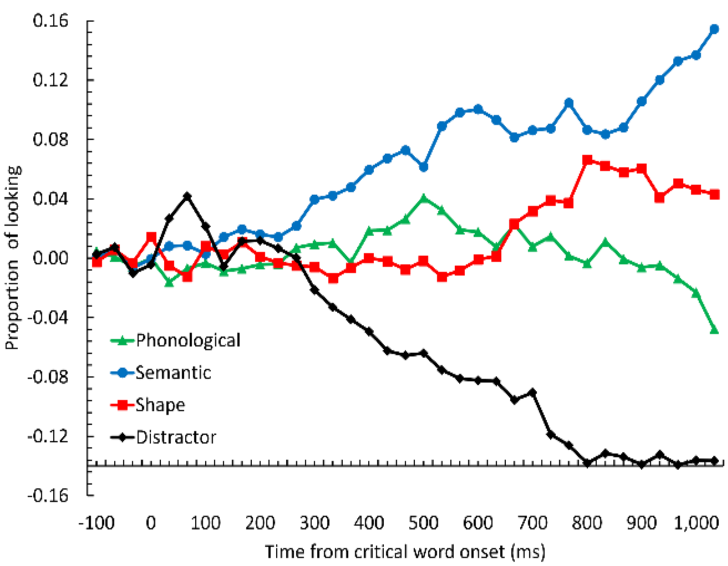
Bonferroni's comparison to explore the interaction of Competitor and Bin showed that both groups looked at the four competitors a similar number of times during the -100 to 399 ms time window. From 400 to 499 ms, participants looked more at the semantic competitor than at the distractor ($\bar{x} = .04, p = .002$). During the 500 to 599 ms time window, they looked more at the phonological and semantic competitors than at the distractor ($\bar{x} = .05, p = .004$). From 600 to 1000 ms, they looked more at the semantic, phonological, and shape competitors than at the distractor ($\bar{x} = .08, p < .001$).

Finally, during the 900 to 1000 ms time window, participants looked more at the semantic competitor than at the phonological competitor ($\bar{x} = .09, p < .001$). That is, overall, participants looked more at the semantic competitor.

Additionally, post-hoc *t*-test comparisons to detect significant effects due to chance (0.0) were performed for both groups. The results were as follows, with the values for the semantic competitor in parentheses, since the analysis showed it to be the competitor of interest. During the -100 to 399 ms time window, there were no significant differences. From 400 to 499 ms, the semantic competitor and the distractor were significantly different from chance ($\bar{x} = .01, t = 2.3, p = .02$). During the 500 to 599 time window, the phonological and semantic competitors and the distractor were significantly different from chance ($\bar{x} = .05, t = 2.1, p < .04$). From 600 to 699 ms, the semantic competitor and distractor were significantly different from chance ($\bar{x} = .08, t = 4.0, p = .00$), and from 700 to 1000 ms, the semantic and shape competitors and the distractor were significantly different from chance ($\bar{x} = .09, t = 3.7, p = .00$).

The time course of the proportion of looks at each competitor is presented in Figure 2. It is important to note that there were no differences between the LP and HP groups.

Figure 2: Time-course graph showing proportion of looks of both groups of participants at each competitor.



4. DISCUSSION AND CONCLUSIONS

The results support the notion of lexical processing in cascade, as reported by Huettig and McQueen [4]. However, lexical access to L2 was observed in the following order, according to the proportion of looks: semantic competitor, phonological competitor, and shape competitor. In contrast, the route found in native speakers showed a preference for the shape competitor [4]. This result is close to that of Huettig, Singh, and Mishra [2], suggesting that lexical access in L2 may be possible through L1 semantic knowledge – word's meaning-. This path might lead to a co-activation of both languages in this sample.

Furthermore, participants with HP showed no differences from LP students in the lexical access time course. This result can be explained by environmental conditions of HP participants, Although, they had high proficiency in the standardized test, they were not immersed in a bilingual context. It is possible that participants in a bilingual environment show different patterns of lexical access. Additionally, it would be advisable to employ more tools to assess L2 proficiency in order to explore further on the factors involved in a L2 learning and proficiency. Therefore, more studies are needed to survey on the development of the HP in bilinguals.

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