Implicit Memory Support for Bilingual Speech Processing: An Investigation of Auditory Word Priming in English-Spanish Bilinguals

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1. Introduction

1.1. Bilingual speech learning

Of all aspects of language, phonology arguably poses the most difficulty for adult bilinguals and second-language learners.[1] For example, bilinguals' second-language (L2) production is frequently marked by an accent (Flege, Munro, & MacKay, 1995) residing in, but not limited to, non-native articulation of sounds (Guion, Flege, Liu, & Yeni-Komshian, 2000). Bilinguals' L2 comprehension is similarly characterized by perceptual confusions arising whenever contrasting L2 sounds are subsumed perceptually by similar native-language (L1) sounds (Guion, Flege, Akahane-Yamada, & Pruitt, 2000), implicating an L1 bias in L2 processing. In addition, bilinguals' difficulty in L2 perception and production is also revealed in training studies, which yield relatively minor improvements and little generalization beyond training materials, in spite of massive instruction (Bradlow, Pisoni, Akahane-Yamada, & Tohkura, 1997).

However, these difficulties inherent in learning L2 phonology stand in stark contrast to many bilinguals' near-native attainment in learning an L2 lexicon (Weber-Fox & Neville, 1996), illustrating a striking discrepancy between their ability to acquire the meaning of an unfamiliar word and their capacity to accurately perceive and produce it. This discrepancy is in fact even more perplexing given that, in L1 development, learning the lexicon predominantly entails a (nearly) simultaneous and successful acquisition of both the phonological and referential properties of words. The present study adopted an information-processing perspective to investigate possible reasons for this discrepancy and thus sought an explanation for bilinguals' difficulty in acquiring L2 phonology at the level of language-processing mechanisms.

One question central to an investigation of language processing lies in identifying a potential mechanism which operates at the level of spoken-word processing and underlies word learning. Another related question resides in developing an adequate description of this mechanism, a description which may be applied to both L1 and L2 development. Thus the overall objective of the present study was to answer both of these questions. In particular, the present study extended the study of spoken-word processing from an L1 to an L2 to determine whether and to what extent auditory word priming—one mechanism of spoken-word processing—is available in L2 spoken-word processing. In so doing, the present study sought to explain why learning L2 phonology so often poses a considerable problem for adult bilinguals.

[1] Acknowledging the theoretical and practical features of the distinction between bilinguals and second-language learners, both second-language learners and bilinguals are here described as are bilinguals. The term "native language" is here used to refer to a language which bilinguals acquire first and to which they are exposed from early infancy. The term "second language" is here used to refer to a language which bilinguals acquire after infancy. See Mack (2003) for further clarification of this distinction.

1.2. Definition of auditory word priming

The present study was situated within a theoretical framework which postulates that knowledge of language structure is an emergent property of lexical learning. That is, such knowledge emerges as a "by-product" of a learner's experience with language, in particular with the lexicon (Bates & Goodman, 1997; Beckman & Edwards, 2000). In essence, phonological and syntactic generalizations, typical of a native speaker's knowledge of language, are viewed as an emergent property of lexical development. Inherent in this position is the claim that lexical learning does not constitute the process of mere memorization of distinct word forms. Rather, lexical learning represents the process of learning phonological, morphological, and syntactic regularities of language from the ambient linguistic input. In the course of such learning, language learners apply their knowledge of such regularities, derived from already familiar words, to the acquisition of novel words. (See Broe & Pierrehumbert, 2000, and MacWhinney, 1999, for reviews.)

An important step in developing a comprehensive account of language learning as part of learning the lexicon undoubtedly constitutes a systematic investigation of a viable mechanism enabling the learner to both build robust lexical representations and acquire important phonological regularities inherent in the lexicon. In L1 development, one such candidate mechanism capable of building and updating auditory representations of words in response to recent experience is exemplified by auditory word priming (Church & Fisher, 1998; Schacter & Church, 1992).

Auditory word priming illustrates the phenomenon of unconscious and unintentional facilitation in auditory processing of words. Defined as a time and/or accuracy benefit for repeated (and therefore familiar) versus non-repeated (novel) linguistic material, auditory word priming is a ubiquitous outcome of processing auditorily presented verbal information in a variety of memory tasks. For example, listeners are more likely to process more rapidly and/or to identify more accurately the words they have heard in recent experience (repeated words) than the words they have not heard in recent experience (unrepeated words). This processing advantage (defined as more rapid and/or more accurate responses) that such repeated words have over unrepeated words is here referred to as an "auditory word-priming effect." Following the practice of Church and Fisher (1998), the term "auditory word priming" here refers to the mechanism that underlies priming effects in spoken-word processing.

1.3. Properties of auditory word priming

Auditory word priming displays a number of important characteristics, one of which is its stimulus-specific nature. Stimulus specificity of auditory word priming ensues from the observation that the amount of processing facilitation is further enhanced for those words that are also matched for a number of contextual details. For example, repeated words spoken in a familiar voice promote more rapid and accurate responses in a word-recognition task than the same words spoken in an unfamiliar voice (Craik & Kirsner, 1974). Other investigations have revealed similar additional processing benefits due to listeners' familiarity with other contextual details of spoken words—speaker's gender (Schacter & Church, 1992), the intonation in which a spoken word is uttered (Church & Schacter, 1994), its pitch (the perceptual equivalent of fundamental frequency, Church & Schacter, 1994), and phonetic context (Fisher, Hunt, Chambers, & Church, 2001). Word-priming effects are thus largest when two renditions of a spoken word also share one (or more) context-specific details.

In contrast to the facilitative effects of a repeated phonological context (Goldinger, Luce, & Pisoni, 1989) or of a semantically related word (Neely, 1991), which rarely last more than a second, auditory word-priming effects are long lasting. For example, reliable processing benefits for repeated spoken words are maintained over delays of 8 seconds (Cole, Coltheart, & Allard, 1974), several minutes (Church & Schacter, 1994), days, and even weeks (Goldinger, 1996). These findings suggest that auditory word-priming effects have a long-term memory component.

Another attribute of auditory word priming lies in its relative insensitivity to the type of processing in which listeners engage during their initial exposure to words. This is most clearly observable in experimental manipulations of listeners' attentional processing orientation. Thus the magnitude of processing facilitation is relatively uniform whether or not listeners are oriented, at the time of initial exposure to spoken words, to the auditory/perceptual or semantic/conceptual properties of words (sounds or meanings of words, respectively, Church & Schacter, 1994). More importantly, this finding suggests that auditory word-priming effects emerge as an automatic consequence of word processing (Church & Fisher, 1998).

Finally, auditory word priming displays a constancy in language development. Church and Fisher (1998) examined whether auditory word-priming effects would be manifest in very young monolingual children. Indeed, children as young as 2 showed robust processing facilitation in their identification of previously studied words, whether or not their attention had been directed to the semantic properties of words during study. These results underscore the involvement of auditory word priming in speech processing by children and adults and implicate its perceptual rather than conceptual nature.

1.4. Auditory word priming as a learning mechanism

As these findings suggest, auditory word priming emerges as a context-specific, long-lasting, non-semantic, and apparently developmentally constant phenomenon—a characterization which perhaps accentuates its important role in speech processing by children and adults. In fact, Church and Fisher (1998) recently identified auditory word priming as a likely mechanism supporting spoken-word processing and learning. In particular, they argued, auditory word priming may provide the support for building and using auditory representations of words in language development. First, because auditory word priming does not require access to word meaning, it may reflect the process whereby listeners build and use pre-semantic *auditory* representations. Second, because the magnitude of auditory word priming depends on the perceptual match between words, word priming most likely arises as a consequence of creating and using context-specific auditory word representations. Finally, the long-lasting and developmentally constant nature of auditory word priming renders it an automatic mechanism for the encoding and retrieval of auditory word representations. Thus, according to Church and Fisher (1998), auditory word priming may provide the necessary support for building word representations that do not require prior knowledge of word meaning and that generalize across linguistic and nonlinguistic variability found in speech.

It is therefore possible that auditory word priming may also support spoken-word processing in an L2; hence the overall objective of the present study was to determine whether and to what extent this mechanism is available to bilinguals. Conversely, however, auditory word priming may not play such a role or it may be involved differently in L1 vs. L2 spoken-word processing. For example, auditory word priming may be mediated or even eliminated in situations when listeners' attention is directed away from the perceptual details of spoken words in an L2. In fact, such situations may not be unusual in those learning contexts where the formal (i.e., auditory and structural) properties of a language are not emphasized to the same extent as are its meaningful (i.e., semantic and conceptual) properties. Whatever their underlying source, such differences, if demonstrated, may provide at least one reason why learning L2 phonology seems to pose such a considerable problem for adult bilinguals.

Overall, research on auditory word priming in monolinguals provides the necessary theoretical and empirical foundation for extending the investigation of auditory word priming to include bilinguals. Thus Experiment 1 of the present study determined whether and to what extent auditory word priming, as a mechanism of spoken-word processing, is available to bilinguals. In turn, Experiment 2 examined the effect of attentional processing orientation on auditory word priming, one factor which may cause potential differences in the involvement of auditory word priming in L1 vs. L2 processing.

2. Experiment 1

2.1. Auditory word priming in bilinguals' L1 and L2

Because, as numerous visual word-priming studies have demonstrated (e.g., Durgunoğlu & Roediger, 1987), visual word processing evinces priming benefits in bilinguals' two languages, it is likely that comparable benefits arise in bilinguals' auditory word processing as well. However, only three studies have, to date, examined auditory word priming in bilinguals and only one has done so in detail. For example, Woutersen, Cox, Weltens, and de Bot (1994; de Bot, Cox, Ralston, Schaufeli, & Weltens, 1995; Woutersen, de Bot, & Weltens, 1995) measured auditory word priming in a lexical-decision task to examine interdialectal influences on lexical processing in speakers of different dialects of

Dutch. (The testing was restricted to the auditory modality because the Maastricht dialect of Dutch does not have an orthography which is distinct from standard Dutch.) Woutersen et al. reported the processing benefits in bilinguals' both dialects. More recently, Ju and Church (2003) extended these results in a study with English-Spanish bilinguals by providing evidence of auditory word priming in Spanish, the bilinguals' less dominant language.

Although these findings provide support for the existence of auditory word-priming effects in an L2, they do not suggest that such effects are quantitatively identical in bilinguals' two languages. That is, the involvement of word priming in an L2 does not necessarily entail that a specific speech-processing capacity is transferred in its entirety from an L1 to an L2, or that the same type of capacity is used in L1 and in L2 processing. One possibility may be that the magnitude of priming effects is dependent on bilinguals' amount of experience, greater proficiency, or stronger dominance in a language. For example, Kirsner, Smith, Lockhart, King, and Jain (1984) demonstrated that English-French bilinguals who were native speakers of English and claimed at least 10 years of experience with French showed larger visual word-priming effects in English than in French, implying greater processing benefits in their perhaps more dominant language. In a similar visual lexical-decision experiment, Scarborough, Gerard, and Cortese (1984; see also Ju & Church, 2001) found that English monolinguals, who effectively had no familiarity with Spanish, displayed a smaller amount of processing facilitation in Spanish than did Spanish-English bilinguals. Similarly, Smith (1991) reported that English-French bilinguals, high-school students participating in a French immersion program, showed larger visual word-priming effects in English than in French. Taken together, these findings suggest that, at least in the visual modality, word-priming effects are reduced in bilinguals' less dominant language.

The objective of this experiment was thus to determine whether and to what extent auditory word priming is involved in spoken-word processing in bilinguals' two languages. Two hypotheses were proposed. One hypothesis was that auditory word priming was involved in spoken-word processing in bilinguals' two languages. The other hypothesis was that the involvement of auditory word priming would be greater in bilinguals' more dominant than in their less dominant language. To test these hypotheses, English-Spanish bilinguals, all native speakers of English, were tested in tests of auditory word priming in English and Spanish. If bilinguals benefit from previous experience with spoken words in their two languages, they should process repeated words more rapidly than unrepeated words, and such processing benefits should be comparable in both English and Spanish. Conversely, if bilinguals demonstrate substantially reduced levels of sensitivity to previously encountered words in their less dominant language, processing benefits should be larger in English, bilinguals' L1, than in Spanish, their L2.

2.2. Participants

The participants in this experiment were 20 English-Spanish bilinguals (13 females and 7 males). All were adult college-age (*M* = 19.6; *SD* = 1.0 years) native speakers of English who were enrolled in a third-semester course of Spanish as a second language. Prior to testing, the participants had completed on average .5 semesters of Spanish instruction in middle school, 5 semesters in high school, and 1 semester in college, for an average of 6.4 semesters all together. The participants started learning Spanish as adolescents (*M* = 14.1; *SD* = 1.3 years). For those who indicated using Spanish outside the classroom, the use of Spanish was minimal and primarily involved the use of individual Spanish words or phrases in conversations with (predominantly) non-native speakers of Spanish. Individuals of Latino descent, those who had had extensive experience speaking Spanish, as well as those who had been exposed to Spanish outside regular Spanish instruction were excluded from the participant pool.

The participants were asked to rate their language proficiency on a scale between 1 ("I do not know any English/Spanish") and 10 ("I am a native speaker of English/Spanish") to verify that they were all native speakers of English and had a comparable level of proficiency in Spanish. The analysis of these ratings yielded a mean proficiency score of 9.8 (*SD* = .4) in English and a mean proficiency score of 4.6 (*SD* = 1.2) in Spanish. Two production tasks were administered to obtain additional measures of the participants' proficiency in Spanish. The tasks consisted of (a) reading a passage of approximately 80 words in Spanish taken from an introductory Spanish textbook (VanPatten, Lee, & Ballman, 1996), and (b) speaking extemporaneously in Spanish in response to questions posed orally by the experimenter. Analyses of reading accuracy were performed by the experimenter; ratings of foreign accent in extemporaneous speech were performed by ten judges, all of whom were native speakers of Spanish. The participants made an average of 6.3 errors (*SD* = 2.7) and were rated with a mean score of 3.7 (*SD* = 1.4) on a 9-point scale (1="heavy foreign accent," 9="no foreign accent"). The participants' self-ratings and the results of the production tasks indicated that the participants were at a native-speaker level of proficiency in English and at a low-intermediate level of proficiency in Spanish.

2.3. Materials

The materials consisted of two sets of 72 words, one set in English and the other in Spanish (see Appendix). No translation equivalents or cognates were used. The English set consisted of common English words familiar to college-age native speakers of English. For the construction of the Spanish set, 108 Spanish words had been drawn from the pool of the core vocabulary taught in an introductory course in Spanish (VanPatten et al., 1996), a course immediately preceding the one from which the participants were drawn.[2] The selected words were pre-tested with 286 learners of Spanish from this course to further ensure that the participants were familiar with the words included in the final Spanish set. (Each Spanish word was rated by at least 69 learners.) The learners translated each Spanish word into English, rated their familiarity with each word on a scale from 1 to 7 (1= "unfamiliar word," 7= "familiar word"), and rated each word for its cognate status, indicating how similar the Spanish word looked and sounded to an English word on a scale from 1 to 7 (1="word does not look and sound similar to any English word," 7="word looks and sounds similar to an English word"). Included in the Spanish word set were only those words that were translated by at least 80% of the raters, whose mean familiarity was 5 or higher, and whose mean cognate status was 4 or lower.

The selected English words were recorded by 6 adult native speakers of American English from the U.S. (3 males and 3 females). The selected Spanish words were recorded by 6 adult native speakers of Spanish from Spain (3 males and 3 females). The recordings took place in a sound-attenuated booth. Two repetitions of 112 words (72 target words and 40 fillers) were visually presented on a computer screen in 4 randomized lists one at a time with a 2-sec inter-stimulus interval (ISI). The speakers were asked to read the words aloud as naturally as possible. Their production was recorded using a Tascam DAT taperecorder (DA-P1) and a Shure unidimensional head-mounted microphone (SM10A). The recorded words were digitized at 16 kHz, ramped off during the first and last 15 msec to eliminate audible clicks, and normalized for peak intensity and perceived loudness. The words were not edited in any other way and were thus representative of the acoustic-phonetic variability found in speech. The better token of each word (of the two recorded) was selected for inclusion in the word sets.

The words in the English and Spanish word sets did not differ in syllable length, word frequency, or spoken-word duration. The words in both sets were on average 2.3 syllables long and included an equal number of high-, medium-, and low-frequency words. The English word set contained words with a mean frequency of 169.6 (21-1171) occurrences per million (Kucera & Francis, 1967). The Spanish word set contained words with a mean frequency of 127.9 (2-831) occurrences per million (Juilland & Chang-Rodríguez, 1964). The English word set contained words of a mean duration of 495 msec. The Spanish word set contained words of a mean duration of 457 msec.

The 72 English and 72 Spanish words were further divided into 2 sets of 36 words for which 6 words were randomly chosen from each speaker's productions, with each speaker therefore contributing 6 words to each set. In each language, the two sets of 36 words were used to construct 4 study-test list pairs. Each pair contained a 36-word study list and a 72-word test list. The test list included the entire list of study words (36 repeated words) and a list of test words (36 unrepeated words). Each word equally often appeared in study and test lists.

[2] No words contained the letters and letter sequences *z*, *ce*, or *ci* that are pronounced as a voiceless dental fricative /θ/ in peninsular Spanish and as a voiceless alveolar fricative /s/ in Latin-American varieties of Spanish. The inclusion of such words would have biased the word set toward those learners who had been exposed in their classes to the peninsular variety of Spanish.

2.4. Procedure and design

The testing was conducted individually in a quiet location using a personal computer and speech-presentation software (Smith, 1997). Each experimental session lasted approximately 60 minutes. The participants were seated at a desk with a set of loudspeakers (Harman/Kardon) positioned in front of them. The instructions were given in English, the participants' native language. In the first phase of the experiment, the study phase, the participants were asked to listen to 46 words (36 study words and 10 fillers) auditorily presented with a 5-sec ISI. Following the study phase of the experiment, the participants engaged in a simple distractor task spanning approximately 3-4 minutes: The participants performed a series of simple arithmetic problems printed on a sheet of paper. The purpose of this task was to clear the participants' short-term memory and to allow some time to pass between the study and the test phases of the experiment. Immediately following the distractor task was the test phase of the experiment conducted in the same language as the preceding study phase. An immediate-repetition task (Onishi, Chambers, & Fisher, 2002) was used in the test phase of the experiment to estimate auditory word priming. In this task, the participants were instructed to listen to 80 words (72 test words and 8 fillers) auditorily presented one at a time over loudspeakers and to repeat each word as rapidly and as accurately as possible. The participants' responses were audiotaped using a Tascam DAT recorder (DA-P1) and a Shure head-mounted microphone (SM10A). The participants were given 5 sec to repeat each word.

Considering the total duration of the study phase, the distractor task, and the test phase, the time that elapsed between the first presentation of a word in the study phase and its subsequent presentation in the test phase varied between 4 and 28 minutes, with a mean of 16 minutes. Thus auditory word priming was measured with a mean time lag of 16 minutes. In the remainder of the experimental session, the study and test phases of the experiment, including the intervening distractor task, were conducted in the other language.

A 2×2 mixed factorial design was used in this experiment. The within-participant variables, each composed of two levels, were language (English vs. Spanish) and repetition (repeated vs. unrepeated words). The participants were tested in both languages on both repeated (primed) and unrepeated (unprimed) words. The order of testing (English vs. Spanish) was counterbalanced across the participants. Thus half of the participants completed the study and test phases of the experiment in Spanish followed by the study and test phases of the experiment in English. The other half of the participants performed the language tests in the reverse order. The participants were equally frequently assigned to the 4 study-test list pairs.

2.5. Data analysis

Included in the final data analyses were only words familiar to the participants. Word familiarity was established in a Spanish word-knowledge test administered at the end of the testing session. (No such test was administered in English because all participants had been exposed to English from birth and spoke English natively.) In this test, the participants were asked to translate each Spanish word into English and then rate, on a scale between 1 ("I don't know the word at all") and 7 ("I know the word very well"), how familiar they were with the word. The data based upon responses to unknown and unfamiliar Spanish words (i.e., the words the participants were unable to translate) were excluded from the final data analyses. The final dataset thus only included the participants' responses to well-known and familiar Spanish words.

The dependent variable used in this experiment was response latency, defined as the length of time (in milliseconds) between the offset of the stimulus word and the onset of the participant's response (i.e., repetition of the word). (See Figure 1 for a schematic representation of this variable.) Response latency had been used extensively to investigate auditory word-priming effects in a native language (e.g., Onishi et al., 2002). If response latency provides an accurate measure of processing time (Sternberg, 1966), then a comparison of response latencies for repeated vs. unrepeated words may help determine the extent to which repeated words are processed faster than unrepeated words—i.e., to measure an auditory word-priming effect.

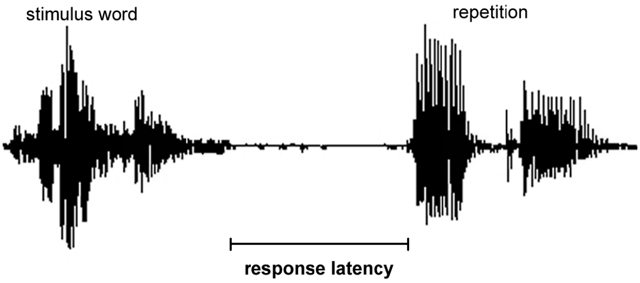

Figure 1. Schematic representation of response latency.

Measurements of response latency were made from digital audiotaped recordings of the test phase of the experiment in English and in Spanish. The recordings were transferred onto a computer for further analyses using *CoolEdit,* a digital speech-analysis software (Syntrillium Corporation, 2000). Durational measurements were taken directly from the waveform display. Response latency was measured between two cursors placed to demarcate the end of phonation of a stimulus word and the beginning of phonation of a participant's response (i.e., a participant's repetition of the stimulus word; Figure 1).

The obtained response-latency data were tabulated separately in each language (English, Spanish) for 36 words that appeared in both the study and the test phases of the experiment (repeated words) and for 36 words that appeared only in the test phase of the experiment (unrepeated words). Response-latency scores were computed in two ways: (a) for each subject by averaging durational measurements across items (words), and (b) for each item by averaging durational measurements across subjects. These subject- and item-based scores were subsequently submitted to separate analyses of variance (ANOVAs). (Results of the subject analyses are designated by the subscript "1" [e.g., F_1 or t_1]. Results of the item analyses are designated by the subscript "2" [e.g., F_2 or t_2].) In all ANOVAs, alpha (α) was set at .05. Significant main effects and interactions were explored using Bonferroni tests (t-tests with α adjusted for number of pairwise comparisons).

2.6. Results

The response-latency data were submitted to a two-way ANOVA with language and repetition as within-subjects factors. This analysis yielded a significant main effect of language, $F_1(1,19) = 10.37$, $p < .025$, $F_2(1,35) = 42.34$, $p < .001$, and repetition, $F_1(1,19) = 40.14$, $p < .001$, $F_2(1,35) = 13.99$, $p < .001$, but no significant language × repetition interaction. Bonferroni tests ($\alpha = .01$) revealed that response latencies were shorter in English than in Spanish for both unrepeated words, $t_1(19) = 3.11$, $p < .01$, $t_2(35) = 4.34$, $p < .001$, and repeated words, $t_1(19) = 3.30$, $p < .01$, $t_2(35) = 9.00$, $p < .001$. These tests also revealed that response latencies were shorter for repeated than for unrepeated words in both English, $t_1(19) = 6.13$, $p < .001$, $t_2(35) = 3.24$, $p < .005$, and Spanish, $t_1(19) = 4.17$, $p < .001$. (In Spanish, this difference did not reach statistical significance in the item analysis.) Mean response latencies for repeated and unrepeated words in English and Spanish are plotted in Figure 2.

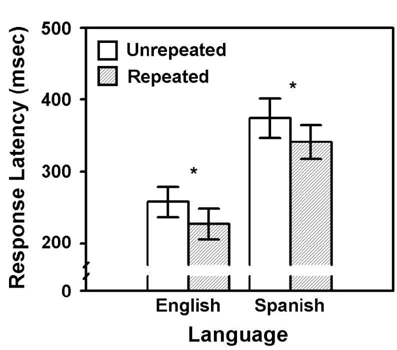

Figure 2. Mean response latency (± 1 SE) as a function of language and repetition (*p < .001).

2.7. Discussion

The objective of this experiment was to determine whether and to what extent auditory word priming is involved in the processing of spoken words in an L1 and in an L2. One hypothesis was that auditory word priming was involved in speech processing in bilinguals' both languages. In support of this hypothesis, results of this experiment revealed that, in both English and Spanish, the bilinguals were faster at initiating word production in response to a repeated than an unrepeated word. That is, an auditory word-priming effect—a temporal benefit in the processing of repeated vs. unrepeated words—was obtained in both languages (although the bilinguals responded less rapidly in Spanish, their L2, than in English, their L1). If response latency provides an accurate measure of processing time (Sternberg, 1966), then this finding suggested that spoken words encountered in recent experience are processed faster than words not encountered in recent experience. More importantly, this finding indicated that listeners benefit from prior experience with spoken words not only in their L1 (Schacter & Church, 1992) but also in their L2. The results of the present study thus complemented the findings of one other study that examined auditory word priming in English-Spanish bilinguals using a perceptual-recognition task (Ju & Church, 2003). These two studies provided the first demonstration that auditory word priming is involved in speech processing in bilinguals' two languages.

The other hypothesis was that the involvement of auditory word priming would be greater in bilinguals' more dominant language than in their less dominant language. However, results of this experiment revealed that the involvement of auditory word priming was comparable in magnitude in both L1 and L2. That is, the English-Spanish bilinguals were on average as fast in English (L1) as they were in Spanish (L2) at initiating word production in response to a repeated word. These findings were consistent with the results of those investigations that found comparable word-priming effects in bilinguals who are proficient in their two languages—both in the visual (Kirsner et al., 1984) and in the auditory (Ju & Church, 2003) modalities—and suggested that word-priming effects are reduced in an L2 only when speakers are unfamiliar with it—i.e., in the earliest stages of L2 learning (Ju & Church, 2001; Scarborough et al., 1984). Overall, these findings emphasized a developmental continuity and constancy in the involvement of auditory word priming in bilinguals' two languages and underscored similarities in bilingual L1 and L2 speech processing.

3. Experiment 2

3.1. Processing orientation and auditory word priming

Although Experiment 1 revealed comparable auditory word-priming effects in bilinguals' two languages, there may be some differences in the extent to which auditory word priming is involved in bilingual L1 and L2 speech processing. For example, auditory word priming in an L2, but not in an L1, may be contingent on attentional processing orientation, a factor which reflects information-processing demands imposed on a language user by a task. This experiment thus systematically examined the effect of processing orientation on auditory word priming in bilinguals' two languages.

The distinction drawn in this study is that between perceptual and conceptual processing orientation (Blaxton, 1989). Under a perceptual processing orientation, a language user largely relies on form-related, perceptual characteristics of verbal or non-verbal stimuli to perform a task. Examples of such tasks include tests of word identification (especially under degraded listening conditions) or word-fragment completion (e.g., e_e_h_ _ t to be completed as *elephant*). The processing involved in these tasks will be termed auditory processing in the present study. Under a conceptual processing orientation, a language user establishes or activates semantic or meaning-related relations between the studied event and the already-known information. Exemplifying conceptual tasks are those requiring a language user to generate an instance of a specific semantic category or to translate a word. The processing involved in these tasks will be termed semantic processing in the present study.

Whereas auditory word priming in an L1 is relatively insensitive to the nature of a processing task—i.e., whether or not listeners' attention is directed to the meaning or form of spoken words (Church & Schacter, 1994; Church & Fisher, 1998), there exists some evidence that auditory word priming in an L2 is susceptible to variations in processing orientation. Thus word-priming effects may be effectively abolished, even under the most favorable of conditions, whenever semantic properties of an

L2 are accentuated during processing. In other words, an explicit emphasis on meaning-based properties of L2 input may eliminate word-priming effects—i.e., benefits arising as a consequence of repeated word forms. For example, Heredia and McLaughlin (1992) demonstrated that visual word-priming effects were heavily attenuated when Spanish-English bilinguals were instructed to recall and translate the words they had previously studied. In essence, a translation task encouraged conceptual processing of words and eliminated any perceptual processing benefits. This finding suggested that priming benefits are effectively removed when a language task does not require the use of perceptual information (see also Basden, Bonilla-Meeks, & Basden, 1994; Smith, 1991). More importantly, this finding underscored one possible L1-L2 difference in speech processing: Whereas a semantic processing orientation may not affect auditory word-priming benefits in an L1, it may substantially reduce or altogether eliminate those in an L2.

The objective of this experiment was thus to determine the effect of processing orientation on auditory word priming in bilinguals' two languages. Two hypotheses were proposed. One hypothesis was that attention to either auditory or semantic properties of spoken words would influence auditory word priming in an L2 but not in an L1. The other hypothesis was that the involvement of auditory word priming would be reduced under a semantic processing orientation. To test these hypotheses, English-Spanish bilinguals were tested in tests of auditory word priming in English and Spanish under two processing-orientation conditions—auditory and semantic. Overall, these tests sought to establish whether auditory word priming is more susceptible to a manipulation of processing orientation in an L2 than in an L1. If so, this finding may provide at least one reason why learning L2 pronunciation often poses a considerable problem for adult bilinguals and may indicate that bilinguals could benefit from an explicit instruction to attend to perceptual properties of spoken words.

3.2. Participants

The participants in this experiment were 40 English-Spanish bilinguals (24 females and 16 males) who were drawn from the same participant pool as in Experiment 1. The participants were randomly assigned to two groups of 20 participants, with each group representing one of the two experimental conditions: (a) auditory, and (b) semantic. One-way ANOVAs were carried out to determine if the participants in these two groups and those who participated in Experiment 1 differed in a number of variables. Results revealed no statistically significant differences among the three groups for any of the 7 variables examined: (a) age, (b) self-rating of proficiency in English, (c) self-rating of proficiency in Spanish, (d) age at the onset of Spanish learning, (e) number of semesters of Spanish taken, (f) number of errors in the reading passage, and (g) accent score. A summary of the participants' characteristics in the three groups is presented in Table 1. (The condition used in Experiment 1—i.e., the condition that contained no explicit processing orientation—will be referred to as the "baseline (none)" condition.)

Table 1
Characteristics of Participants in Three Experimental Conditions

	Experiment 1		Experiment 2			
	None (*N*=20)		Auditory (*N*=20)		Semantic (*N*=20)	
Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*
Chronological age[a]	19.6	0.96	19.7	1.57	20.5	2.79
Age of learning[a]	14.1	1.26	13.5	2.52	13.9	1.09
Semesters of Spanish	6.4	1.84	7.1	4.19	6.5	1.65
English self-rating[b]	9.8	0.41	9.9	0.22	9.9	0.31
Spanish self-rating[b]	4.6	1.23	4.8	1.33	4.3	1.03
Reading errors	6.3	2.67	5.0	2.52	5.9	2.27
Foreign accent[c]	3.7	1.44	3.7	1.41	3.3	1.26

[a]In years. [b]Measured on a 10-point scale (1="I do not know any English/Spanish," 10="I am a native speaker of English/Spanish"). [c]Measured on a 9-point scale (1="Heavy foreign accent in Spanish," 9="No foreign accent in Spanish").

3.3. Materials

This experiment used the same materials as described earlier for Experiment 1.

3.4. Procedure and design

The testing procedure used in this experiment was the same as described earlier for Experiment 1, with one exception. In this experiment, the study phase was different from the study phase in Experiment 1. Depending on the processing-orientation condition (i.e., semantic or auditory), the participants were asked to perform an additional task whose purpose was to orient their attention during processing to either the semantic or auditory properties of the spoken words. In the semantic condition, the participants were asked to rate subjective word pleasantness (pleasantness of the word meaning) on a scale between 1 and 7, with "7" indicating that the word meaning was pleasant and "1" indicating that the word meaning was not. In the auditory condition, the participants were asked to rate subjective word clarity on a scale between 1 and 7, with "7" indicating that the word sounded clearly enunciated and "1" indicating that it did not. In both conditions, upon hearing each word, the participants circled the appropriate rating on an answer sheet. The participants were allowed 5 sec to listen to each word and to mark the appropriate rating.

A 3 × 2 × 2 mixed factorial design was used in this experiment. The between-participant variable—processing orientation—had three levels: (a) auditory, (b) semantic, (c) baseline (none). (Because the objective of this experiment was to determine auditory word-priming effects in English and Spanish in two processing-orientation conditions—auditory and semantic—and to compare these results with those obtained in the baseline (none) condition, the data from Experiment 1 and Experiment 2 were analyzed together.) The within-participant variables, each composed of two levels, were language (English vs. Spanish) and repetition (repeated vs. unrepeated words). Within each of the processing-orientation conditions, the participants were tested in both languages on both repeated (primed) and unrepeated (unprimed) words. The order of testing (English vs. Spanish) and testing materials (4 study-test list pairs) were counterbalanced across the participants at each level of the between-participant variable.

3.5. Data analysis

As in Experiment 1, included in the final data analyses in this experiment were only words familiar to the participants. Word familiarity was established in the word-knowledge test described earlier in Experiment 1. The same dependent variable, data measurement and tabulation procedures, and statistical analyses were used in this experiment as well.

3.6. Results

The response-latency data obtained in the three processing-orientation conditions (none, auditory, semantic; $N = 20$ per condition) were submitted to a three-way ANOVA with processing orientation as between-, and language and repetition as within-subjects factors. This analysis yielded a significant main effect of orientation, $F_1(2,57) = 3.89$, $p < .05$, $F_2(2,105) = 31.91$, $p < .001$, language, $F_1(1,57) = 25.78$, $p < .001$, $F_2(1,105) = 264.78$, $p < .001$, and repetition, $F_1(1,57) = 104.43$, $p < .001$, $F_2(1,105) = 44.32$, $p < .001$, and a significant language × orientation interaction (in the item analysis), $F_2(2,105) = 11.41$, $p < .001$.

Bonferroni tests were used to explore a significant main effect of repetition. These tests revealed an auditory word-priming effect in English in all conditions: (a) baseline (none), $t_1(19) = 6.13$, $p < .001$, $t_2(35) = 3.24$, $p < .005$, (b) auditory, $t_1(19) = 4.80$, $p < .001$, $t_2(35) = 3.71$, $p < .001$, and (c) semantic, $t_1(19) = 3.95$, $p < .001$, $t_2(35) = 3.08$, $p < .005$. Bonferroni tests revealed an auditory word-priming effect in Spanish only in two conditions: (a) baseline (none), $t_1(19) = 4.17$, $p < .001$ (in the subject analysis only), and (b) auditory, $t_1(19) = 4.35$, $p < .001$, $t_2(35) = 3.43$, $p < .005$. No auditory word-priming effect was obtained in the semantic condition in Spanish. Mean response latencies for repeated and unrepeated words in the auditory and the semantic condition are plotted in Figure 3.

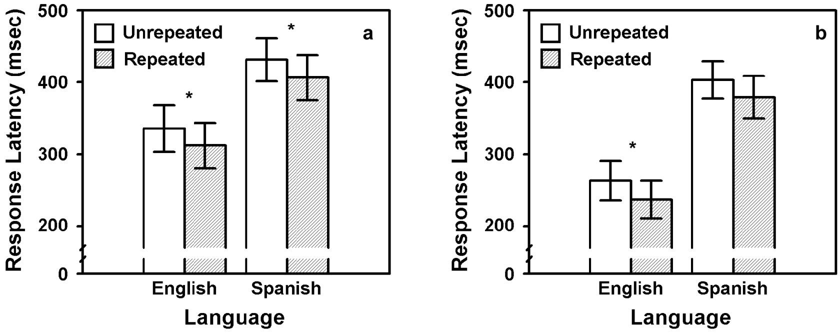

Figure 3. Mean response latency (± 1 SE) as a function of language and repetition in the auditory (a) and the semantic (b) condition (*p < .001).

3.7. Discussion

The objective of this experiment was to determine the effect of processing orientation on auditory word priming in bilinguals' two languages. One hypothesis was that attention to either auditory or semantic properties of spoken words would influence auditory word priming in an L2 but not in an L1. The other hypothesis was that the involvement of auditory word priming would be reduced under a semantic processing orientation. Results revealed an effect of processing orientation on spoken-word processing. This effect was asymmetrical: The semantic processing orientation affected auditory word priming in an L2 but not in an L1. That is, the participants were faster at initiating word production in response to a repeated than an unrepeated word in all conditions in English and only in the auditory and the baseline (none) conditions in Spanish. Thus an auditory word-priming effect—a temporal benefit in the processing of repeated vs. unrepeated words—seemed to be reduced (and failed to reach statistical significance) when listeners attended to the semantic properties of spoken words in an L2.

At least one explanation for the effect of semantic processing orientation upon auditory word priming in an L2 may be found in analyses of word-priming effects in the visual modality. Semantic influences on word-priming effects have been documented in the visual modality in a variety of tasks—perceptual identification (Jacoby, 1983), word-fragment completion (Blaxton, 1989), and lexical decision (Levy & Kirsner, 1989). Such influences are typically noted when words are presented in a larger semantic context (e.g., in the context of a semantically related word or a phrase; Smith, 1991) or when words are manipulated in a conceptual task (e.g., translation from L1 to L2; Basden et al., 1984; Heredia & McLaughlin, 1992).

One common finding of these and other investigations of word priming in the visual modality is that priming effects depend upon the degree of contextual binding of words in context. That is, the likelihood of word-priming effects increases as the word moves from being presented in a meaningful discourse, to being included in an incongruent context (i.e., in a situation when the word does not fit sensibly in a connected discourse), to being individuated in a word list (MacLeod, 1989).

Masson and MacLeod (2000) recently modified this "contextual-binding" explanation of word-priming effects by proposing that the presence of word-priming effects is contingent upon a certain degree of "distinctiveness" of the perceptual stimuli at study. Their hypothesis was based on the finding that word-priming effects may be reduced not only for words presented in the context of other words or for words presented in a larger discourse but also—under certain circumstances—for words found in isolation. In their study, such circumstances were created by means of a serial-rapid presentation of word lists. It was argued that the serial-rapid presentation of word lists reduced the distinctiveness of individual words and therefore prevented them from being encoded and responded to as distinctively as when such words were presented at a slower rate.

The "distinctiveness" account of word-priming effects is relevant to the findings of this experiment. In particular, this account suggests that perceptual distinctiveness may be achieved by individuating words in word lists, by increasing the amount of experience with words, or by emphasizing their close processing. The obtained auditory word-priming effects were therefore a likely consequence of individuating words in word lists (in the baseline condition) and emphasizing a close processing of words (in the auditory condition). The obtained auditory word-priming effects in the baseline and auditory conditions were comparable in magnitude, suggesting that individuation of words in spoken input may be achieved in several ways. In fact, these findings were in accord with previous reports of significant word-priming effects for individual words presented in word lists (Schacter & Church, 1992), for words presented in conditions that render words somewhat atypical (e.g., for low-frequency words embedded in a phrase, Nicolas, 1998), or for words presented in conditions that direct participants' attention to surface characteristics of words (e.g., for words read under the instructions to proofread textual passages for potential typographical errors; Wippich & Mecklenbräuker, 1995).

The "distinctiveness" account of word-priming effects also suggested that, at least in an L2, a semantic processing orientation (achieved here by means of a secondary task of rating word pleasantness) may reduce the "distinctiveness" of spoken words. Apparently, a semantic processing orientation diverts listeners' attention from individually presented spoken words, reducing the "distinctiveness" of word forms (i.e., perceptual characteristics of words), preventing them from being encoded fully, and thus diminishing priming effects. In this respect, the effect of the semantic processing orientation on priming is akin to that imposed on word priming by a serial-rapid presentation of word lists (Masson & MacLeod, 2000) or by a presentation of words embedded in reading passages (Levy & Kirsner, 1989).

4. General discussion

4.1. Auditory word priming as a bilingual speech-processing mechanism

Taken together, the results of the present study revealed an auditory word-priming effect in bilinguals' both languages, suggesting that—in their L1 and L2 alike—bilinguals benefit from their (repeated) experience with spoken words. Assuming that auditory word priming exemplifies a likely mechanism supporting the processing and learning of a native language (Church & Fisher, 1998), the results of the present study suggested that this mechanism also supports the processing and learning of a bilingual's less dominant language or a learner's second language. In other words, auditory word priming appears to be a mechanism that supports the development of auditory representations of L2 words and the use of such representations in processing.

Although the precise psychological and neural underpinnings of auditory word priming are yet to be determined in future research, the results of the present study were suggestive. They indicated that the processing benefits exemplified by auditory word priming likely represent outcomes of implicit perceptual learning driven by input (Church & Fisher, 1998; see Bower, 1996, Johnstone & Shanks, 2001, and Nosofsky & Johansen, 2000, for theoretical motivations). Whether or not such perceptual learning is specific to language learning or is representative of a general-cognitive learning capacity (Poldrack, Selco, Field, & Cohen, 1999), these findings are important to research in bilingualism and L2 processing and learning. They not only highlight similarities in L1 and L2 processing and learning but, more importantly, also provide a convenient research framework for examining sources of differences between L1 and L2 processing and learning.

4.2. Auditory word priming and L1 vs. L2 speech processing

The findings of the present study indicated that the involvement of auditory word priming in bilinguals' less dominant language (usually L2) may crucially depend upon the nature of a processing task. That is, auditory word-priming effects may be reduced (and perhaps even eliminated) in an L2 in situations when a (predominantly) semantic/conceptual learning task diverts bilinguals' attention from auditory/perceptual properties of spoken words. In other words, auditory word-priming effects may be reduced and even eliminated in situations when the demands of the task do not encourage individuation of spoken words or do not highlight their perceptual (i.e., form-related) distinctiveness.

There are several factors that may contribute to explaining these L1-L2 differences in bilingual spoken-word processing. For example, unlike young children who extract their first words based on acoustic-phonetic properties of spoken words given ample native-speaker input (Gleitman, Newport, & Gleitman, 1984), most adult bilinguals often acquire their L2 without sufficient native-speaker input and by learning semantic and conceptual aspects of L2 words concurrent with, or prior to, learning their perceptual and articulatory correlates. Thus adult bilinguals may tend to process the available input for meaning before encoding the perceptual details of its form (Sharwood Smith, 1986; VanPatten, 1990). Similarly, bilinguals may rely on a semantic processing strategy more in situations when input is complex and learning conditions are not ideal (Rosenberg & Jarvella, 1970). A semantic/conceptual input-processing strategy may also be characteristic of adult bilinguals—i.e., those who acquire their L2 as adults (Bisanz, Kail, Pellegrino, & Siegel, 1979; Segalowitz & Lambert, 1969). If these explanations based on language-learning contexts, the complexity of L2 input, and bilinguals' age are valid, then a semantic attentional orientation imposed on bilinguals by a processing task may further capitalize on their already predominant strategy of processing input for meaning at the expense of form, thus reducing and perhaps even eliminating auditory word-priming effects in bilinguals' L2.

Finally, a related factor that may encourage adult bilinguals to employ a semantic/conceptual strategy to a greater extent in processing spoken words in their L2 than in their L1 may be related to their limited short-term memory capacity. Indeed, at least in the initial stages of L2 learning, bilinguals demonstrate impaired or greatly reduced short-term working-memory spans which improve as they gain more experience in their L2 (Brown & Hulme, 1992). Given an important causal relationship between short-term working-memory capacity and listener's ability to repeat (Papagno, Valentine, & Baddeley, 1991) and eventually learn (Gathercole, Willis, Emslie, & Baddeley, 1991) unfamiliar spoken words, adult bilinguals' limited short-term working-memory capacity may constrain the amount of perceptual detail they comprehend, promoting their reliance on semantic and conceptual processing of L2 input.

Whatever possible reasons for the obtained L1-L2 differences in bilingual spoken-word processing, the findings of the present study prompted the conclusion that perceptual fluency, including the ability to perceive important details of the phonological and morphological structure of an L2, may require an individuation of relevant perceptual information presented in context (cf. Mondria & Wit-De Boer, 1991).

4.3. Concluding remarks

The present study was motivated by a general observation that bilinguals' ability to acquire the meaning of an unfamiliar word is often incommensurate with their capacity to accurately perceive and produce it. Assuming that learning lexical/semantic and phonological aspects of words is driven by learners' experience with language (Bates & Goodman, 1997; Beckman & Edwards, 2000), it was argued that this discrepancy is striking. It was proposed that possible sources of this discrepancy may be found in a study of the mechanisms underlying the processing and learning of bilinguals' L1 and L2. Situated within an information-processing approach to language learning, the present study investigated whether and to what extent auditory word priming—a potential mechanism involved in the processing and learning of spoken words—is involved in bilinguals' L1 and L2.

The results of the present study indicated that bilinguals are sensitive to the "structure" of auditory input (conceptualized within the present study as auditory/perceptual properties of spoken words) not only in their L1 but also in their L2. These results also suggested that this sensitivity is a likely consequence of implicit learning driven by linguistic input (Church & Fisher, 1998). Finally, they emphasized similarities in bilinguals' L1 and L2 development, indicating that the same cognitive processing and learning mechanisms underlie the development of bilinguals' both languages (Ellis, 2002).

More telling for bilingual language processing was the finding of the present study that pointed to at least one L1-L2 difference in bilingual speech processing. In particular, the present study provided evidence that the demands imposed on bilinguals by a perceptual learning task may have a different effect on spoken-word processing in bilinguals' L1 and L2. In other words, the nature of the processing in which bilinguals are engaged may have direct consequences upon the outcomes of bilingual language processing in general and L2 learning in particular. This L1-L2 difference in bilingual speech processing may help explain why learning the pronunciation of spoken words in an L2 so often poses a considerable problem for adult bilinguals.

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Appendix

Spanish Words

abuelo	creer	lavar	poner
adiós	derecha	leche	porque
amigo	después	leer	pregunta
ayer	dinero	libro	querer
ayudar	donde	limpiar	rojo
bailar	escribir	luego	ropa
bajo	escuchar	mano	salir
beber	fiesta	mesa	saludo
boca	fuerte	mirar	semana
bonito	guapo	mujer	siempre
bueno	gusto	nadie	también
caliente	hablar	noche	tarea
casa	hijo	nunca	temprano
chico	huevo	ojo	tiempo
comida	iglesia	oreja	trabajo
compras	invierno	pagar	verano
copa	joven	perro	verde
correr	jugar	poco	vivir

English Words

abroad	corner	husband	ready
advice	country	improve	remain
afraid	demand	income	remember
again	dirty	judgment	review
agreement	discover	laughter	seldom
almost	effort	magic	severe
alone	even	manager	sister
already	expensive	many	stomach
answer	factory	matter	story
area	failure	mistake	suddenly
attitude	finger	officer	summary
average	follow	often	supper
avoid	foreign	pattern	today
become	forgive	pencil	together
belong	government	people	unique
building	happy	properly	water
ceiling	healthy	provide	welcome
city	hungry	random	wonderful

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