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Research report

Language effects in second-language learners: A longitudinal electrophysiological study of spanish classroom learning

Laura Soskey [a], Phillip J. Holcomb [b,c], Katherine J. Midgley [b,c,*]

[a] Department of Psychology, University of Rochester, Rochester, NY, USA
[b] Department of Psychology, San Diego State University, San Diego, CA, USA
[c] Department of Psychology, Tufts University, Medford, MA, USA

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ABSTRACT

How do the neural mechanisms involved in word recognition evolve over the course of word learning in adult learners of a new second language? The current study sought to closely track language effects, which are differences in electrophysiological indices of word processing between one's native and second languages, in beginning university learners over the course of a single semester of learning. Monolingual L1 English-speakers enrolled in introductory Spanish were first trained on a list of 228 Spanish words chosen from the vocabulary to be learned in class. Behavioral data from the training session and the following experimental sessions spaced over the course of the semester showed expected learning effects. In the three laboratory sessions participants read words in three lists (English, Spanish and mixed) while performing a go/no-go lexical decision task in which event-related potentials (ERPs) were recorded. As observed in previous studies there were ERP language effects with larger N400s to native than second language words. Importantly, this difference declined over the course of L2 learning with N400 amplitude increasing for new second language words. These results suggest that even over a single semester of learning that new second language words are rapidly incorporated into the word recognition system and begin to take on lexical and semantic properties similar to native language words. Moreover, the results suggest that electrophysiological measures can be used as sensitive measures for tracking the acquisition of new linguistic knowledge.

1. Introduction

The question of how the mature brain acquires a second language, particularly later in life after a first language has become well established, has received increasing attention in recent years (e.g., Doughty, 2003; Kroll and Tokowicz, 2005). Second language learning, especially in the school setting, presents certain challenges to the language learner and there is evidence that such learning is both more difficult and less likely to result in native-like competence in both language production and comprehension (e.g., Johnson and Newport, 1989; Weber-Fox and Neville, 1996). Here we sought to determine whether previously reported very early changes in the neural response to words in a newly learned language (L2 – McLaughlin et al., 2004) differ from similar neural responses to words in a well-established native (L1) language.

Fundamental to second language learning is acquisition of a new vocabulary (e.g., Nation, 1993). However, most of the work on L2 word processing has focused on advanced classroom learners and behavioral measures of language processing (e.g., Domínguez et al., 2013; Elgort and Piasecki, 2014; Veivo and Jarvikivi, 2013). Comparatively less is known about the timing and sequence of the neuro-cognitive mechanisms that are used by L2 learners during the acquisition of words in their new second language (L2).

Recently a small group of studies has demonstrated the utility of the event-related potential (ERP) technique in examining neuro-cognitive changes underlying word learning in beginning L2 users. In a seminal study, McLaughlin et al. (2004) investigated L2 acquisition at the earliest stages of L2 learning using a paradigm developed by Chwilla et al. (1995). Chwilla et al. had observed that the N400 for the target words in a semantic priming paradigm was largest when the target letter string was a pseudoword, was of intermediate amplitude for target words that followed unrelated primes, and the least negative when a target word was preceded by a semantically related word. In the procedurally similar Mclaughlin et al. study participants were university students who had never studied the target second language (French) prior to

* Correspondence to: SDSU Research Foundation, 6505 Alvarado Rd, Suite 203, San Diego, CA 92180, USA.
E-mail address: kmidgley@sdsu.edu (K.J. Midgley).

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enrollment in an introductory university course in that language. ERPs and behavioral data were collected during three sessions spaced over the first semester of French learning. McLaughlin et al. found that even in the first session, after an average of 14 h of classroom instruction, learners' ERPs demonstrated changes in that pseudoword target items elicited a larger N400 than unrelated or related prime-target pairs. This is very similar to what Chwilla et al. had previously reported for monolingual language processing. McLaughlin et al. also found that these priming effects became more pronounced across sessions (session 2=63 h of instruction, session 3=138 h), suggesting that the effects were a direct result of increasing L2 proficiency. Importantly, ERP data from the first session suggested significant cognitive learning had occurred before behavioral data showed any difference between the experimental group and the control group. The results from this study suggest that the neural consequences of L2 learning can be measured throughout the earliest phases of word acquisition and that the N400 component is a good measure for assessing such learning.

Another study that addresses early L2 learning in university students was conducted by Stein et al. (2006). Participants were English-speaking students in a German language-immersion exchange program in Switzerland. Experimental sessions were conducted before German (L2) learning occurred, and then about 5 months later after intense L2 instruction. ERPs were collected to individual word items from English (L1), German (L2), and Romansh (an unknown language) on both days. Although Stein et al. did not report amplitude differences between L1 and L2 in the N400 during either session, they did find that the duration of the L2 N400 waveform was reduced at the second (post-learning) session.

Finally, more recently Yum et al. (2014) examined the very initial phases of orthographic and semantic acquisition in monolingual native English speakers exposed to Chinese words under controlled laboratory conditions over 10 sessions. Behavioral performance on tests of L2 word learning showed steady improvement over sessions, and these data were used to separate the learners into those who learned quickly and those that took longer to learn new L2 words. ERPs to new L2 words in the two groups revealed qualitatively distinct learning patterns. While fast learners showed an increase in anterior N400 amplitude with training, slow learners showed increasingly more posteriorly distributed positive-going ERPs with learning. The authors suggested that these different patterns might reflect underlying learning strategies used by the two groups with slow learners relying more on holistic pattern processing of Chinese characters and fast learners using a strategy whereby they kept track of a limited set of character parts and their relationships (much like what happens in alphabetic languages).

A parallel (and larger) literature has looked at ERP changes as a function word learning in general – i.e., without telling participants the newly learned items are in a new L2 and/or using items that plausibly could be new L1 words (e.g., Bakker et al., 2015; Borovsky et al., 2010, 2012; Mestres-Miss,é et al., 2007; Perfetti et al., 2005). One prominent theme in this literature is whether there is a need for a consolidation period after new words are learned in terms of their incorporation into the lexical system. Several studies have suggested that new L1 words can be lexicalized very quickly after just a few learning encounters and that word-like N400 effects can be obtained from these items (e.g., Borovsky et al., 2010; Mestres-Miss,é et al., 2007). However, more recently Bakker et al. (2015) have reported evidence that the nature of the ERP effects obtained immediately after learning are somewhat different from those where a longer period of consolidation (24 h in their case) had taken place. Only after consolidation to new word ERPs show effects of lexicalization. In the current study we took advantage of this finding and used a relatively long consolidation period between testing sessions (see below).

1.1. The present study

McLaughlin et al. (2004) and Yum et al. (2014) both demonstrated the rapidity of changes in early L2 acquisition in the form of increases in N400 amplitude as a function of learning. One inference that can be drawn from these findings is that as learners acquire words in their new L2 these new lexical items rapidly start to be processed in a similar fashion to L1 items. In this way L2 word acquisition might be viewed as being similar to learning new words in L1. However, McLaughlin et al. and Yum et al. did not directly compare processing of new L2 items to established L1 items, so it is not clear from their studies how the changes in the N400 they reported are related to those generated by L1 items. This is important because a recent study by Midgley et al. (2009) demonstrated that comparisons between L1 and L2 words in participants learning a new L2 actually show an attenuation of the N400 in L2 compared to L1 and this L1–L2 difference (what they called "language effects") was smaller in more proficient bilinguals. This suggests that the N400 in addition to being sensitive to early learning might also be a more stable marker of language proficiency. However, Midgley et al. did not do a fine grained comparison of L2 learners over the early course of learning and their sample of learners was on average more advanced than those in McLaughlin et al. or Yum et al. So, it is possible that the changes reported by these latter authors actually reflect a short term modulation of the N400 to new lexical items, and that after more extensive L2 learning takes place, the N400 to L2 words declines somewhat. This could happen because initially L2 words might be processed via strong lexical links to their L1 translations, which in turn are used to access meaning. Large N400s would then be due to the strong mapping between the L1 translations and meaning (e.g., as in the RHM model of Kroll and Stewart, 1994). According to this view N400s to new L2 items should not necessarily differ from those recorded to their L1 translation equivalents, although there might be a delay in the time course of the N400 due to the extra step of L2 to L1 lexical mapping. Alternatively, N400s to L2 items during very early learning (as in McLaughlin et al. and Yum et al.) might be on the continuum reported by Midgley et al. – that is, they might be smaller than L1 N400s, but with increasing proficiency they would continue to grow in amplitude. The present study sought to determine (a) whether, with learning, new L2 items show increasing N400 amplitude; and (b) if N400 amplitude to L2 items during learning is smaller than N400 amplitude to equivalent L1 items.

In order to longitudinally examine changes to the N400 to new L2 words, the current study recruited native English-speakers enrolled in an introductory university Spanish course. All participants were initially naïve L2 learners. The stimuli for the experiment were taken from the course curriculum such that data would reflect learning due to formal classroom instruction. ERPs were collected from all participants to both L1 and L2 words in a go/no-go lexical decision paradigm where go events were pseudowords and no-go events were real words. Learners were tested at three time points over the course of the four-month academic semester. We made the following predictions. First, we predicted that we would replicate findings from Midgley et al. (2009), such that L1 items would elicit larger N400 waveforms than L2 words. Second, because Midgley et al. (2009) compared intermediate and proficient bilinguals and showed that the language effect at the N400 was reduced in the more proficient bilinguals, we predicted that as in McLaughlin et al. and Yum et al., as Spanish proficiency increased across sessions, the N400 to new L2 items would increase