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Neural changes underlying early stages of L2 vocabulary acquisition

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ABSTRACT

Research has shown neural changes following second language (L2) acquisition after weeks or months of instruction. But are such changes detectable even earlier than previously shown? The present study examines the electrophysiological changes underlying the earliest stages of second language vocabulary acquisition by recording event-related potentials (ERPs) within the first week of learning. Adult native English speakers with no previous Spanish experience completed less than four hours of Spanish vocabulary training, with pre- and post-training ERPs recorded to a backward translation task. Results indicate that beginning L2 learners show rapid neural changes following learning, manifested in changes to the N400 – an ERP component sensitive to lexicosemantic processing and degree of L2 proficiency. Specifically, learners in early stages of L2 acquisition show growth in N400 amplitude to L2 words following learning as well as a backward translation N400 priming effect that was absent pre-training. These results were shown within days of minimal L2 training, suggesting that the neural changes captured during adult second language acquisition are more rapid than previously shown. Such findings are consistent with models of early stages of bilingualism in adult learners of L2 (*e.g.* Kroll and Stewart's RHM) and reinforce the use of ERP measures to assess L2 learning.

1. Introduction

Learning a second language (L2) is a critical step to succeeding in an increasingly linked world. In addition to the obvious communicative benefits of bilingualism, there has been some evidence suggesting a bilingual advantage in executive control across both linguistic and nonlinguistic domains (*e.g.* Bialystok, Craik, Green, & Gollan, 2009; but see Paap & Sawi, 2014 for an alternative view). Of particular importance is L2 vocabulary acquisition, an integral part of L2 learning that predicts lexical richness in language production, verbal fluency, reading ability, and reading comprehension (Nation, 1993; Laufer & Nation, 1995; Luo, Luk, & Bialystok, 2010; Qian, 2002). Previous research using event-related potentials (ERPs) has shown L2 vocabulary acquisition to be accompanied by neural changes (McLaughlin, Osterhout, & Kim, 2004; Osterhout et al., 2008; Soskey, 2010; Yum, Midgley, Holcomb, & Grainger, 2014). However, while these studies examined beginning L2 adult learners, their assessments followed after weeks or even months of L2 instruction. In the present study, we utilized ERPs to

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track the neural changes during the earliest stages of L2 vocabulary acquisition in naïve learners who began to acquire vocabulary in an L2 and were tested within the same week.

When acquiring words in a new language, learners must first establish knowledge about word forms and then about word meanings. Evidence for this learning trajectory comes from McLaughlin et al.'s seminal study examining beginning classroom learners of French (2004). Using a semantic priming lexical decision task in L2, McLaughlin and colleagues demonstrated that learners show a word-pseudoword N400 ERP effect after only 14 h of classroom instruction. Such lexicality effects have been interpreted in prior studies of first language (L1) to reflect the ability to differentially process known and unknown word forms (*e.g.* Holcomb & Neville, 1990). A semantic priming N400 effect, where learners show smaller N400 amplitudes to target words following related compared to unrelated prime words, manifested after 63 h of instruction, reflecting word meaning activation. This timing difference indicates that acquisition of word form knowledge precedes word meaning knowledge and suggests that a certain L2 proficiency threshold must be reached prior to any word meaning modulations of the N400. Importantly, learners showed these N400 effects in the absence of behavioral effects, indicating that ERPs can be a sensitive methodology for tracking early neural changes in L2 learners.

Models of L2 acquisition, such as the Revised Hierarchical Model (RHM) (Kroll & Stewart, 1994) and the developmental Bilingual Interactive Activation Model (BIA-D) (Grainger, Midgley, & Holcomb, 2010), have characterized this L2 vocabulary acquisition trajectory in adult learners. Specifically, both models propose that the earliest stage of adult L2 vocabulary learning is typically supervised and associative (*e.g.* learners of Spanish are explicitly told that '*cama*' means 'bed'). Learners thus acquire new L2 wordforms simultaneously with their L1 translation wordform activation, such that a strong L2 to L1 lexical link is established. This link leads to differential processing between L1 and L2 words in adult L2 learners, where L1 meaning access is direct while L2 meaning access is indirect/lexically-mediated. In other words, beginning L2 learners access L2 word meanings through their L1 translation wordforms, which are directly connected to meaning representations. One consequence of this architecture is the strong L2 to L1 connection that allows for fast, lexically mediated backward translation (L2 to L1) relative to slower, meaning mediated forward translation (L1 to L2) (Kroll & Stewart, 1994).

ERP support for a stronger backward than forward connection in L2 learners comes from N400 translation priming effects in unbalanced bilinguals that show earlier effects in the L2 to L1 direction than in the L1 to L2 direction (Alvarez, Grainger, & Holcomb, 2003). This effect appears to be lexically mediated as predicted by both the RHM and BIA-D: subsequent findings in another group of unbalanced bilinguals show larger L2 to L1 than L1 to L2 N250 translation priming effects (Schoonbaert, Holcomb, Grainger, & Hartsuiker, 2011). The N250 component has been argued to reflect sublexical to lexical form mapping (Holcomb & Grainger, 2006). However, most asymmetric N400 translation priming effects in unbalanced bilinguals have been found in the opposite direction, with forward, rather than backward, translation priming leading to significant effects (for review, see Duñabeitia, Perea, & Carreiras, 2010). This asymmetry disappears in balanced bilinguals, with similar N400 translation priming effects in both forward and backward directions (Duñabeitia et al., 2010).

One explanation for such progression of translation priming effects is the development of L2 proficiency and its effects on meaning access. Both the RHM and BIA-D posit that as L2 proficiency increases, L2 meaning access becomes less reliant on the L1 system. In highly proficient bilinguals, L2 wordforms are directly connected to meaning and these connections are stronger than any lexical connections from L2 to L1 (Kroll & Stewart, 1994). The BIA-D extends this further by proposing that such a change is due to improved inhibition of L1 lexical representations during L2 processing (Grainger et al., 2010). Specifically, L1 and L2 translation wordforms develop inhibitory links between them as L2 proficiency increases, such that activation of an L2 word no longer activates its L1 translation wordform (Grainger et al., 2010; Grant, Fang, & Li, 2015). This development suggests that moderately proficient bilinguals are in a transitional stage of inhibiting L1 lexical translations during L2 processing, such that L2 to L1 lexical links are weakened while direct L2 to semantics links are strengthened. For balanced bilinguals, L2 to L1 connections are thus semantically mediated and are similar in strength to L1 to L2 connections. With regards to L2 to L1 connections, this progression thus posits that 1) low proficiency adult bilinguals demonstrate strong lexically mediated L2 to L1 processing, 2) moderate proficiency adult bilinguals demonstrate weaker lexically mediated L2 to L1 processing, and 3) balanced adult bilinguals demonstrate strong semantically mediated L2 to L1 processing. Put together, this can explain the different asymmetrical ERP translation priming effects seen across unbalanced bilinguals as well as the symmetrical effects seen in balanced bilinguals.

Focusing on the early stages of L2 vocabulary acquisition, the establishment of the aforementioned lexicosemantic networks can be directly captured by changes in the N400 component. In particular, the amplitude of the N400 grows as a function of L2 learning and can thus be used as a measure of L2 proficiency. Soskey found that learners who were enrolled in Introductory Spanish classes showed increasingly larger N400s to L2 words as the semester progressed (2010). Specifically, the smallest N400 was seen after 34 days of instruction and the largest after 153 days. Similarly, lab-based L2 learning has also elicited N400 growth as sessions advanced across 4 weeks (Yum et al., 2014). These findings indicate that the N400 component can be a useful tool for gauging L2 learning progression in both classroom and lab settings. As L2 proficiency increases, so should N400 amplitudes to L2 words. Importantly, N400 growth due to L2 learning reflects increased lexicosemantic processing rather than just L2 word repetition. Simple repetition of items predicts increases in the late positive component (LPC) and not the N400 (Nagy & Rugg, 1989). N400 amplitude changes to L2 learning therefore index lexicosemantic activity indicative of stronger L2 wordform representations and/or L2 lexicosemantic connections.