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Brain signatures of early lexical and morphological learning of a new language

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ABSTRACT

Morphology is an important part of language processing but little is known about how adult second language learners acquire morphological rules. Using a word-picture associative learning task, we have previously shown that a brief exposure to novel words with embedded morphological structure (suffix for natural gender) is enough for language learners to acquire the hidden morphological rule. Here we used this paradigm to study the brain signatures of early morphological learning in a novel language in adults. Behavioural measures indicated successful lexical (word stem) and morphological (gender suffix) learning. A day after the learning phase, event-related brain potentials registered during a recognition memory task revealed enhanced N400 and P600 components for stem and suffix violations, respectively. An additional effect observed with combined suffix and stem violations was an enhancement of an early N2 component, most probably related to conflict-detection processes. Successful morphological learning was also evident in the ERP responses to the subsequent rule-generalization task with new stems, where violation of the morphological rule was associated with an early (250–400 ms) and late positivity (750–900 ms). Overall, these findings tend to converge with lexical and morphosyntactic violation effects observed in L1 processing, suggesting that even after a short exposure, adult language learners can acquire both novel words and novel morphological rules.

1. Introduction

A fundamental aspect of learning a new language is the acquisition of its vocabulary. While word acquisition both in L1 and L2 has received considerable attention (e.g. Davis and Gaskell, 2009; López-Barroso et al., 2013; McLaughlin et al., 2004; Tamminen and Gaskell, 2013), there are only a few experimental studies on the acquisition of the building blocks of words, namely morphemes (Ferman et al., 2009; Havas et al., 2015; Merkxet al, 2011; Tamminen et al., 2015). To take a concrete example, each of the three morphemes that form the morphologically complex word *dance+r+s* carries distinct information that has to be recognized to grasp the full meaning of the word. Besides the semantic contents, morphemes and their combinations carry grammatical information, making the encoding of the internal structure of polymorphemic words essential for successful language learning. At the same time, there is extensive behavioural evidence indicating that acquisition of L2 inflection e.g. in subject–verb agreement, tense, and gender marking is hard for adult second language learners (e.g. Hopp, 2010). In the present study, we examined the neurophysiological signatures of the earliest stages of lexical and morphological learning in adults acquiring a novel, artificial language. Previous experiments have mainly dealt with morphosyntactic agreement in L2 learners at different phases of their language training (Gillon Dowens et al., 2011; McLaughlin et al., 2010) or the acquisition of novel morphemes in L1 (Merkx et al., 2011; Tamminen et al., 2015). Here we examined the neural signatures of the earliest moments of incidental morphological learning of natural gender.

1.1. Morphosyntactic learning: previous neurophysiological evidence

Second language acquisition proceeds through different stages, and this has been argued to be the case also for morphological learning. For example, Zobl (1998) put forth a two-stage developmental model according to which language learning has two distinct phases based

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on two psychological mechanisms: listing and computation. He claims that at early stage learners do not have access to functional, independent representations of affixal information. Instead, they store learned words individually as wholes without decomposition of their internal morphological structure. As they advance, the second, computational, stage emerges. At this stage, the learner masters the internal architecture of morphologically complex words.

The basic idea of two-stage learning of morphologically complex words appears compelling: at least during the first exposures to a novel morphologically complex word where both the stem and the affix(es) are unfamiliar, the learner should encode the word form as a whole. At issue here is if and when an adult learner becomes able to encode the constituent morphemes of novel multimorphemic words.

In a series of ERP experiments, McLaughlin et al. (2010) studied the different stages of morphological rule acquisition in learners of French, German and Finnish that were enlisted in university courses in these different languages. Each experiment targeted a different morphological or rule-based process (verb-noun number agreement in German, subject-verb number agreement and definite determiner and noun number agreement in French, and vowel harmony in Finnish). Nevertheless, a common pattern emerged: at a first stage of language learning (4 weeks to 12 months after the beginning of the language course), morphological violations elicited an N400 ERP component when compared to correct morphological forms. At later stages of language learning, participants with more training (either the same participants at a later stage or more advanced students) showed evidence for an L1-like processing in their second language where morphological violation elicited a P600 ERP component, taken to indicate that morphological processing took place. This led the authors to conclude that the grammatical rules of a second language can be mastered by adult language learners at a near-native level, but this process can take months or even years of training. Foucart and Frenck-Mestre (2012) found similar evidence in a noun-adjective gender agreement paradigm.

An ERP study by Weber-Fox and Neville (1996) found that the efficiency of morphosyntactic learning shows maturational constraints. For L2 syntactic violations, early anterior negativity was present in late but not early (10-year-olds or younger) L2 learners, being larger over the right than the left hemisphere. On the other hand, the late positivity (P600) was present in early learners, but showed increased latency for the 11–13-year-old group and was absent in participants who started L2 learning later in life. Lexical/conceptual violations, however, yielded a typical N400 negativity in all the age groups. In a different study, Hahne and Friederici (2001) tested a group of native Japanese speakers who had learned German as a second language after puberty and found a robust N400 effect for semantic violations, but no effect for syntactic violations in a sentence comprehension task. These results are in line with the declarative/procedural model by Ullman (2001) that assumes that the less efficient morphosyntactic learning by late L2 learners depends on their higher reliance on the declarative (lexical) memory system. At word level, reliance on the declarative system would mean that the late L2 learner employs full-form storage of multimorphemic words as opposed to L1 processing where decomposed representations of multimorphemic words are acquired with the procedural memory system.

However, Ullman's model was critiqued by Hahne et al. (2006) who found evidence for L1-like morphosyntactic decomposition for late L2 learners of German. Their adult L2 learners responded differently to violations of regular and irregular inflection during on-line morphological processing, eliciting LAN/P600 effects in the case of misapplications of regular rules of inflection and N400 effects in misapplications of irregular inflection. In other words, these results indicate that the participants employed regular rules of inflection in on-line morphological processing. There are also other studies that have found qualitatively similar ERP patterns of aspects of morphosyntactic processing in native speakers and highly proficient late L2 learners, with early negativity followed by P600 (Dowens et al., 2011).

In summary, the ERP studies shortly reviewed above indicate that even adult learners can attain native-like on-line morphosyntactic processing skills if they reach a high level of proficiency in their L2. However, L2 learning in these studies has lasted from several weeks up to decades, and it remains open whether even a short exposure to a novel morphological rule can elicit neurophysiological responses indicative of morphological decomposition in adult learners.

1.2. Present study

The aforementioned studies reported a slow change in grammar-related neurophysiological responses during long-term L2 learning. However, there is also evidence suggesting that quick changes in language learning are possible. For example, Mestres-Missé et al. (2007) showed that new words produced ERP signatures similar to real L1 words after only three exposures when the meaning of the new word could be inferred from the context but not when the new word remained meaningless (for similar findings, see Borovsky et al., 2010; Dobel et al., 2009; Frishkoff et al., 2010). In the same vein, De Diego Balaguer et al. (2007) found evidence for fast ERP changes in a word and rule learning experiment where violation of syntactic-like rules in an artificial language produced a late positivity after only a four-minute exposure to the new language. These authors also found an N400 lexical effect during exposure to non-words vs. trained words shortly after training.

In a recent behavioural study (Havas et al., 2015) we used an incidental learning paradigm to examine morphological learning in an artificial language in adult Spanish and Finnish speakers (see Fig. 1). The participants were shortly exposed to pairs of novel words and pictures that they were instructed to learn. Part of the words carried an embedded morphological marker, namely a suffix that signalled the natural gender of the animate object they were paired with. Note that gender marking is absent in the L1 of Finnish speakers. The aim of the experiment was to see if a short exposure to morphologically complex words and their meanings enabled language learners to uncover the morphological rule embedded in the new language. Furthermore, we sought to study the influence of the morphological structure of L1 on L2 learning. Even though both groups were equally efficient in lexical learning (i.e., matching the word stems with the corresponding pictures), the Finnish speakers were better at discovering the hidden morphological gender rule and in applying that rule to novel lexical items presented after the learning phase. The group difference was quantitative rather than qualitative, as also the Spanish participants performed above chance in all experimental tasks, including the rule generalization task. This indicates that, at least under specific circumstances, adult language learners are able to quickly acquire morphological information from a new language even when the morphological feature in question is absent in their L1.

To investigate the neurophysiological correlates of the early stages of morphological learning, we applied our earlier paradigm (Havas et al., 2015) and shortly trained the present participants on novel words paired with pictures of either cartoon-like animals with prototypical female or male characteristics (targets) or with various animate and inanimate objects (fillers). The words paired with the animal characters contained a morphological regularity, namely a suffix marking natural gender, which the participants were not informed about. After a short training session, they were asked to come back a day later for testing. During the test phase we recorded EEG while the participants performed a recognition memory test and a rule generalization task to assess whether they successfully memorized the word-picture pairs (lexical learning) and to evaluate if they learned the gender rule (morphological learning). Based on earlier studies, we expected that successful acquisition of the embedded morphological rule would lead to early negativity (LAN) and/or late positivity (P600) in the case of violation of the gender rule. If, on the other hand, the participants