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Electrophysiological evidence for modulation of lexical processing after repetitive exposure to foreign phonotactic rules

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ABSTRACT

In two experiments we investigate how repeated exposure to native and non-native phonotactic regularities alters the N400, an event-related potential related to lexico-semantic access. Participants underwent a Passive Listening (Experiment 1) or a Categorization Training (Experiment 2) for monosyllabic pseudowords over 3 days. During Passive Listening participants solely listened to the stimuli while for Categorization Training they learned to assign items to two arbitrary categories by feedback. Notably, this task did not rely on phonotactic regularities. Before training, N400 was larger for legal compared to illegal items. Over the 3-day exposure Passive Listening yielded a significant decrease in N400-amplitude for illegal pseudowords, however, this effect was abolished and partially inverted by the Categorization Training. We suggest the decrease in N400-amplitude indicates more efficient discrimination between native and non-native pseudowords since only the former are potential lexical candidates. On the contrary, Categorization Training introduces a 'protosemantic' context overriding prelexical selection processes.

1. Introduction

One crucial challenge during language acquisition is to acquire fast access to the meaning of words and sentences. In this process word learning relies on (1) successful segmentation of the auditory speech stream into single units such as syllables or words and (2) the establishment of a firm association between the novel word form and a usually pre-established semantic concept. During native language (L1) acquisition prelinguistic infants tackle this task surprisingly well. Although initially largely lacking conceptual knowledge and without undergoing formal lexical training they identify lexical candidates from the auditory stream. This is the prerequisite to later establish lexico-semantic mapping with emerging conceptual knowledge (Friedrich & Friederici, 2010).

During second language (L2) acquisition in adulthood, however, learners regularly experience that even words successfully acquired during classroom instruction are not easily accessible when listening to speech in a natural L2 environment. Partially this is due to inefficient segmentation abilities since natural connected and colloquial speech supplies little or no overt cues (e.g., pauses) to signal word boundaries. A large body of literature has shown that proficient listeners rely on *prelexical cues* such as phonotactic con-straints to segment the incoming speech stream to improve word recognition (Jusczyk, 1999; McQueen, 1998; Sebastián-Gallés, 2007). Phonotactics governs the existence or 'legality' of phoneme combinations in a given language (Trask, 1996). For example, /br/ at the onset of an English or German word is legal, however, /bz/ is not, while the latter onset is legal in a number of Slavic languages. Phonotactic properties are processed implicitly and are established early in language development (Rossi, Telkemeyer, Wartenburger, & Obrig, 2011). Since they act on an early, prelexical stage of speech comprehension their processing should be highly automatic: even in the absence of semantic context the brain should be sensitive to whether phoneme clusters are phonotactically legal or illegal with respect to a given language. Indeed we have previously shown that pseudowords starting with an illegal onset cluster trigger a lesser lexico-semantic search when compared to those with a legal onset cluster (Rossi, Jürgenson, et al., 2011). Notably, such differential processing was evident when participants passively listened to very uniform meaningless material, consisting of monosyllabic legal and illegal pseudowords.[1]

In the present study we investigate whether and how such prelexical regularities impact on lexico-semantic access and how they can be modified in fully language competent adults. We investigate

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[1] We use the terms 'legal' vs. 'illegal' pseudowords throughout the text to indicate whether an item complies with German phonotactics or not. Note that the literature sometimes uses the terms 'pseudowords' versus 'nonwords' for the very same distinction.

how a short repetitive exposure alters the processing of phonotactically legal and illegal pseudowords. In two experiments, German participants were exposed to pseudowords starting with either native (i.e., legal in German) or non-native (i.e., illegal in German, but legal in Slovak) consonant clusters. Behavioral measures to assess the influence of phonotactic structure on lexical access usually require lexical decision tasks which inevitably trigger some sort of conscious lexical search strategy. To avoid such strategies we assessed lexical access by an electrophysiological marker, namely the N400 component of the event related brain potential (ERP). This negativity, some 400 ms after word onset is sensitive to lexico-semantic processing (for a recent review see Kutas & Federmeier, 2011) and its amplitude has been shown to inversely correlate with the ease of lexical access in a number of experimental designs. Frequent or strongly primed words elicit a smaller N400, while pseudowords when contrasted to real words elicit larger N400 amplitudes. This reflects that lexical access to familiar real words is less demanding. Even infrequent lexico-semantic entries require a lesser lexical search than the (eventually unsuccessful) search for the meaning of a pseudoword (Bentin, McCarthy, & Wood, 1985; Chwilla, Brown, & Hagoort, 1995; Soares, Collet, & Duclaux, 1991). Interestingly, however, phonotactically illegal pseudowords elicit a smaller N400 when compared to legal pseudowords (Friedrich & Friederici, 2005; Rossi, Jürgenson, et al., 2011). This suggests that pseudowords with an illegal phonotactic structure are more efficiently discarded to not qualify as a lexical candidate and hence attenuate the cerebral processes related to lexico-semantic search. During the acquisition of a foreign language such an implicit rejection of words containing illegal clusters may interfere with successful lexical access. Therefore the modification of established phonotactic rules during L2 acquisition may be a prerequisite for effortless comprehension of naturally spoken L2.

Previous research has shown that the modulation of the N400 can witness lexical learning effects. Using a prime-target paradigm an increase of the N400 amplitude for pseudowords in contrast to real words of a foreign language was demonstrated after only 14 h of classroom instruction (McLaughlin, Osterhout, & Kim, 2004). Other studies have shown that also associative learning, providing a semantic context, leads to efficient lexicalization of pseudowords. After a 5 day picture-pseudoword training for about 20 min daily, participants could translate most of the 45 novel word forms into the corresponding German words (Breitenstein et al., 2007). An MEG study (Dobel, Junghöfer, et al., 2009) using a similar design showed that the enhanced N400m for pseudowords compared to real words as seen before training, decreased over the course of associative learning. Since after training successfully learnt pseudowords showed a similar N400 as the real words the authors conclude that these pseudowords had been integrated into the lexicon. On a prelexical level it was demonstrated that phonemes not present in the subjects' native language were integrated into the phonetic repertoire when trained in the context of associative novel word learning (Dobel, Lagemann, & Zwitserlood, 2009). After a 5 day picture-pseudoword associative training the N400 amplitude increased in response to pseudowords containing the unknown phoneme. This suggests that pseudowords containing a non-native phoneme lost their nonword status by associative lexico-semantic training due to the integration of the unknown phoneme into the phonetic repertoire of the participants.

Apart from classroom instruction and semantic associative learning the mere repetitive exposure to linguistic regularities without any additional context has been demonstrated to lead to very fast neuronal changes with respect to the to-be-learned new regularities (Citron, Oberecker, Friederici, & Mueller, 2011).

The present study builds on the evidence that phonotactic status triggers differential processing of pseudowords beyond any semantic context. To investigate whether and how adults can modify already acquired prelexical cues of their native language and how they deal with the repetitive presentation of non-native regularities we model two different scenarios of L2 exposure: In the first experiment participants passively listened to the material without any overt task or semantically relevant context. The second experiment introduced a learning task which was orthogonal to the phonotactic properties of the material. By feedback participants implicitly learned whether a given pseudoword belonged to the arbitrary Category A or B, both of which contained the same number of illegal and legal items. Both trainings were performed over three consecutive days. The two scenarios model elements of language acquisition by exposure: The Passive Listening Experiment supplies highly repetitive exposure to novel potential lexical candidates without any explicit task supporting the access of meaning of these items. Such a passive listening scenario may take place during early stages of 'immersion' into a foreign language. The categorization task of the second experiment introduces a potentially semantically relevant context (i.e., a "protosemantic" context) and thus models a very basic discrimination of the unknown potential lexical items ('belongs to Category A or B'). Notably, also in the latter scenario phonotactic status is not relevant for task performance.

Prior to training we expected to replicate the effect that legal pseudowords elicit a larger N400 than illegal pseudowords (Rossi, Jürgenson, et al., 2011). In response to repetitive exposure we expected a differential modulation in the response to legal and illegal pseudowords: (i) Passive Listening to legal pseudowords should not substantially change the N400 over time, since the underlying phonotactic rules are implicit to the native listener. Repeated exposure should potentially slightly attenuate N400 amplitude due to the lesser novelty of the items after training. (ii) For illegal pseudowords different results might be expected: if illegal pseudowords elicit an increasing N400 with repetitive exposure by Passive Listening this suggests repetitive exposure is sufficient to modulate prelexical phonotactic regularities. On the contrary, a decrease in N400 for illegal pseudowords would suggest that based on the long established native regularities a more efficient discrimination between legal and illegal items is supported by repetitive exposure: passive repetitive exposure should ease deselection of the illegal items during lexical search. (iii) For illegal items the introduction of a (proto)semantic context such as a categorization task should abolish a potential decrease in N400, since deselection of the illegal items during the training would be detrimental to the acquisition of the categories. Note that this 'protosemantic' categorical feature of items was arbitrary but orthogonal to phonotactic status. This latter scenario models the fact that during foreign language immersion when acquiring new words in a semantically relevant context, word forms obeying novel phonotactic rules need to be accepted as lexical candidates.

2. Materials and methods

2.1. Subjects

Fifty-two right-handed German native speakers without any knowledge in Slavic languages, no hearing or neurological disorders participated in the two experiments. These subjects were subdivided into two independent groups of subjects: the first group undergoing the Passive Listening (Experiment 1) and the second group of subjects performing a Categorization Training (Experiment 2). Due to technical problems 9 subjects had to be excluded from data analyses in experiment 1. Thus 17 subjects (8 women; mean age: 25 years, range: 18–29 years) took part in experiment 1 (Passive Listening) and 26 subjects (13 women; mean age: 25 years, range: 22–31 years) took part in experiment 2 (Categorization). All participants were paid for their participation at three consecutive days.