IMPLICIT LEARNING OF LEXICAL STRESS PATTERNS

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ABSTRACT

The possibility of implicit learning (i.e. learning without intention or awareness) of prosodic features has been little investigated, despite a great deal of studies in other areas of language. We tested whether a lexical stress pattern could be implicitly learned after short exposure. We found that English-speaking subjects showed learning of the Spanish-based lexical stress patterns from the exposure phase. The response patterns support a model in which both abstract rules and probabilistic information were learned.

Keywords: prosody, rhythm, implicit learning

1. INTRODUCTION

In recent years, extensive research has been done in the area of implicit learning in language, especially learning of patterns and grammar rules. However, very little of the work in implicit learning has extended into the realm of phonology, and almost none of this has considered prosodic features, despite the fact that prosody is known to be an important tool for listeners as they process an incoming speech signal (see Cutler [3] for a review). This study addresses the question of whether prosodic features can be implicitly learned, and what implications this might have for theories of language learning and processing.

We will follow characterizations by Schachter [14] and Dienes and Perner [6] by defining implicit learning as learning which takes place without an intention to learn or awareness of what has been learned. Implicit learning may take place alongside conscious or explicit learning, and it may also facilitate later explicit learning of knowledge that was implicitly learned at some earlier stage (Williams [15]).

A question consistently raised with regard to implicit learning research is whether the knowledge acquired in such experiments is actually an abstract rule (or set of rules), or whether the improvement in performance observed after training is a result of the acquisition of a set of probabilities about the material exposed. Knowlton and Squire ([9, 10]) have argued that both concrete information about stimuli as well as abstract information about grammar patterns or rules may be implicitly learned. Furthermore, they claim that neither of these elements has an independent influence on the outcome of their grammaticality judgement tasks, but that the two interact. The issue of rule learning versus probabilistic learning is particularly relevant in the realm of prosody, where it is still unclear which elements of the speech signal may be described by abstract phonological rules.

1.1. Implicit learning of phonology

Some implicit grammar-learning experiments have been carried over into the arena of phonology, especially segmental phonology. An influential study in this area is that by Dell, et al. [5], who investigated implicit learning of phonotactic constraints after short exposure. Participants in Dell et al.'s study read aloud sequences of nonsense syllables that followed a set of phonotactic rules constraining whether certain segments appeared in only onset or coda position or both. Participants' speech errors were recorded and analysed, and were found to obey the artificial phonotactic constraints in 97.7% of all cases, despite the fact that participants were unable to verbalize rules describing the distribution patterns.

This finding has been supported and extended by several other studies. Onishi, et al. [12] found that legal syllables were repeated more quickly than illegal syllables after short exposure to a set of phonotactically constrained words, suggesting that constraints on consonant position (either onset or coda within a syllable) could be implicitly learned. In addition, they found that constraints specific to the vowel present in the syllable could be implicitly learned. Goldrick [7] manipulated segment position within syllables to create alternations where the probability of a set of features (in this case, labiodental fricatives) appearing in one position was balanced by the probability of a given segment (/f/ or /v/) appearing in either position. He found that listeners could learn not only the distributions of individual segments, but also the distributions of featural combinations, and that the featural combinations could interfere with the segmental distributions. In an autosegmental framework in particular, the learning of features below the level of the segment is suggestive in terms of the learnability of prosodic features, above the level of the segment.

The only prior work on implicit learning of lexical stress patterns of which we are aware is that of Bailey, et al. [2], who tested implicit learning of primary word stress patterns from natural languages. Bailey et al.'s work substituted pitch patterns for stress patterns, arguing that pitch patterns are more perceptually salient indicators of lexical stress than syllable duration or intensity. They found evidence that their subjects were able to learn the training patterns in the experiment. However, Bailey et al. fail to provide compelling support for their assumption that the learning of a musical pattern can be generalized to the learning of a linguistic pattern; and this assumption goes in the face of evidence that amplitude, rather than pitch, is the primary acoustic correlate of stress in (many varieties of) English (Kochanski, et al. [11]). Furthermore, other research suggests that speech perception is a special mode of perception (see Repp [13] for a review). Therefore it is difficult to accept this study as sound evidence that lexical stress patterns can be implicitly learned.

1.2. Motivation and hypotheses

The possibility of implicitly learning prosodic characteristics of a language is particularly relevant in the context of second language learning. It has been shown that differences in prosody between first and second language can impact listeners' ability to parse the speech signal (Cutler [3]; Bagou, et al. [1]). The focus of our research was to determine whether speakers of English could implicitly learn a simplified version of the lexical stress pattern occurring in Spanish, and whether they would make use of this pattern in making judgements about their familiarity with nonsense words after training on a learning set. Our hypotheses were as follows:

- Both the lexical stress pattern and the phonotactic constraints will be learned implicitly during the exposure phase.
- Familiarity with the lexical stress pattern will influence judgements about whether a word was heard during training; untrained words with correct lexical stress will be rejected less frequently than untrained words with incorrect lexical stress.

2. METHODS

The experiment consisted of a short learning phase followed by testing. The stimuli were words from an artificial language created specifically for the study. The artificial language consisted of syllables containing the following possible segments: consonants /p, b, t, d, k, g, m, n, r, l, s, f/ and vowels /a, æ, e, ɛ, i, o, ɔ, u/. All syllables had CV structure except for word-final syllables, which could be CV or CVC. All consonants appeared in all positions and with all vowels, and syllables were combined randomly to create words. 50% of words had two syllables and 50% had 3 syllables; 50% of each group ended in open syllables and 50% ended in closed syllables.

Lexical stress was assigned to the words according to a simplified version of the lexical stress rules for Peninsular Spanish as follows (cf. Harris [8]): Words ending in an open syllable, or ending in a syllable closed by /s/, had the primary lexical stress fall on the penultimate syllable (e.g. /fuf ému/, /l áis/). All other words (those with the final syllable closed with a consonant other than /s/) had the primary lexical stress on the final syllable (e.g. /bunǽl/, /kibagíb/). The Spanish lexical stress rules were chosen to contrast with (British) English, in which 90% of multisyllabic words have initial stress (Cutler & Carter [4]).

In addition to the lexicon of "legal" words (those following the phonotactic and lexical stress rules just described), two sets of "illegal" words were created. The first set consisted of words which followed the phonotactic rules of the artificial language, but which did not obey the lexical stress rules (e.g. /g ídɛk/, /tekef é/). This set also included words from the "legal" set which had had their stress pattern altered. The second set consisted of words which followed the lexical stress rules but disobeyed the phonotactic constraints (e.g. /spǽru/, /derɛ́nda/).

2.1. Phase 1—learning phase

During the first phase of the experiment, participants performed a short-term memory task exposing a set of 100 legal words from the artificial language. Participants heard words in groups of 3, 4, 5, or 6; each of the 100 words was presented a total of 3 times during the training phase. Participants were asked to repeat aloud each set of words after they heard it, or to say as many as they could remember if they were unable to recall the entire sequence; each sequence was heard only once. Participants moved through the task at their own pace. The word sequences were presented in a randomized order.

2.2. Phase 2—testing phase

During the second phase of the experiment, 100 words were presented at a fixed interval of 1000ms. Participants were asked to indicate whether or not they had heard each word during the first phase of the experiment, and to guess if they were not sure. Approximately 20 words were presented in each of 5 conditions:

- Words presented in the practice phase (rhythmically legal trained)
- Legal words not presented in the practice phase (rhythmically legal untrained)
- Words presented in the practice phase, but presented in this phase with the lexical stress changed to make it illegal (rhythmically illegal trained)
- Words with illegal lexical stress not presented in the practice phase (rhythmically illegal untrained)
- Phonotactically illegal words with legal lexical stress (phonotactically illegal)

Words were presented in a random order for each participant. Thirteen participants were tested, 7 female and 6 male, ranging in age from 19 to 33 (mean age 25). Subjects were self-selected in response to a call for non-Spanish-speaking participants with normal hearing. All were monolingual native speakers of English (dialect was not controlled).

3. RESULTS

Figure 1 shows participants' responses to the three sets of untrained stimuli: rhythmically legal and illegal, and phonotactically illegal. As expected on the basis of Dell, et al. [5], most responses to phonotactically illegal items were correct (that is, participants responded correctly that they had not heard the item in the training phase). When the items were phonotactically acceptable, however, there was still a difference in responses based on the rhythmic legality of the item in question.

Items in the rhythmically illegal category obtained more correct responses, while items in the rhythmically legal category obtained a higher number of incorrect responses ($\chi2=68.66$, df=2, $p<0.01$). In other words, when words followed both the phonotactic and rhythmic patterns presented in the training phase, participants were more likely to say that they had heard the word in the training phase, suggesting that they had learned something about the rhythm pattern.

Figure 1: Number of correct and incorrect responses for each untrained condition.

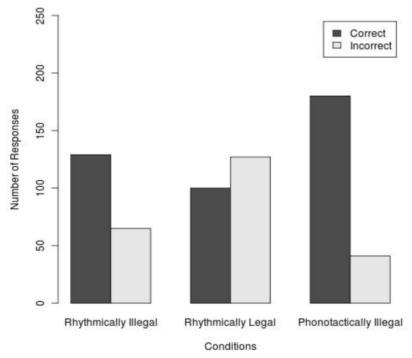
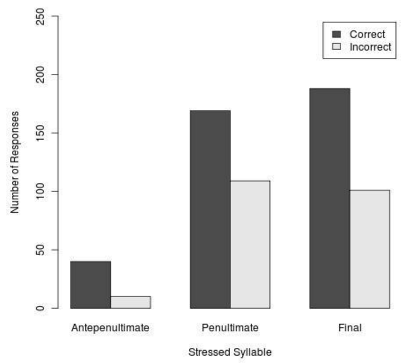


Figure 2: Number of correct and incorrect responses for each syllable structure type.



In order to address the question of whether the information learned was an abstract rule or a set of probabilities, we may consider the number of correct responses given for different stressed syllable positions. Figure 2 shows the distribution of correct and incorrect responses for untrained items across the different stressed syllable locations. Items in the antepenultimate stress condition were more likely to obtain a correct response (i.e. that they had not been heard previously) than items in the penultimate and final stress conditions ($\chi2=6.9343$, df=2, $p<0.05$). However, there was no difference in response patterns between items with penultimate and final stress ($\chi2=0.9278$, df=2, n.s.).

In the post-experiment questionnaire, 9 out of 13 participants reported that their response strategy was to make a guess or rely on their gut reaction to the word. The other participants used various lexical strategies, saying they were most likely to remember words that sounded like English words. None was able to describe a pattern distribution.

4. DISCUSSION AND CONCLUSION

The data reported above suggest that participants were able to learn the rhythmic pattern of the words in the training phase without any conscious attempt at learning. Furthermore, participants were unable to verbalize the rule they had learned. In other words, on the basis of these data we may assert that participants were able to implicitly learn the rhythmic pattern after only a short exposure to the set of training items.

We can conclude that language learners are sensitive to rhythmic patterns in language just as they are sensitive to other grammatical aspects. When addressing the question of the degree to which prosodic phenomena are part of linguistic systems versus general communicative strategies, the implicit learning results reported here lend support to accounts which include rhythmic and other prosodic phenomena in descriptions of language systems.

It is not clear on the basis of these data whether what was learned was a set of probabilities or an abstract rule, but it is possible to make some initial comments on this matter. It appears that the requirements for penultimate stress and final stress were both correctly learned (although the results for the /s/-final condition were inconclusive and are therefore not reported here). This means at the very least that listeners were sensitive to the difference between open and closed syllables receiving final stress. However, this distinction by itself is not sufficient evidence for the existence of rule-learning, since it is common across many languages for heavy (i.e. closed, in this case) syllables to be stressed. Therefore, although participants were sensitive to the difference between these two patterns, it may have had little to do with the learning of a specific rhythm pattern.

A better piece of evidence for the learning of the rhythm pattern as an abstract rule rather than as a simple probability is the fact that participants were much more likely to respond correctly to items with antepenultimate stress (i.e. when lexical stress fell on the first syllable of a trisyllabic word). Although this may initially seem to be based on probabilities since antepenultimate stress never occurred in the training phase of the experiment, this antepenultimate stress could also be characterized as initial stress, and both the training phase and the testing phase involved legal disyllabic words with initial stress. This means that participants were not simply making a blanket rejection of words with initial stress, but rather that they took into account other elements of the word structure when making their decisions.

The combination of these two pieces of evidence is consistent with a model in which both abstract and concrete information are learned (cf. Knowlton and Squire [9, 10]). The better accuracy rate for the antepenultimate stress condition could result from a combination of rule-learning as well as the lower probability of occurrence of initial stress in the training phase (25% of training items). Since this probability can be interpreted as resulting from the rule, it seems likely that the two types of information support each other in the learning context, and that learners can make use of both to increase accuracy.

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