THE INFLUENCE OF VOWEL HARMONY ON TURKISH SPEAKERS LEARNING AN ARTIFICIAL LANGUAGE*

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Abstract

In this study, the acquisition of an artificial language that is constructed according to vowel harmony (VH) rules is investigated. There were three groups of participants that took part in the experiments: the first group was trained in vowel harmony condition, the second group in vowel disharmony and the third group in a mixed condition. The results of the experiment suggested that participants can learn both vowel harmony and vowel disharmony conditions that they were trained on. They obeyed the phonological rules of the condition even in their speech errors. The harmony subjects maintained VH in their errors. At the end of the experiment phase, the participants from three groups were presented with twenty pairs of words, one of which had vowel harmony and the other vowel disharmony. The participants trained in VH chose the words that had vowel harmony. In view of the data and analysis of speech errors, it was revealed that vowel harmony and disharmony are tools that can aid in learning a language.

Key words: Vowel harmony, artificial language learning, constraints on speech sounds, speech errors.

Yapay Bir Dil Ediniminde Ünlü Uyumu Kuralının Türkçeyi Ana Dil Olarak Konuşanlardaki Rolü

Özet

Bu çalışmada Türkçe konuşan bireylerin ünlü uyumu kurallarına göre oluşturulmuş yapay bir dili deneyler aracılığıyla nasıl öğrendikleri incelenmektedir. Katılımcılar üç sınıfa ayrılmış, birinci gruba ünlü uyumu, ikinci gruba ünlü uyumsuzluğu ve üçüncü gruba da karışık sözcükler içeren yapay bir dil gösterilerek, ekranda gördükleri sözcükleri okumaları istenmiştir. Araştırmadan elde edilen bulgular, katılımcıların hem ünlü uyumu hem de ünlü uyumsuzluğunu öğrendiklerini göstermiştir. Katılımcılar sesletim hatalarında bile gördükleri koşulun kurallarını korumuşlardır, örneğin ünlü uyumu grubundaki katılımcılar sesletim hatalarında da ünlü uyumu kurallarına uymuşlardır. Deneyin sonunda üç farklı gruptaki katılımcılara biri ünlü uyumu içeren biri içermeyen yirmi çift sözcük sunulup hangisinin deneyde gördükleri

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sözcüklere benzediği sorulmuştur. Bu bölümde de, ünlü uyumu görmüş olan katılımcılar ünlü uyumu içeren sözcükleri seçmişlerdir. Yapılan sesletim hataları ve verilerin incelenmesi sonucunda, ünlü uyumu ve hatta ünlü uyumsuzluğunun yapay bir dili öğrenmekte yardımcı bir olgu olduğu ortaya çıkmıştır.

Anahtar kelimeler: Ünlü uyumu, yapay dil edinimi, sesletim konusundaki kısıtlamalar, sesletim hataları, Türkçe.

1. Introduction

Languages utilise many different speech sounds and these can be combined in order to form words. However, not all sound combinations are possible. For example, the combination /ks/ would never occur at the beginning of a native Turkish word. The set of all such restrictions are known to be phonotactic constraints. Among the sound combinations that do occur, some are more common than others. These patterns are referred to as phonotactic probabilities.

There is a large body of research demonstrating the role of phonotactics in language processing in learning an artificial language. Vitevich and Luce (1999) found faster processing for nonwords with high compared to low phonotactic probability in a judgement task. There is also some evidence that non-words with high phonotactic probability are retained better in short term memory (Gathercole, Pickering, Hall and Peaker, 1999; Majerus, Linden, Mulder, Meulemans and Peters, 2004). Pylkkanen, Stringfellow and Marantz (2002) reported a different timecourse of brain activity for listening to words with high versus low phonotactic probability. Speakers are more likely to make speech errors that change a low probability combination of sounds into a high probability combination than vice versa (Motley and Baars, 1984) that is, if a sound combination does not often occur in the language, speakers are more likely to change it to a more frequently attested combination in their speech errors. In general, speakers rarely produce speech errors that violate the phonotactics of their native language (Fromkin, 1971; Sofu, 2001), that is, even the speech errors follow the sound patterns of the language spoken.

Dell et al. (2000) proposed that phonotactic constraints may be acquired via a mechanism of implicit learning, based on experience with the language. That is, producing or hearing certain combinations of sounds tunes the language processing system to favor those combinations and disfavor others. They tested this claim in a series of four experiments in which English speakers pronounced sequences of nonsense words, where some consonants were always onsets and some codas, e.g. ‘feng keg hem nes’. These nonsense words were constructed according to a novel phonotactic constraint that is not valid for English. For example, a given participant might see sequences in which /f/ only appeared at the beginning of the syllable, while /s/ only at the end (note that English normally allows both sounds in both positions). Speakers were required to pronounce the nonsense words at a rapid rate, with the result that they sometimes made errors. The critical finding was that within these errors, speakers almost always obeyed the phonotactic properties of the language they were trained on and never pronounced /s/ at the beginning of a syllable and /f/ at the end. This experiment demonstrated that speakers can learn a phonotactic constraint in an artificial language that is different from those in their native language and even obey that new constraint in their speech errors.

Following Dell et al. (2000) and other studies in artificial language learning and speech errors, this study aims to investigate whether native Turkish speakers would learn vowel harmony (VH) in an artificial language system, presented by an experiment to be described in detail in the method section, and to account for their speech errors based on different language systems they are subject to, by adopting a psycholinguistic approach. The ultimate aim is to tell whether vowel harmony is a more natural phonological system compared to vowel disharmony or no coherent pattern. If Turkish speakers are found to be sensitive to VH, then they would have less difficulty pronouncing the words in the vowel harmony sets and they would learn the rules of the artificial system more easily.

This study further seeks to discover whether vowel harmony facilitates speech production. It is speculated that, if found, the facilitative effect is likely attributable to economy in motor articulation or economy in speech planning. A facilitative effect is to be found if made up of words with harmonic vowel combinations can be produced more quickly or with fewer errors. Specifically, whether back harmonic vowel combinations can be produced more quickly or with fewer errors (or both) than vowel combinations that are disharmonic with respect to those features will be tested. If the answer is yes, it is likely that the benefit to production lies in reduced muscular effort in articulation of harmonic vowel sequences or in advantages in speech planning related to production.

Last but not least, the goal of the experiment conducted is to explore whether the ease of articulation could be a factor in the development of vowel harmony. Lewis (1967) asserts that such is the case, saying that vowel harmony is attributable to a reduction of muscular effort. Pulleybank (in press) argues that articulatory inertia leads to vowel harmony and VH arises because languages try to minimize the resetting of articulators. Given these findings, trying to learn if vowel harmony does indeed facilitate speech production is quite justified. However, facilitation — if exists — may not be solely attributable to the physical fact of the ease of articulation. It is possible that a facilitative effect derived from vowel harmony can be traced to economy in speech planning.

Thus, the artificial language experiment intends to demonstrate whether Turkish speakers find it easier to learn VH in an artificial language and explain the possible phonotactic and articulatory reasons behind it. My prediction was that participants would produce harmonic words more quickly or with fewer errors compared to disharmonic words. Such a finding would be evidence of the facilitative effect of vowel harmony.

This facilitative effect of vowel harmony was also attested for Turkish speakers' speech errors in natural language production, since as noted by Sofu (2001) they preserved vowel harmony even in their speech errors (such as *benim-banım*). Previous studies on the acquisition of vowel harmony (Altan, 2009) also demonstrated that Turkish children do not experience any problems with the vowel harmony rules, they do not make any mistakes with the rule, and they overgeneralize the rule to apply it to exceptions and can even apply those rules to pseudo-words.

This would be easy to predict since VH is a very strong phonological phenomenon in Turkish, and probably the most widely known phonological characteristic of Turkic languages. In general terms, vowel harmony can be defined as a set of constraints on the co-occurrence of vowels; these constraints are valid both within a morpheme and across morpheme boundaries. The vowels /e/, /i/, /ö/ and /ü/ belong to one class, while the vowels /a/, /ı/, /o/, and /u/ belong to another. Turkish has backness (palatal) and rounding harmony applying to roots and suffixes (Inkelas et al., 2001). Palatal harmony is defined as a vowel agreeing in backness with the preceding vowel; rounding harmony, on the other hand, is defined as a high vowel agreeing in roundness with the preceding vowel. There have been many previous studies on the theoretical perspective of vowel harmony. One among these is Clements and Sezer (1982) who defined vowel harmony in Turkish as all vowels agreeing in their specification for backness and all high vowels agree with preceding vowels in their specification of roundness. In this paper, two experiments are presented investigating the acquisition and representation of a VH constraint not exactly the same but similar to that in Turkish.

2. Overview of the experiment

In this experiment, whether vowel harmony is a phonotactic property that can be learned in an artificial language system will be tested. The logic of the experiment presented here parallels that of Dell et al. (2000), except that the focus is on speech errors involving vowels, rather than consonants. In the experiment, speakers pronounced sequences of four disyllabic nonsense words under time pressure, a procedure which results in many vowel errors. The nonsense words were designed so that they either obeyed a typical vowel harmony constraint, observed a reverse VH constraint (disharmony) or reflected no vowel constraints (mixed). Knowledge of the harmony constraints was assessed both via an explicit forced-choice test and by examining the nature of the speech errors that were produced.

3. Method

3.1. Participants

36 undergraduate students, between ages 18-24, from Hacettepe University participated in the experiment. There were 12 participants in each condition (harmony, disharmony and mixed). All participants were native speakers of Turkish.

3.2. Materials

The experimental items consisted of CVCV nonsense words. For all of these words, the consonants were drawn from [p], [b], [t], [d], [k], [g], [f], [v], [s], and [z], with the constraint that the voiceless consonants ([p], [t], [k], [f], and [s]) were only used in the word-initial position. This was done to keep the features of the consonants constant among all items since a voiceless consonant between two vowels was very likely to be pronounced as its voiced counterpart. The consonants were limited to stops and fricatives because these had a minimal impact on the pronunciation of the adjacent vowels. Theoretical support comes from Frisch et al. (2000) whose similarity metric suggests that the liquids are phonologically more similar to each other than the high vowels. This is why liquids were avoided when constructing the words.

Consonants were not repeated within a word. Each consonant was used once in a made up word. The strings were formed such that two words beginning with the same consonant would never follow each other.

As mentioned above, languages with vowel harmony generally require that all vowels within a word belong to the same vowel class. Vowels are defined in terms of articulatory features, such as backness, height and rounding. In the current study only backness harmony is used. The vowels used in experiment 1 are presented in Table 1:

Table 1. Vowels used in the experiment

	Front	Back
High	[i]	[u]
Mid	[e]	[o]

The vowels were drawn from the set [e], [o], [u], [i], with the constraint that both vowels in a word must come from the same “class”. In backness harmony condition, the classes were ([e], [i]) and ([o], [u]). So, [e] and [i] were used in a word and [o] and [u] was used in another word. These words constituted the backness harmony items, as the vowels within a class had the same value for both backness and rounding. The only variable that differentiates [e] from [i] and [o] from [u] is height. For the backness disharmony items, the classes were ([e], [u]) and ([i], [e]), where vowels within a class had different values on both the backness and the rounding features. The use of [i] and [u] or [e] and [o] in the same word for backness disharmony words was avoided since that would result in height harmony. These four vowels were used since the same experiment was conducted to English native speakers (see Altan, 2004 for details) and English generally does not allow lax vowels in CV syllables, only tense vowels were chosen. In both backness harmony and disharmony conditions the vowels differed in height. As with consonants, vowels were never repeated within a word.

The words generated from this template were used to construct three lists, as follows: of the 180 possible words respecting backness/rounding harmony, 20 (five for each of the four possible pairings of vowels) were randomly chosen to be used in the test phase of the experiment (see below). The remaining 160 harmony words were used to generate a harmony list of 80 quadruples, a total of 320 words. In order to provide adequate exposure to the vowel harmony constraints, each word occurred in two separate quadruples. Each quadruple contained one word representing each of the four possible pairings of vowels, in pseudo-random order. The order of quadruples within the list was also randomized. An analogous procedure was used to generate a disharmony training list containing 180 unique words each used twice, again setting aside 20 words to be used in the test phase of the experiment. Finally, a mixed list was created which contained all 320 words that appeared in the harmony and disharmony training lists, combined into 40 harmony quadruples and 40 disharmony quadruples, again arranged in random order. Four examples of quadruples from each of the three lists are shown in Table 2:

Table 2. Sample items (in the same transcription as presented to the participants)

Harmonic items	Disharmonic items	Mixed items (harmony&disharmony)
sebi zogu fuzo vize	vezu fuze vizo kogi	bive fevi dogu tuzo
guvo dize tegi vozu	segu fude zivo godi	kuvo give tebi bovu
zibe bezi bogu vugo	dezu tuve bido fogi	fube bido zobi pegu
pide febi vobu budo	kube zido vobi sedu	kigo fegu bozi kude

Finally, twenty test items were created by pairing one harmony word and one disharmony word (drawn from the set of words set aside earlier), such that each combination of vowel classes was represented by five pairs. None of the test words were contained in any of the training lists.

3.3. Procedure

Stimuli were presented on a laptop computer running the FLXlab experiment software. Each experimental session consisted of a training phase and a test phase (forced-choice task). During the training phase, participants were presented with a quadruple at a time on a computer screen, and were asked to read them aloud. A timing bar was also presented under the word pair to indicate how quickly the words should be pronounced; the timing bar filled up in four steps, one step for each word in the quadruple. Once the timing bar filled up, the quadruple was removed from the screen and the next quadruple was presented.

At the beginning of the list the participants were given 4.2 seconds to pronounce each quadruple (a comfortable speaking rate); the time allotted was gradually decreased over the course, ultimately reaching 2.6 seconds per quadruple (a rapid speaking rate). To help participants with the procedure, five practice quadruples were presented at the beginning of the training phase, followed by a brief break to allow participants to ask questions.

At the conclusion of the training phase, participants immediately moved on to the test phase. The test phase consisted of 20 trials. On each trial, two nonce words (one exhibiting backness/ rounding harmony and one exhibiting disharmony) appeared on the screen. Participants were instructed to say each word aloud, and press one of the two buttons to indicate which word sounded more similar to the words that were encountered during the training phase. The same test items were used for all three conditions.

4. Analysis and Discussion

4.1. Speech Errors

After the audio tapes recorded in each session were played back, each trial was coded by the experimenter as either successful or having an error. Then, the speech errors of participants were transcribed by the experimenter. In order to avoid any possible errors, two native speakers of Turkish also transcribed 80% of the recordings. Furthermore, to avoid any bias that can be caused by the phonology of Turkish, 40% of the tapes were also transcribed by a Polish speaker.

Responses were categorized as vowel errors if one or both of the vowels in a word were replaced with another vowel, and as to whether or not the consonants were produced correctly. The words that were not pronounced within the time limit were excluded from the analysis.

For the analysis of errors, comparisons were made between the harmony condition and the harmony quadruples of the mixed condition, and between the disharmony condition and the disharmony quadruples of the mixed condition. This allowed a comparison of attempts at producing the exact same words when the training contained a systematic pattern to when it did not.

4.1.1. Consonant errors

Consonant errors included changing the phonetic properties or the order of consonants, repeating the first or the second consonant. The results indicated that harmony participants had a higher rate of speech errors with consonants. Whereas backness disharmony participants made a total of 71 consonant errors, backness harmony participants made 149 errors with consonants, which pointed out to the negative effect of the native language. A common feature in all consonant errors was that the consonant that replaced the original consonant was always a member of the set of consonants used in the experiment: [p], [b], [t], [d], [k], [g], [s], [f], [v] and [z]. This indicates that the participants learned the phonetic inventory of the artificial language. Voicing was one of the most commonly changed features in errors with consonants. This result is parallel to the study conducted on natural language speech errors in Turkish (Sofu, 2001) and other languages (Shattuck-Hufnagel, 1986). Participants in all three groups made more errors with plosive sounds than they did with fricative sounds. The reason for this may be that the production of plosives required more phonetic effort than fricatives.

4.1.2. Vowel errors

A comparison of the speech errors of participants among the three conditions revealed that participants trained on the mixed condition made more number of errors with vowels. Whereas the participants trained in backness harmony and disharmony made 18 and 16 vowel errors, respectively; mixed condition participants made a total of 39 errors with vowels. This was parallel with the predictions of the experiment in that a lack of pattern is confusing for the participants and even a disharmonic pattern was easier than no pattern.

Once the vowel errors of participants trained on different conditions were compared with each other, it was observed that the vowel errors shared some common properties. Harmony and disharmony participants made switch errors more than other errors. Switch errors are not really vowel harmony errors since the properties of the vowels are constant and only the order varies. This is evidence that harmony participants were more likely to maintain the rules of the conditions they are trained on even in their speech errors. There was only a single error in the data where a harmony participant violated VH.

The reason for backness harmony subjects' making fewer errors may be that backness harmony is simpler. Since by definition the back vowels used in the experiment were round, backness harmony also meant rounding harmony. The fact that vowels were phonetically similar to each other both in backness/ frontness and in rounding features, may have eased their pronounciation even under time constraints. Furthermore, since backness harmony condition was similar to VH in Turkish this might be another factor to ease their speech production.

It can also be observed from the vowel errors that harmony participants were more likely to create identical vowels. No speech error resulted in identical vowels in the speech errors of disharmony participants. It is also worth noting at this point that there were also two instances of vowel identity attested by participants trained in mixed condition. A closer look at the properties of these type of errors reveal that the mixed condition participants created vowel identity from harmonic roots, which also confirms that harmony is closer to vowel identity. This conclusion also comes from the nature of the vowels, since participants only needed to change one feature of a vowel to get identity. Non-sense words which happen to be real words in Turkish (e.g: bezi, pide, vize) were also analyzed to see if they were easier or more difficult to pronounce, however statistically no such effect was attested.

The mixed condition also showed a different pattern in that those participants made comparatively much less vowel switch errors. This may be due to the fact that harmony and disharmony participants almost always did not disrupt the condition they were trained on. On the other hand, participants trained on the mixed condition showed their confusion about the lack of a systematic pattern by the errors they made: they created height harmony from disharmony, they created backness harmony from disharmonic roots and they created disharmony from backness harmonic roots. Since mixed condition was formed by combining words from the list of harmony and disharmony lists, the words were actually the same but the problem was that there was no system. The exact same word was mispronounced in the mixed condition, whereas it was correctly pronounced in the harmony or disharmony condition. This lack of systematic pattern to the phonetic properties of the words was the reason for more speech errors among mixed condition participants. The fact that there were also instances where mixed condition participants inserted a fifth vowel other than the vowels used in the experiment, [ü], also clearly confirms the predictions that the lack of a pattern is indeed confusing. Neither the harmony nor the disharmony participants inserted a vowel that is not used in the experiment.

The findings of Sofu (2001) established that Turkish participants tended to switch the initial phonological units with other initial segments. The speech errors participants made in these current experiments also indicated that they substituted the initial sound of the next word as the initial sound of the word they made a speech error with. Another finding of Sofu (2001) was that vowels tended to switch place with other vowels and consonants with other consonants. This was also confirmed by the speech error data in the artificial language system that was used in our study. Participants never substituted vowels for consonants and consonants for vowels. They still conformed to the phonological properties of the system. That is, even in their speech errors they followed the CVCV pattern of the language and they still used a sound from the limited set of phonemes that they were given in the artificial language. This finding is also supported in natural language speech errors, since as Sofu (2001) also demonstrated in her research that even if a word that is not a part of the language's lexicon is created as a result of a speech error, the word still conforms to the phonological rules of the language in question. Sofu (2001) noted that Turkish speakers preserved vowel harmony even in their speech errors. Our data analysis also showed that harmony participants maintained VH in their utterances. Moreover, as indicated by their speech errors, participants trained on disharmony also maintained disharmony in their speech errors.

The CVCV pattern of the artificial language system used in the experiment may also have had an effect on the consonant errors. The consonants that the participants produced were always next to vowels due to the characteristic of the artificial system. It is also known from natural languages that vowels have an effect in the surrounding consonants. Wilson (2007) found that post- velar consonants have an effect on vowels in Nuuchahnulth. Coleman (1994) and Koenig & Fuchs (2007) can also be referred to as some of the many studies showing the effect of vowels on the neighboring consonants in natural languages. This effect of vowels coupled with the time constraint on the production in the experiment may be the reason of consonant errors.

4.2. Analysis of the results of the forced-choice task

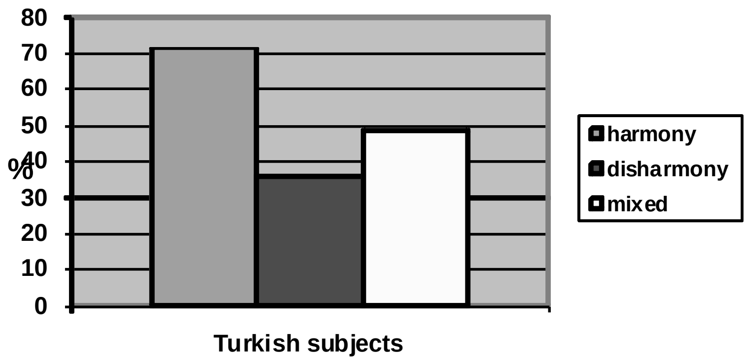
As was discussed before, participants were asked to choose between two words in the forced-choice task. One of the words was constructed so that it obeys the condition they were trained on and the other word violated the condition. That is, if a participant was trained on backness harmony condition, then one of the two words she/he saw would have backness harmony and the other word violated the harmony. Her/his choosing the word containing harmonic sounds thus meant that the participant learnt the rules of the condition he was trained on. For the forced-choice task, planned comparisons were conducted to compare both the harmony and the disharmony conditions against the mixed baseline. Mixed condition eliminated the effect of training and was used to show whether participants had any bias towards harmony or disharmony.

Harmony participants chose harmony 14.3 times out of 20 items (71.5%). This showed that they preferred harmony over disharmony since their training had vowel harmony as well.

The average mean of disharmony participants choosing the word with harmony was 7.25 times out of 20 items (36.25%), as can be observed from the table below. This meant that, they chose disharmony more, at an average of 12.75 out of 20 items. This again showed the participants' preference towards the condition they were trained on.

Mixed condition participants chose harmony 9.75 times out of 20 items (48.75%). That is, they chose the word with disharmony at an average of 10.25 words out of 20 words. This showed that they almost did not have a preference towards any of the condition. If the participants chose according to chance, they would pick words with harmony 10 out of 20 times, and the actual results were very close to that.

Graph 1. Comparison of results in different conditions for backness harmony participants



As can be observed from the graph 1 above, Turkish participants seemed to master the backness vowel harmony condition they were presented with. It can also be said that Turkish participants trained on vowel disharmony learnt the condition they were trained on, as indicated from their choice of disharmony in the test condition. It is also noteworthy that Turkish participants did not have a preference for harmony when they were not presented with a consistent pattern, as illustrated from the responses of participants trained in mixed harmony condition.

Kruskal-Wallis test was used to test whether there were significant differences between the three groups trained in the backness harmony condition and revealed that the results were significant (Asymp. Sign <.05) The non-parametric, two independent samples test Mann-Whitney-U test was also conducted to evaluate whether the medians on attest variable differed significantly between two groups. The results showed that the difference between backness harmony and backness disharmony groups was significant.

5. General Discussion

The comparison of speech errors made by participants trained in different conditions showed that the properties of the condition they were trained on had an effect on the property of speech errors. Both harmony and disharmony groups adhered to the properties of the condition they were trained on even in their speech errors. The participants followed the phonological rules of the system but they needed a consistent pattern. As can be observed from the speech errors of mixed condition participants, they fail to generalize the vowel harmony rule if they are exposed to both a harmonic and disharmonic system. As long as the system has a pattern that was consistent, the participants master that pattern that is not even found in their native language, as can be observed from the data of the disharmony participants.

The results of the current experiment provide strong support for the claim that speakers of Turkish can acquire a novel vowel harmony constraint from brief exposure to words embodying that constraint. First, speakers in both the harmony and disharmony conditions were able to identify novel harmonic and disharmonic words, respectively, more accurately than speakers in the mixed condition. It is important to note that this forced-choice task was a measure not just of learning but of generalization since all the test items were novel words never presented during training.

Second, speakers in both the harmony and the disharmony conditions showed a tendency to produce speech errors respecting harmony and disharmony constraints, respectively, more often than speakers in the baseline mixed condition. Following Dell et al. (2000), we would argue that this is evidence that the production system was 'tuned' to favor production of the vowel pairings present in the training stimuli.

The results of the same experiment when conducted with height harmony (Altan, 2008) rather than backness/ rounding harmony provided different results. In the height harmony experiment, speakers showed a much lower tendency to respect the pattern they saw in their speech errors. This was true for both speakers of Turkish and of English (Altan, 2004). However, the effect of a consistent pattern facilitating learning was still present since across two experiments, speakers showed evidence of successful acquisition of backness/ rounding harmony, height harmony and a disharmonic system. This clearly suggests that whether or not speakers have vowel harmony in their native language; or whether the vowel harmony is the same type or not, they master VH in another system. Hence, these results add to a growing body of data showing that, implicit learning from hearing and/ or speaking words in a language may be sufficient to account for acquisition of phonotactic knowledge.

Conclusion

This work showed that vowel harmony is a pattern that was easy to master for Turkish speakers. In the artificial language used, the back harmonic forms were also obeying rounding harmony by definition, since the back vowels used in the experiment were also rounded. It is possible that the ability to recycle two features, backness and rounding made it easier. This is parallel to the findings of Linebaugh (2007), where English and Spanish participants were reported to have more difficulty with height harmony when compared to backness harmony. However, the fact that the same effect was found for Korean speakers (Oh and Cole, 2006) only on backness harmony items but not on height harmony items suggested that it cannot be attributed to the sharing of two feature values as opposed to sharing one feature value. These results lead out to the conclusion that there is a facilitative affect for back harmonic sequences, which is not dependent on the number of features shared. It appears that back harmony provides a benefit that is not found for height harmony.

The divergent findings which were also attested in our study with respect to the two different types of vowel harmony are more understandable when looking at potential benefits related to economy in the movement of articulators. If the influence of vowel harmony in facilitating speech production derives from ease of articulation, facilitation would be expected when features have clear articulatory correlates. Compared to the [high] feature, the articulatory correlates for the [back] feature are much more isolable and, therefore, back harmonic sequences may facilitate speech production in a way that height harmonic sequences do not (Linebaugh, 2007). The results of this study also indicate that back vowel harmony facilitates speech production. Fewer errors were made when words contain back harmonic vowel combinations. This study was conducted using Turkish speakers. But similar results have been found for English speakers (Cole, Dell, & Khasanova, 2002), Spanish speakers (Linebaugh, 2007) and Korean speakers (Oh & Cole, 2006) pointing out to the finding that vowel backness harmony is easier for speakers than height harmony.

The finding that harmony participants also did not insert a vowel other than the four vowels used in the experiment in their speech errors supports previous studies done on artificial language learning by Dell et al. (2000). In their study they also found that speech errors obey language-wide phonotactic constraints, so all the errors lead to possible sound sequences in the language. Another point they underlined is that there is an effect of recent experience, that is recently experienced sound forms are more accessible. This is also valid for the current study since participants obeyed the vowel harmony rules of the artificial language rather than the actual rules of vowel harmony in their native language.

In a more general framework, this experiment supports both Walker (2005) and Kaun (2004) in that vowel harmony was found to facilitate both production and perception, respectively. The finding that participants trained on vowel harmony made fewer speech errors support the claim that VH facilitates language production. As Walker suggested, harmony acts to increase the similarity of nearby phonemes and facilitate speech production. One possible reason for this is that making certain types of articulatory gestures consistent across a word allows a speech production system to focus on the remaining variable aspects of the word. This was the case for the backness/ rounding harmony words used in the experiment, where the same lip shape can be maintained throughout a word. Kaun (2004) has argued that vowel harmony may facilitate the identification of certain contrasts (such as round versus unround) by introducing redundancy into the speech signal. For example, in a language with rounding harmony it is only necessary to identify the rounding feature of one of the vowels in the word; this feature can then be deduced for the remaining of the vowels. This seemed to help harmony participants in the task since they performed better on the forced-choice task, which illustrates that VH was a phenomenon that helped in learning and remembering the artificial language system.

In conclusion, previous work has demonstrated both that novel phonotactic constraints can be acquired in an implicit learning paradigm, and that listeners can acquire non-adjacent dependencies between phonemes and speech stream. However, these findings have involved relatively simple constraints or a relatively small number of items. It was therefore unclear whether these results would scale up to a situation that more closely approximates the complexities of natural language. The current study found evidence for learning of a complex non-adjacent constraint of a type that commonly occurs in the world's languages, based on exposure to a training set that contained a large number of words. Furthermore, participants were able to generalize knowledge of this constraint to novel items. These findings provide further evidence that a process of 'tuning', as proposed by Dell et al. (2000), may play an important role in the acquisition of phonotactic knowledge.

These results are in line with the phonological properties of languages. Speakers use the phonotactics properties of the language system they are exposed to. They do not tend to violate the basic properties of the system. It thus appears that the task is sensitive to the properties speakers use in speech.

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