Vowel harmony is a phonological phenomenon, present in many languages (e.g., Turkic Languages [e.g., Turkish, Kazakh, Uzbek] (Göksel & Kerslake, 2010), Finno-Ugric Languages [e.g., Finnish, Hungarian] (Karlsson & Chesterman, 2015), Korean (Yeon & Brown, 2019), Japanese (Kaiser, 2013)). This phenomenon is the situation in which, for a given monomorphemic words, some vowels cannot be used together with others. It is thought that the vowel harmony that occurs naturally in the language reduces the effort during speaking (Khalilzadeh, 2010). It is characterized by phonological features, which include rules about language sounds, and categorizes vowels according to the position and auditory characteristics of the language (e.g., front/back harmony, height harmony vowels) (Yavuz et al., 2011).

The present study aims to investigate vowel harmony (front and back) in Turkish language. In vowel harmony in Turkish, if the initial syllable of a word begins with a front vowel, the following syllables also align with front vowels (e.g., güven [trust] and ödül [award]). Conversely, when the first syllable starts with a back vowel, the subsequent syllables consistently have back vowels (e.g., karar [decision] and yakın [near]). This configuration of back and front vowel harmony facilitates the pronunciation of a word (Acartürk et al., 2023).

Previous studies have demonstrated that vowel harmony serves as a reliable indicator of signaling word boundaries.

Add Finnish examples Suomi et al. (1997)

Ketrez and Fatma (2013) examined child-directed speech in a corpus-based study that compared non-harmonic languages (Farsi and Polish) with harmonic languages (Turkish and Hungarian) and concluded that harmonic languages give learners harmony cues for word segmentation.

According to another study comparing French and Turkish speakers regarding the impact of word stress versus vowel harmony on word segmentation, French speakers only used stress cues for word recognition, while Turkish speakers were more sensitive to vowel sequences in word segmentation and combined them with regularities (Kabak, Maniwa & Kazanina, 2010).

For instance, in Turkish, there are four front vowels (i, ö, ü, e; [/i/, /ø/, /y/, /e/]) and four back vowels (ı, o, u, a [/ɯ/,/o/,/u/,/a/]) as can be seen in Table 1. Typically, monomorphemic Turkish words are composed of only front vowels or only back vowels. Vowel disharmony occurs in some compound words (e.g. gökdelen [skyscraper]) and loanwords (e.g., parti, [party], or haber [news]).

Table 1

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Vowel Harmony | | | | | | | |
| Turkish Vowels | | | | | | | |
| Front | | | | Back | | | |
| e | i | ö | ü | a | ı | o | u |

For instance, Finnish speakers have difficulty pronouncing the word (olympia [Olympic], /ˈolymp(ː)iɑ-/) because the front vowel /y/ would not be harmonic with the other vowels and indeed they often normalize it to /ˈolimp(ː)iɑ-/.

Perea et al (2021) examined whether vowel harmony facilitates word recognition with single-presentation lexical decision tasks. Since disharmonious words are rare in Finnish, they only used harmonic words as target words, and both harmonic and disharmonic words were used as pseudowords. They observed faster and more accurate responses to disharmonic pseudowords than harmonic pseudowords.

In the present study, we design two separate experiments to investigate the impact of vowel harmony on Turkish visual word recognition. In Experiment 1, we examined whether vowel harmony is a cue for word-likeness in both words and pseudowords. Therefore, we present words and pseudowords with both conditions as harmonic and disharmonic. Furthermore, in Experiment 2, disharmonic words were excluded and only harmonic words and harmonic and disharmonic pseudowords were compared (as Finish doesn't have disharmonic word conditions).

Turkish and Finnish have commonalities and differences in terms of vowel harmony. Both languages display disharmony in borrowed lexemes (e.g., for Turkish; parti, [party], for Finnish; olympia [Olympic]), deviating from native patterns during assimilation. Additionally, vowel disharmony is observed in compound lexemes in both languages (e.g., for Turkish; gökdelen [skyscraper], for Finnish; öljyonnettomuus [oil accident]).

Interestingly, Even though Turkish underwent a profound transformation into Modern Turkish during the 20th century, with the establishment of Turkey, it was influenced by different civilizations over the centuries. Notably, it has been estimated that more than half of the Turkish lexicon has a different origin (around 32% of the lexicon is Turkish, 39% is Arabic, 12% has Persian, and 17% originates from Western languages [Exampled Great Turkish Dictionary, 2005]) (Bıyıklı, 2020). In this linguistic landscape, it is apparent that Turkish has a higher frequency of borrowed and therefore higher frequency disharmonic lexemes than Finnish.

Research

There have been many experiments conducted in the past on vowel harmony. In an experiment conducted on vowel harmony in Turkish, Kiliç (2015) showed that primary vowel harmony facilitates visual word recognition. And she believed that vowel harmony occurred through the use of phonemic cues during word recognition. In a second experiment, showed that nonword harmony words affected accuracy and time. However, while it is possible to occasionally come across disharmonic single-form words in Turkish, in languages such as Finnish, which do not contain letters from two different categories, the only incompatible words are loan and compound words. Perea et al. (2022), in their recent study on Finnish, proved that although it is not useful in recognizing the first moments of words, vowel harmony has a strong effect in the following processes, both in front vowel and back vowel words. The results show that the fact that all words except loan words and compound words have vowel harmony makes it difficult for native Finnish speakers to read loan words. In a Finnish eye movement study on the processing of compound words with vowel mismatches, it was shown that compound words that both have different harmony types are processed faster than compound words that both have the same harmony type. This situation, which only occurs when the first compound word is long, provides a morphological separation by marking the vowel mismatch between compound words. The results prove that letter mismatch facilitates compound word recognition (Bertram et al., 2004). In addition, disharmony words, which are rare in Turkish, are recognized slower than harmonious words (Kiliç, 2015).

1.1.Phonomic Features

Words with phonemic clues contain letters with similar sounds and mouth movements that help achieve vowel harmony. Therefore, it ensures that the word has a certain group feature. Related to this, in a study conducted on the effect of vowel harmony on visual word recognition in Turkish, it was seen that phonemic cues played a role. In the study, it was shown that participants recognized Turkish words containing harmony faster and more accurately than words without harmony. The results of the study confirm the existence of vowel harmony (Kiliç, 2015).

In a statement regarding the importance of vowel harmony, Khalilzadeh (2010) said that it would not be possible to speak Turkish if this rule was removed from the sound system. This means that vowel harmony in the language serves the spoken language as well as the written language. In other words, there is a perception that arises spontaneously through phonology. For example, the structure of the word can be predicted from lip movements during speech. There is some evidence for the effects of vowel harmony on spoken word recognition in languages with vowel harmony. For example, Vroomen et al. (1998) showed that vowel harmony can be used as a cue to determine word boundaries in a cohesive manner in Finnish.

When we look at the interaction between spoken and written language, we can see the importance of the relationship between them more clearly. Because the systems that represent the spoken language in a language are written languages. Therefore, in a psychological procedure that involves written language, there must be an understanding of spoken language. Katz and Frost (1992) emphasized that although the production of phonological codes requires a certain amount of repetition, when repeated enough, it is a natural way of using the codes and can be easily accessed later. Additionally, using phonological information provides more advantages in some languages. For example, in languages with shallow spelling rules, such as Turkish, using phonemic clues strengthens vowel harmony more than in languages with deep spelling. In the study, it was pointed out that the use of phonemic clues facilitates vowel harmony. In the same study, it was stated that when reading Hebrew, participants preferred to use phonological information as long as it was available (Katz & Frost, 1992).

It seems that naturally occurring phonemic cues are a facilitating factor in using and recognizing language. In languages with vowel harmony, it has a function used in word recognition. Thus, we can say that in a language where almost all words contain harmony, a word that does not contain vowel harmony will be noticed directly. Looking at the subject in more detail, a study showed that native Finnish speakers use vowel dissonance as a word boundary cue to understand the spoken language. Words containing vowel harmony were accepted by the participants at first and there was a slowdown in understanding whether they were words or not. As a result, participants recognized words with vowel mismatches faster and received help from phonemic cues to distinguish whether they were words or not (Vroomen et al., 1998).

It is known that this rule (VH) is a facilitating factor in word recognition in Turkish and some other languages. For example, in a study on tracking eye movements in silent and oral reading, a significant effect of the "fixation speech interval (FSI)" on the phonological feature was observed in languages such as Turkish and Finnish, which have shallow word spelling (Acartürk et al., 2023).

Words that have no meaning in the language they are examined in, but that comply with the rules of the language (such as vowel harmony) and give the impression of being words at first sight, are called pseudowords. It has been observed that pseudo-word lists were prepared in some studies in the past to evaluate the effect of phonemic features. For example, in a study on fake word reading in Turkish based on word recognition in sentences, the fake word read for the first time was followed by the 2nd reading. Participants assumed that they misread false words with vowel harmony and declared them as correct words. In other words, fake words created the impression of words when they carried the harmony existing in the language. As a result of studies, it is seen that phonotactics, which plays an important role in linguistic analyzes and language learning processes, has an effect on word reading (Acartürk et al., 2017).

Dil öğrenme süreçleriyle ilgili olarak yapılan başka çalışmalarda da benzer sonuçlar elde edilmiştir. Örneğin In the target words in the Kiliç, (2015) sözcük ögelerinin başına veya sonuna, uyumlu veya uyumsuz türde heceler eklendiğinde, uyum uyumsuzluğu olan kelimelerin daha hızlı ve daha yüksek doğrulukta tanındığı gösterdi. Böylece çalışma eşleşme uyumunun kolaylaştırıcı etkilerini kanıtlamıştır.

Görüldüğü üzere Türkçe de kelime tanıma üzerine yapılan çalışmalarda kelime sıklığı, kelime uzunluğu, ünlü uyumu, kelime ekleri gibi kelimeleri manipüle edebilecek birçok değişken vardır. Bu deneyde Türkçe ön ve arka ünlülerden oluşan birinci ünlü uyumunun görsel kelime tanımayı kolaylaştırılacağı varsayılmıştır. Fince gibi uyum kuralları olan dillerde tek biçimli kelimelerde disharmony bulunmamaktadır. Ve yapısında yer alan sığ imla kuralları nedeniyle fonemlerle mükemmel uyum içerisinde olan kelimeler için fonolojik kodları çözmek basittir. Bu sebeple telaffuz etmekte yaşanan zorlukla beraber uyumsuz kelimelerin tanınmasına da hızlı tepki vermektedirler (Perea vd., 2022). Bu da çalışmayı kontrol etmeyi zorlaştırmaktadır.

Fakat Türkçe de tek biçimli disharmonic kelimelerin bulunması, her iki taraftan da kontrol edilebilmesini sağlayan dilin ayırt edici bir özelliğidir. Bu özelliği sayesinde disharmonic kelimeleri manipüle edebiliriz. Tek biçimli sözcüklerin nadiren yer alması sebebi ile Türkçe de aynı etkiyi gösterip göstermeyeceğinin araştırılması deneyin ilk hedefidir.

İkinci olarak iki türü de içinde bulundurması sebebiyle Harmonic ve disharmonic Sahte kelime listeleri yaratmak mümkündür. Böylece Türkçe de ünlü uyumunun görsel kelime tanımaya etkileriden eğer varsa faydalanabileceğiz.

**Experiment 1**

**Method**

*Participants*

This sample procedure and analysis was pre-registered at <https://osf.io/ep3gx> . Thirty-six Turkish participants took part in the experiment. The participants were recruited from online settings and all of them were native speakers of Turkish. None of them reported having any speech/reading problems.

*Materials*

We selected 142 nouns -half are harmonic and the other half are disharmonic- of 4-5-6 letters long in Turkish from an online blog corpus [WordLex, (Gimenes & New, 2015)]. The harmonic words had an average frequency of 135,84 occurrences per million words (Zipf = 4.941, OLD20 = 1.604) and the disharmonic words had an average frequency of 112,66 occurrences per million words (Zipf = 4.845, OLD20 = 1.654). Target words were either harmonious (all vowels were from the same type, front or back, for instance, SANAT [art]) or disharmonious (words contained both front and back vowels, for instance, ZAFER [victory]). The manipulation for the target nonwords was the same (harmonic pseudowords vs disharmonic pseudowords). These pseudowords were generated with the target words and the bigram algorithm with the help of the pseudoword generator (Wuggy, Keuleers & Brysbaert, 2010).

*Procedure*

The experiment was implemented by PsychoPy (Peirce et al., 2019) and Pavlovia.org was used as the platform of the experiment. The typical lexical decision task procedure was followed. Participant first asked the demografic information by Pavlovia Survey (Open Science Tools, Nottingham, UK). Additionally, there was a brief practice session before the experiment, consisting of 16 trials. Each trial began by a fixation cross with 500ms. While participants had unlimited time to respond in practice rounds, in experimental trials, after the presentation of the target (either word/pseudoword with harmony/disharmony), they had 2 seconds to respond. Every 120 trials, participants were asked to take a short break before continuing the experiment.

*Data analysis*

Reaction times shorter than 250 ms were disregarded (%0.06, N=7). A response deadline of 2000 ms was set, and any response exceeding this timeframe was automatically classified as an error by the program (%0.33, N = 37). There were no participants whose accuracy fell below the threshold of %75.

A Bayesian linear mixed model was employed for data analysis, with separate analyses conducted for word and non-word targets. In the case of word targets, only fixed factor considered was the type of word (harmonious vs. disharmonious). The analysis incorporated a maximal random structure model (Barr et al., 2013), encompassing both by-subject and by-item intercepts and slopes for the type of word. The exgaussian family was utilized to model reaction time, while the Bernoulli family was employed for accuracy data. The analyses for the pseudoword targets will be the same for the word targets. The model implementations involved the use of 4 chains and 10,000 iterations (with a warm-up phase of 2000 iterations).

Results

Table X provides the descriptive statistics associated with response times and accuracy for both words and nonwords within the vowel harmony conditions.

|  |  |  |  |
| --- | --- | --- | --- |
| **Table x.** Means and standard deviations (inside of the brackets) of reaction time and accuracy for word conditions and vowel harmony conditions. | | | |
|  |  | *RT* | *Accuracy* |
| *Word* | |  |  |
|  | Harmonic | 604.28 (….) | 0.97 (…) |
|  | Disharmonic | 623.24 (….) | 0.97 (…) |
| *Pseudoword* | |  |  |
|  | Harmonic | 684.59 (…) | 0.95 (…) |
|  | Disharmonic | 686.46 (…) | 0.94 (…) |

The reaction times were slightly faster for disharmonic pseudowords compared to harmonic pseudowords (effect; … ms, *b* = .., 95% CrI […..]), However, it can be interpreted that this difference is not decisive since 0 is in the credible interval.

The accuracy rate was marginally higher for disharmonic pseudowords compared to harmonic pseudowords (effect; …., *b* = 0.., 95% CrI […..]), nonetheless, it cannot be interpreted that this difference is decisive since 0 is in the credible interval again.

**Experiment 2**

**Method**

*Participants*

This sample procedure and analysis was pre-registered at ...... Thirty-six Turkish participants took part in the experiment. The participants were recruited from online settings and all of them were native speakers of Turkish. None of them reported having any speech/reading problems.

*Materials*

The harmonic nouns utilized in the first experiment were maintained, and disharmonic nouns were replaced with new harmoinc nouns from the same corpus. This adjustment was made to ensure that there is no significant difference between the Zipf of all Turkish words in Experiment 1 and in Experiment 2 (Zipfexp1 = 4.845, Zipfexp2 = 4.906, *t* = 0.302). Same pseudowords in experiment 1 used in the experiment 2.

*Procedure*

The procedure is the same as experiment 1.

*Data analysis*

Reaction times shorter than 250 ms were disregarded (….). A response deadline of 2000 ms was set, and any response exceeding this timeframe was automatically classified as an error by the program (….). There were no participants whose accuracy fell below the threshold of %75.

Data analysis method is the same as experiment 1.

*Results*

Error responses and response times (RTs) lower than 250 ms were removed from the latency and accuracy analyses *(N =*  435, %4.5). Table X provides the descriptive statistics associated with response times and accuracy for both words and nonwords within the vowel harmony conditions.

|  |  |  |  |
| --- | --- | --- | --- |
| **Table x.** Means and standard deviations (inside of the brackets) of reaction time and accuracy for word conditions and vowel harmony conditions. | | | |
|  |  | *RT* | *Accuracy* |
| *Word* | |  |  |
|  | Harmonic | 585.10 (159.9) | 0.97 (0.18) |
| *Pseudoword* | |  |  |
|  | Harmonic | 668.20 (181.6) | 0.95 (0.23) |
|  | Disharmonic | 664.00 (187.9) | 0.96 (0.21) |

The reaction times were slightly faster for disharmonic pseudowords compared to harmonic pseudowords (effect; 4.20 ms, *b* = -8.18, 95% CrI [-17.26, 0.84]), However, it can be interpreted that this difference is not decisive since 0 is in the credible interval.

The accuracy rate was marginally higher for disharmonic pseudowords compared to harmonic pseudowords (effect; 0.1, *b* = 0.14, 95% CrI [-0.13, 0.13]), nonetheless, it cannot be interpreted that this difference is decisive since 0 is in the credible interval again.

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