Do We Find
That They Rhyme?

A Corpus-Based Approach to Analyzing Phonological Similarity Using Imperfect Rhymes

by,
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Abstract

The art of rhyme has been analyzed by linguists in the past to deepen our understanding of speakers' implicit knowledge of phonological properties. Through several studies, linguists have theorized that individuals possess rich knowledge of speech sound similarity and that sound similarly forms a gradient rather than a binary. Studies have been conducted on various corpora that contain rhymes and found that the frequency of sound mismatches of various sounds in imperfect rhymes often correlates with how similar those two sounds are based on predetermined metrics, such as phonological features. In this paper, we use computational methods to investigate and present data about imperfect rhymes in the Billboard Year-End Hot 100 Singles from 1964-2015. For these imperfect rhymes, we keep track of the frequency and type of sound mismatches. We find that frequency of sound mismatches generally aligns with similarity of the sounds in top pop songs, providing further evidence for the theory that speakers possess knowledge of sound similarly.

Contents

1 Introduction

"Verbal art" is a term used to describe any art that is "expressed in words, whether spoken or written, but commonly spoken" (Bascom 1955:246). Poems and songs are examples of verbal art. For thousands of years, language has been used as a tool to produce art by setting words to music or a specific rhythm or pattern. American classicist Milman Parry (1930) reports that as early as the 8th century B.C.E, poetic works were intended to be recited and were composed as oral poetry and verbal art. Homer's *Iliad* is an example of such verbal art (Parry 1930:77).

Throughout this long history of the pairing of language and rhythm however, there have been vastly different understandings as to what constitutes a well-formed match between the two. Different trends have thus emerged as to how to pair language with music and rhythm. In Old English, for example, alliteration (which involves pairing words with the same initial sound) was the ideal "systematic sound patterning device" (Holtman 1996:21). This was the standard aesthetic for combining language and sound. In fact, alternative processes, such as homeoteleuton, which refers to the pairing of words with similar ending sounds in the last syllable (also known as rhyme), were considered bad form and were even discouraged (Harmon 1987:365). However, as time progressed into the Middle Ages, the aesthetics of verbal art changed and rhyme became much more common and was even seen as "obligatory" in poetry, a notable departure from the "bad form" view of rhyme of the previous centuries (Holtman 1996:22; Harmon 1987:365). Now, in the 21st century, it is common to see verbal art and verse that either does not contain any rhyme at all, or that contains pairs of words that form imperfect rhymes - rhymes that match in some sounds of the last stressed syllable, but not others.

While it may seem as though the different trends in the ways language pairs with rhythm simply reflect different preferences, when analyzed through a linguistic lens, it becomes clear that these trends, and the conventions used within each trend, may be described as something more than simply a preference. The patterns are, in fact, rooted in the properties of language. For example, the lack of rhyme in Old English, at least early on, was due in part to the language's structure as a synthetic and suffixal language which does not lend itself to rhyming because of the prevalence of unstressed syllables at the end of words (Harmon 1987:367). In this example, the structure of the language affected the aesthetics. Similarly, the change reflected in the Middle Ages that we noted above aligns with a period of dramatic change in the English language: a large number of French and Latin words that did contain stressed syllables entered the language, a property that lends itself more naturally to rhyme (Holtman 1996:22). This caused an increase in rhyme usage.

In general, it is clear that aesthetic trends in verbal art over have reflected properties of the language. Linguist Paul Kiparsky confirms this. He wrote, "A good number of what we think of as traditional and arbitrary conventions are anchored in grammatical form, and seem to be, at bottom, a consequence of how language itself is structured" (Holtman 1996:39). In making this connection, Kiparsky established that the study of linguistics need not be separated from the study of poetry and music. In fact, one can illuminate the other. In a somewhat self-referential way, language in verbal art can be used to convey human knowledge about language. For this reason, music and other art forms that involve language have been used by linguistics for many years as a tool to examine a variety of linguistic theories from the phonetic level to the pragmatic level.

One of the phonological linguistic theories that has been explored through verbal art (and specifically music) is the idea that humans possess a "richly encoded" knowledge of "scales" of phonological similarity and that phonological similarity forms a gradient rather than a binary (Avidan 2017:1). Knowledge of sound similarity is general the notion that humans can distinguish sounds from one another and the degree of difference between those sounds varies (Avidan 2017:1). Phonological similarity specifically refers to the sharing of distinctive phonological features (van der Schelde 2020:8). Some sounds are more similar than others and therefore, certain sounds can be combined to create similar sounding words. A number of studies have been conducted to develop hierarchies of phonological feature similarity and to understand speakers' knowledge about these hierarchies.

We established thus far that verbal art can be used to explore linguistic theories and that one of those theories is about phonological similarity. In this paper, we also use verbal art to explore a linguistic theory of phonological similarity. We ask, to what extent do trends in the types of imperfect rhyme used in top pop songs from 1964-2015 reflect notions of phonological similarity? We employ computational methods to answer this question. We seek to shed light on the belief that individuals possess unconscious knowledge of sound similarity.

2 Background and Literature Review

Below, we define and describe necessary terms for this paper in the realms of phonology and rhyme and provide a brief explanation on previous studies that have been conducted that connect phonology and rhyme.

2.1 The Sound System and Phonological Similarity

Because rhyme is characterized by matchings of certain sounds, understanding the aesthetic and nature of rhyme necessitates an understanding of the structure of the phonetic and phonological system (the sound system) of spoken language. We only examine consonant similarity in our research, so we restrict our description here to the sound system of consonants.

The study of phonetics and phonology looks at the smallest building blocks of language: individual sounds. A notable property of an individual sound is that it does not contain any intrinsic meaning (unless that sound is also deemed a morpheme). Rather, individual sounds can be used to create meaningful structures though novel combinations (Hayes 2008:19). As linguist Bruce Hayes (2008) explains, “the only real purpose of a speech sound is to sound different from other sounds of the language; this is what makes a spoken vocabulary possible." There are a number of properties and features that make a speech sound different from other sounds and linguists make use of these properties to describe a sound system.

Consonants can be described to differentiate one from the other using different properties and sets of features including state of the vocal folds, place of articulation, and manner of articulation (which includes numerous features such nasality, and central vs lateral airflow). Figure (1) shows the organization of English consonants using international phonetic alphabet symbols. The distinct voice, place, and manner of articulation of a consonant are used to describe an individual consonant. Consonants can also be grouped together based on these properties to form natural classes.

Manner of Articulation	Place of Articulation															
	Bilabial		Labio-dental		Inter-dental		Alveolar		Post-Alveolar		Palatal		Velar		Glottal	
Stop	p	b					t	d					k	g	ʔ	
Fricative			f	v	θ	ð	s	z	ʃ	ʒ					h	
Affricate									ʧ	ʤ						
Flap								ɾ								
Nasal		m						n						ŋ		
Lateral Liquid								l								
Retroflex Liquid								ɹ								
Glide	w̥	w[3]										j				

State of the Glottis	Voiceless	Voiced

Figure (1): *English Consonants IPA Chart (Lionnet 2022)*

We provide [d] as an example. Using the above chart, it is clear that [d] and [t] differ only in the state of the vocal folds, [d] and [b] differ only in place of articulation, and [d] and [ɹ] differ in manner of articulation, as do [d] and [n] which specifically differ in nasality. It is important to note that not all languages consider different sounds to be distinct even if they sound distinct acoustically. Some speakers of languages that do not consider sounds to be distinct may not even hear an acoustic difference between two sounds with different properties. In English though, the example sounds provided above are distinct and contrastive, but because [d] differs with each of these other sounds only in one or two features, the sounds seem similar. “Similar consonants” can be thought of as consonants that share some of the properties and features noted above.

This notion of similarity is important for this paper because in our research, we examine whether sounds that are “more similar” by sharing more properties are more frequently involved in mismatches in imperfect rhymes than those that share fewer properties. We look at which of the kinds of features described above are most salient in determining how similar two sounds are, and we also examine whether speakers seem to possess a robust knowledge of a scale of phonological sound similarity or not.

2.2 Rhyme

The sound system described above is useful for describing rhyme, and will be especially useful for our definition of the term “imperfect rhyme.” As mentioned in the introduction, verbal art has progressed a long way from the Middle Ages when a rhyme was rarely considered acceptable, and when it was, it was only under a strict set of constraints. Now, there are many types of rhyme that are considered acceptable in verbal art and there exist many definitions of rhyme and many different purposes for rhyme (Rickert 1978). In the following section, we describe a basic definition of rhyme as well as some variations. We focus mainly on imperfect rhyme, since this is the rhyme variety we use in our research.

2.2.1 Structure and Types of Rhyme

Rhyming pairs are commonly understood as two words whose sounds are identical following the final stressed vowel in the words. This corresponds with the final stressed syllable (Popescu-Belis et al. 2023:11). Therefore, understanding rhyming pairs necessitates knowledge of syllables. A syllable is a method for clustering segments into sequences. It always consists of a nucleus which is the most sonorous part of the syllable and is usually a vowel. A syllable can also contain an onset, which is a consonant or a set of consonants that comes before the nucleus, and a coda, which is a consonant or set of consonants that comes after a nucleus. The rime in a syllable consists of the nucleus and the coda (Zec 2007:177). In the paper, we use "rhyme" to describe two words that sound similar and we use "rime" to describe the subset of a syllable that contains the nucleus and the coda. In a common definition of rhyming pairs, the final stressed syllables must contain matching rimes (Popescu-Belis et al. 2023:11). Figure 2 is a diagram that demonstrates the syllable breakdowns for the rhyme pair "dog" and "hog."

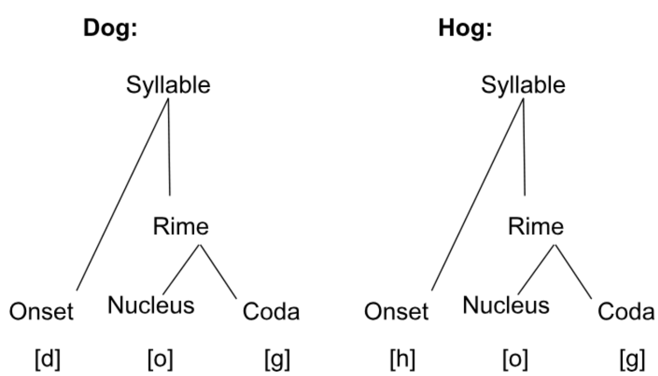

Figure (2): *Syllables and Rime in "dog" and "hog"*

Because the sounds in the nucleus and coda (which form the rimes) are identical, the words above form a perfect rhyme. Throughout this paper, we use the term "perfect rhyme" to refer to words that perfectly match in sounds starting with the nucleus of the final stressed syllable. Imperfect rhyme, by contrast, is a type of rhyme that involves words which are paired together but do not match in all sounds in the final stressed syllable following the vowel. We specifically define "imperfect rhyme" as the pairing of words that contain the same nucleus but different codas in the last syllable. This definition matches up with the definition of imperfect rhyme in previous studies, though some use the term "assonant rhymes" to refer to the same idea (Popescu-Belis et al. 2023:11). In this paper, any consonants or consonant clusters can be in the coda and the words can still be considered rhyming as long as the nucleus in the final syllable is the same. When consonants do differ from one another in the coda, we call that a "consonant mismatch." Imperfect rhymes may be more acceptable or recognizable depending on which consonants are mismatched in the codas.

There are two types of consonant mismatches in imperfect rhyme referenced in the literature. Subsequence rhyme is a type of imperfect rhyme that inserts or deletes a consonant in the final codas of paired words so that the codas contain different numbers of phonemes [1] (Holtman 1996:195). Feature rhyme is a type of imperfect rhyme that refers to any pairing of words that replaces one consonant in the final coda with another so that the codas contain the same number of phonemes (Holtman 1996:195). In this paper, we use consonant mismatch pairs from both subsequence and feature imperfect rhymes as data. Figure (3) is a diagram that demonstrates the syllable breakdowns for the imperfect subsequence rhyme "not and "pots." Figure (4) is a diagram that demonstrates the syllable breakdowns for the imperfect feature rhyme "hop" and "pot".

[1] We use "insert" and "delete" here to simply refer to a rhyming pair which differs in the number of phonemes in each word's coda. This paper does not consider it of any importance to examine whether the difference is an insertion (the word with the extra consonant came second in the lyrics) or a deletion (the word with the extra consonants came first in the lyrics).

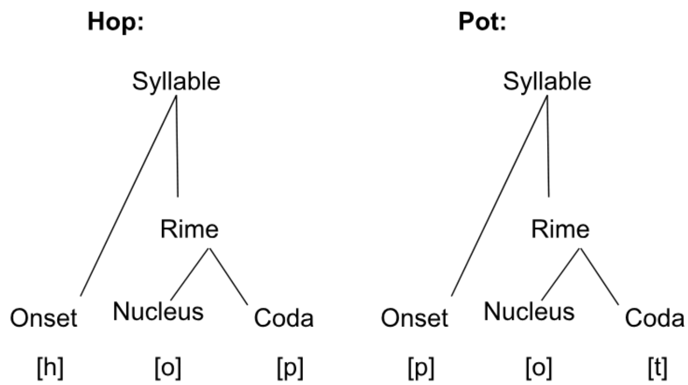

Figure (3): *Syllables and Rime in Feature Rhyme "Hop" and "Pot"*

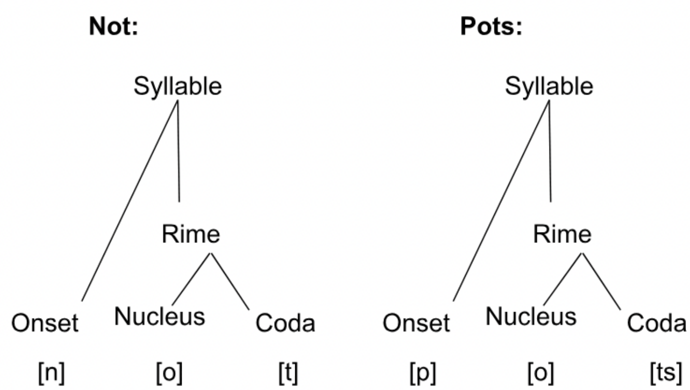

Figure (4): *Syllables and Rime in Subsequence Rhyme "Not" and "Pots"*

2.2.2 Function of Rhyme

Having explained rhyme and the definitions of perfect and imperfect rhyme in this paper, we now provide a brief explanation on three main functions of rhyme. First, rhyme has a structural function. Rhymes can signify the end of lines and can mark off specific groupings and segments (Wesling 2021:5). Rhymes can break up poems and break up stanzas to help the reader understand what to anticipate as they move through a poem's structure. Second, rhyme has a semantic function. Russian Linguistic Roman Jakobson claims that rhyme "necessarily involves the semantic relationship between rhyming units" (Wesling 2021:53). When writers pair words together in a rhyme, they make a connection between the two words that highlights their meaning and contributes to the understanding of the poem. Third, rhyme has a poetic and aesthetic function. English literature professor Donald Wesling (2021) says that rhyme is an "auxiliary for rhythm" and uses the term "harmony of sound" to describe the effect of rhyme. The musical nature of rhyme has certain tones that differ depending on the patterns of rhyme. All of these functions of rhyme have effects on the reader/listener. Structured sound in music and poetry can be linked to biological rewards including dopamine releases (Patel 2014). Rhymes, whether perfect or imperfect, can be examples of this idea of structured sound referenced above that release dopamine. This paper will look at the types of imperfect rhymes that are most commonly used as structured sound in music.

2.3 Previous Research on Rhyme and Phonology

A number of studies have been conducted that make use of the properties of sound and rhyme described in section 2.1 and section 2.2 of this paper. These studies inform our own research.

In 1996, linguist Astrid Holtman proposed a hierarchy of preferences for manipulating certain kinds of sounds in rhyme that is solely based on sound similarity (van der Schelde 2020). Various phonological features of sound (that we described in 2.1) were ranked by Holtman in terms of how much each feature affects the human perception of the similarity of two sounds. For example, differences in the features of place are found at the top of Holtman's hierarchy. Sounds that only differ in place are therefore considered the most similar. Holtman derived this theory by analyzing 70 songs of artist Lou Reed and combining those findings with previous song lyric analyses. Holtman specifically looked at imperfect rhymes (rhymes that contain at least one phonological mismatch) in these songs and poems (Holtman 1996). Figure (5) shows Holtman's hierarchy.

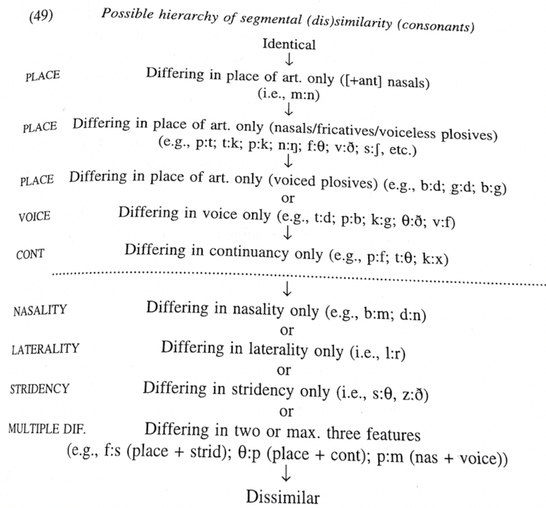

Figure (5): *Holtman's Hierarchy of Similarity (van der Schelde 2020; Holtman 1996:249)*

Holtman's (1996) work on exploring the notion of sound similarity through imperfect rhyme proved foundational and inspired others to similarly develop sound similarity hierarchies through rhyme in music. One study, conducted by linguist Jonathan Avidan (2017), tracked 842 sets of imperfect rhymes in American Broadway musicals and found a number of patterns in the consonant mismatches. For example, the study found that nasals were most often the natural class that differed in place, followed by stops, then spirants. Avidan (2017) concluded that humans have a notion of scales of phonological difference, which matches up with Holtman's claim. Beyond analyzing patterns, Avidan (2017) also made the claim that speakers seem to "discreetly compute for the possibility of an imperfect rhyme." He says that they can anticipate a phonologically similar word that isn't a perfect match even when singers trail off before completing a rhyme (a phenomenon known as "inferred rhyming").

Linguist Jonathan Katz (2015) performed a similar study with imperfect rhymes taken from a corpus of African American English hip hop lyrics. He found that the most common mismatches in imperfect rhymes tended to be between sounds that generally are not contrastive in many parts of the world. This led him to not only conclude that individuals possess knowledge of speech sound similarities, but also that this knowledge extends beyond the speech sounds of an individual's first language and generalizes to all languages (Katz 2015). This correlates with findings from Jona van der Schelde (2020) who used a corpus of Dutch hip-hop lyrics to record imperfect rhymes and conclude that Dutch rappers use feature similarity, whether consciously or not, to create lyrics.

3 Hypothesis

The above studies are examples of previous research that examined imperfect rhyme in song. This research paper similarly uses imperfect rhyme data in songs to explore song artists' knowledge of sound similarity. However, this paper is unique in that it looks at a corpus of top pop songs from 1964-2015, a corpus that has not been used before to track imperfect rhymes. Also, this corpus uses computational methods to acquire the data and is, therefore, able to look at a much larger dataset than previous studies. In this paper, we hypothesize that the frequency of various consonant mismatches in imperfect rhymes matches up with similarity of mismatched consonants based on hierarchies of phonological features from previous studies. For example, we suspect that place is the most common mismatched type of feature. The aim of this research is to seek to reject the null hypothesis H_0 and provide support for the hypothesis H_1.

H_0: The frequency of consonant mismatches in imperfect rhymes is not predictable and does not reflect properties and notions of sound similarity.

H_1: The frequency of consonant mismatches in imperfect rhymes is predictable and reflects properties and notions of sound similarity.

This finding has implications for theories of phonological similarity. If we find that the frequency of mismatches of various types of consonants reflects groupings of natural classes, this can provide evidence that singers possess an implicit knowledge of these natural classes and their relative perceptual similarities. If the frequent natural classes align with previous hierarchies, then it would seem as though there is some generalized understanding of what makes a well-formed imperfect rhyme. If we do not find that imperfect rhyme mismatch frequencies correlate with natural classes or previous hierarchies, this can provide evidence that there is no notion of well-formed rhymes that correlates with phonological similarity or that individuals lack an implicit knowledge of perceptual similarity.

4 Methods

Coding for this project was organized in two processes. In the first, we acquired a corpus of song lyrics through web-scraping. In the second, we collected data about the perfect and imperfect rhymes in the songs.

4.1 Song Lyric Corpus

We used a corpus of songs that included a range of 52 years and 5,200 songs because this provided us with a large dataset that would lead to more reliable results than previous studies which only used 10-15 songs. We specifically used the time period of 1964-2015 because nearly all the songs in this period have publicly available song lyrics online, and because we found roughly the same amount of data per year in this range. We started with 1964 since this year marked the beginning of a "revolution" that led to a period of change in music, with notable "expansions of several styles" of music that made their way to the Billboard Hot 100 (Mauch et al. 2015).

4.1.1 Billboard Hot 100 Song Chart

Songs in this corpus were selected by compiling 100 songs each year from Billboard magazine's measure of the "Year End Hot 100 Singles." Billboard picks the top 100 songs by examining both retail sales and airplay (Bradlow and Fader 2001:369). This chart has come to be the "premiere singles chart" for America's most popular songs (Giles 2007). The Hot 100 chart was used in this study because it contains songs from a wide variety of genres and artists, which is important for this paper that is designed to look broadly across a range of music, unlike other studies that have only looked within one genre or one artist. This specific chart was also ideal because it has been utilized extensively in scientific research in the past (Meindertsma 2019).

4.1.2 Web-scraping

We were unable to find a pre-existing corpus of top 100 songs from the past 50 years that included line breaks and stanzas (which is a crucial part of the rhyme analysis). We found one GitHub project that web-scrapes 100 songs from the Billboard Hot 100 chart each year from 1964-2015 (Pavlik 2016). But, the corpus from this GitHub project scraped the song lyrics without line breaks and stanzas. The project included code for scraping the data. We used this code after adjusting it to scrape the song lyrics with line breaks and stanzas included. The code from the GitHub project was written in R, and since this paper uses Python, we asked ChatGPT to convert the code from R to Python. This was the sole instance of ChatGPT use for this research project. ChatGPT converted a significant portion of the R code, but created a number of bugs. Other bugs were found because the GitHub project relied on 2015 versions of lyric websites from which the code scraped. After converting from R to Python using ChatGPT and fixing many bugs, we changed some lines of code and scraped the songs with stanza and line breaks using a python library called Beautiful Soup. The code acquired a list of the titles and artists for the Hot 100 songs each year by scraping the Wikipedia page "`http://en.wikipedia.org/wiki/Billboard_Year-End_Hot_100_singles_of_{INSERT_YEAR}`" For each song title from the webpage, the code then searched songlyrics.com for the lyrics and put them into a csv file. Songlyrics.com is a site that contains publicly available lyrics to millions of songs (SongLyrics).

Pre-processing and cleaning of the song lyrics was completed through a different function in the code described below. This was an intentional choice to ensure that the corpus we scraped can be used by other projects in the future that have different preprocessing and cleaning needs.

4.1.3 Song Corpus Description

In total, the code scraped 4,588 songs out of 5,200 songs in the chart from the period of 1964-2015. The code didn't find song lyrics on the website for 293 songs (either because the website did not have song lyrics or the song lyrics were listed under a different url that didn't match the standard url that the code relies upon). 14 songs were instrumental only and did not contain lyrics at all. And, 305 songs contained only two stanzas or fewer, which were scraped and put into the database, but were not included in the data because two stanzas was deemed not enough stanzas to accurately detect rhyme. This is because two stanzas or fewer signals some kind of web-scraping error or formatting issue that would impact accurate rhyme counting. This corpus thus contains data for 91.76 percent of songs from the Hot 100 lists from 1964-2015.

4.2 Rhyme Data

After acquiring a song lyric corpus, rhyme data was collected from each song in the corpus.

4.2.1 Rhyme Collection

To collect our data, we build upon publicaly available code. In 2023, a study was conducted to train a language model for rhyme generation on synthetic data (Popescu-Belis et al. 2023). As part of their project, the study provided code for finding both perfect and imperfect rhymes in a poem stanza. We adapted this code to find perfect and imperfect rhymes given a song stanza. The code from the study obtains pronunciations for end-of-line words by using the Carnegie Mellon Pronouncing Dictionary of English (CMPD) which contains phonetic transcriptions for 123,621 English words. The transcription uses ASCII characters, not IPA characters, but one can be mapped onto the other. If a word is not in the CMPD, the code searches for the most similar word that is in the CMPD based on the similarity metric of string edit distance. Once it obtains a pronunciation for a word, it records the word's final vowel and consonants (which is necessary for testing a perfect rhyme) and the word's final vowel without the final consonants (which is necessary for testing an imperfect rhyme pair). The study placed all of this data into a python dictionary and stored that rhyming dictionary in a pickle file so that anyone could use the dictionary to compare the perfect and imperfect rhyme parts of two words to test for rhymes. The study also provided a function for comparing each word to every other word in a stanza (Popescu-Belis et al. 2023).

In this research, we used both the rhyming dictionary and the comparison function from the study described above. In our code, we create two new dictionaries to record the number of instances of each type of perfect and imperfect rhyme in the corpus. We also create two dictionaries to keep track of which words form rhyming pairs. We then loop through each song in the csv file of 4,588 songs and clean each set of lyrics to remove non lyric words such as "verse" and "chorus." We also remove all non-alphabet symbols except the line break symbols. We separate the song by stanza and, one at a time, put each stanza into a function that finds all perfect and imperfect rhyming pairs of end-of-line words in the stanza using the pickle file from the earlier study. Each pair that this code finds is added to the respective dictionaries mentioned above. If the end-of-line-words are the same, it skips this pair and does not consider it a perfect rhyme.

4.2.2 Rhyme Data Decisions and Description

Two key decisions were involved in how to count rhymes in a song. First, we chose to keep track of end-of-line rhymes only, even though rhymes within lines exist, because end-of-line is a very common type of rhyme (Holtman 1996:7) and easily extracted through computational methods. Secondly, we chose to compare every line with every other line in a stanza because different songs follow different rhyming schemes, such as AABB or ABAB, and if we only looked at lines that were right next to each other, we would miss a large number of intended rhymes.

In total, our code found 27,751 perfect rhymes and 24,192 imperfect rhymes.

5 Results

We now present the data collected about rhymes in the corpus of Year-End Hot 100 Singles song lyrics from 1964-2015. Figure (6) shows the number of perfect rhymes and the number of imperfect rhymes found in the corpus. These two types of rhyme differ in counts by 3,559 pairs: perfect rhymes make up 53.4 percent of the total rhymes and imperfect rhymes make up 46.6 percent of total rhymes.

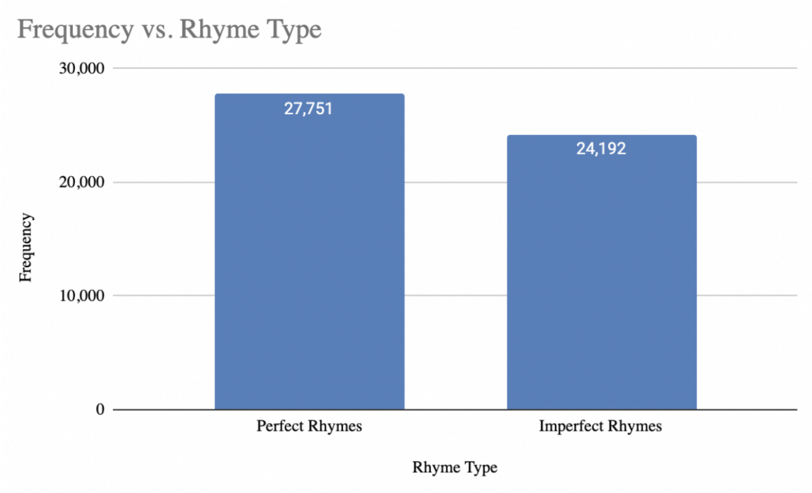

Figure (6): *Counts of Types of Rhyme*

In the remainder of this paper, we focus on the analysis of the phonological properties of imperfect rhymes in our data only.

Within the 24,192 imperfect rhymes in the corpus, there were 757 different coda mismatch pairs that were used to form an imperfect rhyme. Example (A) shows how a coda mismatch pair was acquired from a rhyming lyric. The lyric that contains the imperfect rhyme is written below. The rhyme tree in Figure (7) is provided to show the mismatched part of the codas of the two rhyming words in the lyric using ASCII alphabet transcription. The representation of the coda pair is also provided.

Example (A)

Song Lyrics:

"so come on, every guy grab a **girl**

everywhere around the **world**"

(from “Dancing in the Street” by Martha and the Vandellas 1964)

Rhyme Tree:

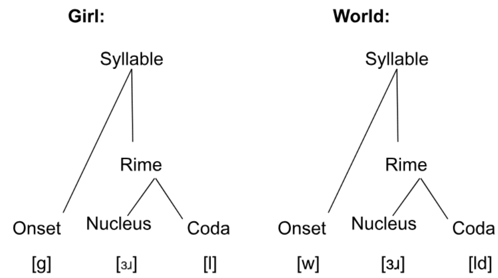

Figure (7): *Syllables and Rime in "Girl" and "World"*

Mismatch in Coda Pair:

('', 'd')

Notation for insertion of 'd' in one coda.

Below, Figure (8) and (9) visualizes the relative frequencies of each imperfect rhyme-coda pair (like the one above in example (A)), one on a linear scale and on a log-log scale. These graphs aim to test whether Zipf's law holds true on this dataset. Zipf's law states that, in a large dataset, the frequency of any element is inversely proportional to its rank (Zipf 1936). Thus, if Zipf's law holds, there should exist many occurrences of only a small set of elements and there should be a large number of elements which occur only infrequently. Based on Figure (8) and Figure (9), we find that Zipf's law does hold.

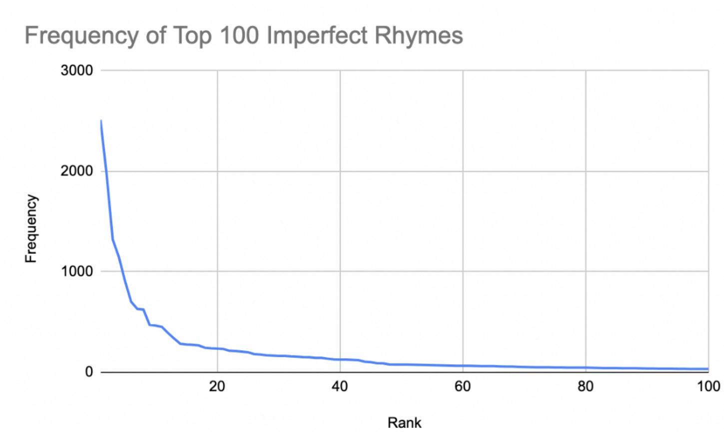

Figure (8): *Linear Scale Graph of Rank vs Frequency of Imperfect Rhyme Pairs*

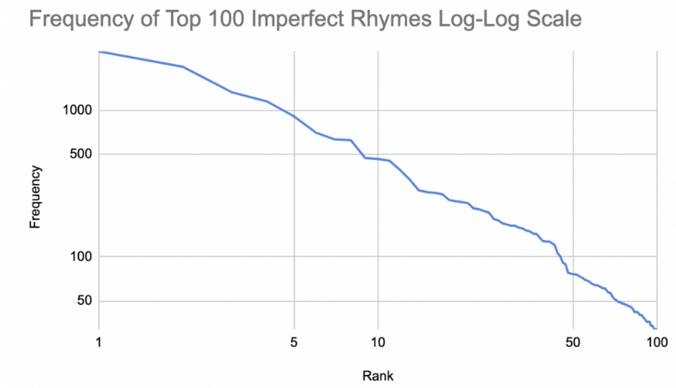

Figure (9): *Log Scale Graph of Rank vs Frequency of Imperfect Rhyme Pairs*

We now limit our detailed analysis to the top forty pairs of imperfect rhyme codas. These correspond with 70.77 percent of all imperfect rhymes in the dataset. Figure (10) shows a table of the coda pairs of these top forty pairs.

Rank	Rhyme	Frequency
1	(", 'd')	2513
2	('z', ")	1974
3	(", 't')	1322
4	('n', 'm')	1147
5	(", 'n')	908
6	(", 'm')	702
7	(", 's')	631
8	(", 'l')	624
9	('k', 't')	472
10	(", 'v')	464
11	('nd', 'm')	452
12	('d', 't')	391
13	('n', 't')	336
14	(", 'nd')	284
15	(", 'k')	276
16	('z', 'd')	273
17	('n', 'ng')	267
18	('t', 's')	244
19	('f', 't')	239
20	('p', 't')	236
21	('m', 't')	232
22	(", 'r')	214
23	('n', 'v')	211
24	('z', 't')	205
25	('n', 'd')	200
26	(", 'p')	181
27	('ng', 't')	177
28	(", 'dz')	169
29	(", 'mz')	166
30	('z', 'n')	163
31	('nd', 't')	163
32	('z', 's')	158
33	('n', 's')	156
34	(", 'ld')	151
35	('n', 'l')	149
36	(", 'f')	144
37	('v', 's')	143
38	('f', 's')	135
39	(", 'ts')	128
40	('f', 'v')	127

Figure (10): *Most Frequent Forty Imperfect Rhyme Coda Pairs*

The top forty pairs of mismatched codas include feature rhyme mismatches (which contain the same number of phonemes in the codas) and subsequence rhyme mismatches (which contain different numbers of phonemes in the codas) (See section 3.1). Figure (11) shows a breakdown in the relative frequencies of each type of imperfect rhyme out of the 17,121 rhymes that make up the top forty pairs[2]. Figure (12) shows the eight most frequent imperfect rhymes.

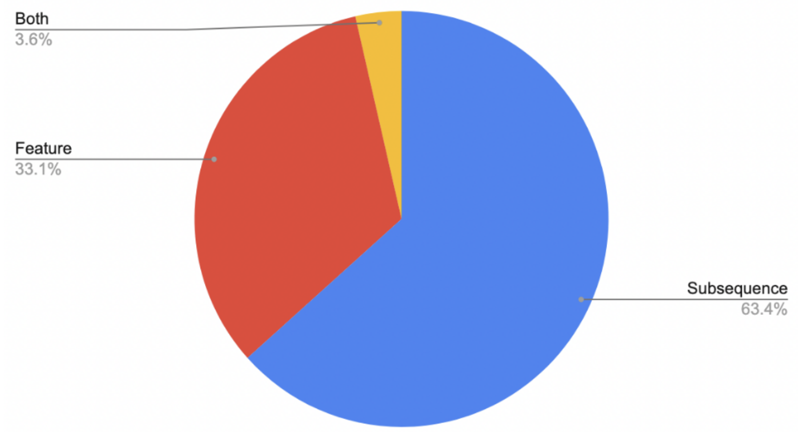

Figure (11): *Subsequence and Feature Rhyme Frequencies*

Rank	Rhyme	Frequency	Type of Imperfection	Type of Insertion
1	(", 'd')	2513	Subsequence	Coronal
2	('z', ")	1974	Subsequence	Coronal
3	(", 't')	1322	Subsequence	Coronal
4	('n', 'm')	1147	Feature	
5	(", 'n')	908	Subsequence	Coronal
6	(", 'm')	702	Subsequence	Labial
7	(", 's')	631	Subsequence	Coronal
8	(", 'l')	624	Subsequence	Coronal

Figure (12): *Top Eight Imperfect Rhymes - Imperfection and Insertion Types*

Figure (11) above shows that there are substantially more subsequence rhymes than feature rhymes in the top 70 percent of the data. And, as seen in column four of Figure (12), the subsequence rhymes are generally concentrated to the highest ranked mismatches. The top three most frequent imperfect rhyme pairs ((”, ’d’),

[2] In Figure (11) "both" refers to a coda pairing such as (’nd’, ’m’). We assume that the "n" and "m" part of the codas represent a feature mismatch and that the "d" represents a subsequence insertion. We always take the leftmost consonants as the mismatches and the additional ones as the insertions. In this case, this choice seems to make sense because (’n’, ’m’) is a frequent feature rhyme and (”,’d’) is a frequent subsequece rhyme.

('z', ''), ('', 't')) are of the subsequence variety and eight out of the top ten imperfect rhymes are subsequence imperfect rhymes. As one goes down the list, feature rhymes become more common and subsequence rhymes become less common.

Subsequence rhymes can be further broken down in the types of consonants that were added in one coda but not the other. We use phonological features to describe these types of coda consonants. We focus on the set of place features, since these have been used in previous studies to compare subsequence rhymes. Figure (13) shows a chart of these patterns and we turn back to column five in Figure (12) for the table of these patterns in the top 8 imperfect rhymes.

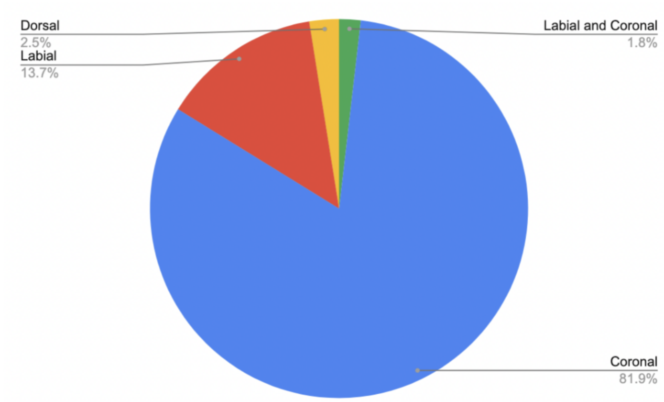

Figure (13): *Types of Subsequence Rhyme Insertions*

Figure (13) above shows that coronals are the most frequently inserted (or deleted) consonant in the coda to form a subsequence rhyme. Column five in Figure (12) above shows that these coronal additions are concentrated to the highest ranking (most frequent) subsequence rhyme pairs. The top four most frequent subsequence imperfect rhymes pairs only involve coronals and six out of eight of the most frequent ones involve coronals. As we go down the list, we can see that other types of subsequence additions are used more.

For feature rhymes, we examine what kinds of phonological feature mismatches are most common as well as whether number of feature differences plays a role in the frequency of mismatches. Broadly, we look at place, manner, and voicing.

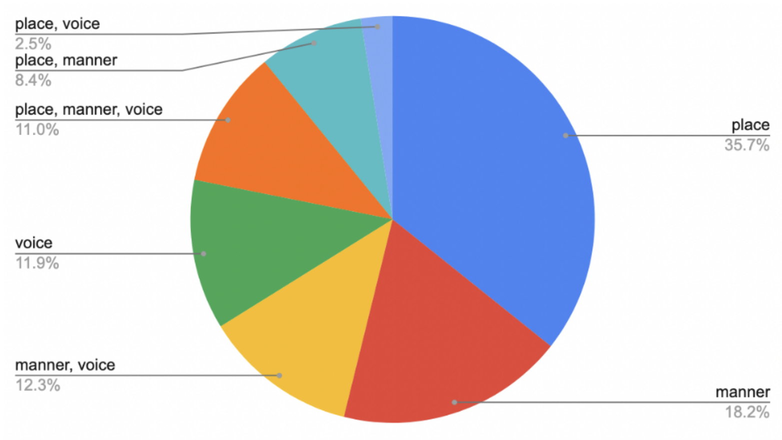

Figure (14): *Types of Feature Mismatches in Imperfect Rhymes*

As demonstrated in Figure (14), we find that place is the most common type of feature that is mismatched. We also find that one type of feature mismatch (either in place or manner) is more common than mismatches that differ in multiple types of features. However, this pattern notably does not follow for the voice set of features.

6 Discussion

Through our research, we sought to provide support for our hypothesis (H_1) that states that patterns within imperfect rhyme usage are predictable and that frequency of consonant mismatches in these imperfect rhymes aligns with the similarity of these mismatches. This hypothesis was motivated by the theory that individuals possess robust implicit knowledge of phonological similarity.

Our findings suggest that there is indeed a relationship between the types of consonants that are used in mismatches in imperfect rhyme and the degree to which these consonants are similar or cause the words to sound similar. It seems as though speakers possess unconscious knowledge of feature similarity. Our findings generally match up with findings from previous studies, though there are some surprises.

Figure (8) presents a frequency graph which shows that there are certain consonant mismatches in imperfect rhymes that occur much more frequently than others and that this is generally proportional to the rank of the mismatch in order of frequency order. This graph alone already suggests that there may be patterns in the imperfect rhyme usage.

6.1 Subsequence Rhyme Patterns

To find patterns, we focus on the types of imperfect rhymes in the top 70 percent of rhymes. In Figure (11) we see that subsequence rhymes (rhymes that have different numbers of phonemes in the rimes) make up nearly 65 percent of the most frequent 70 percent of imperfect rhymes. Despite previous literature also finding that subsequence rhymes are more common (Zwicky 1976:680), upon initial reflection, this finding might seem surprising because one might expect two words that differ by a full consonant to sound less similar than two words that only differ by some features in their consonants. For example, it might seem surprising that two words that differ in their rime by the presence of a ‘d’ (which is a full consonant difference) is more common than two words that have an (‘m’, ‘n’) mismatch in the rime (which only changes the place of articulation of a consonant). The fact that full consonant insertions are more common than a small set of feature mismatches seems to reject H_1 because it seems as though imperfect rhyme frequencies don’t align with similarity.

However, it is not necessarily true that subsequence rhymes sound less similar than feature rhymes. The patterns within the subsequence rhymes provide an explanation which shows that subsequence rhyming pairs could sound more similar than feature rhyme pairs even though there is an addition of a full consonant in subsequence rhymes. One of these patterns is the presence of coronal consonants. Coronals account for 82.2 percent of subsequence rhyme insertions. This aligns with previous studies that also find coronals most frequently in subsequence rhymes (Holtman 1996:42; Zwicky 1976:680). One possible explanation for the frequency of coronals in imperfect rhyme matches could simply be that coronals are used more frequently because coronals are naturally found more frequently than non-coronals in coda positions in words in English (Kessler and Treiman 1997:301). It follows that they would be more likely to be mismatched, since mismatches always involve the coda consonants. Even if song artists are looking to create novel rhymes that don't sound like cliches (by trying to avoid rhyme pairs that are used very frequently), they are likely to pick a word that happens to end in with a coronal coda since this is more common in English than non-coronal codas.

However, there are also robust theories in linguistics surrounding the special status of coronals that could account for why artists use coronals when trying to create rhymes (Holtman 1996:43). Coronals are often referred to as "unmarked" or "neutral." This means that they are understood as "somehow simpler, less complex" (Paradis and Prunet 2014:2). It is often claimed that they are more likely to undergo assimilation processes, that they are sometimes "invisible to phonological processes," and that they are "transparent to vowels" (Paradis and Prunet 2014:2). For example, it is often found that vowels that are separated by a coronal consonant behave as though they are directly next to one another through harmony, even though vowels separated by a non-coronal consonant do not experience harmony (Paradis and Prunet 1989:318).

The cross-linguistic tendency for coronals to be understood as nearly invisible could cause words that differ only in the presence of a coronal in their rime to sound very similar. Because coronals are the most frequently used consonant in imperfect rhyme mismatches both in our data and in previous studies, it seems as though artists possess awareness of this knowledge about coronals and use it to form imperfect rhymes, which supports H_1. And, because these coronal subsequence rhymes are found more frequently than feature rhymes, it suggests that a difference of a full coronal consonant might be less impactful than even a difference of a single feature. Therefore, their presence in imperfect rhymes seems as though it is not just a consequence of coronals frequently sitting in coda positions in English words.

It remains unclear (from a similarity perspective) why labial consonants are used more frequently than dorsal consonants, though perhaps this has to do with the number of labial vs. dorsal consonants in English.

6.2 Feature Rhyme Patterns

The patterns found in the feature rhyme data (rhymes that have the same number of phonemes in the rime) provide further support for H_1, the hypothesis that speakers possess implicit knowledge of cross-linguistic tendencies that affect sound similarity. Figure (14) shows that coda mismatches with differences in place of articulation only make up the largest percentage of types of feature differences and that differences in manner only make up the second largest percentage of types of feature differences. Together, these make up more than half of the feature imperfect rhymes. Generally, it seems as though differences in one type of feature only (such as place or manner) are more common than differences in multiple types of features (such as place and manner or manner and voice). This seems to suggest that song artists have implicit knowledge of the sounds that share more features than others and use those more frequently.

It is important to note that the pattern found above does not hold for the voice feature set in our data. Voicing differences are found less frequently than some pairs that differ in multiple features. Yet voicing has a specific property, which could explain why we don't find it being mismatched as frequently, that can still support H_1; it is a robust theory in linguistics that a vowel that precedes a voiced obstruents is pronounced as longer than when it precedes a voiceless obstruent (Morley and

Smith 2023). This means that simply changing voicing means not only changing a feature in a consonant, but also changing the realization of the preceeding vowel. For this reason, two words whose rimes differ only in the feature of voicing may not sound very similar and artists may feel that it does not make a good imperfect rime. Artists are aware that using mismatches in their imperfect rhymes that involve differences in voicing will cause vowels to sound different and therefore words to sound different. Thus, it makes sense that we see these types of mismatches less frequently than even some sounds that differ in multiple features[3].

Generally, we find that the more similar two consonants are, the more likely they are to be mismatched in feature rhymes. The more similar mismatches are found at the top of the list. As we go far down the frequency-ordered list, we find that artists create word pairs that are maximally different from one another in the coda of the rime and sometimes also involve multiple consonants that are replaced with other maximally different consonants. However, because these are lower on our list, they are less frequent, showing that speakers do rely on implicit knowledge of features when constructing imperfect rhymes. Holtman (1996) also noted this trend in her hierarchy (see Figure (5)). At a certain point, some might not even consider these maximally different mismatches to form imperfect rhymes at all.

While this generally holds true, we notice that the ('v','n') mismatch is very common. It ranks 23 in our results, yet those consonants are maximally different except for in their voicing. We wonder why these seemingly different consonants are frequently mismatched. Is it enough that they share a voicing feature?

[3]We note that in Holtman 1996's data, differences in voice are found more frequently than differences in manner. We suspect that this is simply due to the smaller, and therefore less representative, amount of data that Holtman found.

7 Limitations and Future Work

This paper sought to collect imperfect rhyme data from songs from 1964-2015. While our computational method allowed us to acquire a large amount of data in a small time frame, there were also some confounds that arose from our method regarding the collecting of imperfect rhymes. Songs are a verbal art, but we used standard pronunciations of words in song lyrics to find rhymes. This means that we weren't able to account for an artist's unique pronunciation of a word. Perhaps we neglected to find certain rhymes or overcounted certain rhymes because the artist pronounced two words differently than the pronunciation dictionary version. Another confound is that the pronunciation dictionary does not know which pronunciation to choose when a single word has multiple pronunciations (heteronyms). The creators of the pronunciation dictionary made choices in those instances. Similarly regarding the collection of imperfect rhymes, as mentioned in section 4.2.2, we looked at end-of-line rhyme only and compared every word to every other word in a stanza as long as a stanza was less than six lines. We may be missing some rhymes that occur within a single line. And, we may have considered two items a rhyme because they are in the same stanza, even if the artist would not consider them a rhyme.

There are a number of areas in which to adapt our research and conduct future research. First, one could adapt our research by not only keeping track of imperfect rhyme mismatches in end-of-line song lyric data, but also keeping track of the consonant frequencies in codas in all words at the end of lines in these lyrics. Researchers could then use this to normalize the data in a way that we did not do in our own research to confirm that trends do indeed reflect similarity of sounds and not just popularity of sounds.

One could also conduct the similar research using a different corpus: they could examine song lyrics of other languages or specific genres using computational methods to see if the hypothesis still holds true. It would specifically be interesting to look at a language with a weaker voicing effect (which doesn't change vowel length before voiced obstruents as much as English) to see if this affects the usage of voice mismatches in imperfect rhymes. It would also be worthwhile to use an experimental method, instead of a computational method, to see which imperfect rhymes listeners successfully perceive most frequently. Are there similar trends in more perception of rhyme for more similar mismatches? Do listeners recognize subsequence or feature rhymes more easily? Does the coronal trend still hold? Finally, future researchers can also look at different types of rhyme. Some studies have been conducted that look at vowel mismatches and it would be interesting to conduct vowel mismatch research using computational methods.

8 Conclusion

In this paper, we sought to answer the question: do trends in the types of perfect and imperfect rhyme used in top pop songs from 1964-2015 reflect notions of phonological similarity? We build upon previous research by using computational methods to look at a corpus that has not been studied before and to collect a large amount of data. We find support for our hypothesis that the frequency of consonant mismatches in imperfect rhymes is predictable and reflects natural classes and notions of phonological similarity. We specifically find that coronals are used most frequently in forming subsequence rhyme pairs and that place is the most frequent type of feature that is manipulated in feature rhymes. For feature rhymes, we also find that differences in one type of feature only is more common than differences in multiple types of features. These findings shows that song artists who write in English have unconscious knowledge of cross-linguistics tendencies of similarity that have been previously established and that they rely on this unconscious knowledge to make conscious choices about imperfect rhyme creation. This paper thus joins previous literature that suggests that verbal art, and more generally, conscious use of language, can be used to illuminate and reflect unconscious knowledge of linguistic theory.

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10 Honor Code

This paper represents my own work in accordance with University regulations

Gillian Rosenberg. April 19, 2024