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Title: Half rhymes in Japanese rap lyrics and knowledge of similarity

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Abstract

Using data from a large-scale corpus, this paper establishes the claim that in Japanese rap rhymes, the degree of similarity of two consonants positively correlates with their likelihood of making a rhyme pair. For example, similar consonant pairs like {m-n}, {t-s}, and {r-n} frequently rhyme, whereas dissimilar consonant pairs like {m-Σ}, {w-k}, and {n-p} rarely do. The current study adds to a body of literature that suggests that similarity plays a fundamental role in half rhyme formation (Holtman 1996; Jakobson 1960; Steriade 2003; Zwicky 1976). Furthermore, it is shown that Japanese speakers take acoustic details into account when they compose rap rhymes. This study thus supports the claim that speakers possess rich knowledge of psychoacoustic similarity (Steriade 2001ab, 2003).

1. Introduction

Much recent work in phonology has revealed that similarity plays a fundamental role in phonological organization. The list of phenomena that have been argued to make reference to similarity is given in (1).

(1) The effects of similarity in phonology

Input-output mapping:

Phonological alternations often take place in such a way that the similarity between input and output is maximized; the rankings of faithfulness constraints (McCarthy and Prince 1995; Prince and Smolensky 2004) are determined by perceptual similarity rankings (Fleischhacker 2001, 2005; Kawahara 2006; Steriade 2001ab; Zuraw 2005; see also Huang 2001; Hura et al. 1992; Kohler 1990).

Loanword adaptation:

Borrowers strive to mimic the original pronunciation of loanwords as much as possible (Adler 2006; Kang 2003; Kenstowicz 2003; Kenstowicz and Suchato 2006; Silverman 1992; Steriade 2001a; Yip 1993).

Paradigm uniformity:

Morphologically related words are required to be as similar as possible both phonologically (Benua 1997) and phonetically (Steriade 2000; Yu 2006; Zuraw 2005).

Reduplicative identity:

Reduplicants and corresponding bases are required to be as similar as possible; as a consequence, phonological processes can under- or over-apply (McCarthy and Prince 1995; Wilbur 1973)

Gradient attraction:

The more similar two forms are, the more pressure they are under to get even more similar (Burzio 2000; Hansson 2001; Rose and Walker 2004; Zuraw 2002).

Similarity avoidance (OCP):

Adjacent or proximate similar sounds are avoided in many languages, including Arabic (Greenberg 1950; McCarthy 1988), English (Berkley 1994), Japanese (Kawahara et al. 2006), Javanese (Mester 1986), Russian (Padgett 1992), and others; see also Côté (2004), Leben (1973), McCarthy (1986), and Yip (1988).

Contrast dispersion:

Contrastive sounds are required to be maximally or sufficiently dissimilar (Diehl and Kluender 1989; Flemming 1995; Liljencrants and Lindblom 1972; Lindblom 1986; Padgett 2003; see also Gordon 2002).

As listed in (1), similarity is closely tied to the phonetic and phonological organization of a grammar. Therefore, understanding the nature of linguistic knowledge about similarity is important to current theories of both phonetics and phonology.

Against this background, this paper investigates the knowledge of similarity that Japanese speakers possess. I achieve this goal by examining the patterns of half rhymes found in Japanese rap lyrics.[1] A half rhyme, also known as a partial or imperfect rhyme, is a rhyming pair that falls short of strict identity. To take a few English examples, in *Oxford Town*, *BOB DYLAN* rhymes *so**n*** with *bo**m**b* (Zwicky 1976); in *Rapper's Delight* by *THE SUGARHILL GANG*, *sto**p*** and *ro**ck*** rhyme (in this paper, song titles are shown in *italics* and artists names in *CAPITAL ITALICS*). Even though the {n-m} and {p-k} pairs do not involve strictly identical consonants, the rhyming consonants are nevertheless congruent in every feature except in place. Previous studies since Jakobson (1960) have noted this increasing production of half rhymes in a given pair of consonants that share similar features: the tendency for half rhymes to involve similar consonants has been observed in many rhyming traditions, including several African languages (Tigrinya, Tigre, Tuareg: Greenberg 1960, 941-2, 946), English Mother Goose (Maher 1969), English rock lyrics (Zwicky 1976), German folk songs (Maher 1972), Irish verses (Malone 1987), Romanian half rhymes

[1] The terms "rap" and "hip hop" are often used interchangeably. However, technically speaking, "rap" is a name for a particular musical idiom. "Hip hop" on the other hand can refer to the overall culture including not only rap songs but also related fashions, arts, dances, and others activities. See Manabe (2006) for the sociological development of rap songs and hip hop culture in Japan, as well as the evolution of technique in rap rhyming in Japanese. See Kawahara (2002) and Tsujimura et al. (2006) for previous linguistic analyses on rhyme patterns in Japanese rap songs.

(Steriade 2003), 18th and 19th-century Russian verses (Holtman 1996, 34-35), and Turkish poems (Malone 1988a). The role of similarity in poetry has been pointed out also for alliterations in languages such as Middle English (Minkova 2003), Early Germanic (Fleischhacker 2005), Irish (Malone 1987, 1988b), and Somali (Greenberg 1960). Finally, imperfect puns are also known to involve pairs of similar consonants in English (Fleischhacker 2005; Zwicky and Zwicky 1986) as well as in Japanese (Shinohara 2004). In a nutshell, cross-linguistically, similar consonants tend to form consonant pairs in a range of verbal art patterns.

This paper establishes the claim that the same tendency is observed in the rhyming patterns of Japanese rap lyrics—the more similar two consonants are, the more likely they are to make a rhyme pair. The folk definition of Japanese rap rhymes consists of two rules: (i) between two lines that rhyme, the line-final vowels are identical, but (ii) onset consonants need not be identical (see e.g. http://lyricz.info/howto.html). For example, *KASHI DA HANDSOME* ends two rhyming lines with *made* 'till' and *dare* 'who' (*My Way to the Stage*), where the corresponding vowel pairs are identical ({a-a}, {e-e}}, but the consonant pairs are not ({m-d, d-r}). However, despite the fact the folk definition ignores consonants in rap rhyming, it is commonly the case that similar consonants make rhyme pairs. An illustrative example is given in (2).

(2) *Mastermind* (DJ HASEBE feat. MUMMY-D & ZEEBRA)

a.

kettobase	**kettobase**		
kick it	kick it		

‘Kick it, kick it’

b.

kettobashita	kashi	de	**gettomanee**
funky	lyrics	with	get money

‘With funky lyrics, get money’

In (2), *MUMMY-D* rhymes *kettobase* ‘kick it’ and *gettomanee* ‘get money’, as suggested by the fact that all of the vowels in the two words agree ({e-e}, {o-o}, {a-a}, {e-e}). Except for the second pair of consonants ({tt-tt}), the consonants ({k-g}, {b-m}, and {s-n}) are not strictly identical.

However, similar to the English half rhymes cited above, these rhyming pairs nevertheless involve similar consonants—all of the pairs agree in place. An example like (2) suggests that similar consonants tend to form half rhymes in Japanese, just like many other rhyming traditions. Parallel examples are commonplace: in *Forever*, *LIBRO* rhymes ***d****ai****sh****oo****t****ai* ‘big invitation’ with ***s****ai****j****oo****k****ai* ‘top floor’, which involves pairs of similar obstruents ({d-s}, {Σ-(d)Z}, {t-k}).[2] Similarly, in *Project Mou*, *TSURUGI MOMOTAROU* rhymes ***r****en****ch****uu* 'they' and ***n****en****j****uu* 'all year', and this rhyming pair again involves similar consonant pairs ({r-n}, {tΣ-(d)Z}).

In order to provide a solid statistical foundation for the claim that similarity plays a role in Japanese rap rhyme formation, this paper presents data from a large-scale corpus showing that if a pair of two consonants share increasingly similar features, the more likely they are to form a rhyme pair.

Not only does this paper show that similarity plays a role in half rhyme patterns, it also attempts to investigate what kind of knowledge of similarity is responsible for the similarity pattern observed in Japanese rap lyrics. Specifically, I argue that we need to take acoustic details into account when we compute similarity—i.e. Japanese speakers have a fairly rich sensitivity to detailed acoustic information when they compose rhymes. This conclusion accords with Steriade's (2001ab) recent claim that speakers possess what she calls the P-Map—the repository of their knowledge about a similarity matrix between sounds.

In short, the present study is a detailed investigation of Japanese speakers' knowledge

[2] [dZ] is said to allophonically alternate with [Z] intervocalically (Hattori 1984, 88). However, in conversational speech, both variants occur in both positions—they are more or less free variants of the same phoneme. I therefore treat this phoneme as [dZ] in this paper.

of similarity through the analysis of half rhymes in Japanese rap songs. More broadly speaking, this work follows a body of literature that analyzes poetry as a source of information about the nature of linguistic knowledge (in addition to the references cited above, see Fabb 1997; Halle and Keyser 1971; Kiparsky 1970, 1972, 1981; Ohala 1986; Yip 1984, 1999 among others).

The rest of this paper proceeds as follows. §2 describes how the data were collected and analyzed, and gives an overview of the aspects of Japanese rap rhymes. §3 presents evidence for the correlation between similarity and rhymability in Japanese rap songs. §4 argues that speakers take acoustic details into account when they compose rhymes.

2. Method

2.1. Compiling the database

This subsection describes how the database was compiled for this study. In order to statistically verify the hypothesis that similarity plays a crucial role in the formation of Japanese half rhymes, lyrics in 98 Japanese rap songs were collected (the complete list of songs is given in Appendix I).

In Japanese rap songs, the rhyme domain of two lines is defined as the sequence of syllables at the ends of the lines in which the vowels of the two lines agree. This basic principle is illustrated by an example in (3).

(3) *Hip-hop Gentleman* (DJ MASTERKEY feat. BAMBOO, MUMMY-D & YAMADA-MAN)

a. geijutsu wa **bakuhatsu**
   art TOPIC explosion
   'Art is explosion.'

b. ikiru-no ni **yakudatsu**
   living for useful
   'Useful for life.'

As seen in (3), a rhyme domain can—and usually does—extend over more than a single syllable. The boundary tone is usually a high tone (H) followed by a low tone (L) (with subsequent spreading of L), and this boundary tone can replace lexical tones.[3] For example, in (3), *bakuhatsu* 'explosion' and *yakudatsu* 'useful' are pronounced with HLLL contours, even though their lexical accentual patterns are LHHH and LHHL, respectively. Given a

[3] Other types of boundary tones can sometimes be used. In *Jibetarian*, for example, *SHIBITTO* uses HLH boundary tones to signal the onset of rhyme domains. *LIBRO* uses LH tones in *Taidou*.

rhyme pair like ***b***_a_***k***_u_***h***_a_***ts***_u_ vs. ***y***_a_***k***_u_***d***_a_***ts***_u_ in (3), the following consonant pairs were extracted: {b-y}, {k-k}, {h-d}, {ts-ts}.

Another noteworthy fact about Japanese rhymes is the occasional presence of an “extrametrical” syllable, i.e. a word-final syllable in one line occasionally contains a vowel that does not have a correspondent vowel in the other line (Kawahara 2002; Tsujimura et al. 2006). An example is shown in (4), in which the final syllable [hu] is excluded from the rhyme domain; the extrametrical elements are denoted in < >.

(4) *Koko Tokyo* (AQUARIUS feat. S-WORD, BIG-O & DABO)

a.

biru	ni		umaru	**kyoo**
building	DATIVE		buried	today

‘Buried in the buildings today.’

b.

Ashita	ni	wa	wasurechimaisouna	**kyoo<hu>**
tomorrow	by	TOPIC	forget-Antihonorific	fear

‘The fear that we forget by tomorrow.’

Some other examples of extrametrical syllables include ***kuruma*** ‘car’ vs. *ooban****buruma****<i>* ‘luxurious behavior’ (by *ZEEBRA* in *Golden MIC*), ***iiyo***_<ru>_ ‘talk to’ vs. ***iiyo*** ‘good’ (by *GO* in *Yamabiko 44-go*), and ***hyoogenryo***_<ku>_ ‘writing ability’ *vs.* ***foomeeshon*** ‘formation’ (by

AKEEM in *Forever*).[4] Extrametrical syllables whose vowels appear only in one line of the pair were ignored in compiling the database for the current study.

Some additional remarks on how the rhyme data were compiled are in order. First, when the same phrase was repeated several times, the rhyme pairs in that phrase were counted only once, in order to prevent such repeated rhyme pairs from having unfairly large effects on the overall corpus. Second, only pairs of onset consonants were counted in this

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[4] As implied by the examples given here, it is usually high vowels that can be extrametrical. My informal survey has found many instances of high extrametrical vowels, but no mid or low extrametrical vowels (a systematic statistical study is yet to be performed). This observation correlates with the fact that Japanese high vowels can devoice and tend to become almost inaudible in some environments (Tsuchida 1997), and also with the claim that high vowels are perceptually closest to zero and hence are most likely to correspond with zero in phonology—i.e. they are most prone to be deleted and epenthesized cross-linguistically (Davis and Zawaydeh 1997; Howe and Pulleyblank 2004; Kaneko and Kawahara 2002; Pulleyblank 1998; Tranel 1999).

To the extent that this correlation is valid, we may be able to examine the extent to which each consonant is perceptually similar to zero, by looking at the likelihood of consonants rhyming with zero. Unfortunately, in compiling the database, rhyme pairs in which one member is zero were often ignored. This topic thus needs to be addressed in a new separate study.

study. Coda consonants were ignored because they place-assimilate to the following consonant (Itô 1986). Third, the compilation of the data was based on surface forms. For instance, [Σi], which is arguably derived from /si/, was counted as [Σ]. The decision followed Kawahara et al. (2006) who suggest that similarity is based on surface forms rather than phonemic forms (see Kang 2003; Kenstowicz 2003; Kenstowicz and Suchato 2006; Steriade 2000 for supporting evidence for this view; see also §4; cf. Jakobson 1960; Kiparsky 1970, 1972; Malone 1987).

2.2. A measure of rhymability

The procedure outlined above yielded 10,112 consonantal pairs. The hypothesis tested in this paper is that the more similar two consonants are, the more frequently they make a rhyme pair—in other words, it is not the case that segments are randomly paired up as a rhyming pair. In order to bear out this notion, we need to have a measure of rhymability between two segments, i.e. a measure of how well two consonants make a rhyme pair. For this purpose, the so-called O/E values are used, which are observed frequencies relativized with respect to expected frequencies.

To explain the notion of O/E values, an analogy might be useful. Suppose that there are 100 cars in our sample; 10 of them (10%) are red cars, and 60 of them (60%) are owned by a male. We expect *ceteris paribus* that the number of cars that are both red and owned by a male is 6 ($=.1\times.6\times100$). This value is called the expected frequency of the {red-male} pair (or the E value)—mathematically, an expected number for pairs of {x y} can be calculated as: $E(x, y) = P(x) \times P(y) \times N$ (where N is the total number of pairs). Suppose further that in reality the car types are distributed as in Table 1, in which there are 9 cars that are both red and owned by a male—we call this value the observed frequency (or the O value) of the {red-male} pair.

	Red	Non-red	Sum
Male	9	51	60
Female	1	39	40
Sum	10	90	100

Table 1: The observed frequencies of car types.

In Table 1 then, {red} and {male} combine with each other more often than expected ($O=9 > E=6$). More concretely, the {red-male} pairs occur 1.5 times as much as the expected value (=9/6). This value—the O value divided by the E value—is called the O/E value. An O/E value thus represents how frequently a particular pair actually occurs relatively with respect to how often they are expected to occur.[5] If O/E > 1, it means that the pair occurs more often than expected (overrepresented); if O/E < 1, it means that the pair occurs less often than expected (underrepresented). To take another example, the {red-female} pair has an O/E value of .25 (O=1, E=4). This low O/E value indicates that the combination of {red} and {female} is less frequent than expected.

In this way, O/E values provide a measure of the combinability of two elements i.e. the frequency of two elements to co-occur. I therefore use O/E values as a measure of the rhymability of two consonants—the higher the O/E value, the more often the two consonants will rhyme. Parallel to the example discussed above, O/E values greater than 1 indicate that the given consonant pairs are combined as rhyme pairs more frequently than expected, while O/E values less than 1 indicate that the given consonant pairs are combined less frequently than expected. Based on the O values obtained from the entire collected corpus (i.e. counts from the 20,224 rhyming consonants), the E values and O/E values for all consonant pairs

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[5] This measure has been used by many researchers in linguistics, and the general idea at least dates back to Trubetzkoy (1939[1969]): "[t]he absolute figures of actual phoneme frequency are only of secondary importance. Only the relationship of these figures to the theoretically expected figures of phoneme frequency is of real value" (1969, 264).

were calculated. The complete list of O/E values is given in Appendix II.

3. Results

The results of the O/E analysis show that rhymability correlates with similarity: the more similar two consonants are, the more frequently they rhyme. The analysis of this section is developed as follows: in §3.1, I provide evidence for a general correlation between similarity and rhymability. In §3.2 and §3.3, I demonstrate that the correlation is not simply a general tendency, but in fact that all of the individual features indeed contribute to similarity as well. Building on this conclusion, §3.4 presents a multiple regression analysis which investigates how much each feature contributes to similarity.

3.1. Similarity generally correlates with rhymability

First, to investigate the general correlation between similarity and rhymability, as a first approximation, the similarity of consonant pairs was estimated in terms of how many feature specifications they each had in common (Bailey and Hahn 2005; Klatt 1968; Shattuck-Huffnagel and Klatt 1977; Stemberger 1991): other models of similarity are discussed below. Seven features were used for this purpose: [sonorant], [consonantal], [continuant], [nasal], [voice], [palatalized], and [place]. [Palatalized] is a secondary place feature, which distinguishes plain consonants from palatalized consonants. Given these features, for example, the {p-b} pair shares six feature specifications (all but [voi]), and hence it is treated as similar by this system. On the other hand, a pair like {Σ-m} agrees only in [cons], and is thus considered dissimilar.

In assigning feature specifications to Japanese sounds, I made the following assumptions. Affricates were assumed to be [±cont]—i.e. they disagree with any other segments in terms of [cont]. [r] was treated as [+cont], and nasals as [-cont]. [h] was considered as a voiceless fricative, not as an approximant. Sonorants were assumed to be specified as [+voi], which thus agree with voiced obstruents in terms of [voi]. Appendix III provides a complete matrix of these feature specifications.

The prediction of the hypothesis presented in §2 is that similarity, as measured by the number of shared feature specifications, positively correlates with rhymability, as measured by O/E values. In calculating the correlation between these two factors, the linear order of consonant pairs—i.e. which line they were in—was ignored. Furthermore, segments whose total O values were less than 10 (e.g. [p^j], [n^j]) were excluded, because since their inclusion would result in too many zero O/E values. Additionally, I excluded the pairs whose O values were zero since most of these pairs contained a member which was rare to begin with; for example, [p^j] and [m^j] occurred only twice in the whole corpus. Consequently, 199 consonantal pairs entered into the subsequent analysis.

Figure 1 illustrates the overall result, plotting on the y-axis the natural log-transformed O/E values[6] for different numbers of shared feature specifications. The line represents an OLS regression line. Figure 1 supports the claim that there is a general correlation between similarity and rhymability: as the number of shared featural specifications increases, so do the O/E values.

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[6] It is conventional in psycholinguistic work to use log-transformed value as a measure of frequency (Coleman and Pierrehumbert 1997; Hay et al. 2003). People's knowledge about lexical frequencies is better captured as log-transformed frequencies than raw frequencies (Rubin 1972; Smith and Dixon 1971). The log-transformation also increases normality of the distribution of the O/E values, which is useful in some of the statistical tests in the following sections.

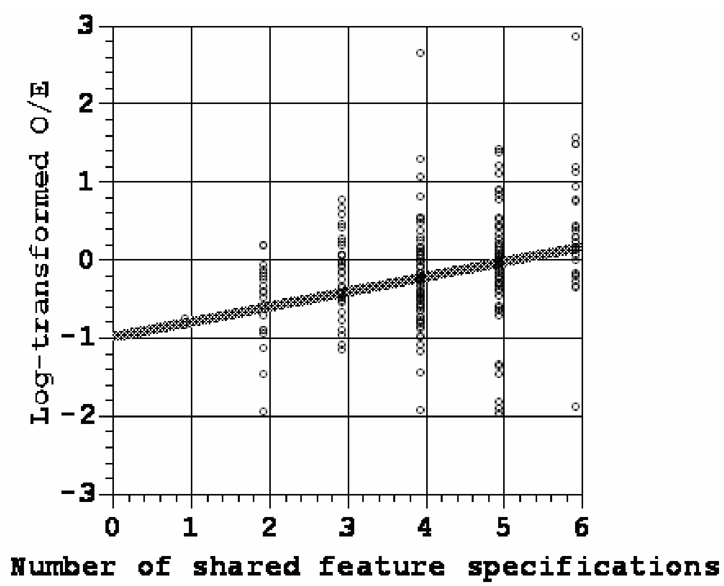

Figure 1: The correlation between the number of shared feature specifications (similarity) and the O/E values (rhymability). The line represents a linear regression line.

To statistically analyze the linear relationship observed in Figure 1, the Spearman correlation coefficient r_s, a non-parametric numerical indication of the strength of linear correlation, was calculated. The result revealed that r_s is .34, which significantly differs from zero ($p<.001$, two-tailed): similarity and rhymability do indeed correlate with each other.

Figure 1 shows that the scale of rhymability is gradient rather than categorical. It is not the case that pairs that are more dissimilar than a certain threshold are completely banned; rather, dissimilar consonant pairs are just less likely to rhyme than pairs that are more similar to one another. This gradiency differs from what we observe in other poetry traditions, in which there is a similarity threshold beyond which too dissimilar rhyme pairs are categorically rejected (see Holtman 1996 and Zwicky 1976 for English; Steriade 2003 for Romanian). The source of the cross-linguistic difference is not entirely clear—perhaps it is related to the folk definition of Japanese rhymes that consonants are "ignored." This issue merits future cross-linguistic investigation. Although the gradient pattern in Figure 1 seems specific to the Japanese rap rhyme patterns, it parallels the claim by Frisch (1996), Frisch et al. (2004), and Stemberger (1991, 78-79) that similarity is inherently a gradient notion.

In order to ensure that the correlation observed in Figure 1 does not depend on a particular model of similarity chosen here, similarity was also measured based on the number of shared natural classes, following Frisch (1996) and Frisch et al. (2004). In their model, similarity is defined by the equation in (5):

(5) $$\text{Similarity} = \frac{\textit{shared natural classes}}{\textit{shared natural classses} + \textit{non-shared natural classes}}$$

A similarity matrix was computed based on (5), using a program written by Adam Albright (available for download from http://web.mit.edu/albright/www/). The scatterplot in Figure 2 illustrates how this type of similarity correlates with rhymability. It plots the natural log-transformed O/E values against the similarity values calculated by (5).

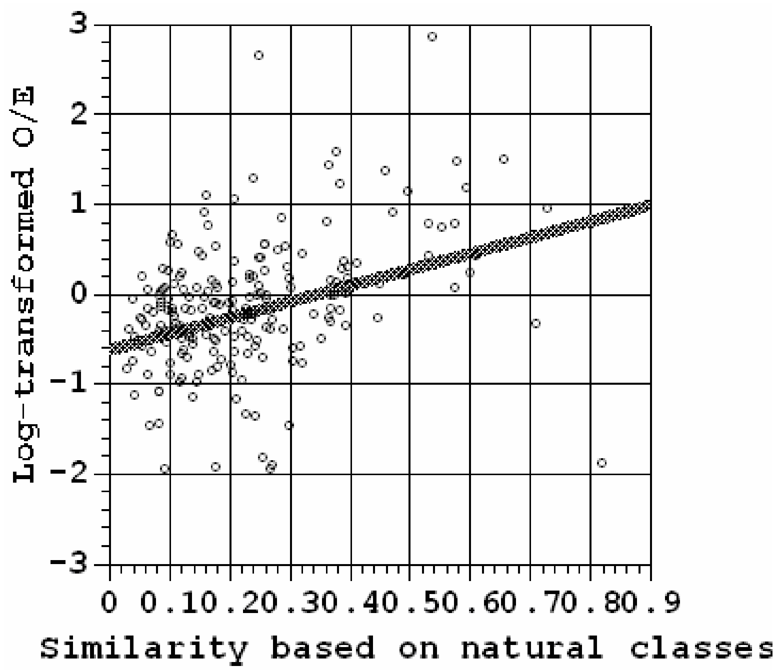

Figure 2: The correlation between rhymability and similarity calculated based on the number of shared natural classes. The line represents a linear regression line.

Again, there is a general trend in which rhymability positively correlates with similarity, as shown by the regression line with a positive slope. With this model of similarity, the Spearman correlation r_s is .37, which is again significant at .001 level (two-tailed).

Although this model yielded a higher r_s value than the previous model (.34), we must exercise caution in comparing these values—r_s is sensitive to the variability of the independent variable, which depends on the number of ties (Myers and Well 2003, 508; see also 481-485). However, there are much more ties in the first model than in the second model, and therefore, the goodness of fit cannot be directly compared between the two models.

Finally, one implicit assumption underlying Figure 1 and Figure 2 is that each feature contributes to similarity by the same amount. This assumption might be too naïve, and §3.4 and §4.1 re-examine this assumption.

In summary, the analyses based on the two ways of measuring similarity both confirm the claim that there is a general positive correlation between similarity and rhymability. The following two subsections show that for each feature the pairs that share the same specification are overrepresented.

3.2. Major class features and manner features

We have witnessed a general correlation between similarity and rhymability. Building on this result, I now demonstrate that the correlation is not only a general tendency, but that all of the individual features in fact contribute to the similarity.

Table 2 and Table 3 illustrate how the agreement in major class and manner features contributes to overrepresentation. In these tables, C1 and C2 represent the first and second consonant in a rhyme pair. Unlike the analysis in §3.1, the order of C1 and C2 is preserved, but this is for statistical reasons, and not crucial for the claim made in this subsection—the O/E values of the {+F, -F} pair and those of the {-F, +F} pairs are always nearly identical. The statistical significance of the effect of each feature was tested by a Fisher's Exact test.

One final note: there were many pairs of identical consonants, partly because rappers very often rhyme using two identical sound sequences, as in ***saa kitto*** 'then probably' vs. ***saakitto*** 'circuit' (by *DELI* in *Chika-Chika Circuit*). It was expected, then, that if we calculated similarity effects using this data set, similarity effects would be obtained simply due to the large number of identical consonant pairs. To avoid this problem, their O values were replaced with the corresponding E values, which would cause neither underrepresentation nor overrepresentations.

Table 2 illustrates the effect of major class features on rhymability.

(i) [son]

C1 \ C2	Sonorant	Obstruent
Sonorant	O=375 O/E=1.66	O=630 O/E=.81
Obstruent	O=666 O/E=.82	O=2960 O/E=1.05

(ii) [cons]

C1 \ C2	Glide	Non-glide
Glide	O=8 O/E=1.69	O=154 O/E=.98
Non-glide	O=131 O/E=.98	O=4338 O/E=1.00

Table 2: The effects of major class features on rhymability.

Table 2(i) illustrates the effect of [son]: pairs of two sonorants occur 1.66 times more often than expected. Similarly, the {obs-obs} pairs are overrepresented, though only to a small extent (O/E=1.05). The degree of overrepresentation due to the agreement in [son] is statistically significant (p<.001). Table 2(ii) illustrates the effect of [cons], which distinguishes glides from non-glides. Although the {glide-glide} pairs are overrepresented (O/E=1.69), the effect is not statistically significant (p=.15). This insignificance presumably owes to the small number of {glide-glide} pairs (O=8).

The next four tables illustrate the effects of manner features.

(i) [cont]

C1 \ C2	Continuant	Non-cont
Continuant	O=598 O/E=1.27	O=804 O/E=.86
Non-cont	O=781 O/E=.86	O=1928 O/E=1.07

(ii) [nas]

C1 \ C2	Nasal	Oral
Nasal	O=203 O/E=1.85	O=541 O/E=.85
Oral	O=480 O/E=.84	O=3413 O/E=1.03

(iii) [pal]

C1 \ C2	Palatal	Non-pal
Palatal	O=185 O/E=2.76	O=313 O/E=.73
Non-pal	O=438 O/E=.79	O=3695 O/E=1.03

(iv) [voi]

C1 \ C2	Voiced	Voiceless
Voiced	O=315 O/E=1.25	O=477 O/E=.88
Voiceless	O=496 O/E=.89	O=1252 O/E=1.05

Table 3: The effect of the manner features on rhymability.

Table 3(i) shows that pairs of two continuants (fricatives and approximants) are overrepresented (O/E=1.27), showing the positive effect of [cont] on rhymability (*p*<.001). Next, as seen in Table 3(ii), the {nasal-nasal} pairs are also overrepresented (O/E=1.85; *p*<.001). Third, Table 3(iii) shows the effect of [pal] across all places of articulation, which distinguishes palatalized consonants from non-palatalized consonants. Its effect is very strong in that two palatalized consonants occur almost three times as frequently as expected (*p*<.001). Finally, Table 3(iv) shows the effect of [voi] within obstruents, which demonstrates that voiced obstruents are more frequently paired up with voiced obstruents than with voiceless obstruents (O/E=1.25; *p*<.001). In a nutshell, the agreement in any feature results in higher rhymability. All of the overrepresentation effects, modulo that of [cons], are statistically significant at .001 level.

Overall, both in Table 2 and Table 3, the {-F, -F} pairs (=the bottom right cells in each table) are overrepresented, but only to a small extent. This slight overrepresentation of the {-F, -F} pairs suggests that the two pairs that share [-F] specifications are not considered very similar—the shared negative feature specifications do not contribute to similarity as much as the shared positive feature specifications (see Stemberger 1991 for similar observations).

We have observed in Table 3(iv) that agreeing in [voi] increases rhymability within obstruents. In addition, sonorants, which are inherently voiced, rhyme more frequently with voiced obstruents than with voiceless obstruents. Consider Table 4.

	[+voi] obstruent	[-voi] obstruent	Sum
[+son]	599 (29.1%)	903 (14.4%)	1502
[-son]	1457 (70.9%)	5355 (85.6%)	6812
Sum	2056	6258	8314

Table 4: The rhyming pattern of sonorants with voiced obstruents and voiceless obstruents.

As seen in Table 4, the probability of voiced obstruents rhyming with sonorants (.29; s.e.=.01) is much higher than the probability of voiceless obstruents rhyming with sonorants (.14; s.e.=.004). The difference between these probabilities (ratios) is statistically significant (by approximation to a normal distribution, z=13.42, p<.001). In short, sonorants are more rhymable with voiced obstruents than with voiceless obstruents,[7] and this observation implies that voicing in sonorants promotes similarity with voiced obstruents (see Coetzee and Pater 2005; Côté 2004; Frisch et al. 2004; Stemberger 1991, 94-96; Rose and Walker 2004; Walker

[7] There are no substantial differences among three types of sonorants: nasals, liquids, and glides. The O/E value for each of these classes with voiced obstruents are .77, .78, .82, respectively. The O/E value with voiceless obstruents are .49, .44, .43, respectively.

2003 for evidence that obstruent voicing promotes similarity with sonorants in other languages).

This patterning makes sense from an acoustic point of view. First of all, low frequency energy is present during constriction both in sonorants and voiced obstruents, but not in voiceless obstruents. Second, Japanese voiced stops are spirantized intervocalically, resulting in clear formant continuity (Kawahara 2006). For these reasons, voiced obstruents are acoustically more similar to sonorants than voiceless obstruents are.

However, given the behavior of [voi] in Japanese phonology, the similarity between voiced obstruents and sonorants is surprising. Phonologically speaking, voicing in Japanese sonorants is famously inert: OCP(+voi) requires that there be no more than one "voiced segment" within a stem, but only voiced obstruents, not voiced sonorants, count as "voiced segments" (Itô and Mester 1986; Itô et al. 1995; Mester and Itô 1989).[8] The pattern in Table 4

[8] One might wonder whether [+voi] in nasals is active in Japanese phonology, since nasals cause voicing of following obstruents, as in /sin+ta/ → [sinda] 'died', which can be captured as assimilation of [+voi] (Itô et al. 1995). However, post-nasal voicing has been reanalyzed as the effect of the constraint *NC∞, which prohibits voiceless obstruents after a nasal. This analysis has a broader empirical coverage (Hayes and Stivers 1995; Pater 1999), and obviates the need to assume that [+voi] associated with nasals is active in Japanese phonology (Hayashi and Iverson 1998).

suggests that, despite the phonological inertness of [+voice] in Japanese sonorants, Japanese speakers know that sonorants are more similar to voiced obstruents than to voiceless obstruents. This conclusion implies that speakers must be sensitive to acoustic similarity between voiced obstruents and sonorants, or at least know that redundant and phonologically inert features can contribute to similarity.

3.3. Place homorganicity

In order to investigate the effect of place homorganicity on rhymability, consonants were classified into five groups: labial, coronal obstruent, coronal sonorant, dorsal, and pharyngeal. This grouping is based on four major place classes, but the coronal class is further divided into two subclasses. This classification follows the previous studies on consonant co-occurrence patterns, which have shown that coronal sonorants and coronal obstruents constitute separate classes, as in Arabic (Frisch et al. 2004; Greenberg 1950; McCarthy 1986, 1988), English (Berkley 1994), Javanese (Mester 1986, 98), Russian (Padgett 1992), Wintu (McGarrity 1999), and most importantly in this context, Japanese (Kawahara et al. 2006). The rhyming patterns of the five classes are summarized in Table 5.

C2 / C1	Labial ($p, p^j, b, b^j, m, m^j, \Phi, w$)	Cor-obs ($t, d, ts, s, z, \Sigma, Z, t\Sigma, dZ$)	Cor-son (n, n^j, r, r^j, j)	Dorsal (k, k^j, g, g^j)	Pharyngeal (h, h^j)
Labial	O=181 O/E=1.50	O=213 O/E=.76	O=183 O/E=1.14	O=152 O/E=.88	O=32 O/E=1.19
Cor-obs	O=191 O/E=.73	O=816 O/E=1.34	O=275 O/E=.79	O=310 O/E=.83	O=53 O/E=.91
Cor-son	O=178 O/E=1.13	O=286 O/E=.78	O=352 O/E=1.68	O=157 O/E=.69	O=24 O/E=.68
Dorsal	O=149 O/E=.89	O=335 O/E=.86	O=142 O/E=.64	O=390 O/E=1.62	O=43 O/E=1.14
Phary	O=33 O/E=1.23	O=61 O/E=.97	O=22 O/E=.62	O=41 O/E=1.07	O=12 O/E=2.06

Table 5: The effect of place homorganicity on rhymability.

Table 5 shows that two consonants from the same class are all overrepresented (shown by shading). To check the statistical significance of the overrepresentation pattern in Table 5, a non-parametric sign-test was employed, since there were only five data points.[9] As a null hypothesis, let us assume that each homorganic pair is overrepresented by chance (i.e. its probability is ½). The probability of the five pairs all being overrepresented is then $(½)^5$=.03. This situation therefore is unlikely to have arisen by chance, or in other words, we can reject

[9] An alternative analysis would be to apply a χ^2-test for each homorganic pair (Kawahara et al 2006; Mester 1986). This approach is not taken here, because the O/E values of the homorganic cells are not independent of one another, and hence multiple applications of a χ^2-test are not desirable.

the null hypothesis at $\alpha=.05$ level that the homorganic pairs are overrepresented simply by chance.

On the other hand, most non-homorganic pairs in Table 5 are underrepresented. One exception is the {labial-pharyngeal} pairs (O/E=1.19, 1.23). The overrepresentation pattern can presumably be explained by the fact that Japanese pharyngeals are historically—and arguably underlyingly—labial (McCawley (1968, 77-79), Ueda (1898)). Therefore for Japanese speakers, these two classes are phonologically related, and this phonological connection may promote phonological similarity between the two classes of sounds (see Malone (1988b), Shinohara (2004) and Steriade (2003) for related discussion of this issue). There might be an influence of orthography as well, since [h], [p], and [b] are all written by the same letters, with the only distinction made by way of diacritics.

The {dorsal-pharyngeal} pairs are also overrepresented (O/E=1.14, 1.07), and this pattern makes sense acoustically—[h] resembles [k, g] in being spectrally similar to adjacent vowels.[10] [k, g] extensively coarticulate with adjacent vowels for tongue backness because there is an extensive spatial overlap of gestures of vowels and dorsals. As a result, dorsals are

[10] The similarity between [h] and dorsal consonants is further evidenced by the fact that Sanskrit [h] was borrowed as [k] in Old Japanese; e.g. Sanskrit *Ma**h**a* 'great' and *Ara**h**ân* 'saint' were borrowed as [ma**k**a] and [ara**k**an], respectively (Ueda 1898).

spectrally similar to the adjacent vowels (Keating 1996, 54; Keating and Lahiri 1993; Tabain and Butcher 1999). As for [h], the shape of the vocal tract during the production of [h] is simply the interpolation of the surrounding vowels (Keating 1988), and thus the neighboring vowels' oral articulation determines the distribution of energy in the spectrum during [h]. Given the acoustic affinity between [h] and [k, g], the fact that these two groups of consonants are overrepresented provides a further piece of evidence that rhymability is based on similarity.[11]

Another noteworthy finding concerning the effect of place on rhymability is that the coronal consonants split into two classes—i.e. the {cor son-cor obs} pairs are not overrepresented (O/E=.79, .78). This finding parallels Kawahara et al.'s (2006) finding. They investigate the consonant co-occurrence patterns of adjacent consonant pairs in the native vocabulary of Japanese (Yamato Japanese), and observe that adjacent pairs of homorganic consonants are systematically underrepresented; however, they also find that the {cor son-cor obs} pairs are not underrepresented, i.e. they are treated as two different classes. Kawahara et al.'s (2006) results are reproduced in Table 6 (the segmental inventory in Table 6 slightly differs from that of Table 5, because Table 6 is based on Yamato morphemes only).

[11] The {labial-cor son} pairs are overrepresented as well (O/E=1.14, 1.13). I do not have a good explanation for this pattern.

C2 / C1	Labial (p, b, m, Φ, w)	Cor-obs (t, d, ts, s, z, Σ, Z, tΣ, dZ, X)	Cor-son (n, r)	Dorsal (k, g)	Pharyngeal (h)
Labial	O=43 O/E=.22	O=374 O/E=1.30	O=312 O/E=1.19	O=208 O/E=1.02	O=0 O/E=.00
Cor-obs	O=434 O/E=1.40	O=247 O/E=.53	O=409 O/E=.97	O=445 O/E=1.35	O=2 O/E=.76
Cor-son	O=132 O/E=1.20	O=182 O/E=1.10	O=69 O/E=.46	O=164 O/E=1.40	O=2 O/E=2.14
Dorsal	O=242 O/E=1.12	O=389 O/E=1.20	O=369 O/E=1.25	O=66 O/E=.29	O=3 O/E=1.63
Phary	O=33 O/E=.60	O=119 O/E=1.45	O=59 O/E=.79	O=54 O/E=.93	O=0 O/E=.00

Table 6: Consonant co-occurrence restrictions on pairs of adjacent consonants in Yamato Japanese (based on Kawahara et al. 2006).

This convergence—coronal sonorants and coronal obstruents constitute two separate classes both in the rap rhyming pattern and the consonant co-occurrence pattern—strongly suggests that the same mechanism (i.e. similarity) underlies both of the patterns. However, similarity manifests itself in opposite directions; i.e. in co-occurrence patterns, similarity is avoided, whereas in rap rhyming it is favored. In fact, there is a strong negative correlation between the values in Table 5 and the values in Table 6 (r=-.79, t(23)=-5.09, p<.001, two-tailed).

3.4. Multiple regression analysis

We have seen that for all of the features (the weak effect of [cons] notwithstanding), two consonants that share the same feature specification are overrepresented to a statistically significant degree. This overrepresentation suggests that all of the features contribute to similarity to some degree. A multiple regression analysis can address how much agreement in each feature contributes to similarity. Multiple regression yields an equation that best predicts the values of a dependent variable Y by *p*-number of predictors X by positing a model, $Y=\beta_0+\beta_1X_1+\beta_2X_2\ldots\ \beta_pX_p+\varepsilon$ (where ε stands for a random error component). For the case at hand, the independent variables are the seven features used in §3.1-§3.3; each feature is dummy-coded as 1 if two consonants agree in that feature, and 0 otherwise. Based on the conclusion in §3.3, coronal sonorants and coronal obstruents were assumed to form separate classes. For the dependent variable Y, I used the natural-log transformed O/E values. This transformation made the effect of outliers less influential, and also made the distribution of the O/E values more normal. Finally, I employed the Enter method, in which all independent variables are entered in the model in a single step. This method avoids potential inflation of Type I error which the other methods might entail.

Regressing the log-transformed O/E on all features yielded the equation in (6).

(6) $\log_e(O/E)=$

$$-.94 +.62[pal]+.25[voi]+.23[nas]+.21[cont]+.11[son]-.008[cons]-.12[place]$$

(where for each [f], [f]=1 if a pair agrees in [f], and 0 otherwise)

The equation (6) indicates, for example, that agreeing in [pal] increases $\log_e(O/E)$ by .62, everything else being held constant. The slope coefficients (b_p) thus represent how much each of the features contributes to similarity. In (6), the slope coefficients are significantly different from zero for [pal], [voi], and [cont], and marginally so for [nas], as summarized in Table 7. R^2, a proportion of the variability of $\log_e(O/E)$ accounted for by (6), is .24 ($F(7, 190)=8.70$, $p<.001$; R^2_{adj} is .21).[12]

[12] All assumptions for a multiple regression analysis were met reasonably well. The Durbin-Watson statistic was 1.65; the largest Cook's distance was .08; no leverage values were larger than the criterion ($=2(p+1)/N=.08$); the smallest tolerance (=that of [son]) is .722. See e.g. Myers and Well (2003: 534-548, 584-585) for relevant discussion of these values.

	b_p	s.e.(b_p)	t(192)	p (two-tailed)
Intercept	-.94	.20	-4.74	<.001
[pal]	.62	.09	6.60	<.001
[voi]	.25	.09	2.66	<.01
[nas]	.23	.14	1.73	.09
[cont]	.21	.10	2.17	.03
[son]	.11	.11	1.03	.31
[cons]	-.008	.14	-.55	.59
[place]	-.12	.11	-1.17	.25

Table 7: The results of the multiple regression analysis. The first column (b_p) shows the estimated slope coefficients; the second column (s.e.(b_p)) shows standard errors of the coefficient estimates. Rows containing at least a marginally significant coefficient ($.05 < p < .1$) are shaded.

The b_p values in Table 7 show that the manner features ([pal, voi, nas, cont]) contribute the most to similarity. The major class features ([cons] and [son]) do not contribute as much to similarity, and the coefficient for [place] does not significantly differ from zero either.

The lack of a significant effect of major features and [place] appears to conflict with what we observed in §3.2 and §3.3; [son], [cons], and [place] do cause overrepresentation when two consonants agree in these features. Presumably, the variability due to these features overlaps too much with the variability due to the four manner features, and as a result, the effect of [place] and the major class features *per se* may not have been large enough to have been detected by multiple regression. However, that [place] has a weaker impact on perceptual similarity compared to manner features is compatible with the claim that manner features are more perceptually robust than place features, as revealed by similarity judgment experiments (Bailey and Hahn 2005, 352; Peters 1963; Walden and Montgomery 1975) and identification experiments (Benkí 2003, Miller and Nicely 1955; Wang and Bilger 1973).[13]

To summarize, the multiple regression analysis has revealed the degree to which the agreement of each feature contributes to similarity: (i) [pal] has a fairly large effect, (ii) [cont], [voi], [nas] have a medium effect, and (iii) [son], [cons] and [place] have too weak an effect to be detected by multiple regression. This result predicts that [pal] should have a stronger impact on similarity than other manner features, and this prediction should be verified by a perceptual experiment in a future investigation (see also §4.1 for some relevant discussion).

4. Discussion: Acoustic similarity and rhymability

In §3, distinctive features were used to estimate similarity. I argue in this section that measuring similarity in terms of the sum of shared feature specifications or the number of shared natural classes does not suffice; Japanese speakers actually take acoustic details into

[13] In Tuareg half-rhymes, a difference in [place] can be systematically ignored (Greenberg 1960); this pattern also accords with the weak effect of [place] identified here.

account when they compose rhymes. I present three kinds of arguments for this claim. First, there are acoustically similar pairs of consonants whose similarity cannot be captured in terms of features (§4.1.). Second, I show that the perceptual salience of features depends on its context (§4.2.). Third, I show that the perceptual salience of different features is not the same, as anticipated in the multiple regression analysis (§4.3.).

4.1. Similarity not captured by features

First of all, there are pairs of consonants which are acoustically similar, but whose similarity cannot be captured in terms of features. We have already seen in §3.3 that the {dorsal-pharyngeal} pairs are more likely to rhyme than expected, and I argued that this overrepresentation owes to the spectral similarity of these pairs of consonants; note that there is nothing in the feature system that captures the similarity between dorsals and pharyngeals.[14]

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[14] No recent models of distinctive features have a feature that distinguishes {dorsal, pharyngeal} from other places of articulation (Clements and Hume 1995; McCarthy 1988; Sagey 1986). *SPE* characterizes velars, uvulars, pharyngeals as [+back] consonants (Chomsky and Halle 1965: 305), but subsequent research abandoned this consonantal feature, since these consonants do not form a natural class in phonological patterns.

Another example of this kind is the {k^j-tΣ} pair, which is highly overrepresented (O/E=3.91): concrete rhyme examples include ***ch**ooshi* 'condition' vs. ***ky**oomi* 'interest' (by *565* in *Tokyo Deadman Walking*), *kai**ch**oo* 'smooth' vs. *kan**ky**oo* 'environment' and (*kan*)***ky**oo* 'environment' vs. (*sei*)***ch**oo* 'growth' (by *XBS* in *64 Bars Relay*), and *gozen**ch**uu* 'morning' vs. *goren**ky**uu* 'five holidays in a row' (by *TSURUGI MOMOTAROU* in *Project Mou*). Similarly, the {k^j-dZ} pair is also highly overrepresented (O/E=3.39); e.g. *too**j**oo* 'appearance' vs. *too**ky**oo* 'Tokyo' (by *RINO LATINA* in *Shoogen*), ***ky**uudai* 'stop conversing' vs. ***j**uutai* 'serious injury' (by *DABO* in *Tsurezuregusa*), and *nen**j**uu* 'all year' vs. *sen**ky**uu* 'Thank you' (by *TSURUGI MOMOTAROU* in *Project Mou*).

These overrepresentation patterns are understandable in light of the fact that [k^j] is acoustically very similar to [tΣ], and to a lesser extent, to [dZ] (Blumstein 1986; Chang et al. 2001; Guion 1998; Keating and Lahiri 1993; Ohala 1989). First, velar consonants have longer aspiration than non-velar consonants (Hirata and Whiton 2005, 1654; Maddieson 1999, 631), and their long aspiration acoustically resembles affrication. Second, [k^j]'s F2 elevation due to palatalization makes [k^j] sound similar to coronals, which are also characterized by high F2.

The similarity of these pairs cannot be captured in terms of distinctive features: the {k^j-dZ} pair and the {k^j-tΣ} pair agree in only three and four distinctive features, respectively, but the average O/E values of such pairs is .87 and 1.05. An anonymous reviewer has pointed out that all of these consonants contain a [+palatalized] feature which plays a morphological role in onomatopoetic words (Hamano 1998; Mester and Itô 1989), and that the Japanese kana orthography has a special symbol for palatalization; s/he suggests that these morphological and orthographic factors might promote the similarity of the {k^j-dZ} and {k^j-tΣ} pairs. This may indeed be the case, but agreement in [palatalized] does not fully explain why we observe high O/E values for the {tΣ-k^j} and {k^j-dZ} pairs. As revealed by the multiple regression analysis, the contribution to similarity by [+palatalized] is $e^{.62}$=1.86, which does not by itself explain the high O/E values. The high rhymability of these pairs thus instantiates yet another case in which similarity cannot be measured solely in terms of distinctive features—Japanese speakers have awareness for detailed acoustic information such as the duration of aspiration and the raising of F2 caused by palatalization.

4.2. The perceptual salience of a feature depends on its context

The second piece of evidence that computations of similarity must take acoustic details into account is the fact that the salience of the same feature can differ depending on its context. Here, evidence is put forth in terms of the perceptual salience of [place].

Cross-linguistically, nasals are more prone to place assimilation than oral consonants (Cho 1990; Jun 1995; Mohanan 1993). Jun (1995) argues that this is because place cues are more salient for oral consonants than for nasal consonants. Boersma (1998: 206) also notes that "[m]easurements of the spectra…agree with confusion experiments (for Dutch: Pols 1983), and with everyday experience, on the fact that [m] and [n] are acoustically very similar, and [p] and [t] are farther apart. Thus, place information is less distinctive for nasals than it is for plosives." Ohala and Ohala (1993: 241-242) likewise suggest that "[nasal consonants'] place cues are less salient than those for comparable obstruents." The reason why nasals have weaker place cues than oral stops is because formant transitions into and out of the neighboring vowels are obscured due to coarticulatory nasalization (Jun 1995 building on Malécot 1956; See also Hura et al. 1992: 63 and Mohr and Wang 1968).

The fact that a place distinction is less salient for nasals than it is for obstruents is reflected in the rhyming pattern. The {m-n} pair is the only minimal pair of nasals that differs in place,[15] and its O/E value is 1.41, which is a rather strong overrepresentation. Indeed the rhyme pairs involving the [m]~[n] pair are very common in Japanese rap rhymes: *yo**n**aka* 'midnight' vs. *o**m**ata* 'crotch' (by *AKEEM* in *Forever*), *ka**n**ame* 'core' vs. *da**m**are* 'shut up'

[15] The other nasal segment in Japanese (a so-called moraic nasal, [N]) appears only in codas, and hence excluded from this study.

(by *KOHEI JAPAN* in *Go to Work)*, and *haji**m**ari* 'beginning' vs. *tashi**n**ami* 'experience' (by *YOSHI* in *Kin Kakushi Kudaki Tsukamu Ougon*).[16]

Minimal pairs of oral consonants differing in place are less common than the {m-n} pair: all minimal pairs of oral consonants show O/E values smaller than 1.41—{p-t}: 1.09, {p-k}: 1.07, {t-k}:.93, {b-d}: 1.25, {b-g}: 1.24, {d-g}: 1.36. To statistically validate this conclusion, a sign-test was performed—the fact that the nasal minimal pair has an O/E value larger than all oral minimal pairs is unlikely to have arisen by chance ($p<.05$).

We may recall that O/E values correlate with similarity, and therefore this result shows that the {m-n} pair is more similar to each other than any minimal pairs of oral consonants that differ in place. This finding in turn implies that place cues are less salient for nasals than for oral consonants. To conclude, then, in measuring (dis-)similarity due to [place], Japanese speakers take into account the fact that [place] distinctions in nasal consonants are weak, due to the blurring of formant transitions caused by coarticulatory nasalization. This finding constitutes yet another piece of evidence that Japanese speakers use their knowledge about acoustic details in composing rap rhymes.

[16] Nasals pairs with disagreeing place specifications are common in English rock lyrics (Zwicky 1976), English imperfect puns (Zwicky and Zwicky 1986), and English and German poets (Maher 1969, 1972).

4.3. The saliency of features is not homogeneous

The final argument that similarity cannot be measured solely in terms of distinctive features rests on the fact that some features are more perceptually salient than other features, as suggested previously in §3.4 (see also Bailey and Han 2005; Benkí 2003; Miller and Nicely 1955; Mohr and Wang 1968; Peter 1963; Walden and Montgomery 1975; Wang and Bilger 1973). What concerns us here is the perceptibility of [voi]. Some recent proposals hypothesize that [voi] only weakly contributes to consonant distinctions (cf. Coetzee and Pater 2005). Steriade (2001b) for example notes that a [voi] distinction is very often sacrificed to satisfy markedness requirements (like a prohibition against coda voiced obstruents), and argues that frequent neutralization of [voi] owes to its low perceptibility. Kenstowicz (2003) observes that in loanword adaptation, when the recipient language has only a voiceless obstruent and a nasal, the voiced stops of the donor language invariably map to the former; i.e. we find [d] borrowed as [t], but not as [n] (see also Adler 2006 for a similar observation in Hawaiian). Furthermore, Kawahara et al. (2006) has found that in Yamato Japanese, pairs of adjacent consonants that are minimally different in [voi] behave like pairs of adjacent identical consonants in that they are not subject to co-occurrence restrictions.

Kawahara et al. (2006) hypothesize that pairs of consonants that differ only in [voi] do no differ enough to be regarded as non-identical, at least for the purpose of co-occurrence restriction patterns.

These phonological observations accord with previous psycholinguistic findings as well: the Multi-Dimensional Scaling (MDS) analysis by Peters (1963) and Walden and Montgomery (1975) revealed that voicing plays a less important role in distinguishing consonants than other manner features. Bailey and Han (2005: 352) find that manner features carry more weight than voicing in listener's similarity judgments. Wang and Bilger's (1973) confusion experiment under a noisy environment revealed the same tendency. In short, the psychoacoustic salience of [voi] is weaker than that of other manner features.

With these observations in mind, we expect that pairs of consonants that are minimally different in [voi] should show greater rhymability than minimal pairs that disagree in other manner features. The multiple regression analysis in §3.4 revealed that [voi], [cont], [nas] had a fairly comparable effect on rhymability, but it is not possible to statistically compare the slope coefficients of these features since all of the estimates are calculated on the basis of one sample (the estimates are not independent of one another). Therefore, in order to compare the effect of [voi], [cont], and [nas], I compare the O/E values of the minimal pairs defined in terms of these features. The data are shown in (7).[17]

(7)	[cont]		[nasal]		[voi]	
	{p-÷}:	1.44	{b-m}:	1.30	{p-b}:	1.98
	{t-s}:	1.01	{d-n}:	1.41	{t-d}:	2.04
	{d-z}:	1.19			{tΣ-dZ}:	4.11
					{k-g}:	1.44
					{k^j-g^j}	16.5
					{s-z}:	3.07

The O/E values of the minimal pairs that differ in [voi] are significantly larger than the O/E values of the minimal pairs that differ in [cont] or [nasal] (by a non-parametric Wilcoxon Rank-Sum (Mann-Whitney) test; *Wilcoxon* W=15.5, z=2.65, p<.01).[18] Indeed even a cursory

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[17] The effect of the [palatalized] feature is not consistent (e.g. {p-p^j}: 0.00, {n}-{n^j}: 3.10, {r-r^j}: 0.78, {k-k^j}: 0.71, {g-g^j}: 1.76). Hence it is difficult to make a consistent comparison between the [voi] and [palatalized] features; however, we may recall that the multiple regression analysis shows that [palatalized] has an outstandingly strong effect on similarity.

[18] Voicing disagreement is much more common than nasality disagreement in other languages' poetry as well (English: Zwicky 1976; Romanian: Steriade 2003). Shinohara (2004) also points out that voicing disagreement is commonly found in Japanese imperfect puns, as in ***T****okoya wa* ***d****okoya* 'where is the barber?' Zwicky and Zwicky (1986) make a similar observation in English imperfect puns.

survey reveals that the minimal pairs differing in [voi] are extremely common in Japanese rap songs; e.g. *too**g**ara**sh**i* 'red pepper' vs. *too**k**ara**j**i* 'not too far' (by *NANORUNAMONAI* in *Kaerimichi)*, (*i*)*ttoku**z**e* 'I'll say it' vs. *toku**s**en* 'special' (by *OSUMI* in *Don't be Gone*), and (*shin*)***j**i**t**ai* 'want to believe' vs. (*jibun*) ***sh**i**d**ai* 'depend on me' (by *AI* in *Golden MIC*).

In summary, minimal pairs that differ only in [voi] are treated as quite similar to each other by Japanese speakers. This characteristic of [voi] in turn suggests that in measuring similarity, Japanese speakers do not treat [voi] and other manner features homogeneously—i.e. Japanese speakers have awareness of the varying perceptual salience of different features.

4.4. Summary: Knowledge of similarity

I have argued that Japanese speakers take acoustic details into account when they measure similarity in composing rap rhymes. Given that the use of featural similarity does not provide adequate means to compute similarity in the rhyme patterns, we might dispense entirely with featural similarity in favor of (psycho)acoustic similarity. Ultimately, this move may be possible, but not within the present analysis: it would require a complete matrix of Japanese sounds, which must be obtained through some extensive psycholinguistic experiments (e.g.

identification experiments under noise, similarity judgment tasks, etc; see Bailey and Hahn 2005 for a recent overview). Constructing the acoustic similarity matrix and using it for another analysis of the Japanese rap patterns are both interesting topics for future research topics, but impossible goals for this paper.

The conclusion that speakers possess knowledge of similarity based on acoustic properties fits well with Steriade's (2001ab, 2003) recent P-map hypothesis. She argues that language users possess detailed knowledge of psychoacoustic similarity, encoded in the grammatical component called the P-map. The P-map exists outside of a phonological grammar, but phonology deploys the information it stores (Fleischhacker 2001, 2005; Kawahara 2006; Zuraw 2005). The analysis of rap rhyme patterns has shown that speakers do possess such knowledge of similarity and deploy it in composing rhymes, and future research could reasonably concern itself with determining whether this knowledge of similarity interacts—or even shapes—phonological patterns.

5. Conclusion

The rhymability of two consonants positively correlates with their similarity. Furthermore, the knowledge of similarity brought to bear by Japanese speakers includes detailed acoustic information. These findings support the more general idea that speakers possess rich knowledge of psychoacoustic similarity (Steriade 2001ab, 2003 and earlier psycholinguistic work cited above).

One final point before closing: we cannot attribute the correlation between rhymability and similarity in Japanese rap songs to a conscious attempt by Japanese rap lyrists to make rhyming consonants as similar as possible. Crucially, the folk definition of rhymes says explicitly that consonants play no role in the formation of rhymes. Therefore, the patterns of similarity revealed in this study cannot be attributed to any conscious, conventionalized rules. Rather, the correlation between similarity and rhymability represents the spontaneous manifestation of unconscious knowledge of similarity.

The current study has shown that the investigation of rhyming patterns reveals such unconscious knowledge of similarity that Japanese speakers possess. Therefore, more broadly speaking, the current findings give support to the claim that investigation of paralinguistic patterns can contribute to the inquiry into our collective linguistic knowledge, and should be undertaken in tandem with analyses of purely linguistic patterns (Bagemihl 1995; Fabb 1997; Fleischhacker 2005; Goldston 1994; Halle and Keyser 1971; Holtman 1996; Itô et al. 1996; Jakobson 1960; Kiparsky 1970, 1972, 1981; Maher 1969, 1972; Malone 1987, 1988ab;

Minkova 2003; Ohala 1986; Shinohara 2004; Steriade 2003; Yip 1984, 1999; Zwicky 1976; Zwicky and Zwicky 1986 among many others).

Appendix I: The list of songs (alphabetically ordered)

The first names in the parenthesis represent artist (or group) names. Names after "feat." represent guest performers.

1. 180 Do (LUNCH TIME SPEAX)
2. 64 Bars Relay (SHAKKAZOMBIE feat. DABO, XBS & SUIKEN)
3. 8 Men (I-DEA feat. PRIMAL)
4. A Perfect Queen (ZEEBRA)
5. Akatsuki ni Omou (MISS MONDAY feat. SOWELU)
6. All Day All Night (XBS feat. TINA)
7. Area Area (OZROSAURUS)
8. Asparagus Sunshine (MURO feat. G.K.MARYAN & BOO)
9. Bed (DOUBLE feat. MUMMY-D & KOHEI JAPAN)
10. Bouhuuu (ORIGAMI)
11. Brasil Brasil (MACKA-CHIN & SUIKEN)
12. Breakpoint (DJ SACHIO feat. AKEEM, DABO, GOKU, K-BOMB & ZEEBRA)
13. Brother Soul (KAMINARI-KAZOKU feat. DEN & DEV LARGE)
14. Bureemen (MABOROSHI feat. CHANNEL, K.I.N & CUEZERO)
15. Change the Game (DJ OASIS feat. K-DUB SHINE, ZEEBRA, DOOZI-T, UZI, JA KAMIKAZE SAIMON, KAZ, TATSUMAKI-G, OJ, ST & KM-MARKIT)
16. Chikachika Circit (DELI feat. KASHI DA HANDSOME, MACKA-CHIN, MIKRIS & GORE-TEX)
17. Chiishinchu (RINO-LATINA II feat. UZI)
18. Cho to Hachi (SOUL SCREAM)
19. Crazy Crazy (DJ MASTERKEY feat. Q & OSUMI)
20. Do the Handsome (KIERU MAKYUU feat. KASHI DA HANDSOME)
21. Doku Doku (TOKONA-X, BIGZAM, S-WORD & DABO)
22. Don't be Gone (SHAKKAZOMBIE)
23. Eldorado Throw Down (DEV LARGE, OSUMI, SUIKEN & LUNCH TIME SPEAX)
24. Enter the Ware (RAPPAGARIYA)
25. Final Ans. (I-DEA feat. PHYS)
26. Forever (DJ TONK feat. AKEEM, LIBRO, HILL-THE-IQ & CO-KEY)
27. Friday Night (DJ MASTERKEY feat. G.K. MARYAN)
28. Go to Work (KOHEI JAPAN)

29. Golden MIC—remix version (ZEEBRA feat. KASHI DA HANDSOME, AI, DOOZI-T & HANNYA)
30. Good Life (SUITE CHIC feat. FIRSTKLAS)
31. Hakai to Saisei (KAN feat. RUMI & KEMUI)
32. Hakushu Kassai (DABO)
33. Happy Birthday (DJ TONK feat. UTAMARU)
34. Hard to Say (CRYSTAL KAY feat. SPHERE OF INFLUENCE & SORA3000)
35. Hazu Toiu Otoko (DJ HAZU feat. KENZAN)
36. Hima no Sugoshikata (SUCHADARA PARR)
37. Hip Hop Gentleman (DJ MASTERKEY feat. BAMBOO, MUMMY-D & YAMADA-MAN)
38. Hi-Timez (HI-TIMEZ feat. JUJU)
39. Hitoyo no Bakansu (SOUL SCREAM)
40. Ikizama (DJ HAZU feat. KAN)
41. Itsunaroobaa (KICK THE CAN CREW)
42. Jidai Tokkyuu (FLICK)
43. Junkai (MSC)
44. Kanzen Shouri (DJ OASIS feat. K-DUB SHINE, DOOZI-T & DIDI)
45. Kikichigai (DJ OASIS feat. UTAMARU & K-DUB SHINE)
46. Kin Kakushi Kudaki Tsukamu Ougon (DJ HAZIME feat. GAKI RANGER)
47. Kitchen Stadium (DJ OASIS feat. UZI & MIYOSHI/ZENZOO)
48. Koi wa Ootoma (DABO feat. HI-D)
49. Koko Tokyo (AQUARIUS feat. S-WORD, BIG-O & DABO)
50. Konya wa Bugii Bakku (SUCHADARA PARR feat. OZAWA KENJI)
51. Koukai Shokei (KING GIDDORA feat. BOY-KEN)
52. Lesson (SHIMANO MOMOE feat. MUMMY-D)
53. Lightly (MAHA 25)
54. Lights, Camera, Action (RHYMESTER)
55. Mastermind (DJ HASEBE feat. MUMMY-D & ZEEBRA)
56. Microphone Pager (MICROPHONE PAGER)
57. Moshimo Musuko ga Umaretara (DJ MITSU THE BEATS feat. KOHEI JAPAN)
58. Mousouzoku DA Bakayarou (MOUSOUZOKU)
59. My Honey—DJ WATARAI remix (CO-KEY, LIBRO & SHIMANO MOMOE)
60. My Way to the Stage (MURO feat. KASHI DA HANDSOME)
61. Nayame (ORIGAMI feat. KOKORO)

62. Nigero (SHIIMONEETAA & DJ TAKI-SHIT)
63. Nitro Microphone Underground (NITRO MICROPHONE UNDERGROUND)
64. Norainu (DJ HAZU feat. ILL BOSSTINO)
65. Noroshi—DJ TOMO remix (HUURINKAZAN feat. MACCHO)
66. Ohayou Nippon (HANNYA)
67. On the Incredible Tip (MURO feat. KASHI DA HANDSOME, JOE-CHO & GORIKI)
68. One (RIP SLYME)
69. One Night (I-DEA feat. SWANKY SWIPE)
70. One Woman (I-DEA feat. RICE)
71. Ookega 3000 (BUDDHA BRAND feat. FUSION CORE)
72. Phone Call (DJ OASIS feat. BACKGAMMON)
73. Prisoner No1.2.3. (RHYMESTER)
74. Project Mou (MOUSOUZOKU)
75. R.L. II (RINO-LATINA II)
76. Rapgame (IQ feat. L-VOCAL, JAYER & SAYAKO)
77. Revolution (DJ YUTAKA feat. SPHERE OF INFLUENCE)
78. Roman Sutoriimu (SIIMONEETAA & DJ TAKI-SHIT)
79. Shougen (LAMP EYE feat. YOU THE ROCK, G.K. MARYAN, ZEEBRA, TWIGY & DEV LARGE)
80. Sun oil (ALPHA feat. UTAMARU & NAGASE TAKASHI)
81. Take ya Time (DJ MASTERKEY feat. HI-TIMEZ)
82. Tengoku to Jikoku (K-DUB SHINE)
83. Ten-un Ware ni Ari (BUDDHA BRAND)
84. The Perfect Vision (MINMI)
85. The Sun Rising (DJ HAZIME feat. LUNCH TIME SPEAX)
86. Tie Break ’80 (MACKA-CHIN)
87. Tokyo Deadman Walking (HANNYA feat. 565 & MACCHO)
88. Tomodachi (KETSUMEISHI)
89. Tomorrow Never Fies (ROCK-TEE feat. T.A.K. THE RHHHYME)
90. Toriko Rooru (MONTIEN)
91. Tsurezuregusa (DABO feat. HUNGER & MACCHO)
92. Ultimate Love Song(Letter) (I-DEA feat. MONEV MILS & KAN)
93. Unbalance (KICK THE CAN CREW)
94. Whoa (I-DEA feat. SEEDA)
95. Yakou Ressha (TWIGY feat. BOY-KEN)

96. Yamabiko 44-go (I-DEA feat. FLICK)
97. Yoru to Kaze (KETSUMEISHI)
98. Zero (DJ YUTAKA feat. HUURINKAZAN)

Appendix II: A complete chart of the O/E values and O values

Provided at the end of this document.

Appendix III: Feature matrix

	son	cons	cont	nasal	voice	place	palatalized
p	-	+	-	-	-	lab	-
p^j	-	+	-	-	-	lab	+
b	-	+	-	-	+	lab	-
b^j	-	+	-	-	+	lab	+
÷	-	+	+	-	-	lab	-
m	+	+	-	+	+	lab	-
m^j	+	+	-	+	+	lab	+
w	+	-	+	-	+	lab	-
t	-	+	-	-	-	cor	-
d	-	+	-	-	+	cor	-
s	-	+	+	-	-	cor	-
z	-	+	+	-	+	cor	-
Σ	-	+	+	-	-	cor	+
ts	-	+	±*	-	-	cor	-
tΣ	-	+	±	-	-	cor	+
dZ	-	+	±	-	+	cor	+
n	+	+	-	+	+	cor	-
n^j	+	+	-	+	+	cor	+
r	+	+	+	-	+	cor	-
r^j	+	+	+	-	+	cor	+
j	+	-	+	-	+	cor	+
k	-	+	-	-	-	dors	-
k^j	-	+	-	-	-	dors	+
g	-	+	-	-	+	dors	-
g^j	-	+	-	-	+	dors	+
h	-	+	+	-	-	phary	-
h^j	-	+	+	-	-	phary	+

* Affricates are assumed to disagree with any other segments in terms of [cont].

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	p	p^j	b	b^j	÷	m	m^j	w	t	d	s	z	Σ	ts	tΣ	dZ	n	n^j	r	r^j	j	k	k^j	g	g^j	h	h^j
p	5.65 *14*	0 *0*	1.98 *15*	0 *0*	1.44 *1*	.7 *8*	0 *0*	.86 *2*	1.09 *17*	.70 *6*	.91 *10*	.97 *4*	.88 *7*	.45 *1*	1.14 *5*	0.22 *1*	.32 *4*	0 *0*	.79 *14*	0 *0*	.63 *2*	1.07 *26*	2.32 *3*	1.02 *8*	0 *0*	1.62 *9*	0 *0*
p^j		0 *0*	0 *0*	0 *0*	0 *0*	0 *0*	0 *0*	0 *0*	0 *0*	0 *0*	0 *0*	0 *0*	0 *0*	0 *0*	17.8 *1*	0 *0*	0 *0*	0 *0*	0 *0*	0 *0*	24.9 *1*	0 *0*	0 *0*	0 *0*	0 *0*	0 *0*	0 *0*
b			*2.41* *56*	0 *0*	.94 *2*	1.30 *46*	0 *0*	1.26 *9*	.52 *25*	1.25 *33*	.72 *24*	.95 *12*	.49 *12*	.29 *2*	.96 *13*	.51 *7*	.62 *24*	0 *0*	1.36 *74*	0 *0*	.72 *7*	.75 *56*	.76 *3*	1.25 *30*	2.82 *3*	1.59 *27*	2.07 *1*
b^j				398 *1*	0 *0*	0 *0*	0 *0*	2.81 *1*	0 *0*	0 *0*	2.87 *1*	0 *0*	0 *0*	0 *0*	0 *0*	0 *0*	0 *0*	0 0	1.76 *1*	0 *0*	9.95 *1*	0 *0*	0 *0*	0 *0*	0 *0*	5.67 *1*	0 *0*
÷					20.5 *4*	.62 *2*	0 *0*	1.53 *1*	.92 *4*	.42 *1*	.65 *2*	0 *0*	.90 *2*	1.59 *1*	1.62 *2*	0 *0*	0 *0*	0 *0*	1.20 *6*	0 *0*	1.13 *1*	.88 *6*	0 *0*	.45 *1*	0 *0*	4.51 *7*	22.6 *1*
m						2.8 *150*	0 *0*	1.11 *12*	.66 *48*	1.00 *40*	.77 *39*	.73 *14*	.41 *15*	.38 *4*	.44 *9*	.52 *11*	1.41 *83*	0 *0*	1.00 *83*	0 *0*	.89 *13*	.91 *103*	.67 *4*	.74 *27*	1.24 *2*	.62 *16*	0 *0*
m^j							0 *0*	0 *0*	0 *0*	0 *0*	0 *0*	0 *0*	9.87 *1*	0 *0*	0 *0*	0 *0*	0 *0*	0 *0*	0 *0*	146 *1*	0 *0*	0 *0*	0 *0*	0 *0*	0 *0*	0 *0*	0 *0*
w								8.17 *18*	.82 *12*	.99 *8*	.48 *5*	0 *0*	0 *0*	0 *0*	0 *0*	.70 *3*	2.01 *24*	8.4 *1*	1.13 *19*	0 *0*	.67 *2*	.79 *18*	0 *0*	1.48 *11*	0 *0*	.57 *3*	0 *0*
t									2.85 *278*	2.04 *110*	1.01 *69*	.69 *18*	.24 *12*	.14 *2*	.22 *6*	.39 *11*	.86 *68*	1.26 *1*	.64 *71*	.30 *1*	.86 *17*	.93 *142*	.49 *4*	.93 *46*	0 *0*	.63 *22*	1.01 *1*
d										3.46 *103*	.92 *35*	1.19 *17*	.40 *11*	0 *0*	.79 *12*	.51 *8*	1.41 62	0 *0*	1.05 *65*	1.08 *2*	1.19 *13*	.80 *67*	.67 *3*	1.36 *37*	.83 *1*	1.04 *20*	0 *0*
s											4.56 *220*	3.07 *56*	.80 *28*	4.14 *41*	.46 *9*	.55 *11*	.55 *31*	1.79 *1*	.73 *57*	.42 *1*	.57 *8*	.75 *80*	.35 *2*	1.10 *38*	.65 *1*	1.10 *27*	0 *0*

z												7.10 *49*	.15 *2*	1.07 *4*	.14 *1*	.13 *1*	.57 *12*	0 *0*	.67 *20*	1.12 *1*	.57 *3*	.59 *24*	.93 *2*	1.22 *16*	0 *0*	.65 *6*	0 *0*
Σ													7.20 *184*	.14 *1*	2.4 *34*	3.73 *54*	.37 *15*	2.47 *1*	.49 *28*	2.32 *4*	.79 *8*	.63 *49*	2.17 *9*	.32 *8*	2.69 *3*	.84 *15*	1.97 *1*
ts														16.3 *33*	.75 *3*	.24 *1*	0 *0*	0 *0*	.43 *7*	0 *0*	0 *0*	1.46 *32*	0 *0*	.70 *5*	0 *0*	1.00 *5*	0 *0*
tΣ															11.1 *87*	4.11 *33*	.13 *3*	0 *0*	.38 *12*	2.10 *2*	.36 *2*	.53 *23*	3.91 *9*	.43 *6*	1.62 *1*	.61 *6*	0 *0*
dZ																6.81 *56*	1.00 *23*	0 *0*	.62 *20*	2.05 *2*	.52 *3*	.54 *24*	3.39 *8*	.35 *5*	3.16 *2*	.99 *10*	3.48 *1*
n																	3.06 *198*	3.10 *2*	1.17 *106*	0 *0*	1.43 *23*	.62 *77*	.30 *2*	.80 *32*	0 *0*	.46 *13*	0 *0*
n^j																		0 *0*	1.10 *1*	36.6 *1*	0 *0*	0 *0*	0 *0*	0 *0*	0 *0*	0 *0*	0 *0*
r																			2.71 *347*	.78 *3*	.75 *17*	.58 *101*	.22 *2*	.87 *49*	.80 *2*	.58 *23*	0 *0*
r^j																				77.4 *9*	2.93 *2*	.38 *2*	0 *0*	0 *0*	13.3 *1*	1.67 *2*	0 *0*
j																					9.95 *40*	.58 *18*	1.82 *3*	.80 *8*	0 *0*	.99 *7*	4.97 *1*
k																						2.11 *501*	.71 *9*	1.44 *111*	.59 2	1.16 63	1.94 *3*
k^j																							14.8	.49	16.5	1.04	12.1

																						10	*2*	*3*	3	*1*
g																							1.76 *44*	0 *0*	.80 *14*	0 *0*
g^j																								20.5 *1*	0 *0*	0 *0*
h																									4.2 *52*	0 *0*
h^j																										0 0

The upper values in each cell represent O/E values.
The lower values, shown in *italics*, represent O values.