Recency, frequency, and phonotactics: Pretonic schwa reduction in Dutch

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Abstract

In reduction processes, frequency is known to be an important factor of variation: high-frequency words tend to undergo more reduction than low-frequency words. Similarly, recency, or repetition, also leads to more reduction. Pretonic schwa in Dutch is susceptible to reduction in which frequency as well as recency are likely to play a role. However, it has been claimed that schwa-deletion also depends on Dutch phonotactics: schwa-deletion would not occur if it results in an ill-formed onset cluster. This paper investigates possible interactions between frequency, recency, and phonotactic structure. The results show that the degree of reduction driven by frequency and recency effects interacts with phonotactics. Schwa reduction occurs more often if the preceding and following consonant together form a phonotactically permissible onset cluster. These results call for an integrated approach of usage-based phonology, which explains the frequency and recency effects, and constraint-based phonology which explains the categorical cluster effect.

1. Pretonic schwa reduction in Dutch

In usage-based phonology, it has often been observed that high-frequency (HF) words are more likely to be reduced than low-frequency (LF) words (Bybee 2010, Phillips 2006). The explanation for this frequency effect is that, if words are often pronounced, the articulatory organs are trained to use them, which by practice becomes gradually easier and faster. This is not unique for speech production, but rather reflects a natural learning process of the motor system. Related to this frequency effect is a so-called recency effect: the time between two occurrences of the word is inversely correlated with the degree of reduction (Bell et al. 2009, Trón 2008). This means that, first, the more often a word is repeated, it undergoes more reduction, and, second, the shorter the time between two repetitions, the stronger the reduction is. Recency effects can be particularly strong; for instance, Abramowicz (2007) notices that in the variation patterning of English *-ing*, recency is stronger than the usual sociolinguistic effects, such as gender, social class, and style. Frequency and recency effects are usage-based effects in language. In natural language use, frequency and recency are strongly related: the more frequent a word is, the shorter the time will be between two occurrences. In an experimental setting, we can tease the two apart and investigate the effect of the two factors on reduction. The present study investigates the effects of frequency and recency in pretonic schwa reduction in Dutch.

Frequency effects as well as recency effects are prone to occur in pretonic schwa in Dutch. Van Oostendorp (1998) observes that, generally speaking, in Dutch, pretonic vowels are likely to get more reduced in HF words than in LF words. If this applies to pretonic schwa as well, then, *ceteris paribus*, we would expect more reduction in words as in (1)a and less reduction in words as in (1)b.

a. Highly Frequent

genoeg /χəˈnuχ/ → [ˈχnuχ] ‘enough’

b. Lowly Frequent

geniep /χəˈnip/ → [ˈχənip] ‘mean’

On the other hand, it has been claimed by Booij (1999) that (pretonic) schwa-deletion actually depends on the phonotactic structure. Schwa-deletion is most likely if the remaining cluster is an obstruent-sonorant cluster.

Deletion resulting in well-formed onset clusters

/bəˈlɑŋrɛɪk/ → [ˈblɑŋrɛɪk] ‘important’ /bl-/

/χəˈledən/ → [ˈχledə] ‘ago’ /χl-/

Deletion resulting in ill-formed onset clusters

/bəˈnedən/ → [ˈbnedə] ‘down’ */bn-/

/dəˈzɛlfdə/ → [ˈdzɛlvdə] ‘the same’ */dz-/

However, Booij (1999: 129) admits that, sometimes, ill-formed clusters may be attested in fast or casual speech. Booij treats pretonic schwa-deletion as an optional rule which is categorical: either pretonic schwa is fully realized or it is deleted. The observations of Booij (1999) as well as Van Oostendorp (1998) seem to be based on introspection by native speakers, not on experimental data. Experimental data on schwa deletion are also available: Kuijpers, Van Donselaar & Cutler (1996) conducted an experiment on schwa deletion in Dutch in which the data were categorically analyzed by native speakers, a methodology which recently turned out to be suspicious, since native speakers, also if linguistically trained, may be biased to other, unknown, factors in transcribing (Hall-Lew & Fix 2012, Sloos 2013). Moreover, the presumed categorical behaviour of schwa deletion is doubtful. Davidson (2006), for instance, observes that English pretonic schwa deletion is not a categorical process, but rather an extreme form of reduction. For French, it has also been assumed that durational variation of schwa is gradient rather than categorical (Eychenne 2006). So the first goal of this paper is to investigate whether durational differences between schwa in Dutch are gradient.

> *Hypothesis 1. Pretonic schwa deletion is not a categorical, but a gradient process.*

However, there is another plausible scenario, namely that both Booij (1999) and Van Oostendorp (1998) are on the right track. In that case, we expect that both the remaining cluster as well as frequency effects affect schwa duration. Since Booij claims that deletion occurs mainly if the resulting cluster is phonotactically well-formed, we would expect variation in duration (on the basis of frequency) mainly in that particular context. If the resulting cluster is be impermissible, deletion is not expected, so frequency effects are also unlikely to occur.

> *Hypothesis 2. High-frequency words undergo more pretonic schwa reduction than low-frequency words, but this frequency effect is more prominent in case the resulting cluster is an obstruent-sonorant cluster than in case the resulting cluster is an impermissible onset cluster.*

The present paper investigates whether, alongside frequency effects, recency effects also may interact with the phonotactic structure, and whether these interactions are comparable. If it were the case that recency-effects are similar in nature to frequency effects, as suggested above, then it should be expected that recency effects also mainly occur if the resulting cluster is an obstruent-sonorant cluster and not otherwise.

> *Hypothesis 3. Each following repetition of a word leads to more pretonic schwa reduction, but this recency effect is more prominent in case the resulting cluster is an obstruent-sonorant cluster than in case the resulting cluster is an impermissible onset cluster.*

This paper reports on a word reading experiment in which extremely LF and extremely HF words were repeatedly spoken. It will be shown that, first, pretonic schwa deletion is not categorical, but gradient. Therefore, in the remainder of this paper, I will refer to the process as pretonic schwa *reduction*. Secondly, reduction occurs as a frequency effect and also as a recency effect. The two processes occur more often if the adjacent consonants form a permissible onset cluster in Dutch. These results show an interaction between two usage-based processes on the one hand and a grammatical property on the other hand.

The remainder of this paper is structured as follows. The next section reports on the approach. Section 3 reports on the methodology and section 4 contains the results of the experiment. Finally, section 5 concludes and discusses the experimental results and speculates on the larger picture of grammar and usage that emerges from these findings.

2. Approach

The experiment consisted of a word reading task, for which stimuli were extracted from the CELEX database (Baayen, Piepenbrock & Van Rijn 1993) and the CGN (Corpus Gesproken Nederlands "Corpus of spoken Dutch" (Van Eerten 2007)). I selected words in four categories:

- HF words with well-formed target onset clusters
- HF words with impermissible target onset clusters
- LF words with well-formed onset clusters
- LF words with impermissible target onset clusters

LF words were defined as words with an occurrence of less than 10 per million. For HF words, I used the criterion of an occurrence of more than 100 per million. Both criteria are common thresholds in research on frequency effects (e.g. Gierut & Dale 2007, Malouf & Kinoshita 2007).

Each HF word with the context CəC- was matched with an LF word according to the following criteria:

- the consonants preceding the schwa and following the schwa are identical

- the number of syllables is identical
- the number of segments are matched as closely as possible
- stress placement is identical

This led to the selection of eight words in both categories, LF and HF words, with well-formed target onset clusters /bl, br, χl, χn, vr/ and eight words with phonotactically impermissible target onset clusters /bd, bχ, bn, dz, χm, χv, χʋ/. The stimuli are provided in table 1.

Table 1: Stimuli, divided by the well-formedness of the target cluster (well-formed vs. ill-formed) and the frequency group (highly frequent (HF) and lowly frequent (LF)).

Onset cluster	HF	LF
well-formed	b[ə]'langrijk	b[ə]'labberd
	b[ə]'roep	b[ə]'rooid
	g[ə]'leden	g[ə]lieve
	g[ə]'lijk	g[ə]'lid
	g[ə]'loof	g[ə]'laat
	g[ə]'lukkig	g[ə]'lazer
	g[ə]'noeg	g[ə]'niep
	v[ə]r'andering	v[ə]r'overing
ill-formed	b[ə]'doel	b[ə]'daard
	b[ə]'gin	b[ə]'gijn
	b[ə]'neden	b[ə]'nijden
	d[ə]'zelfde	d[ə]'zulke
	g[ə]'meente	g[ə]'meier
	g[ə]'val	g[ə]'vat
	g[ə]'weest	g[ə]'wag
	g[ə]'woon	g[ə]'wei

In the ideal case, all stimuli would have the same number of syllables, since duration is shorter if the number of syllables is higher. However, there were not enough tokens in the corpus that where only disyllabic or trisyllabic. Therefore, the words were matched for the number of syllables as illustrated in Table 1. However, in the analysis, it will be checked whether the number of syllables has an effect on the duration of pretonic schwa.

The corpora provide frequency information, but, of course, the corpus counts might not always correlate with the frequencies in the individual lexicons of the subjects. It is well-known that word frequency positively correlates with response times: words with relatively higher frequency have shorter naming latencies (Jurafsky 2003). I tested whether the frequency categorization as described above corresponded with the frequency of the word in the individual lexicon of each subject by measuring naming latencies.

2.1 Design

The test was designed in E-prime 2.0 (Schneider, Eschman & Zuccolotto 2002) and consisted of 10 blocks of 80 stimuli. The stimuli were identical for each block and their order was pseudo-randomized. The order of the blocks was truly randomized. All stimuli were visually presented on a computer screen to the subjects. Subjects were asked to quickly and as accurately as possible read aloud the stimuli. The responses were recorded and simultaneously, naming latencies were measured. Subsequently, the duration of the target vowels was analyzed by using the Praat software (Boersma & Weenink 2010).

3. Methodology

3.1 Stimuli

In all, 32 critical stimuli, 8 HF words with well-formed target onset clusters, 8 HF words with ill-formed target onset clusters, 8 LF words with well-formed target onset clusters, and 8 LF words with ill-formed target onset clusters were selected. Further, 48 filler words were selected, so in sum, 80 different stimuli were used.

3.2 Subjects

Twenty participants, recruited from the personal network of the author, took part in the experiment. The group of subjects consisted of 13 females and 7 males. All of them were native speakers of Dutch. All subjects had normal or corrected-to-normal vision. One of the subjects reported dyslexia afterwards and his data were therefore rejected from further analysis. The subjects took part voluntarily and were not paid for their participation.

3.3 Procedure

The experiment was conducted in individual sessions. The subjects were seated in an isolated booth. They received instructions from the experimenter as well as on a computer screen to quickly, and as accurately as possible, read aloud the words presented. The stimuli were made visible on a computer screen for 500 ms, followed by an interval of 1000 ms. The naming latency was measured and registered, making use of E-Prime 2.0 (Schneider et al. 2002). Each session was recorded with a *Sennheiser* MKH 416 directional condenser to a Marantz recorder. The computer was placed outside the booth. The experimenter was present to ensure that the experiment was carried out in an orderly way.

4. Results

Two subjects were clearly hyperarticulating (probably due to a professional background as speech therapist). One subject was hypoarticulating (due to extreme slow speech rate) in the first responses, but gradually her speech became normally articulated. Since naming latency and/or schwa-duration is influenced by abnormal articulation, the data from these subjects, as well as stimuli for which there were no correct and clear responses, were excluded from the analysis. Stimuli with extreme naming latencies (below 350ms and above 750ms) were excluded and any schwa with extreme duration, longer than 800ms, was also excluded.

4.1 Naming latency and word frequency

The naming latency was measured to ensure that the selection of HF words and LF words from the corpora was justified (see Section 2). A t-test was performed to investigate the differences between the naming latencies of HF and LF words. The mean of the naming latencies for the first responses of LF words and HF words is provided in Table 2.

As expected, the mean latency of HF words is lower than the mean latency of the LF words. The difference is $t(1,15) = 1.754$, the result is just significant ($p = .050$ one-tailed). The differences between latencies of HF and LF words (as defined by the corpus criteria) were checked for each individual subject. One subject showed slightly higher mean naming latencies for HF words than for LF words (LF = 489ms, HF = 498ms). Her responses were therefore also excluded from further investigation.

Table 2: The mean and the standard deviation of the naming latencies in high-frequency and low-frequency words

	Mean (ms)	Standard deviation
HF	483	14
LF	493	60

4.2 Gradiency of schwa reduction

The first hypothesis was that pretonic schwa reduction is gradient. This hypothesis is confirmed: schwa duration ranges from 0 to > 100 ms, in a normal or near to normal distribution. This holds for stimuli with ill-formed as well as with well-formed target onset clusters. In Figure 1, the frequency distribution of duration is illustrated for impermissible or ill-formed target clusters (cluster 1) and well-formed target clusters (cluster 2).

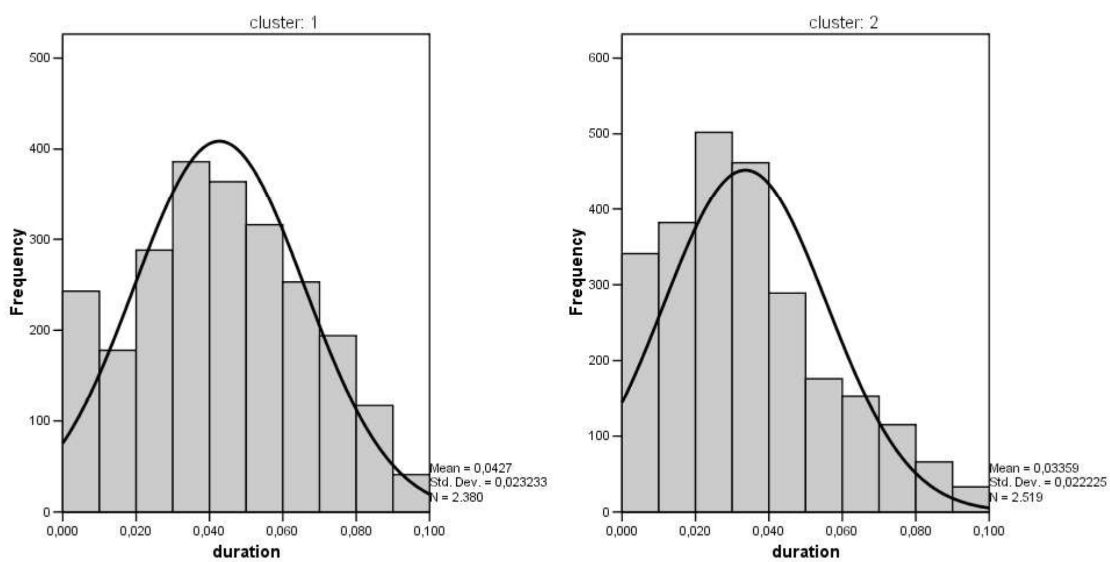

Figure 1: The frequency distribution of pretonic schwa duration is near to normal in ill-formed target onset clusters (cluster 1) and well-formed target onset clusters (cluster 2).

4.3 Recency effects

In order to investigate which factors correlate with schwa duration, a regression analysis was run on frequency, repetition (recency), and cluster type for the whole dataset. The number of syllables was included to check whether schwa duration was affected by the number of syllables in the word. The results show that only recency (repetition) and well-formedness of the cluster have a significant effect on schwa duration. Recency is negatively correlated with duration (t = -8.59, p < .001). Stimuli which have a well-formed onset cluster after deletion have a shorter mean of schwa duration than stimuli that have an ill-formed onset cluster after deletion (t = -10.22, p < .001). In contrast, frequency and the number of syllables did not contribute to the variance of duration of the schwa throughout the whole experiment. The correlation of the model was R^2 = .327 (F = 46.052, p < .001). The results are presented in Table 3.

Table 3: Results of the regression test, showing the Beta coefficient, t-value and significance of repetition, frequency, cluster well-formedness, and the number of syllables. Significance below 0.05 is starred.

	Standardized Coefficients		
	Beta	t	Sig.
(Constant)		20.63	< .001*
number of repetition of stimuli	-.207	-8.59	< .001*
frequency of the stimulus	-.035	-1.45	.147
well-formedness of the cluster	-.259	-10.22	< .001*
Number of syllables	.032	1.26	.209

A frequency effect was not found in the overall regression test. However, it is possible that frequency does play a role within separate blocks of repetition. In addition, if frequency does play a role within separate blocks of repetition, it is possible that the frequency effect interacts with the cluster effect. Therefore, we will now investigate the effect of frequency and the well-formedness of the cluster within the separate blocks of repetition.

4.4 Frequency effect

The effect of the cluster turns out to be robust: over the whole dataset as well as in the separate blocks of repetition, schwa reduction occurs more often if the target onset cluster is a well-formed cluster and schwa reduction occurs less often if the target onset cluster is an ill-formed onset cluster (all results are contained in the appendix). Additionally, some frequency effects are attested: in block 1 there is an interaction between frequency and cluster, in block 5 and block 10, a main effect of frequency is attested.

Table 4: The Sum of squares, degrees of freedom, mean square, F-value and significance of frequency, cluster well-formedness, and their interaction on schwa deletion (Huyhn-Feldt degrees of freedom adjustment).

number of block of stimuli	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
1	freq	< .001	1.000	< .001	.001	.975
	cluster	.001	1.000	.001	32.437	< .001*
	freq * cluster	.000	1.000	.000	5.188	.040*
5	freq	< .001	1.000	< .001	5.388	.037*
	cluster	.001	1.000	.001	12.488	.004*
	freq * cluster	.000	1.000	.000	3.026	.106
10	freq	.000	1.000	.000	5.680	.032*
	cluster	.001	1.000	.001	17.093	.001*
	freq * cluster	< .001	1.000	< .001	.173	.684

Table 4 shows that in the blocks 1, 5, 10, the cluster effect has relatively high F-values and highly significant results. The frequency effect is weaker: the F-values are relatively lower. In the other blocks, no frequency effect could be found at all. In blocks 5 and 10 we find a main frequency effect. In block 1, frequency interacts with the cluster ($F(1,14) = 5.188$ $p = .040$). The interaction is such that for LF words, the difference in schwa duration between well-formed and ill-formed clusters is smaller and that for HF words the difference in schwa duration under the influence of remaining cluster is larger, which is illustrated in Figure 2.

The diverging lines in Figure 2 show an interaction between frequency and cluster type. The difference in duration between well-formed and ill-formed target clusters is larger for HF words than for LF words. These differences in duration between ill-formed and well-formed onset clusters are significant; for LF stimuli, the difference in duration between ill-formed and well-formed onset clusters in LF words is $t = 3.390$,

$p = .005$, for HF stimuli, the difference in duration between ill-formed and well-formed onset clusters is $t = 7.129$, $p < .001$. All possible differences are provided in Table 5.

Hypothesis 2 states that frequency effects would occur more often in words with well-formed target onset clusters. The results show two possible frequency effects. In block 1, we see that HF words are more sensitive to the well-formedness of the cluster. In blocks 5 and 10, HF stimuli in general tend to more reduction.

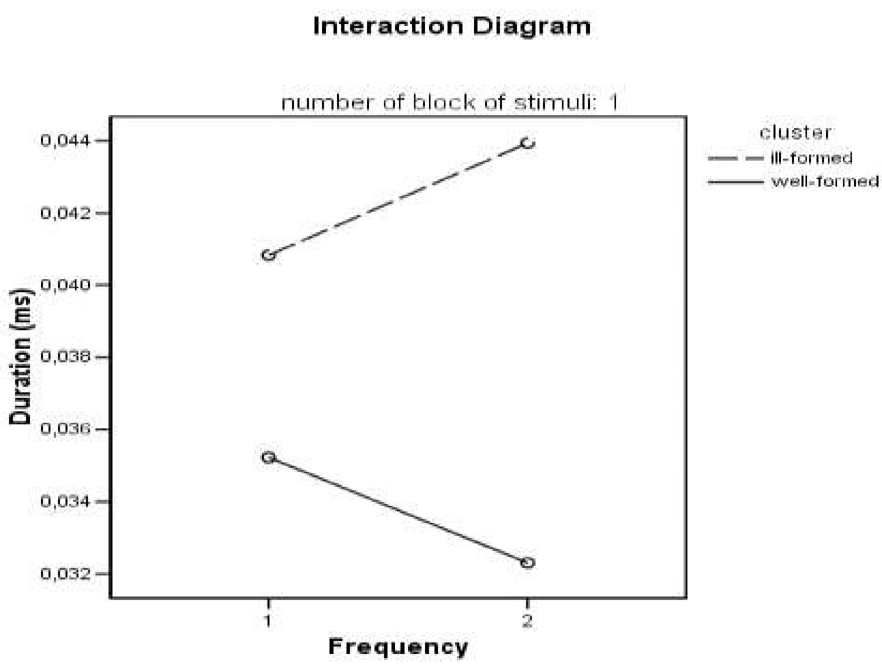

Figure 2: Interaction diagram of frequency and cluster type for schwa duration (1 = LF, 2 = HF)

5. Conclusion and discussion

We found that pretonic schwa reduction in Dutch is a gradient process, which is more likely to occur if the adjacent consonants would yield a phonotactically well-formed onset cluster after deletion, and which is less likely to occur if the adjacent consonants would yield a phonotactically ill-formed onset cluster. Further, we found that in the first responses, high-frequency words are more sensitive to the well-formedness of this cluster than low-frequency words. Finally, repetition leads to more reduction. These results are consistent with recent research of Bell et al. (2009), who showed that frequency and repetition have separate contributions to word duration.

Table 5: Mean values of the schwa and the t-values, degrees of freedom, and significance of the paired t-tests of different word groups in block 1. Further see text.

		Paired Differences							
Pair		Mean	S.D.	S.E.	Lower	Upper	*t*	*df*	*p*
1	duration.LF.ill-formed cluster & duration.LF.well-formed cluster	.006	.007	.002	.002	.010	3.390	14	.005*
2	duration.HF.ill-formed cluster & durtion.HF.well-formed cluster	.012	.007	.002	.008	.016	7.129	14	< 0.001*
3	duration.LF.ill-formed cluster & duration.HF.ill-formed cluster	-.004	.010	.003	-.010	.002	-1.517	14	.153
4	duration.LF.well-formed cluster & durtion.HF.well-formed cluster	.002	.011	.003	-.005	.008	.490	14	.632

The results so far are all gradient and it could be argued that the differences attested between the well-formed and ill-formed clusters is related to their statistical distribution in the Dutch lexicon; since ill-formed clusters do not occur in the lexicon, their frequency is therefore (very close to) zero. On the other hand, permissible clusters frequently occur, which may license deletion in the C_1C_2 context. If this distribution was the reason for the differences in schwa duration between words with well-formed and words with impermissible target clusters, we would also expect differences in the reduction rates within the group of stimuli with well-formed onset clusters. More specifically, we would expect that the reduction rate in words with well-formed clusters after schwa deletion correlates with the statistical distribution of those clusters in the lexicon. In order to investigate a possible correlation between the reduction rate and the statistical distribution, a post-hoc regression test was performed on the basis of the frequency of the existing onset clusters in CELEX and CGN on the one hand and the deletion rates on the other hand. The correlation coefficient is $R^2 = .329$, however, the correlation is far from significant $p = .517$. This means that the deletion rates for the different clusters in our experiment cannot be predicted by word frequency of the databases. This result is consistent with previous investigations of the relation between statistical frequency of phonotactic distribution and phonological processes, in which the probability of a cluster under investigation was no cue for epenthesis (e.g. Coetzee, 2010). So we assume that it is truly the well-formedness of the cluster that is responsible for different degrees of reduction, and that the probability of the cluster does not play a role.

This study shows that usage effects, viz. frequency and recency, may affect the realization of pretonic schwa in general, but the degree of reduction is larger if deletion leads to a permissible cluster and that the degree of reduction is generally smaller if deletion would lead to an impermissible cluster. Generalizing, the results suggest that different usage-based processes may occur over a particular, well-defined phonological category (in this case pretonic schwa), but that they affect different subcategories (phonotactic environment) differently. Thus it turns out that fine-grained, gradient usage-based processes and abstract, categorical grammatical structures are more intimately related than was previously thought, which is in line with recent studies on the interaction of frequency and phonological grammar (Sloos 2013, Van de Weijer 2009, Van de Weijer 2012).

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Appendix

All results of frequency and cluster effects in schwa reduction

Number of block of stimuli	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
1	freq	1.133E-07	1.000	1.133E-07	.001	.975
	cluster	**.001**	**1.000**	**.001**	**32.437**	**< .001***
	freq * cluster	**.000**	**1.000**	**.000**	**5.188**	**.040***
2	freq	5.113E-05	1.000	5.113E-05	2.868	.113
	cluster	**.002**	**1.000**	**.002**	**57.879**	**< .001***
	freq * cluster	2.691E-05	1.000	2.691E-05	.529	.479
3	freq	.000	1.000	.000	2.143	.165
	cluster	**.001**	**1.000**	**.001**	**18.530**	**.001***
	freq * cluster	4.991E-05	1.000	4.991E-05	1.232	.286
4	freq	1.044E-07	1.000	1.044E-07	.001	.973
	cluster	**.002**	**1.000**	**.002**	**22.452**	**< .001***
	freq * cluster	1.969E-06	1.000	1.969E-06	.056	.816
5	**freq**	**8.320E-05**	**1.000**	**8.320E-05**	**5.388**	**.037***
	cluster	**.001**	**1.000**	**.001**	**12.488**	**.004***
	freq * cluster	.000	1.000	.000	3.026	.106
6	freq	5.044E-06	1.000	5.044E-06	.124	.730
	cluster	**.001**	**1.000**	**.001**	**12.865**	**.003***
	freq * cluster	9.830E-05	1.000	9.830E-05	1.436	.252
7	freq	5.304E-05	1.000	5.304E-05	1.940	.187
	cluster	**.001**	**1.000**	**.001**	**16.409**	**.001***
	freq * cluster	7.530E-05	1.000	7.530E-05	4.348	.057
8	freq	.000	1.000	.000	3.046	.103
	cluster	**.001**	**1.000**	**.001**	**5.838**	**.030***
	freq * cluster	9.121E-05	1.000	9.121E-05	3.564	.080
9	freq	3.427E-05	1.000	3.427E-05	.765	.397
	cluster	.001	1.000	.001	6.004	.028
	freq * cluster	3.518E-05	1.000	3.518E-05	.700	.417
10	**freq**	**.000**	**1.000**	**.000**	**5.680**	**.032***
	cluster	**.001**	**1.000**	**.001**	**17.093**	**.001***
	freq * cluster	3.325E-06	1.000	3.325E-06	.173	.684