Non-adjacent Phonological Dependency Effects on Khalkha Mongolian Speech Perception

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1. Introduction

A wide variety of the languages of the world display restrictions on non-adjacent linguistic elements. On a syntactic level, for instance, subjects of a sentence may be required to agree with a verb several words away. For example, subject-verb agreement in English often occurs over a divide of a number of words, as illustrated in (1):

(1) **The girl** from the table in the corner **says** hello.

On a strictly phonological level, vowel harmony is perhaps the best known type of non-adjacent dependency. Vowel harmony restricts the co-occurrence of vowels, regardless of the number of intervening consonants, according to agreement of specific feature or features within a word, a word and its affixes, or sometimes even across word boundaries (van der Hulst & van der Weijer 1995). Mongolian, for example, displays both [ATR] and rounding harmony (Svantesson, Tsendina, Karlsson & Franzén 2005). As shown in (2), vowels are required to agree within a word and its affixes in terms of the feature [ATR][1].

(2)	[-ATR]		[+ATR]	
a.	[pataŋ]	*'broth'*	[elʒeg]	*'liver'*
	[pataŋaa]	*'broth-GENITIVE'*	[elʒegee]	*'liver-GENITIVE'*
b.	[nʊʊtʰaɢ]	*'homeland'*	[uneŋ]	*'truth'*
	[nʊʊtʰaɢaa]	*'homeland-GENITIVE'*	[uneŋee]	*'truth-GENITIVE'*
c.	[pɔlʒɔr]	*'crystal'*	[pompog]	*'ball'*
	[pɔlʒɔrɔɔ]	*'crystal-GENITIVE'*	[pompogoo]	*'ball-GENITIVE'*

Previous research on non-adjacent phonological dependencies has largely focused on participants' ability to acquire them via artificial grammar learning tasks (e.g., Cleeremans & McClelland 1991; Goméz 2002; Onnis et al. 2003, 2004; Newport & Aslin 2004; Bonatti, Peña, Nespor & Mehler 2005). Much of this research shows that such dependencies are acquired with difficulty by participants (e.g., Cleeremans & McClelland 1991; Goméz 2002; Newport & Aslin 2004). Furthermore, there is some debate over the types of non-adjacent phonological dependencies that participants are capable of acquiring: specifically those exhibited by vowels, consonants or syllables (e.g., Newport & Aslin 2004; Bonatti, Peña, Nespor & Mehler 2005). Additionally, it has also been shown that variability of

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[1] [ATR] harmony is also qualified by the presence of [i], which is transparent in non-initial syllable positions. Further, the restrictions of rounding harmony are somewhat more complex and in the interest of brevity are not presented here.

frame material (the material which intervenes between non-adjacent dependencies) has a strong influence on participants' acquisition success (Goméz 2002; Onnis et al. 2003, 2004).

In terms of natural language research, while much work has been done on phonotactic patterns and on frequency effects of phonotactic patterns, all of this work has focused on adjacent phonological patterns (e.g., Bailey and Hahn 2001; Coleman & Pierrehumbert 1997; Frisch, Large & Pisoni 2000; Pierrehumbert 1994; Vitevitch, Luce, Charles-Luce & Kemmerer 1997). Many aspects of natural language non-adjacent dependencies remain unaddressed by the current literature. Yet the prevalence of non-adjacent dependencies, on a variety of linguistic levels, in the world's languages raises interesting questions from the perspective of the lexicon and human cognition. In particular, how might non-adjacent dependencies be represented within the lexicon? Are non-adjacent phonological dependencies, like the vowel patterns displayed in (2), represented independently of whole word lexical entries? For instance, might a Mongolian speaker have lexical entries not only for [pataŋ], but also for [a_a]?

The idea that non-adjacent segments could be represented separately from the word has been well-theorized. For instance, McCarthy (e.g. 1981) proposed that roots and patterns in Semitic languages are stored in separate lexical entries. However, such elements are clearly morphological in nature (see Ussishkin 2011 for a discussion of the relevance of phonological vocalic tiers). Theories of phonological locality and vowel contiguity also offer support to the idea of separate lexical entries for non-adjacent segments. Browman & Goldstein (1986; 1989) theorize that phonetic gestures form the basis of phonological (i.e. lexical) representations. Gafos (1996) offers evidence that non-adjacent vowels behave as contiguous units (articulated by a single tongue body gesture). If vowel patterns are indeed represented as separate lexical entries, then it should be possible to detect frequency effects of this variable in much the same way frequency effects can be found for whole words in lexical decision and well-formedness tasks.

The current paper discusses the creation of the first searchable Khalkha Mongolian corpus, as well as two experiments conducted in Ulaanbaatar, Mongolia on native Mongolian speakers. These experiments, part of a larger psycholinguistic study conducted in Mongolia by the author, are the first psycholinguistic experiments to be conducted on native Mongolian speakers. Experiment 1, in addition to providing the first data on the effects of word frequency and vowel pattern frequency on Mongolian speakers' response time and familiarity ratings, also offers verification of the reliability of the lexical statistics derived from the new corpus. Experiment 2, a nonce-word well-formedness task, demonstrates a significant effect of vowel pattern frequency on participants' ratings and response times. These results offer empirical support to the idea of separate lexical entries for non-adjacent phonological dependencies.

2. Corpus Creation

One of the reasons why no psycholinguistic studies have been conducted on Mongolian speakers prior to this study is the lack of a searchable corpus in order to derive lexical statistics to use as independent variables. Therefore, in order to conduct the experiments presented here, a searchable corpus was created. Because literacy rates of adults (people age 15 and up who can both read and write) are quite high in Mongolia, at 97% (statistics according to the 2003-2008 surveys conducted by the United Nations Educational, Scientific and Cultural Organization (UNESCO) and UNESCO/UIS (UNESCO Institute of Statistics)), it was deemed appropriate to cull online Mongolian text resources in order to create the corpus. Given the high rate of literacy, it was expected that such text resources would be fairly representative of the average Mongolian speaker's lexicon and usage trends.

This corpus, which resulted in a size of roughly 0.5 million tokens, was gathered from several online Mongolian language sources. These sources are, in order of the size of their contribution to the resulting corpus: Onoodor Sonin (Өнөөдөр Сонин: http://www.mongolnews.mn), Mongolian Wikipedia (http://mn.wikipedia.org), and Tsahii Murtuu (http://www.tsahimurtuu.mn). Onoodor Sonin, the newspaper from which the majority of the corpus is derived, is one of the nation's largest daily papers. Mongolian Wikipedia was taken wholesale and added to the corpus. In addition, Tsahii Murtuu, another news site, was also used to add to the corpus. Onoodor Sonin was mined on a daily basis for new content for a total of six months. All text of all articles which appeared in the paper, with the exception of article titles and newspaper headings (which were excluded in order to avoid any possible skewing of lexical usage statistics), were taken and added to the corpus.

This strategy for deriving phonological statistics was highly workable due to the shallow orthography of Mongolian Cyrillic. As the table in (3) illustrates, with a few noted exceptional spelling conventions, there is a near one to one correspondence between Cyrillic graphemes and sound for Khalkha Mongolian.

(3) Grapheme to Sound Correspondences

Consonants

Cyrillic	IPA	Cyrillic	IPA	Cyrillic	IPA
п	p^{h}	ц	ts^{h}	нг	ŋ
б	p	ч	tʃ^{h}	л	lʒ
пь	p^{jh}	ж	tʃ	ль	lʒ^{j}
бь	p^{j}	с	s	рь	r^{j}
т	t^{h}	ш	ʃ	р	r
д	t	хь	x^{j}	з	ts
ть	t^{jh}	х	x	в	ʋ
дь	t^{j}	м	m	вь	ʋ^{j}
гь	g^{j}	мь	m^{j}	я	ja
г	g	н	n	ю	ju
г	ɢ	нь	n^{j}		

Vowels

Cyrillic	IPA
и	i
э	e
ө	o
ү	u
а	a
о	ɔ
у	ʊ
й	i

Once the corpus was compiled, it was fairly straightforward, with the help of several basic Python scripts to convert the data to its IPA equivalents. The above transliterations in (3) were used and in addition, exceptional spelling conventions were also identified and appropriately converted. Once these conversions were complete, another set of Python scripts were created to derive not only lexical statistics but also phonological pattern and distribution information such as word frequency, vowel pattern frequency, harmonic class size, and neighborhood density. The resulting data, a rich and diverse repository, represents a vast step forward in terms of knowledge about the Mongolian lexicon, phonological patterns, distributions and usage statistics. These lexical and phonological statistics were used in the experiments presented in this and further studies conducted on Mongolian by the author.

3. Experiment 1: Word and Vowel Pattern Frequency

In order to test the reliability of the Mongolian corpus generated for this study and to confirm that it offers reliable statistics in terms of word frequency and vowel pattern frequency, Experiment 1 was conducted. Experiment 1, a word familiarity experiment, determines whether Mongolian speakers are sensitive to effects of word frequency and vowel pattern frequency. In line with previous work which shows strong correlations between familiarity and frequency information (Gernsbacher 1984; Connine et al. 1990; Francom, LaCross, & Ussishkin 2010), it is hypothesized that high frequency words and words with high frequency vowel patterns will be rated more familiar and result in faster response times than low frequency stimuli.

3.1. Stimuli

In order to test the effects of both word and vowel pattern frequency, real word items were selected from four different categories, as illustrated in (4). Due to the difficulty of finding real word items in the third and fourth categories, it was not possible to obtain equal item numbers for each category.

(4)

Item Category	Number of Items
High frequency words with high frequency vowel sequences	100
Low frequency words with high frequency vowel sequences	100
High frequency words with low frequency vowel sequences	6
Low frequency words with low frequency vowel sequences	32
Total Number of Items:	238

Frequency of vowel patterns was determined by identifying the fifteen most frequently occurring and the fifteen least frequently occurring vowel patterns of bi-syllabic words. The selection of fifteen as the cutoff limit was entirely arbitrary. These vowel patterns are identified below in (5). All experiment items contained vowel patterns which were selected from within these two ranges.

(5)

High Frequency			Low Frequency		
a_a	e_e	ɔ_ɔ	u_ui	u_ei	i_uu
o_o	a_i	ʊ_a	i_ei	ʊ_ʊʊ	e_uu
ai_i	u_e	i_e	ɔ_ʊʊ	e_ui	a_ii
ii_i	ɔ_i	ee_e	u_uu	i_ui	o_u
ʊʊ_ʊ	a_aa	ɔ_ɔɔ	o_uu	e_u	u_u

3.2. Procedure

Items were presented visually on E-Prime via a word-familiarity task. Participants were instructed to indicate by pushing a key on the keyboard, on a scale of 1-5, how familiar each word was. Responses and response time data were recorded. All instructions and consent procedures, in this experiment and all subsequent, were presented in Mongolian.

3.3. Participants

Participants consisted of 28 female students recruited from the Mongolian State University of Education in Ulaanbaatar, Mongolia. Eight participants were discarded due to high levels of background noise and other disruptions, resulting in a total of 20 participants in Experiment 1. While there is some minor dialectal variation in Khalkha Mongolian, dependent on geographic region, participants were not controlled for dialect. However, in case of any future need to control by geographic region or dialect, the home province and language background of each subject was recorded.

3.4. Results

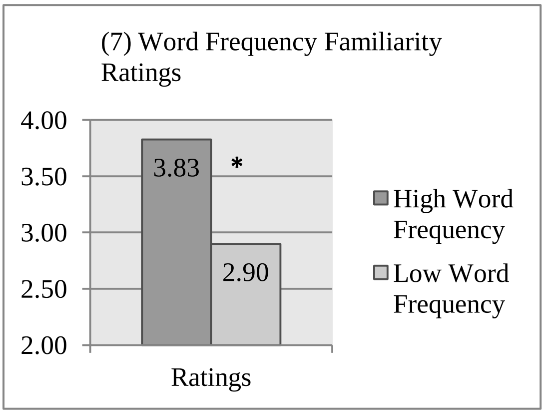
Participants' responses and response time data were first analyzed in order to determine outliers. Because it was unclear how participants might perform in a completely novel experimental procedure, they were allowed up to 10 seconds to make each familiarity rating decision. This resulted in very high standard deviations (SD 1056). Cutoff marks for response time outliers were established at 2500 milliseconds as the upper limit and 50 milliseconds as the bottom limit. All analyses and graphs for Experiment 1 consist of data taken from within the 50-2500 milliseconds response time range.

As the table of means in (6) illustrates, participants' ratings and response times fell in line with the hypothesized outcome: they rated highest and responded fastest to high frequency words with high frequency vowel patterns. The items which were rated the lowest and responded to most slowly were low frequency words with low frequency vowel patterns.

(6)

Item Category	Rating	RT (ms.)
High Frequency Words with High Frequency Vowel Patterns	3.85	1133.77
High Frequency Words with Low Frequency Vowel Patterns	3.81	1169.46
Low Frequency Words with High Frequency Vowel Patterns	3.12	1215.39
Low Frequency Words with Low Frequency Vowel Patterns	2.68	1258

A series of repeated-measures ANOVAs were run in order to analyze the significance of word frequency and vowel pattern frequency on participants' word familiarity ratings and response times. These analyses indicated there was a significant effect, illustrated in the graph in (7), of word frequency on participants' word familiarity ratings both by-subject ($F1(1,19)=53.446$, $p < 0.001$) and by-items ($F2(1,5)=13.695$, $p < 0.01$), such that participants rated high frequency words as significantly more familiar than low frequency words. There was, however, no significant effect of word frequency on participants' response times to high versus low frequency words. Additionally, no significant effect of vowel pattern frequency was found either on participants' ratings or response times[2].



The results of the analyses on Experiment 1 indicate several things. Firstly, the significant effect of word frequency on participants' familiarity ratings indicates that the new corpus produces accurate, and predictive, lexical statistics. This indicates that all subsequent work may reasonably utilize and rely upon statistics derived from this corpus. Additionally, failure to find a significant difference in participants' response times is an interesting result. As this was the first psycholinguistic experiment conducted in Mongolia, it represented a significantly novel experience for all experiment participants. While most of the participants were familiar with the act of sitting in front of and using a computer, none of them had ever participated in a behavioral experiment before and the experience of answering questions on a computer was novel. Due to these factors, the decision to not cap response times resulted in high variability in reaction times. This variability is likely the culprit confounding any possible significance in response times.

However, the failure to reveal significant effects of vowel pattern frequency on familiarity ratings must be examined. Several possible explanations must be considered. Firstly, it must be considered that vowel patterns are not represented lexically and therefore, Mongolian speakers' cognitions simply do not track the frequency with which these patterns occur. Another possibility is that effects of vowel pattern frequency may be weaker than effects of word frequency. Perhaps real word frequency effects obscured and confounded any possible effects of vowel pattern frequency. A third and equally possible explanation lies in the unequal distribution of test items. Recall that it was impossible to use equal item numbers in each of the four item categories. In particular, it was difficult to find items with low frequency vowel patterns. It may be that the uneven distribution of these items resulted in a lack of

[2] The by-subjects analysis of participants' ratings on items with high versus low frequency vowel patterns returned the only significant effect of vowel pattern frequency: $F1(1,19)=8.563$, $p < 0.05$. However, in keeping with the strictest standards, this cannot be considered a significant effect of vowel pattern frequency on participants' ratings.

power for statistical analyses. Therefore, in order to clarify whether there might be an effect of vowel pattern frequency on Mongolian participants, Experiment 2, a well-formedness experiment using nonce items, was conducted.

4. Experiment 2

In order to isolate any reaction time and rating effects to vowel pattern frequency alone, Experiment 2 was a well-formedness task using nonce words. It is hypothesized that participants will rate items with high frequency vowel patterns as more word-like than items with low frequency vowel patterns. Furthermore, given that items are nonce words and the task requires ratings about word-likeness, it is predicted that items with high frequency vowel patterns (those predicted to be most word-like) will result in the slower response times than items with low frequency vowel patterns.

4.1. Stimuli

In order to test the effects vowel pattern frequency, nonce word items were created. They belong to one of two different categories:

(8)

Item Category	Number of Items
Nonce words with high frequency vowel sequences	225
Nonce words with low frequency vowel sequences	225
Total Number of Items	450

Using the Mongolian consonantal inventory (Svantesson, et al. 2005), 450 three-consonant frames were randomly generated with Python scripts. Each of the fifteen high frequency vowel patterns was inserted into a different consonantal frame fifteen times, resulting in 450 unique CVCVC nonce words with high frequency vowel patterns. These same consonantal frames were used for the low frequency vowel patterns, resulting in a total of 900 CVCVC nonce items. (It should also be noted that each item was checked against the corpus of Mongolian to ensure that no item was inadvertently a real lexical item.) High and low frequency vowel pattern items were then split and counterbalanced into two lists, to not only avoid repetition effects of consonantal frames, but also to increase statistical power. This resulted in two counterbalanced lists of 450 unique CVCVC nonce items each. Within each list, no consonantal frame was repeated, and each vowel pattern was repeated fifteen times.

4.2. Procedure

Items were presented visually on E-prime. Participants were instructed to listen to each word and then indicate by pushing a key on the keyboard, on a scale of 1-5, how possible a word of Mongolian each word was. Responses and response time data were recorded. Importantly, in this experiment, as opposed to Experiment 1, response times were capped to 2 seconds. If participants failed to respond after a 2 second interval, the next trial item was displayed.

4.3. Participants

Participants were 40 students from the Mongolian State University of Education in Ulaanbaatar, Mongolia. An additional 4 participants were discarded due to high background noise or computer error.

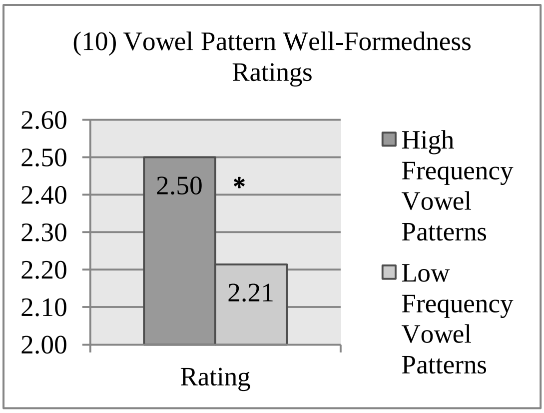
4.4. Results

Participants' responses and response time data were first analyzed in order to determine outliers. Due to the imposed upper time limit of 2000 milliseconds, standard deviations were lower for Experiment 2 than they were for Experiment 1 (SD: 501.173). A minimum response time cutoff was established at 50 milliseconds. All analyses and graphs following consist of data taken from within the 50-2000 millisecond response time range. As the table of means in (9) illustrates, participants' ratings and response times fell in line with the hypothesized outcome: they rated highest and responded slowest to nonce word items with high frequency vowel patterns. The items which were rated the lowest and responded to most quickly were nonce word items with low frequency vowel patterns.

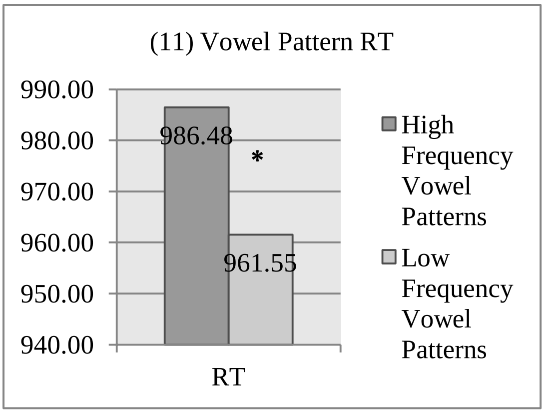
(9)

Item Category	Rating	RT (ms.)
Nonce words with High Frequency Vowel Patterns	2.5	986.48
Nonce words with Low Frequency Vowel Patterns	2.21	961.55

ANOVA analyses revealed a significant difference between well-formedness ratings of nonce items with high versus low frequency vowel patterns, such that participants rated nonce items with high frequency vowel patterns as significantly better formed than items with low frequency vowel patterns ($F1(1,37)=87.956$, $p<0.001$; $F2(1,448)=79.144$, $p<0.001$)[3].



Additionally, there was also a significant difference in participants' response times to high versus low frequency vowel pattern items. As hypothesized, participants responded significantly slower to nonce items with high frequency vowel patterns than to items with low frequency vowel patterns ($F1(1,37) = 10.842$, $p<0.005$; $F2(1,448)=10.906$, $p<0.005$).



The results from Experiment 2 provide strong support to suggest that Mongolian speakers do indeed have some sort of information about non-adjacent phonological dependencies, here vowel

[3] Counterbalance group was also included as a between-subjects variable in the by-subjects analysis. No significant difference was found between groups, which is unsurprising, given that its inclusion was only as a control.

patterns, stored in their lexicon. Furthermore, they are also sensitive to these vowel patterns' respective frequency information, indicating that as a lexical unit they are tracked statistically like other units, such as words. The implications of these results are discussed further in the conclusion.

5. Conclusion

The creation of a searchable text corpus of Mongolian provides an essential step forward in terms of providing statistical usage-based information about the language, making psycholinguistic study of the language possible for the first time. Further, the results of Experiments 1 and 2 offer evidence about Mongolian speakers' lexicons and speech perception processes. The results of Experiment 1 indicate that speakers of Mongolian are subject to word frequency effects, a result consistent with all previous work examining frequency. Also, the results confirm the reliability of the newly created corpus. This confirmation is crucial for continued psycholinguistic research on Mongolian, an exciting proposition in a field that will benefit from psycholinguistic research of understudied languages.

The results of Experiment 2 offer evidence about the status of non-adjacent phonological dependencies as lexical entries. It is unlikely that Mongolian participants would exhibit sensitivity to the frequency of various vowel patterns if they were not represented, in some fashion, lexically. These results, as well as those from Experiment 1, suggest that Mongolian speakers not only have lexical entries for words, but also representations for vowel patterns.

These results also raise more questions. Is the special status of vowel patterns in Mongolian the result of language-specific phonology? Are Mongolian speakers subject to vowel pattern frequency effects only because their language displays vowel harmony? If this is the case, to what extent might language-specific patterns influence or bias cognition? These results raise implications for theories not only about vocalic tiers (McCarthy 1981), but also about theories of phonological locality and vowel contiguity (Gafos 1996; Browman & Goldstein 1986; 1989). If vowels are both articulatorily and phonologically contiguous, then it is expected that speakers of all languages would be subject to vowel pattern frequency effects. Vowel harmonic languages restrict the co-occurrence of vowels, and therefore have a limited number of possible vowel sequences. Given this, it makes sense that speakers of vowel harmonic languages would be sensitive to the frequency of the resulting limited number of vowel sequences. While the distributions of vowels within words in non-vowel harmonic languages might be otherwise constrained by language-specific phonotactic rules, the number of possible vowel sequences is in no way constrained in the same sense that it would be in a vowel harmonic language. Speakers of a non-vowel harmonic language are thus exposed to a much higher number of possible vowel patterns. It seems unlikely that speakers of non-vowel harmonic languages would have lexical representations of such vowel patterns, much less track the frequency with which such vowel patterns occur.

Clearly, more research is needed to address these questions. A replication of Experiment 2 using speakers of a non-vowel harmonic language and its respective vowel pattern frequency information would be particularly telling. In addition, further psycholinguistic research into vowel harmonic languages examining the lexical status of non-adjacent phonological dependencies is needed. As noted earlier, the current literature on non-adjacent phonological dependencies, which primarily employs artificial grammar learning tasks, indicates that participants acquired these dependencies only with difficulty. However, all of these studies use native French or native English speaking participants (Goméz 2002; Newport & Aslin 2004; Bonatti, Peña, Nespor & Mehler 2005; Onnis et al. 2003, 2004). Other work (see LaCross, in Prep), using native Mongolian speakers in similar artificial grammar learning tasks, indicates that participants successfully acquired non-adjacent vocalic dependencies, raising doubts regarding the interpretation of results from work on non-vowel harmonic languages and highlighting the need for psycholinguistic research on under-studied languages such as Mongolian.

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