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Word Frequency Effect in Lexical Decision Task: Evidence from Khalkha Mongolian

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In experimental psycholinguistics, one clue into the architecture of lexical memory comes from the presence of robust frequency effects in lexical decision task (LDT), in which subjects judge whether a written stimulus is a real word or a nonword, and processing complexity is measured by reaction time (RT). For example, in LDT the visual word recognition process is facilitated (or inhibited) by word frequency as measured from the representative corpus. Our study verifies the word frequency effect in standard (“yes/no task”) LDT performed by Khalkha Mongolian subjects. The results showed strong weight of word frequency as RTs predictor ($R^2 = .631$, $F(1, 28) = 50.57$, $p < .000$, $\beta = .802$, $t = 7.111$, $p < .000$). Our experimental results also correspond to experimental findings on word frequency effects for Japanese Katakana (syllabic) and Kanji (logographic) words in standard LDT. Such lexical decision “script moderation” could be the actual clue for further LDT experiments (e. g., relatively “deep” Mongolian script vs. “shallow” Cyrillic Mongolian).

Keywords: lexical processing, lexical decision task, word frequency effect, Mongolian language.

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Introduction

Frequency effects have long been known to account for a large amount of variance in lexical decision latencies (Howes & Solomon, 1951). Proponents of dual-route models (e. g., Baayen et al., 1997; Baayen & Schreuder, 1999; Caramazza et al., 1988) emphasize the role of whole word frequency in word recognition.

Traditionally, the word frequency effect is based on the findings that high-frequency words are responded faster than low-frequency ones in almost any lexical processing task, including lexical decision, reading aloud, semantic categorization, and picture naming (Duyck et al., 2008). This effect is one of the most robust and well-known in word recognition research in different languages (Monsell et al., 1989; Allen et al., 1995; Lien et al., 2012; Kwon et al., 2006). The lexical decision task (LDT) is widely used to reveal this effect. According to Gardner et al. (1987), the difference in reaction times (RTs) is due to the differing frequency of high- and low-frequency words in the general language. This would imply that people making a lexical decision are influenced by their experience with the lexicon, and that greater experience leads to faster decisions. There is also another possible explanation of the word frequency effect. Landauer and Streeter (1973) showed that a number of lexical dimensions are correlated with word frequency. For instance, common and rare words have different distributions of phonemes and graphemes. A number of other differences exist as well. In Coltheart's DRC model the effect of neighborhood size in LDT is proposed (Coltheart et al., 2001). N-value (the number of orthographic neighbors¹) actually may be one of the robust independent variables in studying visual word recognition in LDT. Also, bigram or sound clusters frequencies can significantly affect RTs. But these factors were not taken into account in our study due to the lack of any appropriate databases in Khalkha Mongolian.

Another potential predictor of RTs is word length which can be based both on orthographic measures (number of letters) or phonological measures (number of phonemes and syllables). These different measures are generally highly intercorrelated, and they also correlate with other variables (such as the number of orthographic neighbors and the printed frequency) that influence word recognition.

Recent visual word recognition studies (such as perceptual identification, lexical decision, naming, and eye movement recording) include word length as an independent variable (New et al., 2006). Experiments in English, Dutch, French and

¹ An orthographic neighbor is defined as a word of the same length that differs from the original string by only one letter.

German yielded a mixture of null effects and inhibitory length effects. Investigating French word length and frequency effects, O'Regan and Jacobs (1992) found reliable inhibitory length effects in lexical decision and naming with words ranging from 4 to 11 letters. The effect size was around 15–19 msec per letter both in lexical decision and in naming. Furthermore, the authors showed that frequency and length did not interact. In eye movement study (Vitu et al., 1990) there was also no frequency and length interaction. In Balota, Cortese, Sergent-Marshall, Spieler, and Yap study (2004) the length effect was moderated by word frequency: it was significantly larger for low-frequency words than for high-frequency words. For university students, the length effect was even facilitatory when the analysis was limited to high frequency words and lexical decision. Another important result of Balota et al. (2004) was that their length effect was obtained after partialling out the length in phonemes, suggesting that the letter length effect is not a phoneme length effect in disguise. The results of other different studies tend to be inconsistent (New et al., 2006).

Related works

LaCross's study (2012) is one of the first research in Khalkha Mongolian providing interesting findings on word frequency and vowel pattern frequency effects on RTs and familiarity ratings. The author's results offer the first empirical support to the idea of separate lexical entries for non-adjacent phonological dependencies. Generally, word-familiarity task showed that Khalkha Mongolian subjects rated highest and responded fastest to high-frequency words with high frequency vowel patterns (such as, a_a, e_e, ɔ_ɔ, o_o, a_i, u_a, ai_i, u_e, i_e, ii_i, ɔ_i, ee_e, ʊʊ_ʊ, ɔ_ɔ). But there was no significant effect of word frequency on RTs to high vs. low frequency words. Additionally, no significant effect of vowel pattern frequency was found either on subjects' ratings or RTs. As LaCross revealed the vowel pattern frequency effect only in nonword ratings and RTs, we assume that in real words recognition more frequent patterns of vowels (graphemes) might be less informative than less frequent ones as declares in (New & Grainger, 2011: 326). Thus, LaCross hypothesized that real word frequency effects obscured and confounded any possible effects of vowel pattern frequency. Also, such findings can be explained by unrepresentative corpus size LaCross used in the study.

Recent studies (Brysbaert et al., 2011) claim that word frequency measures should be based on a representative corpus, but the quality of word frequency measures should be ascertained by correlating them with behavioral word processing data.

Thus, the best way to verify LaCross's findings is to take into account the General Corpus of the Modern Mongolian Language and related databases to compute word frequency (Krylov, 2012).

Experiment

To compute word frequency we used the General Corpus of Mongolian (Krylov, 2012). It is the first resource of such type in Mongolian and contains 966 texts of different genres (1155583 words length). The corpus is lemmatized and glossed (in the script of the Leipzig glossing rules). The morphological analyzer (working within the Starling software) is on the experimental stage, 97 % of text word forms (which correspond to 76 % of the word forms which are inputs in the concordance of word forms) can be effectively analyzed. There are also frequency dictionaries of different types, presented on the Starling¹.

The LDT was performed by Khalkha Mongolian adult skilled readers, monolinguals (n=48, 21 males and 27 females).

The list of items consisted of 30 real Khalkha Mongolian words (nouns) with length between 2 and 8 letters. In our study we restrict our analysis to lemmatized words to avoid morphological factor, since complex words frequency could be determined by their components (base, suffixes). Also 30 nonwords were used from the previous studies (Trofimova et al., 2011). The word frequency was computed with "Alphabetical frequency dictionary of Modern Mongolian lexemes with quantitative properties of their grammatical manifestations in corpus"². The whole item list is presented in Table 1.

While a vast number of RT predictors have been proposed in the literature, here we chose predictors which either reflect well-known properties of speeded reading or measure possible frequency effects at different levels of lexical memory. They are word frequency, orthographic word length, number of syllables. It is assumed that word frequency represents the most important predictor of lexical decision latencies (Lignos and Gorman, 2012).

¹ Search for data in: Alphabetical frequency dictionary of Modern Mongolian lexemes with quantitative properties of their grammatical manifestations in corpus. Available at: <http://starling.rinet.ru/cgi-bin/query.cgi?root=mongqrs&morpho=0&basename=mongqrs\mwf02f1a&encoding=utf-eng> ©Krylov

² Krylov, S.A.. "*Quantitative Instance-Oriented Grammatical Dictionary of Modern Mongolian*" database. Available at: <http://starling.rinet.ru/cgi-bin/main.cgi?root=mongqrs> ©Krylov

Table 1. Experimental item list

Word	Word frequency	Characters, N	Syllables, N	Nonwords
ааруул	34	6	2	бкадл
алим	30	4	2	наацаз
аяга	192	4	2	виви
бал	22	3	1	сарв
ваар	39	4	1	гансан
вандан	12	6	2	нинини
гөлөг	37	5	2	бамруг
домбо	15	5	2	ласич
жүнз	6	4	1	дард
зэвсэг	134	6	2	лимар
лаа	28	3	1	кими
морь	1487	4	1	калши
навч	137	4	1	амн
нийслэл	44	7	2	ряаб
нуруу	348	5	2	ооронхүцэн
өвөө	95	4	2	архборбэах
ор	285	2	1	нсодсох
ороолт	9	6	2	водуулцан
соёо	32	4	2	зопигану
сэрээ	15	5	2	унар
тэмээ	417	5	2	жлхртуу
уул	625	3	1	саихрах
үүр	143	3	1	грбад
хивс	36	4	1	храст
цэцэрлэг	43	8	3	царрбго
чийдэн	22	6	2	хрэнсу
эвэр	90	4	2	ахрэнө
эмээ	84	4	2	өдрахлб
үс	202	2	1	мөөндөөг
хаалга	318	6	2	хүүлүү

We used the typical (yes/no) LDT experimental design. As dependent variables, we measured the RTs (in milliseconds) and error rates (in percentages). Stimuli presentation and data collection were controlled by HP ProBook 470 G2 using Inquisit 4 Lab software for Windows (Millisecond Software™). The strings of letters were presented in the center of the screen and in lowercase type. Each trial consisted of a 50-ms blank and the target (word or nonword). Words and nonwords were presented

separately and randomly until the subject decided whether the string of characters was a real Mongolian word. The response keys (“Yes”/”No”) were located at the extreme left and right ends of the bottom row of the keyboard. A practice list preceded the test phase in order to familiarize the subjects with the task and to standardize the RTs.

Results and Discussion

Firstly, we examined the relation between each of the three predictors (word frequency, word length in characters and word length in syllables) and the standardized RTs (in correct responses only), expecting the increase of RTs to the words with lower frequency and greater length (inhibitory effect). As it is assumed that RT distribution generally doesn’t correspond to Gaussian distribution (McGill, 1963) we calculated a nonparametric coefficient of correlation (R for Spearman) for each pair of variables. It was not significant either for word length in characters ($r_s = .228$, $n=30$, $p = .225$), or for word length in syllables ($r_s = .026$, $n=30$, $p = .890$). But we revealed strong negative correlation for RTs and word frequency ($r_s = -.622$, $n=30$, $p < .0001$) (Fig. 1).

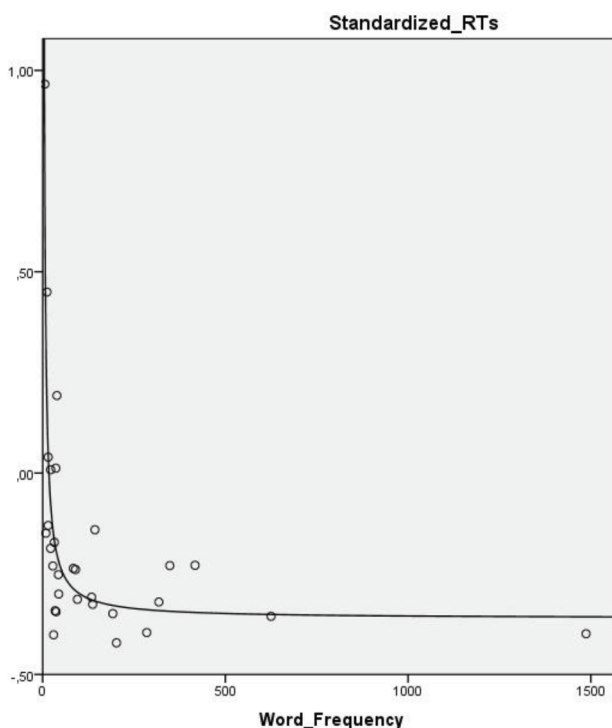


Fig. 1. Results of regression analysis of RTs: inverse linearity between RTs and Word Frequency as a predictor

To verify this, we computed the regression analysis in reciprocal-X model: $Y = a + b/X$. The results showed strong weight of word frequency as RTs predictor ($R^2 = .631$, $F(1, 28) = 50.57$, $p < .0001$, $\beta = .802$, $t = 7.111$, $p < .0001$).

The findings correspond to traditional thesis of Balota and Chumbley (1984) that lexical-selection process might be frequency sensitive precisely in standard LDT. Our findings are also appropriate for dual-route models since it is assumed that the lexical route directly accesses word entries in the mental lexicon in a holistic fashion and is affected by word frequency (Coltheart et al., 2001).

Such “heavy weight” of word frequency as RTs predictor could be also explained with the orthographic depth hypothesis: relatively shallow orthographies with high grapheme-to-phoneme and phoneme-to-grapheme correspondence (such as Cyrillic Mongolian) are more able to easily support a word recognition process that involves the language phonology. In contrast, deep orthographies encourage a reader to process printed words by referring to their morphology via printed word’s visual orthographic structure (Katz and Frost, 1992). For instance, in English (with its relatively deep orthography) printed word frequency, number of syllables, and number of orthographic neighbors all make independent contributions to lexical decision (New et al., 2006). Recent research in French (also with relatively deep orthography) revealed letter frequency effects (New & Grainger, 2011).

To a certain extent, our experimental results also correspond to Hino and Lupker findings on word frequency effects for Japanese Katakana (syllabic) and Kanji (logographic) words in standard LDT. In their study, except the main effect of word frequency, another effect of script type was obtained: RTs were faster for Katakana word as well as nonwords than for Kanji ones. Hino and Lupker emphasize that in standard LDT such effects are specific for lexical-selection process only while the decision-making process involves retrieving phonological, syntactic, semantic information. We suppose that such lexical decision “script moderation” could be the actual clue for further LDT experiments in modern Mongolian speakers living in Mongolia and Inner Mongolia (e. g., relatively “deep” *Hudum Mongol Bichig* (*Mongolian script*) vs. “shallow” *Cyrillic Mongolian*). Thus, lexical decision process requires more analytic processing and needs to verify in different lexical tasks as presented in (Hino and Lupker, 1998).

Conclusion

Our experiment revealed a negative correlation between Khalkha Mongolian (Cyrillic) word frequency and RTs in standard LDT. The results replicated the word frequency effect on visual word recognition obtained in most of the previous studies

in other languages. The substantial portion of the word frequency effect on RTs was due to quantity of word occurrences in corpus. This is close to LaCross's findings in familiarity ratings task: Khalkha Mongolian speakers rated high frequency words as significantly more familiar than low frequency ones (LaCross, 2012).

Psycholinguistic studies on this topic tend to be more accessible in Khalkha Mongolian due to the providing statistical usage-based information about the language, e. g. the General Corpus of the Modern Mongolian Language (Krylov, 2012) and Mongolian Corpus project (Loglo and Sarula, 2011). Creating the corpora and frequency databases in Mongolian (both for Mongolian script and Cyrillic Mongolian) with behavioral word processing data could facilitate special lexical projects, such as English Lexicon Project¹, French Lexicon Project², Chinese Lexicon Project (Sze et al., 2014). Also, subsequent behavioral and psychophysiological auditory and visual word processing studies in agglutinative languages could provide new evidence from word frequency \times vowel harmony interaction.

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¹ English Lexicon Project Web Site. Available at: <http://ellexicon.wustl.edu>

² The French Lexicon Project. Available at: <http://sites.google.com/site/frenchlexicon/home>

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**Эффект частотности слова в задании
на лексическое решение:
экспериментальные доказательства
на материале халха-монгольского языка**

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В экспериментальной психолингвистике один из ключевых элементов моделирования лексической памяти основывается на мощных эффектах частотности при выполнении заданий на лексическое решение (LDT), в которых субъекты оценивают, является ли письменный стимул реальным словом или несловом, а сложность обработки измеряется временем реакции (RT). Распознавание слов облегчается (или подавляется) частотой их употребления в языке, измеренной по репрезентативному корпусу. Наше исследование проверяет влияние эффекта частотности слов в стандартном тесте LDT, выполненном носителями халха-монгольского языка. Результаты подтвердили значимость частотности слова как предиктора скорости распознавания слова (времени реакции) ($R^2 = 0,631$, $F(1, 28) = 50,57$, $p < .000$, $\beta = .802$, $t = 7.111$, $p < .000$). Наши экспериментальные результаты также соотносятся с результатами другого экспериментального исследования эффекта частотности на материале японских лексических единиц, написанных на катакане (слоговом письме) и кандзи (логографическом письме) в стандартном тесте LDT. Данная модификация процесса лексического решения фактором письменности может стать актуальным вопросом для дальнейших экспериментальных исследований (например, на материале слов на относительно «глубоком» (с более слабыми буквенно-звуковыми соответствиями) старомонгольском письме и слов на «поверхностном» (с более развитыми буквенно-звуковыми соответствиями) современном кириллическом монгольском письме.

Ключевые слова: обработка лексической информации, процесс принятия лексического решения, эффект частотности слова, монгольский язык.

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