Formal Distinctiveness of High- and Low-Imageability Nouns: Analyses and Theoretical Implications

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Abstract

Words associated with perceptually salient, highly imageable concepts are learned earlier in life, more accurately recalled, and more rapidly named than abstract words (R. W. Brown, 1976; Walker & Hulme, 1999). Theories accounting for this concreteness effect have focused exclusively on semantic properties of word referents. A novel possibility is that word structure may also contribute to the effect. We report a corpus-based analysis of the phonological and morphological structures of a large set of nouns with imageability ratings ($N = 2,023$). High- and low-imageability nouns differed by length, etymology, prosody, affixation, phonological neighborhood density, and rates of consonant clustering. On average, nouns denoting abstract concepts were longer, more derivationally complex, and emerged in English from a different distribution of languages than did concrete nouns. We address implications for interactivity of word form and meaning as pertain to theories of word concreteness, lexical acquisition, and word processing.

Keywords: Speech recognition; Pattern recognition; Language acquisition; Representation; Imageability; Concreteness; Speech perception; Phonetic symbolism

1. Introduction

A long-standing debate persists in cognitive science regarding the dichotomy between abstract and concrete words (see Locke, 1685). Competing semantic theories have recently emerged to account for the advantages that perceptually salient words enjoy in tasks such as serial recall, naming latencies from written text, lexical decision latency, and age of acquisition (R. W. Brown, 1976; Büchel, Price, & Friston, 1998; Gentner, 1982; Kroll & Merves, 1986; Paivio, 1985; Walker & Hulme, 1999). Theories of word concreteness, although different in

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scope and neural representation, do share one common focus. That is, their predictions pertain exclusively to semantic properties of word referents in isolation of surface structure. If true that there is only an arbitrary relation between word form and meaning, then a purely semantic account of word concreteness is justified. Here, we examine an alternative hypothesis, namely, that rather than an orthogonal relation between imageability and word form, these formal and conceptual variables interact among English nouns.

2. Method

Imageability ratings are typically derived by asking adult participants to rate the ease with which a word rapidly evokes a strong mental image. In contrast, concreteness ratings are obtained by asking participants to rate the extent to which a word's referent can be touched or felt (Barca, Burani, Arduino, 2002; Bird, Franklin, & Howard, 2001; Paivio, 1985; Toglia & Battig, 1978). Although imageability and concreteness are technically different psycholinguistic constructs, the correlation between these variables is so strong that many authors use the terms interchangeably. Here, we make the same assumption of synonymy between imageability and concreteness in terms of theory (i.e., concreteness effects = imageability effects). However, we have restricted our formal analyses to nouns with imageability ratings.

We analyzed surface properties of English nouns ($N = 2,023$) with imageability values obtained from the Medical Research Council (MRC) psycholinguistic database (Coltheart, 1981). This database does not provide novel imageability, frequency, or familiarity values but rather acts as a pool for merging a number of smaller data sets. Three of the most widely utilized imageability data sets in psycholinguistic research include that of Gilhooly and Logie (1980); Paivio, Yuille, and Madigan (1968); and Toglia and Battig (1978) norms. These three separate imageability sets were subsequently merged into one corpus currently accessible through the MRC Psycholinguistic Dictionary Interface (http://www.psych.rl.ac.uk).

We acquired all English nouns with imageability norms from the database. We then dichotomized nouns as either high- or low-imageability using a cutting criterion of $z > \pm 0.50$ beyond the mean imageability value of the database ($\mu = 456$, $SD = 108$). Low-imageability (hereafter Lo-IMG) values indicate that respondents identified words as being less imageable or abstract (e.g., *independence*); high-imageability (hereafter Hi-IMG) values indicate that respondents classified a word as more concrete (e.g., *beach*). We blocked nouns with imageability ratings less than 396 (on a 100–700 scale) as Lo-IMG. Conversely, we classified nouns with imageability values greater than 510 as Hi-IMG. We eliminated from the analysis nouns of average imageability as reflected within the middle range of values ($-.5 < z < .5$). We then cross-referenced all remaining nouns with the *Oxford English Dictionary* ([OED]; 1989), and we eliminated those labeled obscure, colloquial, rare, poetical, or dialectical due to the potentially confounding effects of imageability with unfamiliarity.

We eliminated from these analyses entries with verbal or written frequencies less than two per-million (G. D. Brown, 1984; Kučera & Francis, 1982) as well as nouns that exist in plural form only (e.g., *scissors*) and nouns primarily adjectival in function (e.g., *tweed*). The final exclusion criterion was for noun homophones whose frequency values were dominated by a possible alternative syntactic category. This occurred for instances of nouns that also acted more

Table 1
Correlation matrix representing relations between psycholinguistic variables among English nouns

	CNC	IMG	FAM	KFRQ	BFREQ	NPHON	NSYL	NMORPH
CNC	—	.90**	.23 **	−.07**	−.08**	−.45**	−.44**	−.45**
IMG		—	.32**	−.06*	−.06*	−.43**	−.42**	−.43**
FAM			—	.40**	.30**	−.29**	−.28**	−.20**
KFREQ				—	.70**	−.12**	−.11**	−.07**
BFREQ					—	−.10**	.02*	−.08**
NPHON						—	.89**	.65**
NSYL							—	.64**
NMORPH								—

Note. Values represent Pearson correlations. All variables have >1,800 observations with the exception of variables correlated with X. X. Brown (1982) verbal frequency, which uniformly share 921 observations. CNC = concreteness; IMG = imageability; FAM = familiarity; KFRQ = written frequency (Kučera & Francis, 1982); BFRQ = verbal frequency (X. X. Brown, 1982); NPHON = number of phonemes; NSYL = number of syllables; NMORPH = number of morphemes.

*Correlation is significant at the .05 level. **Correlation is significant at the .01 level.

commonly as verbs, for example, *look, love, must.* The final result of these inclusion criteria was a corpus of Hi-IMG (*n* = 1,385) and Lo-IMG (*n* = 638) nouns. A correlation matrix representing relations between variables in this corpus appears in Table 1.

3. Coding procedures

3.1. Etymology/word origin

We first traced noun origin to its earliest known entry in the English language (OED, 1989). This initial coding resulted in a diverse range of word origins, some with very low frequencies (e.g., Algonquin, Celtic). We then grouped all entries into the five most commonly occurring etymologies across the data set (i.e., Germanic, Latinate, Greek, Unknown, Other).

3.2. Syllable structure, phonological complexity, and word length

We coded syllable structure by discrete vowel–consonant (V–C) combinations, treating diphthongs (e.g., c<u>ow</u>, t<u>oy</u>) as single vowels (Ladefoged, 1993). We coded vocalic 'r', as in *hurt*, as a V–C combination (i.e., /ə/ +/r/). We coded ambisyllabic consonants as reduplicated. For example, a word such as *mirror* was syllabified as "mir" and "ror" (i.e., CVC, CVC). Syllables were also coded using a categorical measure of phonologically simple or complex. *Simple* structures were free of consonant clusters. *Complex* structures contained more than one adjacent consonant (e.g., <u>spl</u>it). According to this criterion, we categorized the following syllable structures as simple: V, CV, VC, CVC. We restricted analyses to the first, second, and third syllables because of the limited number of English nouns greater than four syllables. We coded and subsequently contrasted word length in two ways: total syllables and total phonemes.

3.3. Morphology

English words nominally consist of at least one free morpheme to which derivational or in-flectional morphemes are affixed. We therefore coded morphology by counting stems and af-fixes to obtain a morpheme-per-word count. For example, *independence* was decomposed into three constituent morphemes: a stem (*-depend-*), a prefix (*in-*), and a suffix (*-ence*). We coded compound words (e.g., *fireplace*) as monomorphemic (see Brown, 1976). In addition, we coded the presence of compounding (*yes/no*) as a separate categorical independent variable.

3.4. Prosody

We contrasted prosodic differences by marking primary syllable stress. We limited analyses to nouns less than five syllables and greater than one syllable in length.

3.5. Phonological neighborhood density

The phonological neighborhood for a word comprises the set of words that differ from a target by only the substitution, addition, or omission of one phoneme (Luce & Pisoni, 1998). For exam-ple, a phonological neighborhood for the target *cat* would include neighbors such as *sat, at, cot,* and *cap*. Phonological neighborhood density is a measure that estimates the size of the neighbor-hood for a given target. For this study, we obtained neighborhood density values for all nouns from an online database of the Hoosier Mental Lexicon (http://128.252.27.56/neighborhood/home.asp).

We first submitted orthographic word forms into the database. Because neighborhood den-sity values do not differ for homophonous word forms, not all orthographic word forms gener-ated density values. We resubmitted as phonologic word forms those items missing density values when submitted as orthographic word forms. We estimated neighborhood density val-ues for the remaining small subset of items in the corpus that failed to generate density values when entered in either phonologic or orthographic form. We estimated density values in two ways: (a) the number of word "stem" (*trail* for *trailer*) phonological neighbors that could be af-fixed like the target and remain a real word (*trainer* but not *grail-er*) and/or (b) the number of near word (*sue* for *zoo*) phonological neighbors that could also be counted as phonological neighbors for the target (*coo* but not *stew*).

4. Results

4.1. Differences in word origin

Distributions of etymology were significantly different as a function of noun imageability, $\chi^2(4, N = 2{,}023) = 272.14, p < .001, \Phi = .37$ (a large effect). Lo-IMG English nouns are primar-ily derived from Latinate, whereas Hi-IMG nouns are derived from a more heterogeneous group of languages, with the most common language of origin being Germanic. Fig. 1 illus-trates these distributions of etymology.
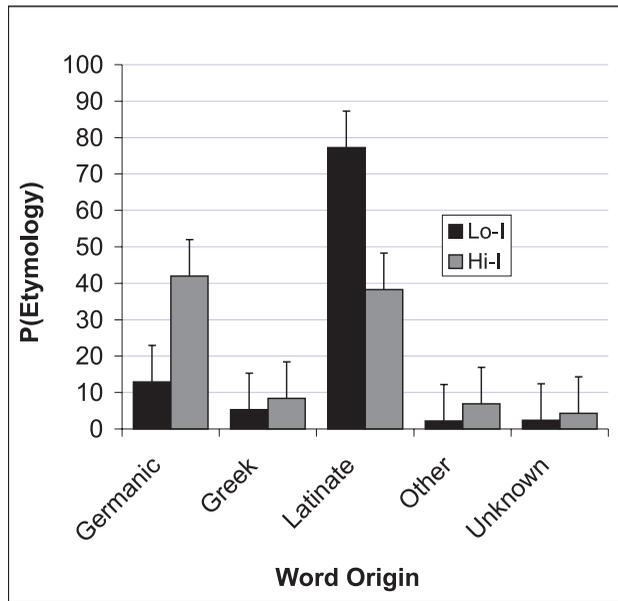
Fig. 1. Distributions of word origins for low-imageability (Lo-I) and high-imageability (Hi-I) nouns.

4.2. Differences in syllable and phoneme length

Lo-IMG nouns were significantly longer than Hi-IMG nouns as measured both in average number of syllables per word, $t(931.36) = 17.68$, $p < .001$, and in average number of phonemes per word, $t(829.38) = 14.75$, $p < .001$. Lo-IMG nouns had an average of 2.65 syllables with 6.69 phonemes per word. Hi-IMG nouns averaged 1.74 syllables with 4.73 phonemes per word.

4.3. Differences in morphology

Patterns of morphology were significantly different between Lo- and Hi-IMG nouns. A linear regression revealed that as imageability increased, total number of morphemes decreased, $R(2,022) = .43$, $p < .001$. This was a strong effect, which indicated a trend toward Lo-IMG nouns containing multiple affixes. In contrast, the majority of Hi-IMG nouns are monomorphemic. The odds in favor of a Lo-IMG noun having a prefix over a Hi-IMG noun were 10:1 and for a suffix, 4:1. These odds reflect a strong tendency for Hi-IMG nouns to remain monomorphemic and when not monomorphemic to resist prefixation. Fig. 2 represents these patterns of affixation.

4.4. Differences in syllable structure and complexity

Phonemic complexity as measured by consonant clustering differed between Lo- and Hi-IMG nouns: first-syllable difference, $\chi^2(1, N = 2,023) = 20.83$, $p < .001$, $\Phi = .10$; second-syllable difference, $\chi^2(1, N = 1,288) = 29.97$, $p < .001$, $\Phi = .18$; third-syllable difference, $\chi^2(1, N = 569) = 207.24$, $p < .001$, $\Phi = .32$. Lo-IMG nouns were consistently more complex
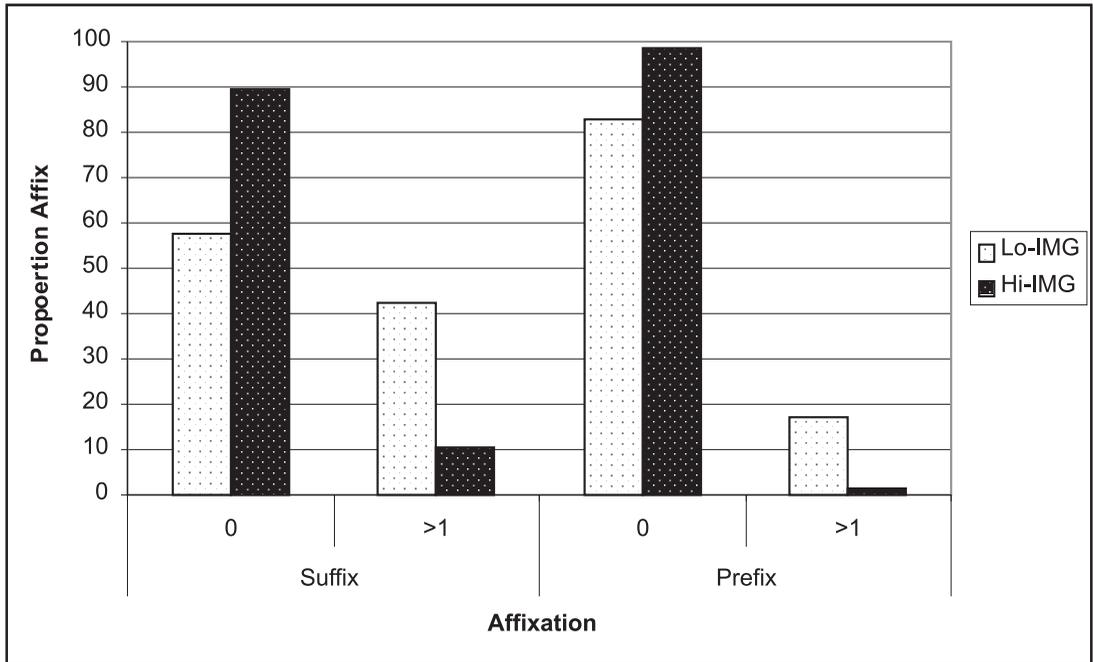
Fig. 2. Proportions of prefixation (Prefix) and suffixation (Suffix) for low-imageability (Lo-IMG) and high-imageability (Hi-IMG) nouns.

across syllable lengths. The largest effect sizes for syllable complexity were observed for the second and third syllables. Morphology may contribute to this reduction between initial syllables, as Lo-IMG nouns frequently carry prefixes (e.g. *con-, in-*). As word length increased, so too did differences in the distributions of syllable structure across imageability conditions. The largest syllable structure differences were apparent in noninitial syllables. In addition to phonemic complexity (i.e., consonant clustering), patterns of syllable structure also differed across all word lengths with the exception of monosyllabic words (e.g., *dog* versus *fate*).

4.5. Differences in phonological neighborhood density

Phonological neighborhoods were similarly dense across monosyllabic Lo-IMG and Hi-IMG nouns. Yet, at increasing word lengths, Lo-IMG nouns had significantly fewer similar sounding neighbors. Table 2 summarizes these differences along with significance tests for words matched by syllable length.

4.6. Differences in syllable stress placement

Two-syllable, Hi-IMG nouns rigidly carried stress on the first syllable (93.34% of all cases). This stress pattern adheres to the typical trochaic meter of English (Kelly, 2004; Kessler & Treiman, 1997). However, at the same syllable length, Lo-IMG nouns showed more variability in prosody, often with stress shifting to the second syllable (24.61% of all cases). A similar pattern was seen for three syllable words, but at this length, second syllable stress was actually

Table 2
Phonological neighborhood density

Word Length (Syllables)	N	M Density	Significance Test (Lo-I Versus Hi-I)
1 (Lo-I)	114	16.68	t = 0.743, df = 149.43, p = .74, ns
1 (Hi-I)	621	16.34	
2 (Lo-I)	191	2.15	t = –4.492, df = 469.26, p < .001
2 (Hi-I)	542	3.48	
3 (Lo-I)	182	.64	t = 1.914, df = 216.77, p = .057, ns
3 (Hi-I)	180	.32	
4 (Lo-I)	111	.27	t = –0.306, df = 44.23, p = .76, ns
4 (Hi-I)	35	.31	

Note. Lo-I = low imageability; Hi-I = high imageability.

more prevalent than first-syllable stress among Lo-IMG nouns. Table 3 summarizes proportions of words at each syllable length carrying stress on a designated syllable.

A likely reason for these stress patterns is the discrepancy in etymology we previously noted. The stress system in the Germanic vocabulary of English tends toward initial stress, and the Germanic vocabulary is heavily composed of Hi-IMG words. The Latinate vocabulary, heavily composed of Lo-IMG words, has an entirely different stress system in which stress placement counts backward from the end of a word, with the exact location of stress depending on a combination of syllable complexity and the syntactic category of the word. This difference between the Germanic and Latinate stress systems has the effect of making stress more likely to avoid initial syllables in the Latinate vocabulary and thus in Lo-IMG words, which predominate in this part of the vocabulary.

4.7. Prediction of imageability from word structure

We then entered sublexical variables previously contrasted in isolation simultaneously into a logistic regression model. Logistic regression is a useful statistical model in that categorical

Table 3
Primary syllable stress across imageability conditions

Word Length (Syllables)	% Stress Syllable 1	% Stress Syllable 2	% Stress Syllable 3	% Stress Syllable 4	Significance Test (Lo-I Versus Hi-I)
2 (Lo-I)	75.31	24.61	—	—	—
					χ^2 (1, N = 2,023) = 45.40, p < .001, Φ = .25
2 (Hi-I)	93.35	6.65	—	—	
3 (Lo-I)	47.80	50.00	2.20	—	—
					χ^2 (2, N = 1,288) = 29.43, p < .001, Φ = .28
3 (Hi-I)	72.78	22.78	4.44	—	
4 (Lo-I)	34.23	45.05	18.92	1.81	—
					χ^2(3, N = 569) = .19, p = .98, ns
4 (Hi-I)	34.23	42.86	20.00	2.86	

Note. Lo-I = low imageability; Hi-I = high imageability.

Table 4
Logistic regression predicting imageability from word structure

Predictor	Odds Ratio	SE	df	Wald Statistic
Total syllables	.75	.08	1	13.12
Syllable stress			3	99.42
Syllable 1	12.56	.31	1	68.04
Syllable 2	5.32	.36	1	22.22
Syllable 3	12.09	.49	1	25.64
Total suffixes	.54	.14	1	18.91
Total prefixes	.31	.26	1	20.43
Etymology (word origin)			4	78.26
Germanic	.30	.29	1	18.31
Latinate	.50	.37	1	3.61

Note. *SE* = standard error. The logistic regression model fit these data well (Hosmer and Lemshow Test statistic), $\chi^2(7, N = 2,023) = 5.89$, $p = .55$. The predictors were significant at $p < .001$. Predictive accuracy for low-imageability nouns was 48.6%; high-imageability noun predictive accuracy was 92.2%.

(e.g., compounding) and continuous (e.g., neighborhood density) variables may be entered as predictors. The difference between logistic regression and standard linear regression is that the dependent measure or criterion of a logistic regression is categorical. Thus, the logistic function is used to predict binary group membership (e.g., abstract or concrete) rather than prediction of a linear continuous variable. The overarching goal of this regression analysis was, therefore, to determine whether a semantic variable could be predicted from a mixed set of continuous and categorical phonological and morphological variables. Table 4 summarizes the weighted contribution of each variable to the overall variance. Of note, several of the original variables entered were not useful predictors in the final step of this model. Noncontributory variables included total number of phonemes, phonological neighborhood density, and presence of compounding.

A testable assumption of phonology-semantics arbitrariness is that word structure should discriminate imageability with chance accuracy when provided with a sufficiently large and representative sample. This hypothesis was not upheld by the outcome of this regression analysis in which word structure predicted imageability (Lo–Hi) with 78.4% accuracy. A real-world analogy to this result is that imageability of a noun randomly selected from an English dictionary is nearly 80% predictable from a combination of the word's length, stress etymology, and derivational complexity.

5. General discussion

Language processing relies on both conceptual and formal processes. Effects of one semantic variable—word concreteness—are apparent throughout early language development, during reading, and in naming deficits associated with aphasia and semantic dementia (Breedin, Saffran, & Coslett, 1994; Reilly, Martin, & Grossman, 2005; Sadoski & Paivio, 1986). The

first words to emerge in a child's productive vocabulary, for example, denote highly imageable concepts (R. W. Brown, 1976). However, the earliest acquired words are also homogeneous in terms of their phonological structures with a tendency toward short, uninflected forms. Throughout later development and in the mature language system of adults, formal properties such as length and prosody continue to influence word processing in many of the same domains in which concreteness effects also lie. Cognitive processes that show shared effects of word concreteness and phonology include speed of lexical access, reading latency, immediate verbal memory span, and vocabulary size (Baddeley, 2000; Gathercole, Frankish, & Pickering, 1999; Majerus, Van der Linden, Mulder, Meulemans, & Peters, 2004; Vitevitch, 2002; Vitevitch, Armbrüster, & Chu, 2004).

Independence of word form and concreteness, although consistent with the thesis of arbitrariness of the linguistic sign (Levelt, 1989; Saussure, 1916), was not supported by the analyses we reported here. Instead, factors such as word length, stress placement, and affixation were strongly predictive of noun concreteness. Although the observed differences may reflect sampling error, we favor an alternative explanation. Namely, these discrepancies mirror a stable underlying property of language. That is, abstract words are most commonly created through affixation of concrete stems (e.g., *man → manliness*). Affixation also has phonological consequences that include inflation of word length, reduction of phonological neighborhood density, and alteration of stress patterns.

Although this morphophonological hypothesis was examined among English nouns, similar patterns may also extend to other natural languages that rely on affixation to create abstract lexical concepts. In one recent study, native speakers of standard American English were randomly assigned to receive approximately 2 min of passive listening exposure to blocks of highly concrete and abstract nouns in one of two unfamiliar foreign languages (i.e., Russian or Finnish; Reilly, 2005). Stimuli were recorded by native speakers of both languages, and participants listened without access to translations. A total of 100 different abstract and concrete nouns were then presented in completely randomized order via self-paced listening. Participants guessed through a forced-choice format whether each unfamiliar item was associated with either an abstract or concrete concept.

Listeners assigned to the Russian condition guessed concreteness correctly at levels far beyond chance, whereas listeners in the Finnish condition remained at chance. Participants in the Russian condition, therefore, appeared to induce phonological and/or morphological patterns underlying word concreteness. Interestingly, however, this effect may have been reduced in Finnish because of the high rate of compounding among Finnish nouns. Similar evidence in support of cross-linguistic variability is found in studies that have examined perception of phonological-syntactic regularities (i.e., nouns vs. verbs) in many but not all languages surveyed (Langenmayr, Gozutok, & Gust, 2001).

It is unclear whether the relation between word length, derivational complexity, and noun concreteness is entirely epiphenomenal or in some way adaptive toward word processing. It is not uncommon for languages truncate highly frequent words (e.g., *facsimile → fax*). Therefore, one might speculate that the observed abstract–concrete word length differences reflect an artifact of word frequency (i.e., truncation on a large scale). Although this account is intuitively appealing, there is little empirical evidence to support a frequency hypothesis, as the statistical correlation between word frequency and noun imageability was very weak ($R =$

−.06; see Table 1). An alternative hypothesis to a frequency effect is that word length differences are adaptive toward lexical acquisition. That is, because highly imageable words are earliest to emerge in a child's productive vocabulary, a reduced word length for concrete concepts might facilitate semantic fast mapping by reducing the load on the developing phonological system. This hypothesis, although also appealing, is highly speculative in that it entails far more phonological–semantics interactivity than has been assumed by contemporary theories of lexical acquisition and language representation (see Juhasz, 2005; Steyvers & Tenenbaum, 2005).

The extent to which language perception exploits word length and derivational complexity as markers of noun imageability remains unclear. However, the possibility that listeners do exploit regularities in word form is not inconceivable. Pattern induction in language perception is believed to begin at an early age. Infants, for example, are remarkably sensitive to patterns of prosody and legality of phonemic constituents in their native language, and it has been argued that these skills are adaptive toward learning critical syntactic distinctions and parsing reasonable word boundaries (Aslin, Saffran, & Newport, 1998; Jusczyk, Luce, & Charles-Luce, 1994; Kelly, 1992, 2004; Saffran & Thiessen, 2003).

The presence of a moderating effect of phonology toward semantic processing is likely to have significant implications for theories of word processing, reading, and language acquisition that have historically relied on a lexical level of representation through which all word–meaning correspondence is mediated. Further investigation of phonological pattern induction toward semantic processing may prove useful toward understanding effects previously attributed to either word concreteness or word structure in isolation.

We encourage researchers to investigate this effect in their own studies. To this end, the noun corpus we described in this study is freely available to other researchers by contacting the correspondence author.

References

Aslin, R. N., Saffran, J. R., & Newport, E. L. (1998). Computation of conditional probability statistics by 8-month-old infants. *Psychological Science, 9,* 321–324.

Baddeley, A. D. (2000). Short-term and working memory. In E. Tulving & F. Craik (Eds.), *The Oxford handbook of memory* (pp. 77–92). New York: Oxford University Press.

Barca, L., Burani, C., & Arduino, L. S. (2002). Word naming times and psycholinguistic norms for Italian nouns. *Behavior Research Methods, Instruments, & Computers, 34,* 424–434.

Bird, H., Franklin, S., & Howard, D. (2001). Age of acquisition and imageability ratings for a large set of words, including verbs and function words. *Behavior Research Methods, Instruments and Computers, 33,* 73–79.

Breedin, S., Saffran, E. M., & Coslett, H. B. (1994). Reversal of the concreteness effect in a patient with semantic dementia. *Cognitive Neuropsychology, 11,* 617–660.

Brown, G. D. (1984). A frequency count of 190,000 words in the London-Lund corpus of English conversation. *Behavior Research Methods, Instrumentation, and Computers, 16,* 502–532.

Brown, R. W. (1976). *A first language: The early stages.* Harmondsworth, MA. Penguin.

Brown, R. W., Black, A. H., & Horowitz, A. E. (1955). Phonetic symbolism in natural languages. *Journal of Abnormal and Social Psychology, 50,* 388–393.

Büchel, C., Price, C., & Friston, K. (1998). A multimodal language region in the ventral visual pathway. *Nature, 294,* 274–277.

Coltheart, M. (1981). The MRC psycholinguistic database. *Quarterly Journal of Experimental Psychology, 33a,* 497–505.

Francis, W. N., & Kucera, H. (1982). *Frequency analysis of English usage.* Boston: Houghton Mifflin.

Gathercole, S. E., Frankish, C. R., & Pickering, S. J. (1999). Phonotactic influences on short-term memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25,* 84–95.

Gentner, D. (1982). Why nouns are learned before verbs: Linguistic relativity versus natural partitioning. In S. Kuczaj (Ed.), *Language development* (Vol. 2, pp. 301–334). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Gilhooly, K. J., & Logie, R. H. (1980). Age of acquisition, imagery, concreteness, familiarity and ambiguity measures for 1944 words. *Behavior Research Methods and Instrumentation, 12,* 395–427.

Juhasz, B. J. (2005). Age-of-acquisition effects in word and picture identification. *Psychological Bulletin, 131,* 684–712.

Jusczyk, P. W., Luce, P. A., & Charles-Luce, J. (1994) Infants sensitivity to phonotactic patterns in the native language. *Journal of Memory and Language, 33,* 630–645.

Kelly, M. H. (1992). Using sound to solve syntactic problems: The role of grammatical category assignments. *Psychological Review, 99,* 349–364.

Kelly, M. H. (2004). Word onset patterns and lexical stress in English. *Journal of Memory and Language, 50,* 231–244.

Kessler, B., & Treiman, R. (1997). Syllable structure and the distribution of phonemes in English syllables. *Journal of Memory and Language, 37,* 295–311.

Kroll, J. F., & Merves, J. S. (1986). Lexical access for concrete and abstract words. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12,* 92–107.

Kučera, H., & Francis, W. N. (1967). *Computational analysis of present-day American English.* Providence, RI: Brown University Press.

Ladefoged, P. (1993). *A course in phonetics.* Orlando, FL: Harcourt Brace.

Langenmayr, A., Gozutok, M., & Gust, J. (2001). Remembering more nouns than verbs in lists of foreign language words as an indicator of syntactic phonetic symbolism. *Perceptual and Motor Skills, 93,* 843–850.

Levelt, W. J. M. (1989). *Speaking: From intention to articulation.* Cambridge, MA: MIT Press.

Locke, J. (1685). An essay on human understanding. In *Of abstract and concrete terms* (chap. 7). Retrieved June 18, 2004, from: http://humanum.arts.cuhk.edu.hk/Philosophy/Locke/echu/

Luce, P. A., & Pisoni, D. B. (1998). Recognizing spoken words: The neighborhood activation model. *Ear and Hearing, 19,* 1–36.

Majerus, S., Van der Linden, M., Mulder, L., Meulemans, T., & Peters, F. (2004). Verbal short-term memory reflects the sublexical organization of the phonological language network: Evidence from an incidental phonotactic learning paradigm. *Journal of Memory and Language, 51,* 297–306.

Nusbaum, H. C., Pisoni, D. B., & Davis, C. K. (1984). Sizing up the Hoosier mental lexicon. In *Research on spoken language processing* (Rep. No. 10, pp. 357–376). Bloomington: Speech Research Laboratory, Indiana University.

Paivio, A. (1985). *Mental representations: A dual coding approach.* New York: Oxford University Press.

Paivio, A., Yuille, J. C., & Madigan, S. A. (1968). Concreteness, imagery, and meaningfulness values for 925 words. *Journal of Experimental Psychology Monograph Supplement, 76*(3, Pt. 2).

Reilly, J. (2005). *A tale of two imageabilities: An interaction of sound and meaning in natural language perception.* Unpublished doctoral dissertation, Temple University, Philadelphia.

Reilly, J., Martin, N., & Grossman, M. (2005). Verbal learning in semantic dementia: Is repetition priming a useful strategy? *Aphasiology, 19,* 329–339.

Sadoski, M., & Paivio, A. (1986). *Imagery and text: A dual coding theory of reading and writing.* Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Saffran, J. R., & Thiessen, E. D. (2003). Pattern induction by infant language learners. *Developmental Psychology, 39,* 484–494.

Saussure, F. de (1916). *A course in general linguistics* (C. Bally & A. Sechehaye, Eds.). New York: McGraw Hill.

Simpson, J. A., & Weiner, E. S. C. (Eds.). (1989). *Oxford English dictionary: OED online* (2nd ed.) Oxford, England: Oxford University Press. Retrieved April 13, 2004, from http://dictionary.oed.com/

Steyvers, M., & Tenenbaum, J. B. (2005). The large-scale structure of semantic networks: Statistical analyses and a model of semantic growth. *Cognitive Science, 29,* 41–78.

Toglia, M. P., & Battig, W. R. (1978). *Handbook of semantic word norms.* Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Vitevitch, M. S. (2002). The influence of phonological similarity neighborhoods on speech production. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28,* 735–747.

Vitevitch, M. S., Armbrüster, J., & Chu, S. (2004). Sublexical and lexical representations in speech production: Effects of phonotactic probability and onset density. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 30,* 514–529.

Walker, I., & Hulme, C. (1999). Concrete words are easier to recall than abstract words: Evidence for a semantic contribution to short-term serial recall. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25,* 1256–1271.