The subtleties of frequency in morphological processing

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Morphological processing; Lexical decision; English

Overview: The role of frequency is a long-standing issue in probing the mechanisms of lexical processing. We explore the effects of frequency in lexical decision by using mega-study-scale data and mixed effects modeling to evaluate the claims of Alegre and Gordon (1999) and Baayen et al. (2007) (henceforth AG1999, B2007) regarding word frequency and present a more nuanced view of frequency effects.

Procedure: We modeled the English Lexicon Project (Balota et al., 2007) database of visual lexical decision trials, analyzing 192,117 correct-response trials of regularly inflected *(-s*, *-ed*, *-ing*) English words for which reliable word and base frequency estimates could be obtained. Mixed effects linear regression models of log reaction time (RT) were fitted with a random effect for subjects and fixed effects of trial number, education level, gender, and item-based predictors: squared orthographic length (New et al., 2006), orthographic neighborhood size (Yarkoni et al., 2008), word frequency (SUBTLEX norms), base (also called root/cluster) frequency, conditional probability of suffix given base, and suffix frequency. Residualization was performed among correlated predictors to eliminate multicollinearity (see Gorman, 2010, for the residualization strategy employed).

Frequency effects: We found significant effects (*pMCMC* = .0001) for all other fixed effects, but no significant effect (*pMCMC* = 0.5344) of word frequency on reaction times after base frequency and other multicollinear predictors (length, neighborhood density, stem/suffix conditional probability) were accounted for.

We additionally modeled the residuals of a mixed effects model that did not include word frequency as a predictor, allowing us to determine the contribution of frequency while other predictors were controlled for. We compared trials of words whose base frequency was near the .10, .25, .50, .75, and .90 quantiles, grouping trials by whether they were base- or word-frequency dominant and using a Bonferroni corrected two-tailed Wilcoxon rank sum test to compare groups within each quantile. At the lowest base frequency quantile (.10), higher word frequency inhibited RT ($p = 0.0046$); at one higher quantile (.75) it facilitated it ($p = .0034$). It was not significant elsewhere. We conclude that, consistent with fully decompositional approaches (Taft, 2004) and contrary to the claims of B2007, when base frequency is correctly accounted for, word frequency plays only a marginal role and its contribution varies drastically across base frequency ranges. AG1999 claimed that there is a threshold above which word frequency should have a linear effect beyond base frequency; after exploring a range of possible thresholds we were unable to replicate this on our larger dataset.

Effect of norms: We found that if we instead used norms based on a smaller sample, such as the Francis and Kučera norms used by AG1999 or the CELEX norms used by B2007, frequency was a significant predictor (*pMCMC* = .0001) even when properly residualized, demonstrating the impact of norm selection. We conclude that the disparity between the AG1999 and B2007 findings and the current study is best explained by methodological issues stemming from their use of poor frequency estimates (Burgess and Livesay, 1998).

References

M. Alegre and P. Gordon. Frequency effects and the representational status of regular inflections. *Journal of Memory and Language,* 40(1):41–61, 1999.

R.H. Baayen, L.H. Wurm, and J. Aycock. Lexical dynamics for low-frequency complex words: A regression study across tasks and modalities. *The Mental Lexicon,* 2(3):419–463, 2007.

D.A. Balota, M.J. Yap, M.J. Cortese, K.A. Hutchison, B. Kessler, B. Loftis, J.H. Neely, D.L. Nelson, G.B. Simpson, and R. Treiman. The English lexicon project. *Behavior Research Methods,* 39(3):445, 2007.

C. Burgess and K. Livesay. The effect of corpus size in predicting reaction time in a basic word recognition task: Moving on from Kučera and Francis. *Behavior Research Methods, Instruments, & Computers,* 30:272–277, 1998.

K. Gorman. The consequences of multicollinearity among socioeconomic predictors of negative concord in Philadelphia. *University of Pennsylvania Working Papers in Linguistics,* 16(2):9, 2010.

B. New, L. Ferrand, C. Pallier, and M. Brysbaert. Reexamining the word length effect in visual word recognition: New evidence from the English Lexicon Project. *Psychonomic Bulletin & Review,* 13(1):45, 2006.

M. Taft. Morphological decomposition and the reverse base frequency effect. *The Quarterly Journal of Experimental Psychology Section A,* 57(4):745–765, 2004.

T. Yarkoni, D. Balota, and M. Yap. Moving beyond Coltheart's *N:* A new measure of orthographic similarity. *Psychonomic Bulletin & Review,* 15(5):971–979, 2008.