**Localist vs. distributed representation in psycholinguistics:**
**An ultra-short summary of some new experiments.**

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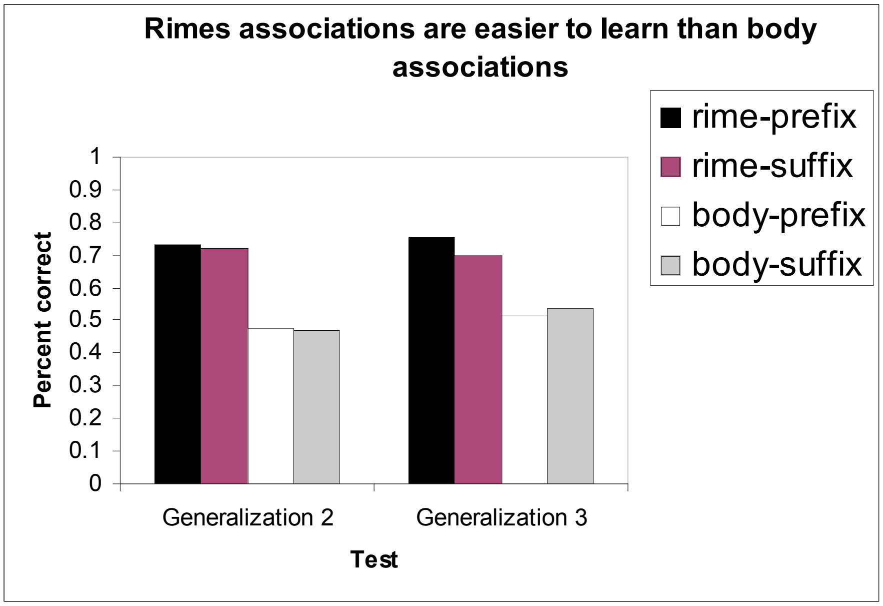
A complex, i.e., non-primitive/compositional, unit is psychologically real if there is something in the mind/brain that participates in representing the complex unit but does not participate in representing any of its parts when they occur outside of the complex unit. In network terms, there is a node or set of nodes whose activation in response to the complex unit is greater than the sum of its activations in response to each of the parts of the complex unit when they are presented outside of the whole (either in isolation or in other complex units).

Since saying that something is a unit is equivalent to saying that there is a node representing it that is not involved in representing its parts, it should be easier to acquire novel associations for units than for non-units of the same size. Kapatsinski (2006) applied this logic to test whether the syllabic constituent rime (the VC in CVC) is a unit in English.

In the study, native English speakers were exposed to an artificial language. There were four groups of subjects, which had to learn one of the following sets of regularities by listening to pairs of syllables for around fifteen minutes.

| Group | Associate | Part relations | Whole relations |
|---|---|---|---|
| I | Rimes & prefixes<br>N Cd | num- CΘC<br>num-CVΣ<br>mIn-C℘C<br>mIn- CVg | mIn- CΘΣ<br><br>num-C℘g |
| II | Rimes & suffixes<br>N Cd | CΘC-num<br>CVΣ-num<br>C℘C-mIn<br>CVg-mIn | CΘΣ-mIn<br><br>C℘g-num |
| III | Bodies & prefixes<br>On N | num-CΘC<br>num-ΣVC<br>mIn- C℘C<br>mIn- gVC | mIn- ΣΘC<br><br>num-g℘C |
| IV | Bodies & suffixes<br>On N | CΘC-num<br>ΣVC-num<br>C℘C-mIn<br>gVC-mIn | ΣΘC-mIn<br><br>g℘C-num |

In the testing stage, the subjects heard novel syllables and were asked to guess whether the syllable should be paired with /mIn/ or /num/. As the figure below shows, subjects were able to learn rime associations but not body associations (chance is 50%).

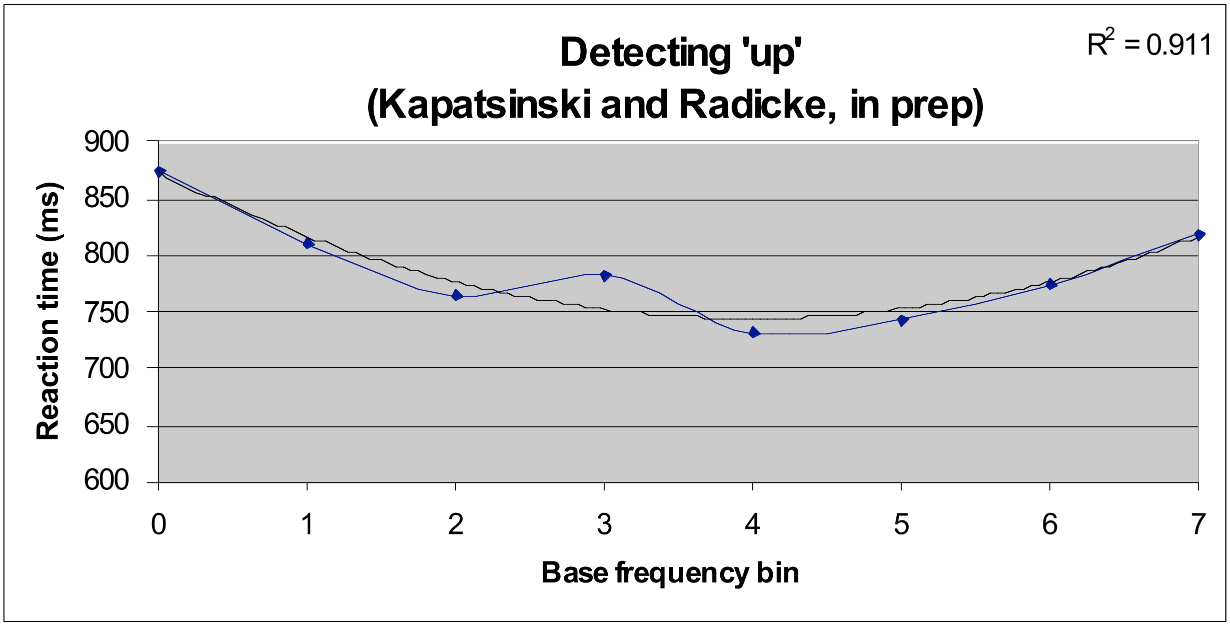



There were no differences in how well the subjects in the four groups learned vowel and consonant associations. Thus, the differences in associability between rimes and bodies cannot be derived from differences between parts of rimes and bodies. Furthermore, given the same amount of exposure, subjects learned rime associations better than they learned consonant or vowel associations. Thus acquiring rime associations is easier than acquiring associations of segments, which is unexpected if rimes are just pairs of strongly associated segments. Acquisition of syllable associations is also ruled out since subjects were just as good on novel syllables containing familiar rimes as on familiar syllables. Thus the results of this study strongly support the existence of rime units in English.

Another type of evidence has been discovered independently by Healy (1976, 1994), Hay (2000, 2003), and Sosa and MacFarlane (2002). The basic finding is that detection of parts in high-frequency wholes is harder than the detection of the same parts in low-frequency wholes. For instance, Healy (1976) found that if subjects are asked to find all tokens of the letter 'h' in a text, they are more likely to skip the ones in the high-frequency word 'the' than the ones in the low-frequency word 'thy'. Later studies, reviewed in Healy (1994), showed that the effect also exists within the class of nouns, suggesting that it is not due solely to the likelihood of foveating the word containing the letter. Healy concludes that high-frequency words are read in units that are larger than the letter.

Sosa and MacFarlane (2002) presented subjects with spoken sentences containing the word 'of'. They were asked to press a button as soon as they hear 'of'. They were more likely to miss 'of' in high-frequency word+*of* combinations, such as *kind of*, *out of*, and *sort of*. Sosa and MacFarlane argue that this is not due simply to articulatory reduction of *of* in the high-frequency phrases since all the tokens used were ones in which *of* contained a consonant. However, the sentences were taken from a corpus of spontaneous speech, which did not allow more precise controlling the degree of reduction. Furthermore, if the prototypical pronunciation of *of* in these contexts lacks the consonant, using the version with a consonant could violate the subjects' expectations leading to delayed processing. Nonetheless, Sosa and MacFarlane conclude that high-frequency word+*of* units are psychologically real.

Kapatsinski and Radicke (In prep) have recently replicated Sosa and Macfarlane's results with the particle *up*, manipulating the frequency of verb+particle combinations and transitional probability between them. *Up* shows much less variation in pronunciation, and this time a much larger set of stimuli and wider range of frequencies was used. A U-shaped pattern was found: as phrase frequency increases, detection of the particle first becomes easier and then becomes harder again. (The 'bump' is probably due to transitional probability being very high in bin 3; frequency bins are based on log root frequency, and are *not equidistant*, so the correlation should not be taken literally as a good fit with a parabola: we can only say that a U-shaped pattern is observed).




These results are expected under the hypothesis that units compete with smaller units during recognition. A high-frequency word or phrase is a stronger competitor than a low-frequency word or phrase, thus making it harder to detect letters in high-frequency words and particles in high-frequency phrases. By contrast, other things being equal, detection of predictable units is easier than the detection of unpredictable units. Thus, as predictability of *up* increases, it becomes easier and easier to detect it until the point at which a larger unit emerges and starts to compete with *up* for recognition. If there were no larger unit, we would expect *up* to become easier to detect when it is highly predictable (the function in the figure above would be monotonically decreasing).

Hay (2000, 2003) proposes a similar account of why morphemes that tend to occur in high-frequency words tend to be less productive than those that occur in low-frequency words. She suggests that morphemes that occur in high-frequency words are less likely to be segmented out of the speech stream because they have to compete for recognition with high-frequency words.

A similar explanation could also be made for priming asymmetries. In several domains, researchers have discovered independently that, given a pair of words that differ in frequency, more priming is observed when the high-frequency one is used as the target than when it is used as the prime (see Koriat 1981, Chwilla et al. 1998 for semantic, Rueckl 2003 for orthographic, Schriefers et al. 1992 and Feldman 2003 for morphological, Goldinger et al. 1989 for phonetic, and Radeau et al. 1995 for phonological priming). This is readily explained in a model that proposes between-level competition: a unit that the prime and the target share is less likely to be parsed out of the prime when the prime has high frequency, reducing priming.

One could also apply this account to explain why increases in frequency start to make processing harder at the ultra-high-frequency end of the word frequency continuum (Balota et al. 2004, Bien et al. 2005, Tabak et al. 2005). These are the cases in which the to-be-recognized word is expected to often form part of a larger unit, making it harder to recognize.

Finally, a number of studies have argued for the psychological reality of syllables based on observing that the amount of phonological priming between a pair of words varies as a function of whether they share a syllable. Phonological priming is usually assessed by comparing reaction times to the same word when it is preceded by a phonologically similar word vs. a phonologically dissimilar word. In experiments reported by Ferrand et al. (1996) for French and Carreiras and Perea (2002) for Spanish, the target word had either the form CVC.CVC or CV.CV.CV. Here, the dots indicate syllable boundaries, 'C' stands for 'consonant', and 'V' stands for vowel. The prime was presented visually and had either the form CV**** or CVC***. It was presented so fast that the subjects did not consciously notice its identity. All segments of the prime were present in the target. For instance, the primes may be *pa***** and *pas**** and the targets may be *pasivo* and *pastor* (Carreiras and Perea 2002).

If all that mattered for phonological priming was the number of segments or letters shared between the prime and the target or the duration of the shared part, we would expect that CVC primes to produce more priming than CV primes for both types of targets. However, both studies showed a reliable interaction: while CVC primes produced more priming than CV primes for CVCCVC targets (*pas**** primes *pastor* more than *pa***** did), CV primes produced more priming than CVC primes for CVCVCV targets (*pa***** primes *pasivo* more than *pas**** does). These results follow directly from the syllable structure of the targets: *pas* shares a syllable with *pastor* but not with *pasivo*, while *pa* shares a syllable with *pasivo* but not with *pastor*. These studies provide convincing evidence that subjects are sensitive to the syllable structure of the word, although ambiguity remains regarding whether the sharing of syllables or syllabic constituents is at issue: the syllable in Spanish and French is taken to consist of an onset (the consonants preceding the vowel) and a rime (the vowel plus the following consonants). While *pas* shares an onset and a rime with *pastor*, it only shares an onset with *pasivo*.

To conclude, the existence of local representations for complex linguistic units is plausible and supported by empirical evidence. Furthermore, assuming the existence of complex units that compete with smaller units for recognition can explain several puzzling effects in language processing.

References:

Balota, D. A., Cortese, M. J., Sergent-Marshall, S. D., Spieler, D. H., & Yap, M. .J. 2004. Visual word recognition of single-syllable words. *Journal of Experimental Psychology: General*, 133, 283-316.

Bien, H., W. M. J. Levelt, and R. H. Baayen. 2005. Frequency effects in compound production. *Proceedings of the National Academy of Sciences*, 102, 17876-81.

Carreiras, M., and M. Perea. 2002. Masked priming effects with syllabic neighbors in a lexical decision task. *Journal of Experimental Psychology: Human Perception and Performance*, 28, 1228-42.

Chwilla, D. J., P. Hagoort, and C. M. Brown. 1998. The mechanism underlying backward priming in a lexical decision task: Spreading activation versus semantic matching. *Quarterly Journal of Experimental Psychology*, 51A.531-60.

Feldman, L. B. 2003. What the repetition priming methodology reveals about morphological aspects of word recognition. In J. S. Bowers and C. J. Marsolek, eds. *Rethinking Implicit Memory*, 124-38. Oxford University Press.

Ferrand, L., J. Segui, and J. Grainger. 1996. Masked priming of words and picture naming: The role of syllabic units. *Journal of Memory and Language*, 35, 708-23.

Goldinger, S. D., P. A. Luce, and D. B. Pisoni. 1989. Priming Lexical Neighbors of Spoken Words: Effects of Competition and Inhibition. *Journal of Memory and Language*, 28, 501–18.

Hay, J. 2001. Lexical frequency in morphology: Is everything relative? *Linguistics*, 39, 1041-70.

Hay, J. 2003. *Causes and consequences of word structure*. Routledge.

Healy, A. F. 1976. Detection errors on the word *the*: Evidence for reading units larger than letters. *JEP: HPP*, 2, 235-42.

Healy, A. F. 1994. Letter detection: A window to unitization and other cognitive processes in reading text. *Psychonomic Bulletin and Review*, 1, 333-44.

Kapatsinski, V. M. 2006. Testing psychological reality of complex units with XOR learning. Paper presented at the 5th International Conference on the Mental Lexicon, Montreal. Online at http://mypage.iu.edu/~vkapatsi/current.htm

Kapatsinski, V. M., and J. Radicke. In prep. Frequency and the emergence of prefabs: Evidence from monitoring.

Koriat, A. 1981. Semantic Facilitation in Lexical Decision as a Function of Prime-Target Association. *Memory and Cognition*, 9.587-598.

Rueckl, J. G. 2003. A connectionist perspective on repetition priming. In J. S. Bowers and C. J. Marsolek, eds. *Rethinking Implicit Memory*, 67-104. Oxford University Press.

Schriefers, H., A. Frederici, and P. Graetz. 1992. Inflectional and Derivational Morphology in the Mental Lexicon: Symmetries and Asymmetries in Repetition Priming. *Quarterly Journal of Experimental Psychology*, 44A, 373-90.

Sosa, A. V., and J. MacFarlane. 2002. Evidence for frequency-based constituents in the mental lexicon: Collocations involving the word *of*. *Brain and Language*, 83, 227-36.

Tabak, W., R. Schreuder, and R. H. Baayen. 2005. Lexical statistics and lexical processing: semantic density, information complexity, sex, and irregularity in Dutch. In M. Reis and S. Kepser, eds. *Linguistic Evidence*, 529-55. Mouton.