1. Introduction

It has long been known that the relationship between form and meaning is generally arbitrary in human languages, that is, forms have no inherent relationships with their meanings (Hockett, 1963). However, it has also been shown that the cumulative cultural evolution of languages does introduce regularities in form–to–meaning mapping (Kirby, Cornish, & Smith, 2008), and that systematicity in this mapping helps learnability, at least in terms of word categorization (Monaghan, Christiansen, & Fitneva, 2011). One apparent end product of this structure–oriented “invisible hand” is linguistic morphology—families of words emerge whose relationship in form predicts their relationship in meaning (e.g., DEAL and DEALER, HUNT and HUNTER). Here we complement this evolutionary evidence with data from Cognitive Neuroscience, showing that the brain codes for these form–to–meaning regularities in a probabilistic way, and uses this information as we process words, either in isolation or embedded in sentence context.

2. Methods

As a test case, we considered the construct developed by Marelli, Amenta, and Crepaldi (2015), Orthography–to–Semantics Consistency (OSC). This is a frequency–weighted average of meaning similarity between any given stem (e.g., DIAL) and all words that include that stem in their orthography (e.g., DIALECT, DIALLED, DIALS, DIALLING, DIALOG, DIALYSIS). Formally:

\[
OSC(t) = \frac{\sum_{j=1}^{k} f_{r_x} \cos(\vec{t}, \vec{r}_x)}{\sum_{j=1}^{k} f_{r_x}}
\]

where \( t \) is a stem, \( f_{r_x} \) is the frequency of its \( k \) orthographic relatives \( r_x \), and \( \vec{t} \) and \( \vec{r}_x \) are vectorial representations of meaning as extracted from a distributional semantic model (Marelli et al., 2015).
Essentially, OSC tracks how strongly form similarity correlates with meaning similarity. This measure was shown to predict word identification times in a large psycholinguistic database (Marelli et al., 2015; Balota et al., 2007). Here we test OSC against a behavioural index of sensitivity to form–meaning regularities, i.e., morphological priming; and against neurophysiological data (Event–Related Potentials, ERP) collected during natural sentence reading (Frank, Otten, Galli, & Vigliocco, 2015).

3. Results

OSC turns out to qualify morphological priming, in such a way that higher frequency primes have more impact on target processing, either strengthening priming, if they are indeed related to the target (e.g., corns–CORN); or weakening it, if they are not (e.g., corner-CORN).

Brain electrophysiology (the LAN and N400 components) is also shown to be modulated by OSC during sentence reading, at least in words that aren’t easily predictable given the available sentence context.

4. Discussion

From a Cognitive Neuroscience point of view, these results suggest some rethinking of linguistic morphology. Rather than a discrete set of operations over a finite set of well-defined mental representations, morphology can (should?) be seen more generally as part of a form–to–meaning mapping effort carried out by the brain, on the basis of probabilistic knowledge that is accumulated through linguistic experience.

From an evolutionary perspective, these data show that the brain takes advantage of regularities in form–to–meaning mapping in language, thus establishing a psychological/neuroscience counterpart to the progressive emergence of structure through iterated learning. Of course, we don’t know whether this phenomenon is an evolutionary reaction of the brain to the independently–triggered emergence of structure in language; or a core feature of the human cognitive machinery, which independently contributed itself to the emergence of structured form–to–meaning mapping. Interestingly, these data also link language learning/evolution/processing to general–purpose cognitive and brain operations (Ellison, 2013).

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