Compositional semantics and the lemma dilemma

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Abstract: We discuss two key assumptions of Levelt et al.'s model of lexical retrieval: (1) the nondecompositional character of concepts and (2) lemmas as purely syntactic representations. These assumptions fail to capture the broader role of lemmas, which we propose as that of lexical–semantic representations binding (compositional) semantics with phonology (or orthography).

Theories of speech production distinguish between two different levels of lexical representations: *lemmas* (abstract representations of the words that *also* contain syntactic information) and *lexemes* (or word forms that specify morphological and phonological information) (Butterworth 1989; Dell 1986; Garrett 1980; Levelt 1989; Levelt et al.'s target article 1998; but see Caramazza 1997). A basic assumption of the theory developed by Levelt et al. is that concepts are represented as undivided wholes, rather than by sets of semantic features. This is implemented in their model by means of *concept nodes,* which are interconnected through labeled links to form a semantic network. Each node in the conceptual network is linked to a single lemma node. The role of the lemma nodes is to connect to syntactic information necessary for grammatical encoding. In this view, lemma nodes are a copy of the conceptual nodes, so that the only architectural distinction between the two levels of representation is the within-level connectivity.[1]

The objective of our commentary is to evaluate the claims by Levelt et al. with respect to the specification of conceptual and lemma level representations. We will present some arguments for compositional semantics and briefly sketch a view in which lemma-level representations would specify lexical semantic information in addition to being connected to syntactic features.

Compositional semantics. Levelt et al. argue that the nondecompositional character of conceptual knowledge in their model overcomes problems such as the so-called "hyponym–hyperonym" problem (sect. 3.1.1). If concepts are represented by sets of semantic features, the active features for a given concept (e.g., "chair") will include the feature set for all of its hyperonyms or superordinates (e.g., "furniture"). The inverse reasoning applies to the hyponym problem (i.e., the erroneous selection of subordinates). This problem (if it is a problem at all) is not peculiar to language production, but also arises in other domains. In visual word recognition, word forms are accessed from active sets of letters (just as lemmas are accessed from active sets of semantic features). When a word like "mentor" is presented, what prevents readers from accessing "men" or "me," which are formed from subsets of the active letters? Connectionist models of reading (e.g., Zorzi et al. 1998) present computational solutions. Even in a localist framework, the problem can be solved using networks trained with algorithms such as competitive learning (Grossberg 1976a; Kohonen 1984; Rumelhart & Zipser 1985). In competitive learning, the weights (w) of each output node are normalized, that is, all connection weights to a given node must add up to a constant value. This takes the selected node (winner) to be the node closest to the input vector x in the l_1 norm sense, that is

$$\left|\overline{w}_{i^0} - \overline{x}\right| \leq \left|\overline{w} - \overline{x}\right|$$

where i^0 is the winning node. For the winning node, the weight vector is displaced towards the input pattern. Several distance metrics can be used, although the Euclidean is more robust. Therefore, the activation of the features for "animal" will not be sufficient for the node "dog" to win, because the links to "dog" will have smaller values than those to "animal" (assuming that the concept "dog" entails more semantic features than "animal"). Conversely, a concept like "chair" cannot activate the superordinate "furniture," because the number of active features (and hence the length of the input vector) for the two concepts is different (a similar solution to the problem is proposed by Carpenter & Grossberg [1987] in the domain of pattern recognition).

What is a lemma? If concepts are represented by sets of semantic features, these features must be "bound" to represent a lexical unit before any other kind of representation can be properly accessed. That is, an intermediate level of representation must exist between semantic features and the phonological (or orthographic) form of the word, because the mapping between meaning and phonology is largely arbitrary. This issue is generally known as the problem of *linear separability* (e.g., Minsky & Papert 1969; Rumelhart et al. 1986). In neural network models, the problem is typically solved using a further layer of nodes (e.g., hidden units) lying between input and output. It is important to note that nothing (except from the choice of learning algorithm) prevents the intermediate layer from developing localist representations. Lemmas provide exactly this kind of intermediate level of representation. If the lemma level has the role of binding semantic and phonological information, then lemmas have a definite content that is best described as lexical–semantic.

The organization of the lemma level will be largely dictated by the conceptual level (semantic features). For instance, the use of an unsupervised, self-organizing learning method (e.g., Kohonen 1984) will result in the lemma nodes being topographically organized to form clusters corresponding to semantic categories (Erba et al. 1998). Evidence compatible with this idea comes from the observation of "semantic field effects" in word substitution errors (see Garrett 1992). Further evidence comes from a study by Damasio et al. (1996). They reported converging evidence from a neuropsychological study on a large group of anomic patients and from a neuroimaging study on normal subjects that an intermediate level of representation, which they describe precisely as "binding" semantic and phonological information, is anatomically localized in the left temporal lobe. Crucially, they found that different categories (e.g., animates vs. artifacts) are clustered in distinct (but contiguous) cortical regions.

In this view, lemmas would also have a syntactic role. It is clear that syntactic properties cannot be directly attached to concepts, because semantic features do not directly map onto syntactic features. The syntactic properties could be attached to the phonological or orthographic word forms; however, this is computationally inefficient because syntactic information is modality-independent (but see Caramazza 1997). Therefore, the intermediate lemma level is the most adequate for accessing syntactic information.

Lexical concepts acquire syntactic properties relatively late in development (between the ages of 2.6 and 4 years; see Levelt et al., sect. 1). This process is termed *syntactization* by Levelt et al. and refers to the development of a system of lemmas. However, the explosive growth of the lexicon takes place between the ages of 1.6 and 2.6. This means that an efficient mapping between concepts and phonological word forms is already established at that onset of the syntactization process. Within the architecture of Levelt et al.'s model, such mapping would presumably involve conceptual nodes and word forms, thus bypassing the yet-to-be-developed lemmas. Therefore, the later development of the lemma level would mean a massive rewiring of the lexical system. We believe that such a process is truly unlikely (both from the neural and computational standpoints). By contrast, if lemmas develop as a necessary component of the mapping between meaning and phonology, syntactization is simply the process of linking syntactic features to the existing lemma representation.

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NOTE

1. This very restricted notion of lemma is what led Caramazza (1997) to argue that lemma nodes are contentless representations (the "empty lemma"), and as such they are dispensed with in his model of lexical access.

Authors' Response