# Distributional Analysis of Function Words

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**Introduction** Theoretical linguists observe with envy the way in which distributional semantics in computational linguistics renders research viable whose foundations were postulated by clear-sighted structuralists (Firth, 1957; Harris, 1954). Their interest diminishes upon seeing computational linguistics dealing mainly with content words, where theoretical linguists firmly believe that function words and morphosyntax define the interesting backbone of natural languages – the exception being prepositions, which are arguably at the boundary between content and function (Schneider et al., 2018).

This paper is a first attempt at reconciling the advanvced tools of computation in distributional semantics with the function word emphasis of formal linguistics. We consider a multiply polysemous function word, the German reflexive pronoun *sich*, and investigate in which ways natural subclasses of this word which are known from the theoretical and typological literature (Kemmer, 1993, cf. Table 1) map onto recent models from distributional semantics. Due to the differences between lexical and functional polysemy, our preliminary results are different from those of studies of content word polysemy in distributional semantics (e.g., Boleda et al., 2012). Nonetheless, we submit that our results open a window onto patterns of polysemy that may, in the long run, turn out at least as interesting and relevant to the computational study of natural languages. What we find in our pilot is that some traditional subclasses of *sich* not only map neatly onto clusters produced by distributional methods, but that others which are predicted by theory to belong to constructional metaclasses with a wider distribution pervade the whole clustering space. What is more, the distribution of causative-transitive vis-à-vis anticausative verb types and of other verb classes partly reproduces the semantic map of the middle domain as first envisaged by Kemmer (1993) on a typological database. We take these results to be promising for more and in-depth studies of function morphemes in distributional semantics.

**Distributional analysis and Data.** Distributional analysis is probably the dominant paradigm for semantic analysis in computational linguistics. Building on the distributional hypothesis, *"you shall know a word by the company it keeps"* (Firth, 1957), they typically represent words as high-dimensional vectors representing the words' contexts and interpret vector similarity as

| Category / Example | predict able | all persons | stress- able | +*lassen* | dispos- ition |
|---|---|---|---|---|---|
| 1. Inherent reflexives: *Paul schämte sich*/'Paul felt ashamed' | + | + | - | - | +/- |
| 2. Anti-causatives: *Die Erde dreht sich*/'The earth revolves' | (+) | - | - | - | +/- |
| 3. Change in posture: *Paul setzte sich hin*/'Paul sat down' | (+) | + | - | (-) | - |
| 4. Typically self-directed: *Paul kämmte sich*/'Paul combed his hair' | (+) | + | (-) | - | - |
| 5. Typically other-directed: *Paul erschoss sich*/'Paul shot himself' | - | + | + | - | - |
| 6. Dispositional middle: *Die Dose lässt sich leicht öffnen*/'The can opens easily' | + | + | - | + | + |
| 7. Episodic middle: *Paul lässt sich beraten*/'Paul gets advice' | + | + | - | + | - |
| 8. Reciprocals: *Die Geraden schneiden sich im Unendlichen*/'The lines intersect in the infinite' | - | - | +/- | - | +/- |

Table 1: Salient uses of *sich* according to Kemmer (1991).

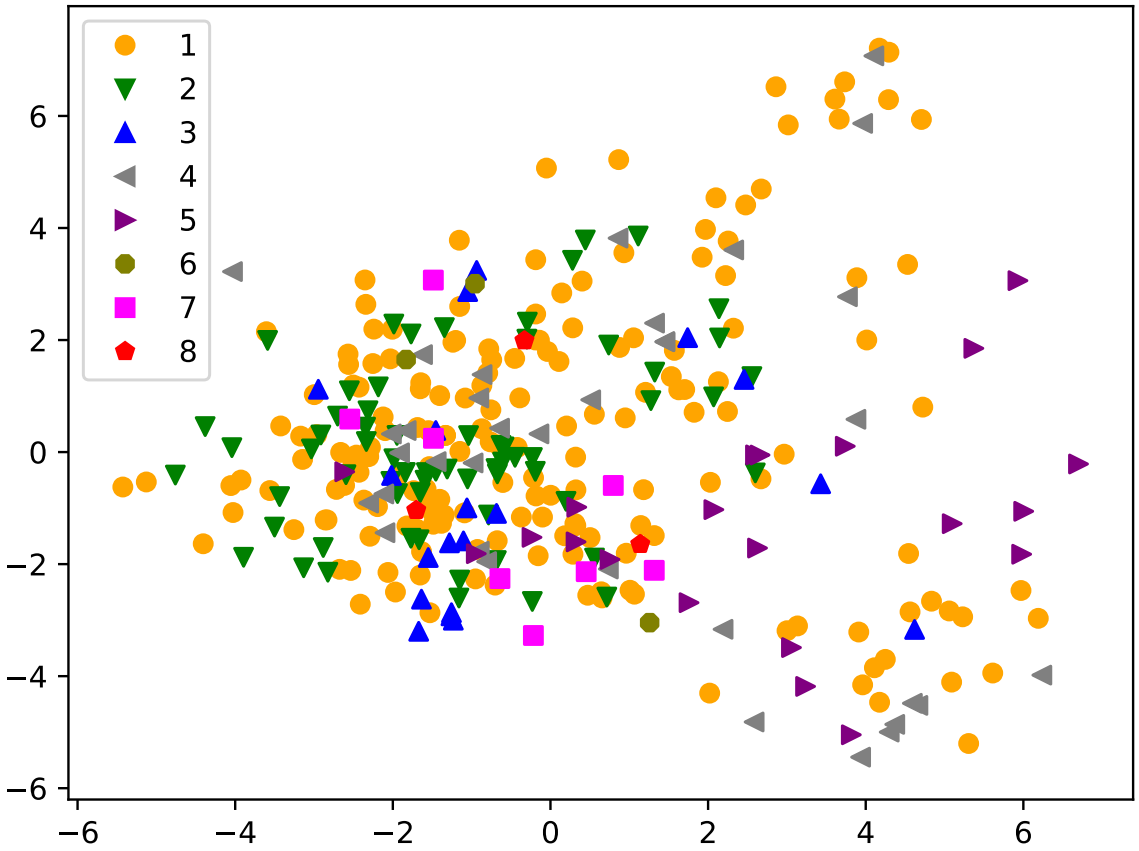


Figure 1: Distributional representations of *sich* instances. Class labels according to Table 1.

semantic relatedness (Turney and Pantel, 2010). Virtually all work in this area has concentrated on *content* words (common nouns, verbs, adjectives), following the intuition that these word classes refer to categories whose properties and relational structure can be learned profitably from distributional analysis (Cimiano et al., 2005).

In this paper, we focus instead on a function word, namely the German reflexive pronoun *sich*. Traditionally, the context of function words was considered to be too general to be amenable to distributional analysis. The situation has changed with recently proposed distributional models which concurrently learn (a) vectors for word types and (b) how to compute a *contextually appropriate* vector for each word in its context. This division of labor circumvents the generality problem: even if the representation of the lemma *sich* is too general to be useful, the analysis can proceed as long as the model learns how the meaning of each instance is constituted through interaction with its context.

Concretely, we use the BERT architecture (Devlin et al., 2019) instantiated with its pre-trained 'multilingual base' model, which provides 768-dimensional vectors for all input words in context. To visualize these vectors, we perform principal components analysis, a standard dimensionality reduction method, to represent instances of *sich* on a two-dimensional plane.

The basis of our analysis is formed by the 700M token SdeWAC web corpus (Faaß and Eckart, 2013). We select the first 335 out of more than 5.5 million instances of *sich* for manual annotation by one of the authors with the eight classes as defined above. We present each instance in its local phrasal context, as approximated by punctuation, to the BERT model.[1] The resulting embeddings are reduced to two dimensions with principal components analysis.

[1]We also experimented with complete sentences, but obtained worse results, since this tended to dilute the effect of the direct context of *sich*.

**Findings.** The resulting two-dimensional instance representations are shown in Figure 1. In our estimation, the overall picture is promising: even though the classes are not completely separated, clear tendencies are visible.

- Inherently reflexive verbs (class 1) are interspersed through all event types and do not form a cluster of their own, as could be expected given their predictable nature.
- Typically other-directed reflexive events like 'shooting oneself' and typically self-directed reflexive events like 'defending oneself' or 'combing' (classes 4, 5) form rather compact neighboring categories in the lower right sector.
- The sectors on the right generally assemble agentive causative verb uses, whereas sectors on the left assemble anticausative verb uses like 'diminishing' or 'revolving' (class 2), all of which involve use of *sich* in German. Hence the bow from left to bottom right forms a path of growing agentivity, with traditional middle constructions (classes 3, 6, 7) literally occupying the middle of the plot.
- Some of the classes show a 'core' surrounded by outlier clouds. For the change-of-posture verbs (class 3), the noticeable string of outliers to the right is formed by non-literal uses (non-physical motion, e.g. 'sich aus dem Verderben erheben' (to rise from doom), 'sich auf die Rechtsgrundlage stützen' (to rest on the legal foundation)).
- The seemingly inhomogeneous behavior of the self-directed verbs (class 4) can be explained in terms of the distinction between PP-*sich* and DP-*sich* (Gast and Haas, 2008): The middle 'core' of class 4 consists of the DP cases, e.g. 'sich unterziehen' (to undergo). In contrast, the cloud on the lower right is made up of PP cases like 'bei sich tragen' (to carry). The latter are clearly more causative, in line with the 'causation' gradient described above. Finally, the outliers in the upper right sector are non-literal instances.

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