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New avenues and challenges in semantic map research (with a case study in the semantic field of emotions)

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Abstract: In this paper, we present an overview of the methods associated with semantic maps, focusing on current challenges and new avenues for research in this area, which are at the core of the contributions to this special issue. Among the fundamental questions are: (1) the validity of the basic assumption, namely, to what extent does coexpression reflect semantic similarity; (2) the central problem of identifying analytical primitives in the domain of semantics; (3) the methods of inference used for creating coexpression maps and the representation techniques (graph structure vs. Euclidean space) as well as their respective merits (including the goodness of fit of the models); and (4) the use of semantic maps to support diachronic and synchronic descriptions of individual languages. In order to illustrate and discuss key aspects, we conduct an experiment in the semantic field of emotions, for which we construct a classical semantic map based on the dataset of CLICS^3.

Keywords: semantic maps, inference, graph, emotions

1 Introduction

The semantic map method – pioneered in linguistics by Anderson[1] (1982; 1986) – has been developed and popularized by linguists such as Croft (2001), Cysouw (2007; 2010), Haspelmath (1997a; 1997b; 2003), and van der Auwera and Plungian (1998). The basic idea underpinning this method is that language-specific

1 Hjelmslev is regularly quoted in the literature on semantic maps as an early practitioner of the method, but his structuralist approach can be shown to be entirely different both in terms of methods and goals from current practices in typology (Cigana and Polis 2022).

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patterns of coexpression point to semantic closeness or relatedness between the meanings that are coexpressed (e. g., Hartmann et al. 2014). This idea reflects the basic premise of Haiman's *Isomorphism Principle*, which assumes that similarity in form entails a similarity in meaning (Haiman 1985; see also Wälchli and Cysouw 2012). The fact that one can use a single form in English, namely the preposition *to*, in order to express a DIRECTION (*I went* ***to*** *Dasha's school*), a RECIPIENT (*I gave the book* ***to*** *Masha*), or a PURPOSE (*Bill went* ***to*** *get vaccinated*) tells us that these three functions are somehow semantically related. The recurrence of similar patterns of coexpression across languages allows typologists to generalize the observations,[2] to infer similarity (or relatedness) between concepts across languages, and to visualize semantic relationships in the form of a map. The resulting map is what Croft (2003: 133–137) christened a *conceptual space* and is most commonly simply called a *semantic map*.[3]

Historically, the first semantic maps took the form of graphs — with nodes standing for meanings and edges between nodes standing for relationships between meanings — and the sets of form-meaning pairs investigated were grammatical (Cysouw et al. 2010). Examples of grammatical phenomena that have been studied include semantic roles (e. g., Narrog and Ito 2007; Grossman and Polis 2012), indefinites (e. g., Haspelmath 1997a), temporal markers (Haspelmath 1997b), aspect (e. g., Anderson 1982; Becker and Malchukov 2022) and modality (e. g., van der Auwera and Plungian 1998) to name but a few. The method was also applied to syntactic constructions, such as intransitive predicates (Stassen 1997) and secondary predications (van der Auwera and Malchukov 2005). The semantic maps represented as graph structures are known as *classical semantic maps*, *implicational maps* or *connectivity maps* (van der Auwera 2013). They are based on two basic principles: they respect the *connectivity hypothesis* (Croft 2001: 96) – which states that any linguistic form must map onto a connected region of the map – and simultaneously they obey the *economy principle* (Georgakopoulos and Polis 2018: 6), according to which a line (technically called an *edge*) can only be added between two nodes if a given linguistic item expresses these two meanings but not the other meaning(s) that already connect(s) these two nodes indirectly. In other words, when plotting a map, one should use the minimum number of

2 As Haiman (1974) describes it: "[i]f a word exhibits polysemy in one language, one may be inclined, or forced, to dismiss its various meanings as coincidental; if a corresponding word in another language exhibits the same, or closely parallel, polysemy, it becomes an extremely interesting coincidence; if it displays the same polysemy in four, five, or seven genetically unrelated languages, by statistical law it ceases to be a coincidence at all."

3 Georgakopoulos and Polis (2018) provide a comprehensive overview of the semantic maps methods, and Georgakopoulos (2019) lists and comments on the main studies in the field.

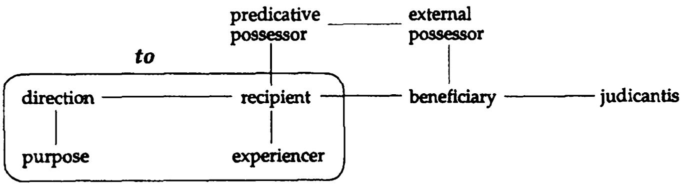

Figure 1: A semantic map of dative functions with the boundaries of English *to* (Haspelmath 2003: 213).

edges required in order to respect the connectivity hypothesis. This principle is best understood by example: in Figure 1, the nodes PURPOSE and EXPERIENCER are not directly connected by an edge because the dataset on which the map is based does not contain any item that expresses both PURPOSE and EXPERIENCER, but not DIRECTION and RECIPIENT.

This point is crucial since it distinguishes semantic maps from *colexification*[4] *networks* – such as those provided in the Database of Cross-linguistic Colexification CLICS[3] (https://clics.clld.org) – in which patterns of coexpression leads to pairwise connections between meanings (Rzymski et al. 2020). As Croft (2022) puts it, the absence of an edge in a connectivity map "encodes an implicational universal", while colexification networks do not visualize such implications: if a language encodes two meanings that are not directly connected in a semantic map, then the meanings from the graph that allow connecting these two meanings are also predicted to be expressed by the said form.[5] Comparing the two approaches, Croft (2022) suggests to refer to classical semantic maps as minimally connected coexpression graphs. Such semantic maps are falsifiable, and they may be enriched and expanded based on additional crosslinguistic evidence (e. g., Andrason 2019a and 2020).

4 Colexification is a type of coexpression. The term was coined by François and refers to "the capacity, for two senses to be lexified by the same lexeme in synchrony" (François 2008: 171). As far as lexical items are concerned, we use here the two terms interchangeably.

5 There are obvious methodological links between the semantic map method and grammaticalization studies – see already the graphs in the influential study of Bybee et al. (1994) and the discussion in Narrog and van der Auwera (2011) – and more broadly with typological hierarchies (see recently Cristofaro and Zúñiga 2018; also Croft 2003). The question as to how typological hierarchies relate to semantic maps is also addressed in Becker and Malchukov (2022). They acknowledge that these are different analytical tools, but they show that there is a particular kind of hierarchy, namely Interaction Hierarchies, that shares features with both semantic maps and typological hierarchies.

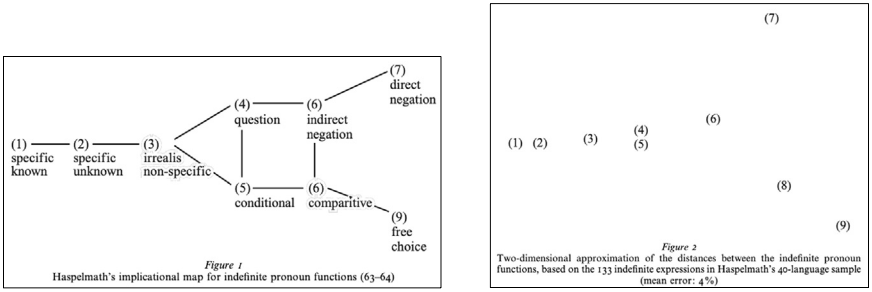

Figure 2: Comparison between a connectivity map and a proximity map based on the data collected by Haspelmath (1997a) for the indefinite pronoun functions (Cysouw 2001: 609, 611).

2 Extending the method and its scope of application

In the 2000s, two new trends emerged which expanded the semantic map model from a methodological viewpoint and in terms of scope of application. As regards methodology, Cysouw (2001: 610–612), Levinson et al. (2003: 503–509), and Croft and Poole (2008) introduced multivariate statistical techniques that position the meanings in a two-dimensional Euclidean space (Figure 2). These visualizations have been labelled *proximity maps* (also *similarity*, *second generation*, *statistical*, or *probabilistic* maps), because the distance between two points (in any direction) represents the degree of (dis)similarity between two meanings. This distance is inferred from the frequency of coexpression of the meanings: points that are near one another are more frequently coexpressed, hence semantically more similar, than points that are further apart. One advantage of this new approach is that such visualizations could be computed automatically at a time when the graph inference problem – i. e., determining the smallest number of edges (economy principle) while respecting the connectivity hypothesis – was considered to be mathematically intractable (see Section 3). As such, it was a way to overcome the practical difficulties of creating maps manually when more than a handful of meanings have to be taken into consideration.

Another significant advantage of this technique is that one does not need to define analytical primitives (Section 4.1) in advance, based on a semantic analysis of cross-linguistic data. Such proximity maps may also be plotted on the basis of data alone (Narrog and van der Auwera 2011: 320–321) and are a way to do "typology without types". Wälchli (2010), for instance, built a proximity map of motion events that took cases and adpositions from the *Gospel of Mark* in 153 languages (Figure 3) as input. The points on the map are the individual contexts: the more

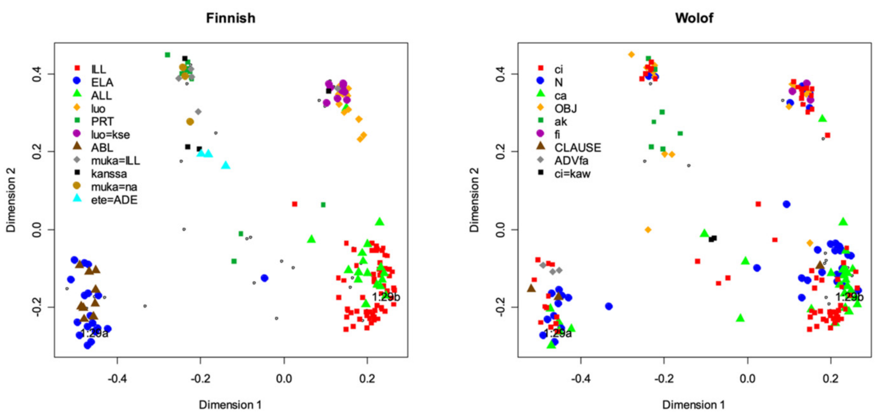

Figure 3: Local phrase markers in Finnish and Wolof mapped onto a proximity map of motion events in 153 languages (Wälchli 2010: 333).

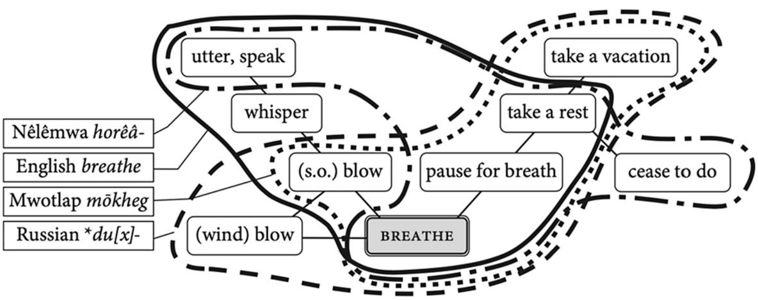

Figure 4: A lexical semantic map of the notion BREATHE with mapping of four lexemes (François 2008: 186).

often these contexts are expressed by the same forms in the language sample, the closer they are on the map.

Next to this *methodological turn*, one observes a *lexical turn* at the same period. This lexical turn started with papers by Majid et al. (2007) – who analyzed cutting and breaking events with multivariate statistics producing proximity maps – and François (2008), who adapted the classical semantic maps method described by Haspelmath (2003) to lexical items. François identified contextual semantic atoms of words having BREATHE as one of their senses and analyzed the cross-linguistic patterns of colexification using a semantic map.

A token of the growing interest in the method was the organization of the workshop on semantic maps, which was held in September 2007 in Villejuif (Paris) as a satellite event of the seventh meeting of the Association of Linguistic

Typology. A selection of presentations given at this workshop were published in a special issue of *Linguistic Discovery* (2010), which discusses the main theoretical, methodological, and practical questions of this approach to linguistic structures.[6] The workshop "Semantic maps: Where do we stand and where are we going?" held on the 26th–28th of June 2018 at the University of Liège (Belgium) was conceived as a small-scale follow up of this meeting ten years later,[7] and the eight contributions to this special issue attest to the vitality of research in this field.

In this introductory paper, we outline the current directions of research resorting to semantic maps that are investigated by the contributions to the special issue. In Section 3, we discuss the automatic inference of graph structures and other methodological challenges related to classical semantic maps. We show that much progress has been made in the area and that most of the problems of the past have now been addressed thanks to new algorithms and tools adapted to the connectivity maps during the last decade. Section 4 discusses three central issues, which are not specifically linked to semantic maps, but rather concern semantic typology as a whole: (4.1) how to identify atomic senses? (4.2) what is the influence of data collection on the results? (4.3) and, ultimately, what does it tell us about the central hypothesis of this approach, namely that coexpression reflects semantic proximity between the coexpressed meanings? Finally, in Section 5, we outline the growing influence of semantic maps to support the study of the diachronic evolution and synchronic distribution of language-specific grammatical and lexical items. Throughout the paper, we illustrate the different points based on a case-study in the semantic field of emotions, which we consider a methodological proof-of-concept.

3 The automatic inference of graph-structures and other issues with classical semantic maps

As appears from the discussion in Section 1, the main difference between a connectivity map and a proximity map is that the former is an *explanans* while the latter is an *explanandum* (Grossman and Polis 2012: 185). With a connectivity map,

6 https://journals.dartmouth.edu/cgi-bin/WebObjects/Journals.woa/1/xmlpage/1/issue/34

7 The invited speakers were Johan van der Auwera, William Croft, Alexandre François, Volker Gast, Maria Koptjevskaja-Tamm, Johann-Mattis List, Natalia Levshina, Silvia Luraghi, Andrej Malchukov, Tatiana Nikitina, Ekaterina Rakhilina, Darya Ryzhova, Martine Vanhove, and Jean Winand.

a semantic analysis necessarily precedes the construction of the map, which is meant to visualize specific semantic relationships (and hence implicational universals), while proximity maps are the point of departure of the study: the dimensions of variation must be interpreted and cannot be used to constraint the data in advance (Malchukov 2010: 177). As such, the two approaches are complementary rather than competing, as stressed by Croft (2022) and Levshina (2022).

However, proponents of the proximity maps have raised three serious objections against the classical type of maps. First, up until recently, these maps could not be generated automatically and were considered "not mathematically well-defined or computationally tractable, making it impossible to use with large and highly variable crosslinguistic datasets" (Croft and Poole 2008: 1). Second, "as the amount of data increases, vacuous maps become more and more widespread since frequent, rare and exceptional patterns will all be represented on the map" (Malchukov 2010: 176).[8] Finally, "the precise predictions that can be formulated on the basis of [an] implicational map are unclear," because it "predicts much more than is actually found" (Cysouw 2001: 609–610). In other words, the model is too strong for the data on which it is based and it over-generates possible constellations of meaning, favoring high coverage over high accuracy (e. g., Cysouw 2007: 234–235). New algorithms and tools that address most of these objections will be discussed below.

3.1 Solving the inference issue

The paper by Regier et al. (2013) was a real game-changer for the connectivity maps, as the authors demonstrated that the classical semantic map inference problem is "formally identical to another problem that superficially appears unrelated: inferring a social network from outbreaks of disease in a population" (Regier et al. 2013: 91). They claimed that although this problem was shown to be computationally intractable, "an efficient algorithm exists that approximates the optimal solution nearly as well as is theoretically possible" (Angluin et al. 2010). Regier et al. (2013) tested the algorithm on the cross-linguistic dataset of Haspelmath (1997a) and Levinson et al. (2003), and concluded that the approximations produced by the algorithm are of high quality: they produce equal or better results than manually plotted maps.

8 See the discussion in Georgakopoulos and Polis (2018: 13–14) for the different kinds of visualization used for representing frequency in classical semantic maps.

Table 1: Abstract form-meaning matrix.

	Meaning A	Meaning B	Meaning C	Meaning D
Form 1	1	1	0	0
Form 2	0	1	1	0
Form 3	1	1	0	1
Form 4	1	1	0	0
Form 5	0	1	1	1

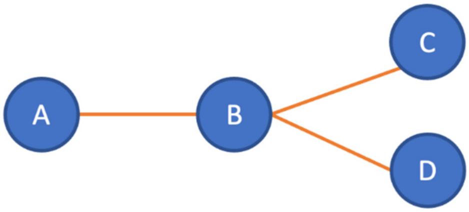

Figure 5: Connectivity map inferred from Table 1.

3.1.1 How does it work?

One starts with a set of nodes (the meanings) and a set of constraints (the linguistic patterns of coexpressions). The goal is to find the minimum number of edges between the nodes such that each pattern of coexpression will pick out a connected region of the graph (which is a way to rephrase the joint *connectivity hypothesis* and *economy principle*). In order to do so, the algorithm will progressively add the edges that satisfy the maximum number of constraints at the same time. We illustrate this principle with an abstract matrix containing four meanings and five patterns of coexpression (Table 1).[9] First, the algorithm takes into account the utility scores of the edges, i. e., the number of constraints that the edges satisfy when they are added to the graph. Before any edge is added to the graph, the utility score of each edge is as follows: 3 for A–B, 2 for B–C, 2 for B–D, 1 for A–D, 1 for C–D, and 0 for A–C. The algorithm will therefore first add an edge between A–B, with a utility score of 3, then an edge between B–C and between B–D, both with a utility score of 2.[10] At this point, the algorithm stops, because the graph is mini-

9 We are grateful to Bill Croft for discussion of these matters, which crucially clarified the distinction between the (dynamic) utility score and the (static) number of forms that coexpress each meaning. See the discussion in Croft (2022).

10 The order of addition of edges with the same utility score is arbitrary (Regier et al. 2013: 95, n. 2).

mally connected and accounts for all the coexpression patterns of Table 1, despite the fact that C and D, which are coexpressed by *Form 5*, are not connected by a specific edge. Indeed, this form already picks up a connected region of the map (C–B–D) and there is consequently no need to insert an additional edge.

3.1.2 Towards a semantic map of emotion predicates

Despite its demonstrated ability to infer connectivity maps based on large crosslinguistic dataset, this algorithm has not been used for actual case studies so far.[11] We therefore offer here an experiment on the semantic field of emotions, which has recently been investigated using colexification networks by Jackson et al. (2019).[12] We start the case-study with emotion predicates – emotion properties and entities will be considered later on – which were identified thanks to the Concepticon (List et al. 2020; https://concepticon.clld.org). We gathered the Concept sets belonging to the semantic field EMOTIONS AND VALUES and to the ontological category ACTION/PROCESS. This yielded a list of 23 potential meanings. We then collected all the lexical items in CLICS^3 that lexify at least one of these meanings, which gave 15201 forms. Among those, only 223 (1,47 %) express more than one meaning and can therefore be used to infer a connectivity map. In total, 19 meanings are coexpressed at least once: BOTHER (HARASS), CHOOSE, CRY, DARE, DISTURB, EMBRACE, FEAR (BE AFRAID), GROAN, HATE, HOPE, HOPE (SOMETHING), KISS, LAUGH, LIE (MISLEAD), LIKE, LOVE, PLAY, REGRET, SMILE, WANT.[13] Running the algorithm of Regier et al. (2013), we get the connectivity map of Figure 6, with 19 meanings connected by 29 edges.[14]

3.2 Enriching the inferred map

For the human eye, this map is certainly easier to interpret than a colexification network representing all the coexpression patterns pairwise, but it still fails to dis-

11 To the best of our knowledge, the only exceptions are Georgakopoulos and Polis (2021), Georgakopoulos et al. (2021), and Levshina (2022).

12 This choice allows us to compare our results with the colexification networks of this study and, for the sake of concision, to refer to its abundant literature and suggestive conclusions.

13 Four concepts are not colexified in the dataset and were therefore discarded: COMMEND, DARE, FORGIVE, URGE (SOMEONE). This a clear limitation of the method which does not allow to position on a map nodes that are never coexpressed.

14 All the maps that we discuss in this paper are visualized with Gephi (https://gephi.org), an open-source visualization and exploration software for graphs.

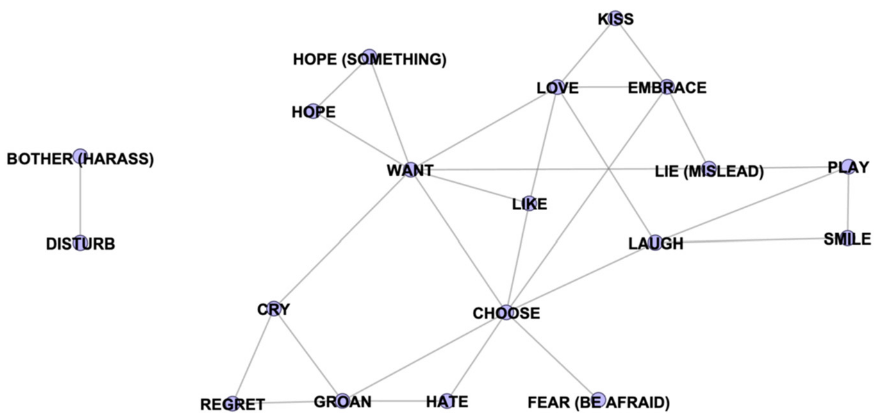

Figure 6: Semantic map of emotion predicates.

tinguish between frequent, rare, and exceptional patterns of coexpression – the second objection frequently raised against the classical maps. In order to address this issue, we adapted the algorithm of Regier et al. (2013) and weighted the edges of the graph based on their utility scores.[15] Furthermore, we used standard statistical methods in order to identify clusters of meanings as well as the importance of each node in the overall graph structure.[16]

Enriched with such information, five main groups of meaning clearly emerge in the graph (see Figure 7): the modules LOVE–LIKE–WANT (green), KISS–EMBRACE (orange), LAUGH–SMILE (blue), GROAN–CRY (purple), and the independent module DISTURB–BOTHER (dark green). Note that some nodes have a high centrality, like CHOOSE that is connected to 7 other nodes, but are scarcely coexpressed, and that some rare coexpression patterns in the dataset lead to connections between meanings that are unexpected from a semantic point of view. The link between CHOOSE and HATE, for instance, is based on two forms: *thuura* in Tigania (a dialect of Meru, a Bantu language of Kenya) and *kuthura* in Chuka (another Bantu variety of Northern Central Kenya). When checking the original data in the *Tanzania Language Survey*, one sees that these transcriptions actually correspond to different words (having respectively the meanings 'to hate, to spit', and 'to choose, to look for'), which CLICS^3 standardized as single forms. Such phenomena show

15 The python script is available as supplementary material (sm_weighted.py). Note that List et al. (2013) already systematically used weighted edges in their colexification networks.

16 Modularity analysis (with a resolution of 1.0) and eigenvector centrality (with 500 iterations) were computed with the tools built in Gephi (see fn. 14).

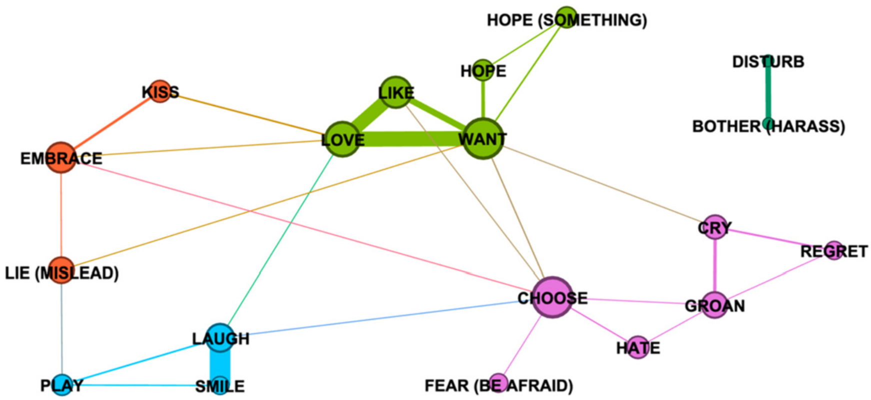

Figure 7: Semantic map of emotion predicates, with weighted edges, modularity analysis, and centrality of the nodes.

why weighted edges are of paramount importance for the method (see further Section 4.3).

Thanks to the weighted edges, one can indeed straightforwardly see which meanings are likely to be coexpressed (e. g., LAUGH–SMILE, 62; LOVE–WANT, 45; LIKE–LOVE, 40, LIKE–WANT, 17; etc.) and which are not. This is one of the big appeals of connectivity maps: they are intuitive, user-friendly (easy to read and interpret) and make predictions. However, unlike proximity maps, they do not tell which clusters of meanings are frequently coexpressed and which are not. For instance, Figure 7 shows that LOVE is frequently coexpressed with LIKE and WANT respectively, but does not tell us whether these three meanings are ever coexpressed by a single word in the dataset. Mapping actual forms on the map, like in Figure 4, is obviously possible, but it quickly leads to overcrowded maps that cannot be interpreted easily.[17]

3.3 Mapping linguistic items

This is where the *formal concept lattices*, first applied in lexical typology by Ryzhova and Obiedkov (2017), might prove to be directly helpful in parallel to connectivity maps (Georgakopoulos et al. 2021: § 3.1). In the context of semantic typology, a formal concept lattice can be understood as a set of words, a set of

17 Note that Levshina (2022) highlights the edges that connect the nodes which are coexpressed by language-specific causative constructions.

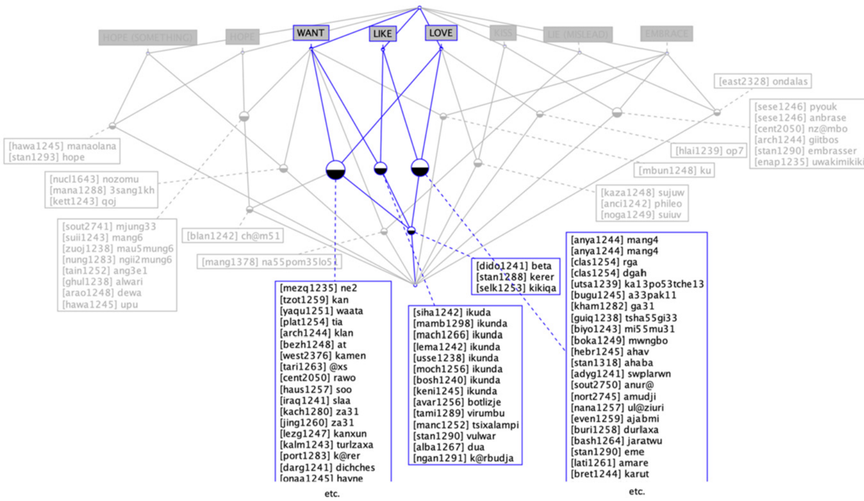

Figure 8: A formal concept lattice visualizing the patterns of coexpression for some verbs of emotion.

meanings, and binary relations which specify which words have which meanings. Figure 8 shows a formal concept analysis of the data corresponding to the clusters LOVE–LIKE–WANT (green) and KISS–EMBRACE (orange) of Figure 7.

This kind of lattice[18] fits the underlying data better than the standard graph-based maps, since no information is lost here in the process of building the lattice. In such a lattice, the meanings represented as grey labels are hierarchically structured and appear here on top (since they are colexified by at least two lexical items). The lexical items (in boxes) are mapped onto nodes of the lattice.[19] In terms of visual conventions, a black lower-half means that a lexical item is associated with the node, and the size of the node is proportional to the number of lexicalizations of a particular concept (ConExp Project 2006). Especially interesting is the fact that the meaning combinations attested in this semantic field are explicitly displayed. For instance, the blue lines in the lattice show that the meanings WANT, LIKE, and LOVE are frequently coexpressed pairwise, but that only three languages of the dataset (Spanish, Selkup, and Tsez) have lexical items expressing these three meanings with a single lexeme. Furthermore, one can easily compute implications (e. g., if HOPE and LOVE, then WANT). And finally, it is trivial to

18 The lattice is visualized with Concept Explorer (https://sourceforge.net/projects/conexp/).

19 The forms are preceded by Glottocodes in brackets.

observe that complex colexification patterns (i. e., patterns involving 3 meanings) are rare. However, the lattices do not conveniently visualize the relationships between the concepts, which points to the complementarity between connectivity maps and formal concept lattices.

4 Meanings and data collection: Is coexpression a trustworthy indicator of semantic relatedness?

In Section 3, for the sake of clarity while presenting new methods and tools, we ignored a series of basic issues pertaining to the identification and selection of discrete meanings, as well as to the collection of data in semantic typology (Evans 2010). These are addressed in this section, which concludes with an evaluation of the validity of the central underpinnings of the approach: is coexpression a good and trustworthy indicator of semantic relatedness?

4.1 Meaning identification and selection

Semantic maps of the classical type – and proximity maps organizing different meanings in a Euclidean space as well – presuppose the identification of atomic senses or semantic primitives. In a typological perspective, this process should ideally be the result of language description and comparison,[20] following the *analytical primitive* principle (Cysouw 2007; 2010). According to this principle, a node is an analytical primitive if it cannot be subdivided into two (or more) meanings based on a semantic contrast between two different forms in at least one language[21] (François 2008). François (2022) introduces the term *dislexification* (as opposed to colexification) in order to refer to this phenomenon with lexical items (see also Rakhilina et al. 2022). In practical terms, this means that a new node may be added to a map if and only if there is at least one language encoding this meaning in a different way than the other meanings already identified (Haspelmath 2003).

20 As opposed to a deductive approach to semantics, as found for instance in the influential studies of Wierzbicka (see, e. g., Wierzbicka 1992).

21 For a discussion of the structuralist foundations of this principle, see Cigana and Polis (2022).

The task is obviously quite painstaking, but Rakhilina et al. (2022) show that even in lexical typology, a combination of inductive language comparison and deductive semantic analysis leads to excellent results when a limited semantic field is investigated. Their approach involves the identification of situations/frames, which should be seen as "elements of a basic universal structure underlying every individual lexical system". Additionally, Levshina (2022), while analyzing different types of causative constructions, suggests a new avenue for identifying analytical primitives using crosslinguistic corpus data: based on a matrix encoding which language specific construction is used in which causative context, she clusters the contexts that are frequently coexpressed by the languages of the sample and, in a second step, she analyzes the clustered contexts and identifies the basic meaning of each of them. This new data-driven approach allows inferring the nodes of a map based on corpus data, as clusters of cross-linguistically regularly coexpressed contexts.

In practice, however, the analytical primitives are often not identified based on language comparison, by scrutinizing semantic nuances in order to assess the granularity and boundary location between meanings. As observed by Evans (2010: 510), "etically-based comparisons remain more tractable and widely used in semantic typology". Consequently, maps of grammatical items quite often assume the traditional grammatical categories to be valid comparative concepts (Haspelmath 2010; 2016), and lexical maps may rely on sets of concepts that are posited in advance, such as the ones found in the Concepticon (Section 3.1.2), with its obvious Eurocentric bias.

A less obvious bias in semantic map research is the fact that one usually focuses on meanings belonging to a specific semantic field, to the exclusion of others (but see Urban 2012). This is of course perfectly legitimate from a practical point of view, but this limitation has a direct influence on the resulting map. In the maps of Figures 6–7, for instance, we limited the investigation to emotional predicates.[22] However, it is expected that other meanings might play a pivotal role in this semantic field:[23] senses that are frequently coexpressed with emotion predicates provide important information about the general structure of this semantic field (they may for example indirectly connect two emotion concepts). In order to address this problem, one can add a semasiological step to the onomasiological

22 Similarly, in Georgakopoulos and Polis (2021), we limited the study to meanings belonging to the semantic field of time and in Georgakopoulos et al. (2021), to meanings belonging to that of perception and cognition.

23 See the observations in the supplementary material of Jackson et al. (2019) about second- and third-order colexifications (https://science.sciencemag.org/content/sci/suppl/2019/12/18/366.6472.1517.DC1/aaw8160-Jackson-SM.pdf).

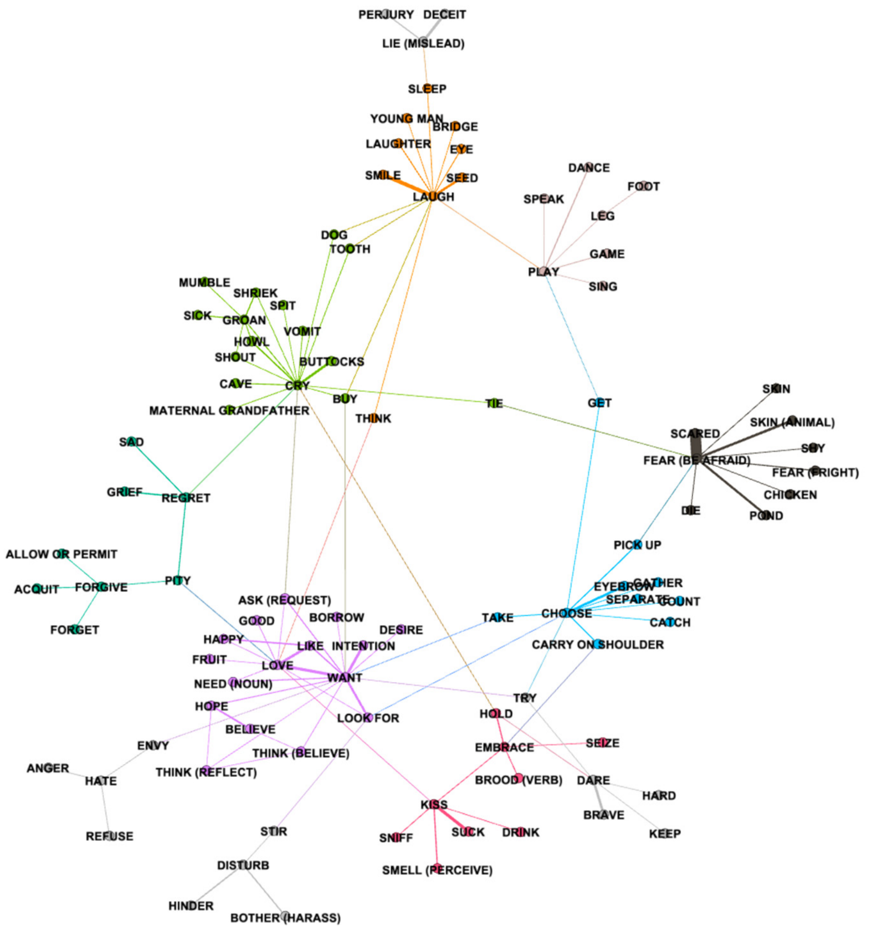

Figure 9: An enriched semantic map of emotion predicates.

procedure described in Section 3.1.2, and take into consideration all the meanings expressed by the forms lexifying at least one emotional predicate.[24]

Practically speaking, in order to plot the map of Figure 9, we followed the method described above (Sections 3.1–3.2), but added one step: having collected all the forms that lexify at least one of the 23 emotion predicates in CLICS^3 (15201 forms), we created a matrix for all the senses expressed by these forms (and not

24 See the method followed by Youn et al. (2016: 2) when constructing a semantic network from translations. As stressed by Croft (2022), the process is recursive, but needs to stop somewhere. Hence, the structure of the network is necessarily incomplete.

just for the emotion concepts). In total, 955 meanings are lexified by these forms. In order to reduce the complexity of the data, we got rid of the meanings that are coexpressed less than five times in total. This led to a total of 121 meanings for 2196 different forms. The inference algorithm of Regier et al. (2013) computed that 324 edges were needed to ensure that the connectivity hypothesis is respected for all the lexical items. Finally, we used the weighted edges in order to visualize only the meanings that are colexified by 3 forms or more in the dataset.

A comparison with Figure 7 shows how much richer the map of Figure 9 is. Crucially, this map displays many coexpressed emotion concepts that are not processes or actions, but rather entities (nouns) or properties (adjectives), and which should be taken into account in order to get a complete picture of this semantic field (see Section 4.3).

4.2 Influence of the quantity of data on the maps and their universality

According to Haspelmath (2003: 217), "[e]xperience shows that it is generally sufficient to look at a dozen genealogically diverse languages to arrive at a stable map that does not undergo significant changes as more languages are considered. Of course, any new language can immediately falsify a map and require a revision, but the map method allows us to generate interesting hypotheses fairly soon." While this might be true for the grammatical functions that he investigated, several papers point to the fact that data collection may have a strong impact on the resulting map and lead to substantial changes. Levshina (2022), for instance, explicitly states that "[t]he idea that both parallel corpora and descriptive grammars only represent doculects (documented lects) (Cysouw and Good 2013), rather than languages as such, is particularly important", and she adds: "[f]rom all this follows that one should be extremely careful when trying to interpret a semantic map as representing some universal conceptual space. A universal space presupposes the same dimensions. However, we have seen that they may differ substantially depending on the type of data." It is indeed quite certain that restricting typological research to some text types or to a few languages would result in overlooking interesting (even if infrequent) connections between meanings (Narrog and Ito 2007: 276) or in missing linguistic and cultural associations that are specific to geographical regions or areas (Georgakopoulos et al. 2021). One important future area of research for the semantic maps method is therefore to test the role of contact/areality and inheritance and to evaluate how widely the maps plotted based on different areally and genealogically stratified samples (with the caveat of Bickel 2015) differ from one another. This would allow assessing the relative

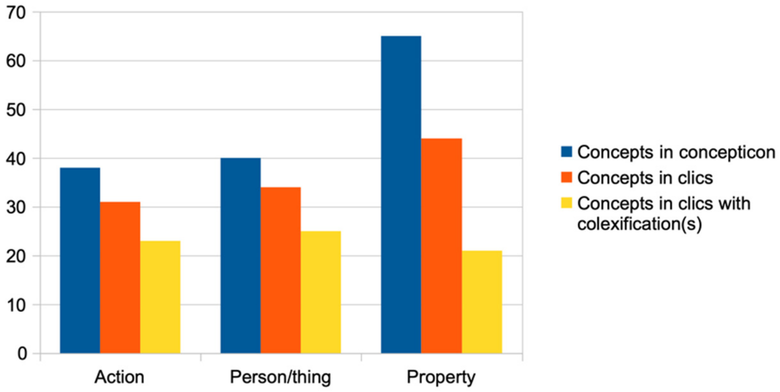

Figure 10: The emotion concepts in the Concepticon and CLICS^3.

contributions of inheritance, language contact, and inherent semantics (see Section 4.3).

A related issue is the quantity of information that one can gather about coexpression patterns in general. Grammatical functions are usually well described in grammars and, as such, they are readily available for studies focusing on cross-linguistic polysemies of grammatical morphemes. Available typological data about the polysemy patterns of lexical items might not be as rich and forthcoming. In order to evaluate this point, we can go back to CLICS^3 and continue the experiment with emotion concepts. If we consider the semantic field of emotions as a whole, including not only the ontological category actions/processes, but also the entities and properties (as suggested in Section 4.1), we observe that, from the 143 concepts in the Concepticon, 109 are available in CLICS^3, but only 69 of them are coexpressed at least once and can therefore be used in order to plot semantic maps.

Among the 3156 linguistic varieties, there are only 1262 lexical items that coexpress more than one of these 69 meaning, which shows that the quantity of data one needs to collect in order to build lexical semantic maps is very high. To some extent, this situation is of course the result of the way data have been aggregated for CLICS^3. One can take a single but telling example to illustrate this point. An important source of CLICS^3 is the *Intercontinental Dictionary Series* (IDS; Key and Comrie 2015). This exceptional resource has not been created to record the polysemy of lexical items: contributors have the possibility to mention more than one lexeme for each of the up to 1308 concepts, but they are not supposed to investigate their polysemy nor to look for different contextual meanings. The IDS therefore contains only the most prototypical lexemes for each meaning, and in-depth studies would definitely reveal much larger polysemy patterns for many lexemes. Correlatively, since the sources of CLICS^3 were not created with the intention of studying coexpression patterns, chances are great that the strict colexification patterns that surface in this database are well-entrenched in the respective languages.

4.3 The coexpression assumption

Cristofaro (2010), Malchukov (2010), van der Auwera (2013), and Croft (2022) – to name but a few – pointed out a series of reasons accounting for coexpression in linguistic systems without semantic similarity: simple homonymy, markedness (and frequency) effects of different kinds (e. g., inflectional syncretisms), language contact situations (e. g., with borrowing of particular or construction-specific meanings; cf. Grossman and Polis 2017), and different processes of semantic change. Two main approaches can be envisioned to avoid these biases. The first, a qualitative approach, which will focus on the study of the language history, is certainly the best option, but historical data are lacking for the vast majority of languages. A quantitative approach to the problem, on the other hand, will simply try to somehow eliminate the less frequent coexpression patterns, in order to simplify the model, limit vacuity in the map, and make it more useful for formulating semantic implicational universals. This is what necessarily happens when visualizing proximity maps, since one can only display two dimensions of variation at a time (and linguists rarely display more than one Euclidean space; see Figure 3). With connectivity maps, one can use the weighted edges, introduced in Section 3.2, in order to get rid of the less frequent coexpression patterns. This is what we did in Figure 9 (visualization of the edges with weight equal or superior to three), but one should now analyze more carefully the consequence of such a simplification.

In order to do so, we took as a point of departure the 69 meanings belonging to the semantic field of emotion in the Concepticon (Section 4.2). As mentioned above, in total 1262 forms in CLICS^3 coexpress two or more meanings in this semantic field; 65 of these 69 meanings are coexpressed by at least one form in CLICS^3 and can be used for plotting a map with Regier's et al. (2013) algorithm.[25] We obtain a graph structure with 65 nodes connected by 160 edges (Figure 11a).

25 Complete list of meanings: ANGER, ANXIETY, BAD, BAD LUCK, BEAUTIFUL, BLAME, BOTHER (HARASS), BRAVE, CHOOSE, CLEVER, COMMEND, CORRECT (RIGHT), CRY, DANGER, DARE, DEAR, DECEIT, DISTURB, EMBRACE, ENVY, EVIL, FAITHFUL, FAULT, FEAR (BE AFRAID), FEAR (FRIGHT), FORGIVE,

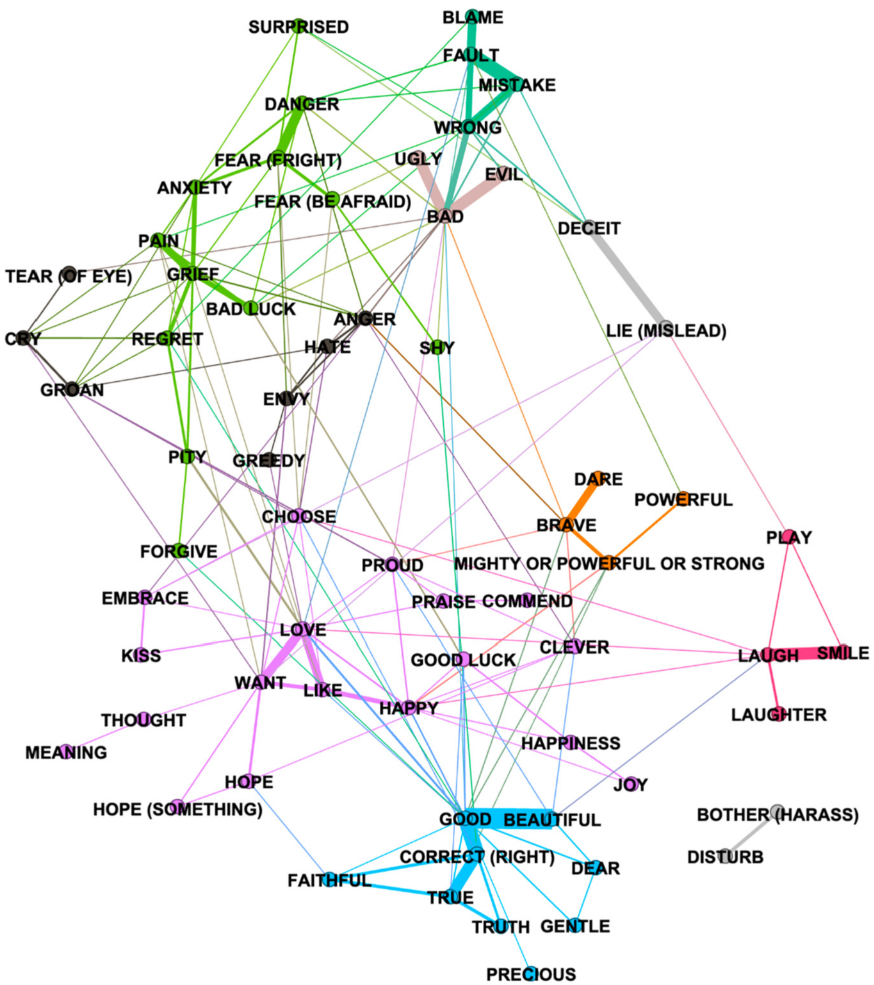

Figure 11a: A semantic map of emotions.

Much like a colexification network, however, this graph is a bit too crowded to be readily interpretable by the human eye. In order to limit the noise resulting from rare coexpression patterns that might not reflect semantic similarity (but

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GENTLE, GOOD, GOOD LUCK, GREEDY, GRIEF, GROAN, HAPPINESS, HAPPY, HATE, HOPE, HOPE (SOMETHING), JOY, KISS, LAUGH, LAUGHTER, LIE (MISLEAD), LIKE, LOVE, MEANING, MIGHTY OR POWERFUL OR STRONG, MISTAKE, PAIN, PITY, PLAY, POWERFUL, PRAISE, PRECIOUS, PROUD, REGRET, SHY, SMILE, SURPRISED, TEAR (OF EYE), THOUGHT, TRUE, TRUTH, UGLY, WANT, WRONG. Note that BOTHER (HARASS) and DISTURB are not colexified with other meanings (see already in Figure 7).

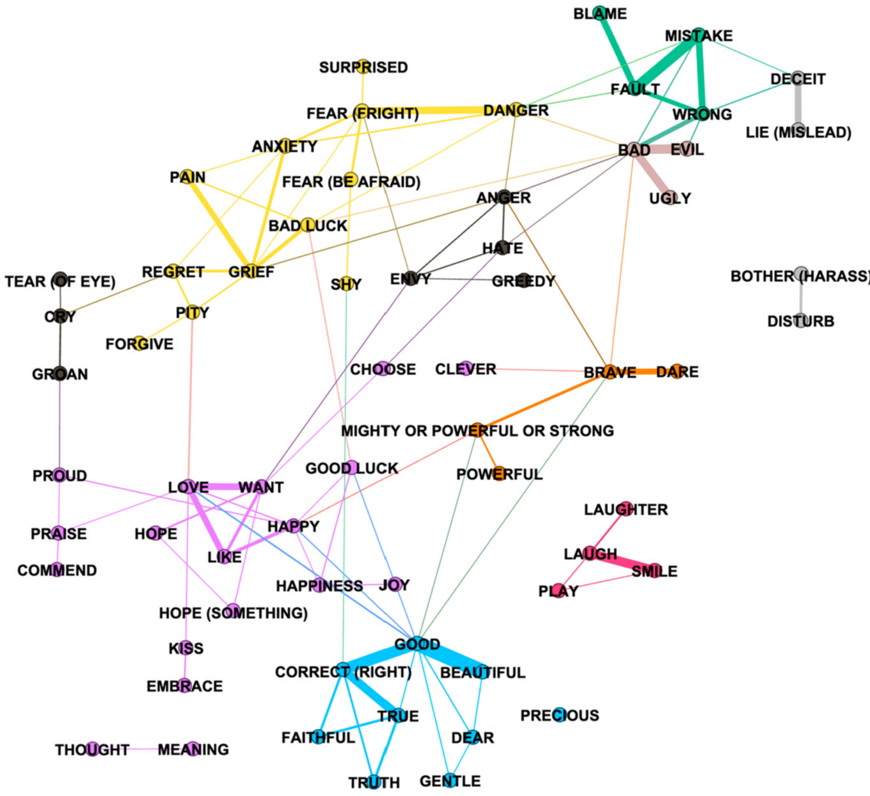

Figure 11b: A semantic map of emotions (with edge of weight 2 and more).

homonymy or other processes of language change), one can get rid of the 67 edges that have a utility score of 1, which leads to Figure 11b.

This map is assuredly easier to interpret and makes much stronger predictions, while retaining a goodness of fit of 95 %,[26] which means that only 5 % of the coexpressions found in the dataset would falsify this map. This obviously comes at a price, since some (clusters of) meanings previously connected to the map (PRECIOUS, MEANING–THOUGHT, LAUGH–LAUGHTER–PLAY–SMILE) are now disconnected from the main graph structure. Interestingly, however, using a purely

26 The global complexity of the graph is 1355 and 67 edges with weight 1 are ignored. As Croft (2022) puts it: "[g]oodness of fit allows us to get an idea of the tradeoff between how much of the cross-linguistic data our representational model captures, and how useful the model is for inferring conceptual similarity/relations, the phenomenon we are most interested in explaining with the coexpression data."

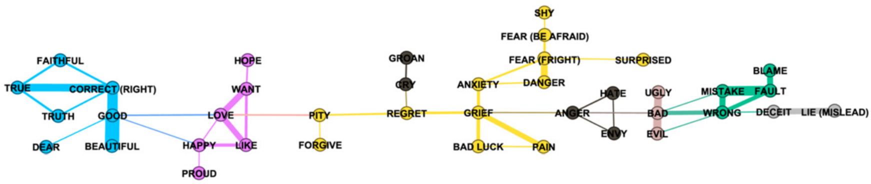

Figure 11c: A semantic map of emotions (with edge of weight 4 and more).

inductive procedure based on coexpression patterns – which means that there is no semantic analysis whatsoever involved in the process of creating this map – we observe 8 main clusters of nodes that makes intuitive sense, at least from the point of view of speakers of some European languages: GOOD & TRUE, LOVE & HAPPINESS, BRAVE & POWERFUL, GRIEF, ANXIETY & FEAR, HATE & ANGER, BAD & UGLY, MISTAKE & WRONG. In our view, this can be considered as a data-driven demonstration that the basic assumption of semantic maps is valid: coexpression patterns do most often reflect semantic similarity.

In order to conclude this case-study on emotions, one can go one step further in the generalization process, and consider only the patterns that are attested more than three times in the dataset (goodness of fit = 89 %). As a consequence, the model is linearized and displays a continuum of emotions – empirically supported by coexpression patterns in the languages of the world – that goes from TRUE–CORRECT–GOOD to BAD–WRONG–LIE (see Figure 11c).

We think that such generalizations would not be possible without the automatic inference of semantic maps based on large-scale datasets and that they have possible applications and consequences far beyond the field of linguistics (such as in psychology and cognitive sciences; see Jackson et al. 2019).

5 Semantic maps in synchrony and diachrony: A method for supporting language-specific descriptions and reconstructions

The discussion so far has shown that semantic maps are an efficient method for suggesting semantic language universals. But this typological tool is also directly relevant for language-specific studies, even if this might not be directly obvious given its primarily cross-linguistic orientation. There are indeed several scenarios for language-internal studies using semantic maps. In these scenarios, cross-linguistic comparison is there, albeit in the background. First, the data from one language can be evaluated against an existing semantic map (e. g., Vanhove 2022). In such cases, the semantic map helps structuring the semantic description of a polysemic item in synchrony and suggests possible diachronic pathways of evolution (see below). In addition, data from a single language can falsify the map and lead to a better understanding of the relationships between meanings (e. g., Grossman and Polis 2012). A second scenario involves the construction of a semantic map on the basis of a limited language sample. As Nikitina (2022) shows, a small-scale comparison can reveal semantic information that may go unnoticed otherwise. In her words, "[l]anguage-internal evidence can occasionally be used to compensate for the missing evidence from large-scale typological sampling." Third, one can enrich an existing semantic map with information about pathways of change. In this case, there is again a typological foundation, and the diachronic data from a particular language are used to dynamicize the synchronic map (van der Auwera 2013). The nature of the diachronic data may vary: the material can consist of attested evolutionary paths, reconstructions, or both.

As appears from the above, such language internal studies can be both synchronic and diachronic. Interestingly, although the role of diachrony in the method has been highlighted since its very beginning (Anderson 1982), semantic change has generally been neglected. It would be inaccurate to state that diachronic studies using the semantic map method are absent,[27] but in research with diachronic orientation, there is a general bias towards the study of the grammatical domain. That is, the situation of the field in synchrony (see Section 4.2) is echoed in diachrony. If the identification of cross-linguistically regularities of semantic extension in the lexicon has been a prominent theme over the last two decades,[28] semantic maps have scarcely been used for capturing graphically the way in which semantic changes take place. A notable exception is Urban (2012), who investigates semantic patterns in the lexicon with a focus on referring expressions, while simultaneously discussing the mechanisms explaining the connections between the meanings within certain semantic domains (e. g., artifacts, body parts and body liquids, phases of the day, etc.).[29] What is common in the majority of the aforementioned studies is the stance that they take towards polysemy in synchrony and its relation to semantic change: they are viewed as

27 For a list, see Georgakopoulos and Polis (2018: 21).

28 See, e. g., Matisoff (1978) for body parts in Tibeto-Burman; Sweetser (1990), Evans and Wilkins (2000) on meaning extensions within the domains of perception and cognition; Evans (1992), Wilkins (1996) for semantic reconstructions in various Australian languages.

29 Note that the adjacency networks of lexico-semantic associations employed in his study might be seen as an effort to combine proximity maps with classical maps.

two sides of the same coin (see also Blank 1997; Geeraerts 1997). As such, synchronic polysemies provide us with information about semantic evolution in action and can even help us predict potential diachronic pathways (Dellert 2016). The inference of diachronic information from synchronic polysemies represents a very promising future avenue of research.

The identification of meaning associations in synchrony is also the first step of the protocol for plotting lexical diachronic semantic maps developed by Georgakopoulos and Polis (2021). This first step is based on large-scale cross-linguistic data and leads to the construction of a synchronic semantic map. The integration of the diachronic dimension within the map, on the other hand, is based exclusively on the semantic evolution of individual lexemes, as attested in historical corpora. To differentiate between (cross-linguistic) synchronic and (language specific) diachronic coexpression patterns, we use different representational conventions in the maps. Furthermore, we distinguish between different kinds of relationships between meanings and different degrees of conventionalization for meaning extensions, concluding that "network visualizations are not just a convenient way of displaying the results, but support the in-depth diachronic semantic analysis in an instrumental and meaningful way."

Because diachronic analyses may inform synchronic ones (e. g., Gil 2017), more studies are needed that will highlight the role of diachrony in the model, both concerning grammar and the lexicon. A step in this direction has been taken by François (2022), who analyses lexification patterns in diachrony, envisioning lexical change as the reconfiguration of sense clusters in a semantic space. He identifies five types of structural innovations in the lexicon: merger, split, competition, shift, and relexification. As far as the grammar is concerned, Vanhove (2022) highlights one additional aspect of diachronic semantic maps: they are useful because they help us "understand the semantic shifts that occurred in the grammar of unwritten languages with no recorded history."

Future research in the field will certainly revisit the questions of directionalities within synchronic, diachronic, and panchronic semantic maps, identify possible mismatches between diachronic semantic extension and synchronic polysemy patterns, report on unexpected directionalities of change, and discuss cases of violations of the connectivity hypothesis.

6 Conclusions

As can be seen, the contributions to this special issue address a series of fundamental issues regarding semantic map methods that have surfaced during the past three decades: (1) the validity of the basic assumption, namely to what extent does coexpression reflect semantic similarity; (2) the problem of identifying semantic analytical primitives; (3) the source of the data – parallel corpora, grammars and dictionaries, questionnaires, recordings – and their influence on the resulting maps; (4) the methods of inference used for creating coexpression maps and the representation techniques (graph structure vs. Euclidean space) as well as their respective merits (including the goodness of fit of the models); (5) the relationships between semantic maps and other types of linguistic hierarchies; and (6) the use of semantic maps to support synchronic and diachronic descriptions of individual languages.

Prominent in most contributions is also the observation that the existing representational conventions used for semantic maps do not always suffice to visualize the generalizations emerging from the cross-linguistic data. As a result, several studies in this volume try to visually capture pieces of information that are usually not taken into consideration. Nikitina (2022), for example, uses dotted lines for meanings that are highly lexicalized or obsolete; and in Becker and Malchukov (2022), arrows on the maps indicate "relative naturalness or unmarkedness."

In several cases, these visualization "problems" relate to theoretical or methodological issues. For Rakhilina et al. (2022), for instance, figurative meanings would require the visualization of an extra dimension, which would reflect the transition from physical to abstract meanings. They argue that these two types of meanings should not be plotted together on semantic maps: "the main semantic map should display only the direct meanings, while their derivational potential could be depicted, for example, as chainlike radial flowcharts arranged individually for each frame or group of frames." In the field of diachrony, the studies by Andrason (e. g., Andrason 2016 and 2019b) are another illustration of the intertwined representational and theoretical dimensions. His 'waves and streams' model is indeed a way to enrich traditional (qualitative) semantic maps with quantitative data and, crucially, with information about the gram environment.

The integration of the said environment, or more broadly context of use, into semantic maps could be seen as one of the main challenges for future research in the field,[30] reuniting the grammatical and the lexical dimensions that have

30 Cf. those models of semantic change that work on a single language, study meaning based on a corpus and look for correlations between frequency and semantic change (Dubossarsky et al. 2015; Hamilton et al. 2016; Kutuzov et al. 2018; Tang 2018). In these models, meanings are inferred from the context of occurrence and the resulting representation is typically a 2-d projection of a high-dimensional vector, in which words are considered to be closer or farther based on meaning.

been, so far, largely kept apart. There are clear signs that the field is moving towards a unified lexico-grammatical or constructional approach (Traugott 2016), acknowledging the different levels of linguistics signification. The contribution by Koptjevskaja-Tamm (2022) demonstrates the feasibility and results of such an endeavor, by articulating explicitly how the interaction between lexicon and grammar can be captured and represented. She introduces a multilayer model of semantic maps, which takes into account the morphosyntactic properties of the linguistic items and the influence of the constructions in which they occur. Such maps are very detailed, and the future will tell how they can be used for the cross-linguistic comparisons (and ensuing generalizations) of broader semantic fields.

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References

Anderson, Lloyd B. 1982. The “perfect” as a universal and as a language-particular category. In Paul J. Hopper (ed.), *Tense-aspect: Between semantics & pragmatics* (Typological Studies in Language 1), 227–264. Amsterdam: Benjamins.

Anderson, Lloyd B. 1986. Evidentials, paths of change, and mental maps: Typologically regular asymmetries. In Wallace Chafe & Johanna Nichols (eds.), *Evidentiality: The linguistic encoding of epistemology*, 273–312. Norwood, NJ: Ablex.

Andrason, Alexander. 2016. From vectors to waves and streams: an alternative approach to semantic maps. *Stellenbosch Papers in Linguistics* 45. 1–29.

Andrason, Alexander. 2019a. The conjunctive coordinator NA in Xhosa – Its categorial status and map of polyfunctionality. *Italian Journal of Linguistics* 31(1). 3–60.

Andrason, Alexander. 2019b. The map of *ti* in Kituba – Testing and expanding the typological model of the polysemy of conjunctive coordinators. *Studies in African Linguistics* 48(1). 85–123.

Andrason, Alexander. 2020. Verifying the semantic maps of adversative-contrastive markers: Evidence from Polish. *Slavia* 89(1). 1–42.

Angluin, Dana, James Aspnes & Lev Reyzin. 2010. Inferring social networks from outbreaks. In Marcus Hutter, Frank Stephan, Vladimir Vovk & Thomas Zeugmann (eds.), *Algorithmic Learning Theory. 21st International Conference, ALT 2010, Canberra, Australia, Proceedings*, 104–118. Berlin: Springer.

Becker, Laura & Andrej L. Malchukov 2022. Semantic maps and typological hierarchies: Evidence for the Actionality Hierarchy. *Zeitschrift für Sprachwissenschaft* 41(1). 31–66.
Bickel, Balthasar. 2015. Distributional typology: Statistical inquiries into the dynamics of linguistic diversity. In Bernd Heine & Heiko Narrog (eds.), *The Oxford handbook of linguistic analysis*, 2nd edn. 901–923. Oxford: Oxford University Press.
Blank, Andreas. 1997. *Prinzipien des lexikalischen Bedeutungswandels am Beispiel der romanischen Sprachen*. Tübingen: Niemeyer.
Bybee, Joan L., William Pagliuca & Revere Dale Perkins. 1994. *The evolution of grammar. Tense, aspect and modality in the languages of the world*. Chicago, IL: The University of Chicago Press.
Cigana, Lorenzo & Stéphane Polis. 2022. Hjelmslev, a forerunner of the semantic maps method in linguistic typology? In Camiel Hamans (ed.), *History of linguistics and its significance* (Selected papers from the workshop held at the International Congress of Linguists, 2–6 July 2018). Delaware: Vernon Press. To appear.
ConExp Project. 2006. The concept explorer. http://conexp.sourceforge.net/users/documentation/index.html (26 April 2021).
Cristofaro, Sonia. 2010. Semantic maps and mental representation. *Linguistic Discovery* 8(1). 35–52. https://doi.org/10.1349/ps1.1537-0852.a.345.
Cristofaro, Sonia & Fernando Zúñiga (eds.). 2018. *Typological hierarchies in synchrony and diachrony* (Typological Studies in Language 121). Amsterdam: Benjamins.
Croft, William. 2001. *Radical construction grammar: Syntactic theory in typological perspective*. Oxford: Oxford University Press.
Croft, William. 2003. *Typology and universals*. 2nd edn. Cambridge: Cambridge University Press.
Croft, William. 2022. On two mathematical representations for "semantic maps". *Zeitschrift für Sprachwissenschaft* 41(1). 67–87.
Croft, William & Keith T. Poole. 2008. Inferring universals from grammatical variation: multidimensional scaling for typological analysis. *Theoretical Linguistics* 34. 1–37.
Cysouw, Michael. 2001. Review of Indefinite Pronouns by Martin Haspelmath. *Journal of Linguistics* 37(3). 99–114.
Cysouw, Michael. 2007. Building semantic maps: The case of person marking. In Bernhard Wälchli and Matti Miestamo (eds.), *New challenges in typology*, 225–248. Berlin & New York: Mouton de Gruyter.
Cysouw, Michael. 2010. Semantic maps as metrics on meanings. *Linguistic Discovery* 8(1). 70–95. https://doi.org/10.1349/ps1.1537-0852.a.346.
Cysouw, Michael & Jeff Good. 2013. Languoid, doculect, glossonym: Formalizing the notion 'language'. *Language Documentation & Conservation* 7. 33–360.
Cysouw, Michael, Martin Haspelmath & Andrej Malchukov. 2010. Introduction to the Special Issue: "Semantic maps: Methods and applications". *Linguistic Discovery* 8(1). 1–3. https://doi.org/10.1349/ps1.1537-0852.a.358.
Dellert, Johannes. 2016. Using causal inference to detect directional tendencies in semantic evolution. In Seán Roberts, Christine Cuskley, Luke McCrohon, Lluís Barceló-Coblijn, Olga Feher & Tessa Verhoef (eds.), *The evolution of language: Proceedings of the 11th International Conference (EVOLANG11)*. Available at http://evolang.org/neworleans/papers/139.html.
Dubossarsky, Haim, Yulia Tsvetkov, Chris Dyer & Eitan Grossman. 2015. A bottom up approach to category mapping and meaning change. In Vito Pirrelli, Claudia Marzi & Marcello Ferro

(eds.), *Word structure and word usage. Proceedings of the NetWordS Final Conference*, 66–70. Pisa: Institute for Computational Linguistics.
Evans, Nicholas. 1992. Multiple semiotic systems, hyperpolysemy, and the reconstruction of semantic change in Australian languages. In Günter Kellermann & Michael D. Morrissey (eds.), *Diachrony within synchrony: Language, history, and cognition*, 475–508. Frankfurt: Peter Lang.
Evans, Nicholas 2010. Semantic typology. In Jae Jung Song (ed.), *The Oxford handbook of linguistic typology*, 504–533. Oxford: Oxford University Press.
Evans, Nicholas & David Wilkins. 2000. In the mind's ear: The semantic extension of perception verbs in Australian languages. *Language* 76. 546–592. https://doi.org/10.2307/417135.
François, Alexandre. 2008. Semantic maps and the typology of colexification: Intertwining polysemous networks across languages. In Martine Vanhove (ed.), *From polysemy to semantic change: Towards a typology of lexical semantic associations* (Studies in Language Companion Series 106), 163–215. Amsterdam: Benjamins.
François, Alexandre. 2022. Lexical tectonics: Mapping structural change in patterns of lexification. *Zeitschrift für Sprachwissenschaft* 41(1). 89–123.
Geeraerts, Dirk. 1997. *Diachronic prototype semantics: A contribution to historical lexicology*. Oxford: Clarendon Press.
Georgakopoulos, Thanasis. 2019. Semantic maps. *Oxford Bibliographies in Linguistics*. https://doi.org/10.1093/OBO/9780199772810-0229.
Georgakopoulos, Thanasis & Stéphane Polis. 2018. The semantic map model: State of the art and future avenues for linguistic research. *Language and Linguistics Compass* 12(2). e12270. https://doi.org/10.1111/lnc3.12270.
Georgakopoulos Thanasis & Stéphane Polis. 2021. Lexical diachronic semantic maps. The diachrony of time-related lexemes. *Journal of Historical Linguistics* 11(3). 367–420.
Georgakopoulos Thanasis, Eitan Grossman, Dmitry Nikolaev & Stéphane Polis. 2021. Universal and macro-areal patterns in the lexicon: A case-study in the perception-cognition domain. *Linguistic Typology*. https://doi.org/10.1515/lingty-2021-2088.
Gil, David. 2017. Roon *ve*, DO/GIVE coexpression, and language contact in Northwest New Guinea. *NUSA: Linguistic Studies of Languages in and around Indonesia* 62. 41–100.
Grossman, Eitan & Stéphane Polis. 2012. Navigating polyfunctionality in the lexicon. Semantic maps and Ancient Egyptian lexical semantics. In Eitan Grossman, Stéphane Polis & Jean Winand (eds.), *Lexical semantics in Ancient Egyptian* (Lingua Aegyptia Studia Monographica 9), 175–225. Hamburg: Widmaier.
Grossman, Eitan & Stéphane Polis. 2017. Polysemy networks in language contact: The borrowing of the Greek-origin preposition κατά/kata in Coptic. In Eitan Grossman, Peter Dils, Tonio Sebastian Richter & Wolfgang Schenkel (eds.), *Greek influence on Egyptian-Coptic: Contact-induced change in an ancient African language*, 335–367. Hamburg: Widmaier.
Haiman, John. 1974. Concessives, conditionals, and verbs of volition. *Foundations of Language* 11. 341–359.
Haiman, John. 1985. *Natural syntax. Iconicity and erosion*. Cambridge: Cambridge University Press.
Hamilton, William L., Jure Leskovec & Dan Jurafsky. 2016. Cultural shift or linguistic drift? Comparing two computational measures of semantic change. In Jian Su, Kevin Duh & Xavier Carreras (eds.), *Proceedings of the 2016 Conference on Empirical Methods in Natural Language Processing*, 2116–2121. Austin, TX: Association for Computational

Linguistics.
Hartmann, Iren, Martin Haspelmath & Michael Cysouw. 2014. Identifying semantic role clusters and alignment types via microrole coexpression tendencies. *Studies in Language* 38. 463–484.
Haspelmath, Martin. 1997a. *Indefinite pronouns*. Oxford: Oxford University Press.
Haspelmath, Martin. 1997b. *From space to time: Temporal adverbials in the world's languages*. München: Lincom Europa.
Haspelmath, Martin. 2003. The geometry of grammatical meaning: Semantic maps and cross-linguistic comparison. In Michael Tomasello (ed.), *The new psychology of language*. Vol. 2, 211–243. Mahwah, NJ: Lawrence Erlbaum.
Haspelmath, Martin. 2010. Comparative concepts and descriptive categories in crosslinguistic studies. *Language* 86(3). 663–687. https://doi.org/10.1353/lan.2010.0021.
Haspelmath, Martin. 2016. The challenge of making language description and comparison mutually beneficial. *Linguistic Typology* 20(2). 299–303. https://doi.org/10.1515/lingty-2016-0008.
Jackson, Joshua Conrad, Joseph Watts, Teague R. Henry, Johann-Mattis List, Robert Forkel, Peter J. Mucha, Simon J. Greenhill, Russell D. Gray & Kristen A. Lindquist. 2019. Emotion semantics show both cultural variation and universal structure. *Science* 366(6472). 1517–1522. https://doi.org/10.1126/science.aaw8160.
Key, Mary Ritchie & Bernard Comrie (eds.). 2015. *The intercontinental dictionary series*. Leipzig: Max Planck Institute for Evolutionary Anthropology. http://ids.clld.org (26 April 2021).
Koptjevskaja-Tamm, Maria. 2022. Semantic maps and temperature: Capturing the lexicon-grammar interface across languages. *Zeitschrift für Sprachwissenschaft* 41(1). 125–177.
Kutuzov, Andrey, Lilja Øvrelid, Terrence Szymanski & Erik Velldal. 2018. Diachronic word embeddings and semantic shifts: A survey. In Emily M. Bender, Leon Derczynski & Pierre Isabelle (eds.), *Proceedings of the 22th International Conference on Computational Linguistics (COLING 2018)*, 1384–1397. Santa Fe, NM: Association for Computational Linguistics.
Levinson, Stephen C., Sérgio Meira & the Language and Cognition Group. 2003. Natural concepts in the spatial topological domain—adpositional meanings in crosslinguistic perspective: An exercise in semantic typology. *Language* 79. 485–516.
Levshina, Natalia. 2022. Semantic maps of causation: New hybrid approaches based on corpora and grammar descriptions. *Zeitschrift für Sprachwissenschaft* 41(1). 179–205.
List, Johann-Mattis, Christoph Rzymski, Simon Greenhill, Nathanael Schweikhard, Kristina Pianykh, Annika Tjuka, Mei-Shin Wu, Carolin Hundt, Tiago Tresoldi & Robert Forkel (eds.). 2020. Concepticon v2.4.0. *A resource for the linking of concept lists*. Jena: Max Planck Institute for the Science of Human History. http://concepticon.clld.org (22 April 2021).
List, Johann-Mattis, Anselm Terhalle & Matthias Urban. 2013. Using network approaches to enhance the analysis of cross-linguistic polysemies. In Alexander Koller & Katrin Erk (eds.), *Proceedings of the 10th international conference on computational semantics (IWCS 2013) – Short Papers*, 347– 353. Stroudsburg, PA: Association for Computational Linguistics.
Majid, Asifa, Melissa Bowerman, Miriam van Staden & James S. Boster. 2007. The semantics of "cutting and breaking" events: A cross-linguistic perspective. *Cognitive Linguistics* 18(2). 133–152.
Malchukov, Andrej L. 2010. Analyzing semantic maps: A multifactorial approach. *Linguistic*

Discovery 8(1). 176–198. https://doi.org/10.1349/ps1.1537-0852.a.350.
Matisoff, James A. 1978. *Variational semantics in Tibeto-Burman* (Occasional Papers of the Wolfenden Society on Tibeto-Burman Linguistics VI). Philadelphia, PA: Institute for the Study of Human Issues.
Narrog, Heiko & Johan van der Auwera. 2011. Grammaticalization and semantic maps. In Heiko Narrog & Bernd Heine (eds.), *The Oxford handbook of grammaticalization*, 318–327. Oxford: Oxford University Press.
Narrog, Heiko & Shinya Ito. 2007. Re-constructing semantic maps: The comitative-instrumental area. *STUF – Language Typology and Universals* 60(4). 273–292.
Nikitina, Tatjana. 2022. Building semantic maps for closely related languages: Words for 'grain' and their kin in South Mande. *Zeitschrift für Sprachwissenschaft* 41(1). 207–230.
Regier, Terry, Naveen Khetarpal & Asifa Majid. 2013. Inferring semantic maps. *Linguistic Typology* 17(1). 89–105.
Rakhilina, Ekaterina, Daria Ryzhova & Yulia Badryzlova. 2022. Lexical typology and semantic maps: Perspectives and challenges. *Zeitschrift für Sprachwissenschaft* 41(1). 231–262.
Ryzhova, Daria & Sergei Obiedkov. 2017. Formal concept lattices as semantic maps. In Ekaterina L. Chernyak, Dmitry Ilvovsky, Daniil Skorinkin & Anna Vybornova (eds.), *Proceedings of the Workshop on Computational Linguistics and Language Science (CLLS 2016)*, 78–87. http://ceur-ws.org/Vol-1886/ (26 April 2021).
Rzymski, Christoph, Tiago Tresoldi, Simon J. Greenhill et al.2020. The database of cross-linguistic colexifications, reproducible analysis of cross-linguistic polysemies. *Scientific Data* 7(13). https://doi.org/10.1038/s41597-019-0341-x.
Stassen, Leon. 1997. *Intransitive predication*. Oxford: Oxford University Press.
Sweetser, Eve. 1990. *From etymology to pragmatics. Metaphorical and cultural aspects of semantic structure*. Cambridge: Cambridge University Press.
Tang, Xuri. 2018. A state-of-the-art of semantic change computation. *Natural Language Engineering* 24(5). 649–676.
Traugott, Elizabeth Closs. 2016. Do semantic modal maps have a role in a constructionalization approach to modals? *Constructions and Frames* 8(1). 98–125. https://doi.org/10.1075/cf.8.1.07tra.
Urban, Matthias. 2012. *Analyzability and semantic associations in referring expressions: A study in comparative lexicology*. Leiden: Leiden University dissertation.
Vanhove, Martine. 2022. A diachronic semantic map of the Optative negative in Beja (North-Cushitic). *Zeitschrift für Sprachwissenschaft* 41(1). 263–277.
van der Auwera, Johan. 2013. Semantic maps, for synchronic and diachronic typology. In Anna Giacalone Ramat, Caterina Mauri & Piera Molinelli (eds.), *Synchrony and diachrony: A dynamic interface* (Studies in Language Companion Series 133), 153–176. Amsterdam: Benjamins.
van der Auwera, Johan & Vladimir A. Plungian. 1998. Modality's semantic map. *Linguistic Typology* 2(1). 79–124.
van der Auwera, Johan & Andrej Malchukov. 2005. A semantic map for depictive adjectivals. In Nikolaus P. Himmelmann & Eva F. Schultze-Berndt (eds.), *Secondary predication and adverbial modification. The typology of depictivs*, 393–423. Oxford: Oxford University Press.
Wälchli, Bernhard. 2010. Similarity semantics and building probabilistic semantic maps from parallel texts. *Linguistic Discovery* 8(1). 331–371. https://doi.org/10.1349/ps1.1537-0852.a.356.

Wälchli, Bernhard & Michael Cysouw. 2012. Lexical typology through similarity semantics: Toward a semantic map of motion verbs. *Linguistics* 50(3). 671–710. https://doi.org/10.1515/ling-2012-0021.

Wierzbicka, Anna. 1992. *Semantics, culture, and cognition: Universal human concepts in culture-specific configurations*. Oxford: Oxford University Press.

Wilkins, David P. 1996. Natural tendencies of semantic changes and the search for cognates. In Mark Durie & Malcolm Ross (eds.), *The comparative method reviewed: Regularity and irregularity in language change*, 264–304. Oxford: Oxford University Press.

Youn, Hyejin, Logan Sutton, Eric Smith, Cristopher Moore, Jon F. Wilkins, Ian Maddieson, William Croft & Tanmoy Bhattacharya. 2016. On the universal structure of human lexical semantics. *Proceedings of the National Academy of Sciences* 113(7). 1766–1771. https://doi.org/10.1073/pnas.1520752113.