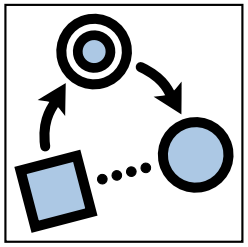
Collaborative Research Center 991

The Structure of Representations in Language, Cognition, and Science

Heinrich-Heine-Universität Düsseldorf



SFB 991

Funding proposal
2/2015 – 1/2019

HEINRICH HEINE
UNIVERSITÄT DÜSSELDORF

Proposal for the continuation of Collaborative Research Centre 991

"The Structure of Representations in Language, Cognition, and Science"

funded since

01 July 2011

for

2015/2 – 2016 – 2017 – 2018 – 2019/1

Coordinating university:

Heinrich-Heine-Universität Düsseldorf
Universitätsstr. 1
D-40225 Düsseldorf

Coordinator:
Prof. Dr. Laura Kallmeyer
Institut für Sprache und Information
Heinrich-Heine-Universität Düsseldorf
Universitätsstr. 1
D-40225 Düsseldorf
Phone:+49 (0)211 81 13899
Fax: +49 (0)211 81 11325
Email: kallmeyer@phil.uni-duesseldorf.de

Office:
Lena Hierl
Sonderforschungsbereich 991
Heinrich-Heine-Universität Düsseldorf
Kruppstraße 108 / Geb. 46.21
40227 Düsseldorf
Phone:+49 (0)211 81 12959
Fax: +49 (0)211 81 03170
Email: sfb991@phil.uni-duesseldorf.de

Contents

1 General information

1.1 Key data

1.1.1 Bodies of the Collaborative Research Centre

The executive committee (Vorstand) of the CRC consists of 9 persons including the coordinator, the deputy coordinator, the principal investigators of MGK and INF and one doctoral student. Its members are:

Prof. Dr. Laura Kallmeyer (coordinator for the 2nd funding period, currently deputy coordinator)
Prof. Dr. Sebastian Löbner (coordinator until 06/15)
Prof. Dr. Peter Indefrey
Dr. Rainer Osswald
Jun.-Prof. Dr. Wiebke Petersen
Koen Van Hooste
Prof. Dr. Robert D. Van Valin Jr.
Prof. Dr. Gottfried Vosgerau
Jun.-Prof. Dr. Alexander Ziem (MGK)

1.1.2 Principal investigators

Principal investigators	Institution & location (all HHU)	Projects[1]
Arndt-Lappe, Sabine, Dr. phil. habil.	Institut für Anglistik und Amerikanistik	C08
Biermann-Ruben, Katja, Dr. rer. nat.	Institut für Klinische Neurowissen-schaften und Medizinische Psychologie	B03
Filip, Hana, Univ.-Prof. Ph.D.	Institut für Sprache und Information	C09
Indefrey, Peter, Univ.-Prof. Dr. med. Dr. phil.	Institut für Sprache und Information	A04, C03
Kalenscher, Tobias, Univ-Prof. Dr. rer.nat.	Vergleichende Psychlogie	D03
Kallmeyer, Laura, Univ.-Prof. Dr. phil.	Institut für Sprache und Information	A02, B08, Z
Kann, Christoph, Univ.-Prof. Dr. phil.	Institut für Philosophie	A05
Latrouite, Anja, Dr.	Institut für Sprache und Information	D04
Löbner, Sebastian, Prof. Dr. phil.	Institut für Sprache und Information	B09, C10
Petersen, Wiebke, Jun.-Prof. Dr. phil.	Institut für Sprache und Information	A01, B09, C10
Plag, Ingo, Univ.-Prof. Dr. phil.	Institut für Anglistik und Amerikanistik	C08
Schnitzler, Alfons, Univ.-Prof. Dr. med.	Institut für Klinische Neurowissen-schaften und Medizinische Psychologie	B03
Schurz, Gerhard, Univ.-Prof. Dr. phil.	Institut für Philosophie	A06,D01
van de Vijver, Ruben, Jun.-Prof. Dr. phil.	Institut für Sprache und Information	D05
Van Valin jr., Robert D., Univ.-Prof. Ph.D.	Institut für Philosophie	B06,D02

[1] This only includes new and continuing projects, not ending projects.

Zielasek, Jürgen, Prof. Dr. med.	LVR-Klinikum Psychiatrie und Psychotherapie	B06
Ziem, Alexander, Jun.-Prof. Dr. phil.	Institut für Germanistik	MGK

1.1.3 Participating institutions

Philosophische Fakultät (Faculty of Arts and Humanities)

- Institut für Sprache und Information (Institute for Language and Information)
- Institut für Philosophie (Institute for Philosophy)
- Institut für Anglistik und Amerikanistik (Institute for English Language and Literature)
- Institut für Germanistik (Institute for German Language and Literature)

Medizinische Fakultät (Faculty of Medicine)

- Institut für Klinische Neurowissenschaften und Medizinische Psychologie (Institute for Clinical Neuroscience and Medical Psychology)
- Klinik und Poliklinik für Psychiatrie und Psychotherapie (Department of Psychiatry and Psychotherapy)

Mathematisch-Naturwissenschaftliche Fakulät (Faculty of Science)

- Institut für Psychologie (Department of Psychology)

1.1.4 Project groups and projects

Project	Title	Research area	PIs, institute
Area A *General aspects of a theory of frames*			
A01-C	Mathematical modeling of frames	Mathematical linguistics, Computational linguistics	Petersen, ISI[2]
A02-C	Argument linking and extended locality. A frame-based implementation	Computational linguistics, Syntax-semantics interface	Kallmeyer, ISI
A03-E	Grounded cognition: Causal indexicals and affordances in frames	Philosophy of mind and cognition	Vosgerau, Philosophy
A04-C	Accessing conceptual information in language production and comprehension	Psycholinguistics, Cognitive neuroscience	Indefrey, ISI
A05-C	Presuppositions of frame theory in the history of philosophy	History of philosophy, history of epistemology	Kann, Philosophy
A06-N	Logic and ontology of the cognitive representation of theories: Frames, sentences and models in comparison	Philosophy, logic, model theory	Schurz, Philosophy
Area B *Dynamic frames in language and science*			
B01-C	Verb frames at the syntax-semantics interface	Syntax-semantics interface, linguistic typology	Van Valin, ISI
B02-E	Dimensional verbs	Semantics, Syntax-semantics interface	Löbner ISI, Geisler, Romance ling.
B03-C	Multimodal cerebral representation of action concepts	Systems Neuroscience	Biermann-Ruben, Schnitzler, Neuro.[3]

[2] Institut für Sprache und Information
[3] Neuroscience

B04-E	A frame-theoretic investigation of unification and reduction in scientific theories	Philosophy of science	Schurz, Philosophy
B05-E	A frame analysis of German legal terms	Semantics, Language and Law	Busse, German Ling.
B06-C	Frames in psychiatric classification	Neurosciences, psychiatry, Philosophy of mind and cognition	Zielasek, Psychiatry, Vosgerau, Philosophy
B08-N	Hierarchical frame induction via probabilistic models	Computational linguistics	Kallmeyer, ISI
B09-N	Modifiers as a probe into the frame structure of events	Semantics	Löbner, Petersen, ISI
Area C *Operations on frames*			
C01-E	Conceptual shifts: typological evidence	Linguistic typology, semantics	Löbner, Stassen, ISI
C02-E	Conceptual shifts: statistical evidence	Statistical linguistics, typology, semantics	Löbner, Petersen, ISI
C03-C	Conceptual shifts: psycholinguistic evidence	Psycholinguistics, cognitive neuroscience	Indefrey, ISI
C04-E	Conceptual shifts: their role in historical semantics	Cognitive semantics, hist. Romance linguistics	Geisler, Romance ling.
C05-E	Frames and nominal word formation	Lexical semantics	Löbner , ISI
C08-N	The semantics of derivational morphology: A frame-based approach	Morphology, semantics,	Arndt-Lappe, Plag, AA[4]
C09-N	A frame-based analysis of countability	Semantics	Filip, ISI
C10-N	A frame analysis for adjective noun combinations	Semantics	Löbner, Petersen, ISI
Area D *Extending the boundaries of frames*			
D01-N	Frame representations of prototype concepts and prototype-based reasoning	Philosophy	Schurz, Philosophy
D02-N	Bridging the gap between individual psychology and public meaning with frames	Cognition, theory of meaning	Vosgerau, Philosophy
D03-N	Conceptual representation in social cognition: frame-theoretical representation of “social partner”	Cognitive science	Kalenscher, Psychology
D04-N	The role of information structure in meaning construal and sentence formation: a frame-based approach	Syntax, semantics, pragmatics	Latrouite, Van Valin, ISI
D05-N	Frames in morphophonology: Modeling paradigms as frames	Morphophonology, experimentation	van de Vijver, ISI
Infrastructure, service and central projects			
INF-E	Information Infrastructure	–	Kallmeyer, ISI
MGK-C	Integrated research training group “SToRE”	–	Ziem, German Ling.
Z-C	Administrative Project	–	Kallmeyer, ISI

[4] Institut für Anglistik und Amerikanistik

1.2 Academic profile of the Collaborative Research Centre

1.2.1 Summary

The CRC 991 is a coordinated interdisciplinary research initiative that investigates the structure of representations in language, cognition, and science. It unites research in linguistics – lexical and compositional semantics, morphology, phonology, discourse, theory of grammar, linguistic typology, psycholinguistics, computational linguistics, and mathematical linguistics – with neuroscience, psychiatry, psychology, philosophy of mind, philosophy of science, philosophy of language, and the history of philosophy. The starting point is the hypothesis that there is a uniform structure of representation underlying the neural level, the cognitive level, the level of linguistic concepts and the level of institutionalized conceptions such as those used in science. This uniform structure is frames, where our notion of frames is inspired by the work of cognitive psychologist Lawrence W. Barsalou (Barsalou, 1992). Barsalou's frames represent information in terms of attributes and the values they take, for example in terms of "shape", "function", "origin" etc. The attributes assign values uniquely to the objects they characterize. The attribute-value structures can be recursive, and they are open to an arbitrary number of attributes and an arbitrary depth of description. According to Barsalou's theory of cognition, frames are grounded in, and interact with, the sensory-motor system. Concepts in human cognition are modal, in this sense, rather than amodal.

Starting from this "frame hypothesis", the CRC has addressed the following aims in its first funding period:

- developing frames for a variety of different nominal concepts;
- exploring the distinction of nominal concepts in language with semantic, typological, psycholinguistic, statistical, and historical approaches;
- modeling the interaction of lexical frames in compounding;
- investigating the structure of fine-grained event frames including causal concept components and aspectuality;
- investigating the formal properties of frames;
- developing a framework for syntax-triggered frame composition;
- separating constructional meaning from lexical meaning;
- modeling conceptual operations such as metonymy, metaphor, and type shifts;
- grounding concepts, including linguistic meanings, in the sensory-motor system;
- applying the frame approach to fundamental issues in philosophy of science and their formalization;
- developing a frame model of the faculties of the human mind and its disorders;
- investigating the history and foundation of the frame conception in philosophy.

In the second phase of the CRC, we want to extend our investigations in various ways. Concerning the linguistic part of the CRC, so far we have concentrated on lexical meaning and frame composition mainly at the level of predicate-argument composition. In the second funding period, we will put a stronger focus on language in context including syntax, semantics, pragmatics and information structure and in particular their interfaces. In this vein, we will investigate ways to characterize concepts of modification, quantification, intensionality, topic and focus. At the same time, we will also investigate morphological and phonological aspects of sublexical frame (de)composition. These extensions pose new and challenging problems for our frame hypothesis and the definition of frame composition. They will go hand in hand with a further development of the formal aspects of the theory of frames, including issues of constraints, of composition and of ambiguity and underspecification. Furthermore, the relation between conceptual knowledge and truth conditions will be further explicated. The linguistic part will be complemented by corpus-based and psycholinguistic empirical investigations of frame structures.

As regards human cognition, in the first CRC period we have examined the empirical evidence for conceptual type shifts, the brain's access to lexical information, and the activation of motor cortex areas during the processing of verbs. In the second funding period, we will continue these investigations in a more multimodal and fine-grained way, extending them to a broader range of phenomena. Furthermore, we will add a new psychological perspective by inspecting concepts of social cognition in animals. Concerning philosophical investigations of concepts, we will move towards aspects of concepts in context, scrutinizing the logic of cognitive representations, developing frame representations of prototype-based reasoning, and bridging the gap between public concepts and their individual use. Moreover, the ontological implications of using frames to describe the structure of the world will be explored, while the historical investigation of the notion of frames will be extended to ontological theories. At the heart of this part of the CRC we address the question of determining the nature of mental representations and their usage in context.

In the first funding period, the CRC has shown the potential to bring together cognitively-oriented approaches to semantics on the one hand and the field of formal semantics on the other hand. The collabo-

ration between these two areas is a unique feature of our CRC. We have shown that this exchange allows us to investigate in detail the common structures underlying cognitive and linguistic representations at the level of lexical meaning and mental concepts and their composition. This highly important dialogue between these two research directions will be continued and intensified in the second funding period. Moreover, the integration of the results of this dialogue with research done in other domains of representations such as animal cognition, cognitive neuroscience or psychology on the one hand, and with research done from the perspective of other disciplines such as philosophy, scientific conceptualization, psychiatry or mathematics, on the other hand, will continue to enrich and mutually stimulate the general investigation of representations.

1.2.2 Research Programme

1.2.2.1 Leading topics and research aims of the CRC

The research aim of the CRC as a whole is the interdisciplinary development of a theory of frames as a universal theory of representation. This theory will cover a broad variety of types of concepts. It will include concepts with dynamic temporal and causal components and predications (= event/state of affairs concepts). It will also account for the dynamics within systems of frames, for instance for modifications and combinations of frames. The core of the CRC is constituted by its linguistic projects, i. e., a principal focus is on representing linguistic concepts, in particular meaning, with frames. From a broader perspective, as part of the general interdisciplinary enterprise of mind and brain research, the theory will unite research on representations at the neural, the cognitive, the linguistic, and the social and scientific level of concept formation.

The frame hypothesis and the Düsseldorf frame model

The guiding hypothesis of the CRC is that there is a uniform structure of representation underlying the neural level, the psychological level, the level of linguistic concepts, and the level of institutionalized conceptions such as those used in science. This uniform structure is frames, where our notion of frames is inspired by the work of Barsalou (1992). Barsalou assumes frames to be attribute-value structures with functional attributes. These structures can be recursive and they allow for structure sharing (value identities of attributes). Furthermore, we also assume them to be typed, where the types are hierarchically related and frame types can constrain the possible attributes and vice versa. Evidence for the frame hypothesis can be found in Löbner (2014).

As an example consider the frame representation of the directed motion event concept expressed by the sentence *John walks into the house* (Fig. 1). The sentence expresses the concept of a walking activity of some person called John. Furthermore, entities such as *the house* come with an interior region (IN-REGION) as one of their attributes. The preposition *into* links the IN-REGION of the house to the end point of the path traversed throughout the walking activity. This can be captured by the (highly incomplete) frame depicted in the middle of Fig. 1 (cf. Kallmeyer & Osswald 2013), with solid edges representing attributes and dotted edges representing possibly non-functional relations. (The latter are allowed only between nodes that are also reachable via functional attributes.) Though simplified (one could for instance further detail that walking consists of a sequence of steps etc.), this frame already gives an idea of the rich information we assume to be represented in frames.

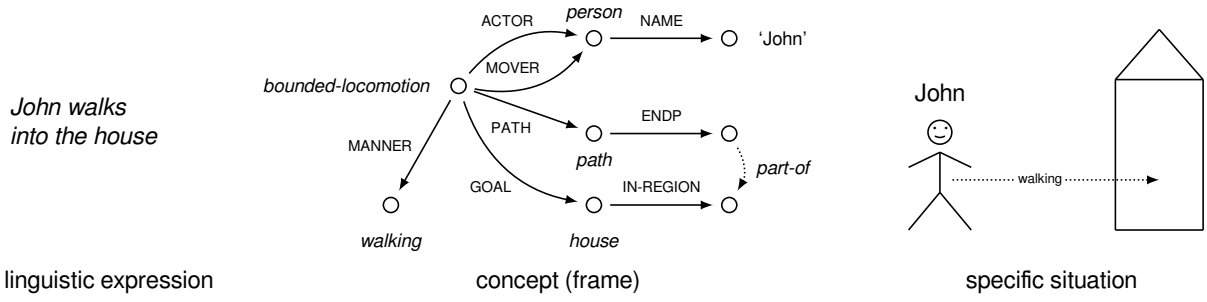


Figure 1: Concepts link linguistic expressions to specific situations

A frame represents a concept that is not situated as such. Rather, it expresses a certain categorization (over entities or situations). But it can serve to link a linguistic expression to a concrete situation, as illustrated in Fig. 1. Concerning the relation to classical model theory and logical truth conditions, the type of semantics most formal linguists are used to, frames represent richer characterizations of predications

since they give more fine-grained information about the events/states of affairs. Moreover, they allow inferring truth conditions and thus deciding whether a specific situation represents an instance of a given concept. Crucially, representing compositional sentence meaning with frames yields structured propositions because frames preserve and integrate all information of their components. Thus, the development of a compositional frame semantics solves a long-standing problem that formal semantics has not been able to deal with in a satisfactory way.

Although the starting hypothesis is that any mental concept can be represented using frames, we assume that there are concepts that are probably better represented by more constrained mathematical models (e.g., syntax trees), though a representation with frames is possible as well. On the other hand, there are concepts that, if represented by frames, require some additional external mechanism such as further operations or constraints on frames.

There are different ways in which the CRC projects focus on frames. However, there is a consensus of what type of structures and representations we mean when using the term *frame*. Let us call our notion of a frame a *Düsseldorf frame*.

Düsseldorf frames can be formalized as typed features structures. Our formalization of frames is inspired by feature logics from unification-based grammar formalisms (Carpenter, 1992; Rounds, 1997). However, the feature structures we assume (see Petersen, 2007; Kallmeyer & Osswald, 2013; Petersen & Osswald, 2014) differ slightly from the standard definition of typed feature structures in that they are more general in the following aspects:

a) There need not be a unique root node, i. e., a single node from which all other nodes are reachable via attribute-value paths. Instead, we can have several so-called *source nodes*, i. e., nodes without incoming edges, that we have direct access to. Every other node is then reachable from one of these source nodes via an attribute path.
b) We can have relations between nodes, not only functional attributes. Such relations are allowed only between nodes that are also reachable via functional attributes from the source nodes.[5]
c) We can focus on internal nodes of a frame, i. e., the frame is not only accessible via a root node. In some contexts, provided we focus only on a single node, this node is called the *central node* or the *referential node* of the frame.

Frames can be represented using different structures such as the attribute-value matrices (AVMs) often used in computational linguistics (cf. Fig. 2), directed graphs with labeled nodes and edges (Fig. 1), Kripke structures (Naumann, 2013), etc. The CRC projects use the different representations depending on what they want to focus on. But the underlying assumption is always that frames are structures of the form just described, i. e., Düsseldorf frames.

Similar though slightly different forms of attribute-value structures have been used in various areas of linguistic research. However, in contrast to other approaches, we adopt more fine-grained frame structures, we apply frame theory not only to language but also to other areas, and we assume that frames are cognitively real. Let us discuss these aspects in detail in the following.

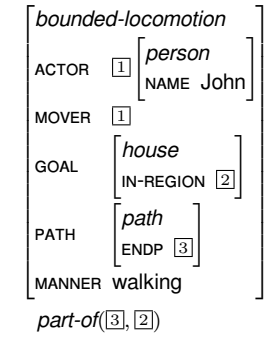


Figure 2: AVM notation

Areas of application: predicative frames and concept frames

In his overview on frame semantics and its applications, Busse (2012) draws a distinction between *predicative frames* and *concept frames*. The former represent events and states of affairs and the participants involved therein, while the latter are primarily concerned with representing properties of entitites, i. e., they are mostly category representations. (Note that this use of the term *concept* is more constrained than the term *concept* used so far in this proposal.) The CRC is concerned with both types of frames.

Regarding concept frames in the sense of Busse, a central contribution of the CRC is the classification of concept types proposed in Löbner (2011) and research based on it. Löbner characterizes concept types with respect to two features, namely inherent relationality and inherent uniqueness. (In Löbner (to appear in 2015), the approach is extended as to include countability as a third distinction.) These binary features yield the four concept types in Fig. 3. The concept type of a category and its representation in a frame structure depend on each other. There is in particular an immediate correspondence between functional concepts and frame attributes, which are inherently functional (see the fourfold classification of lexical frame graphs in Petersen, 2007; Petersen & Osswald, 2014, for sortal, individual, functional and proper relational frames).

[5] Every pair of a relation could actually be represented as a *relation* frame having the two elements of the pair as the values of its two attributes. In this sense, b) is a consequence of a).

	Non-unique reference	Unique reference
Non-relational	sortal concepts *dog*, *house*, *verb*	individual concepts *pope*, *sun*, *Mary*
Relational	proper relational concepts *friend*, *son*, *part*	functional concepts *father*, *age*, *meaning*

Figure 3: Concept type classification from Löbner (2011)

An important topic of CRC investigations is the relation between the concept type of a noun and its possible grammatical uses (Horn & Kimm, 2014; Ortmann, 2014), in particular with respect to determination.

Concerning predicative frames, i. e., the representation of events and states of affairs, the CRC goes far beyond semantic role frames, which merely specify the participants involved. The event frames developed in the CRC provide a more explicit representation of event-internal components by means of attributes and values. In addition, dynamic components are introduced into frames; several projects of the CRC are interested in modeling the dynamic development of events over time. Consider for instance the verb *dry*, describing an incremental scalar change in the moisture property of its theme.

(1) a. The shirt is drying in the sun.
b. The shirt dried.

One way to model this using frames is to use a single frame with types and attributes that describe the dynamic aspects of the event. In the case of *dry*, where we have a change in the degree of moisture, a frame analysis could be as in Fig. 4. The frame on the left, which is the one for (1-a), describes a process of a progression of incremental change events, each of which changes the moisture degree of an entity to a lesser value. The second frame, in contrast, characterizes the accomplishment described in (1-b).

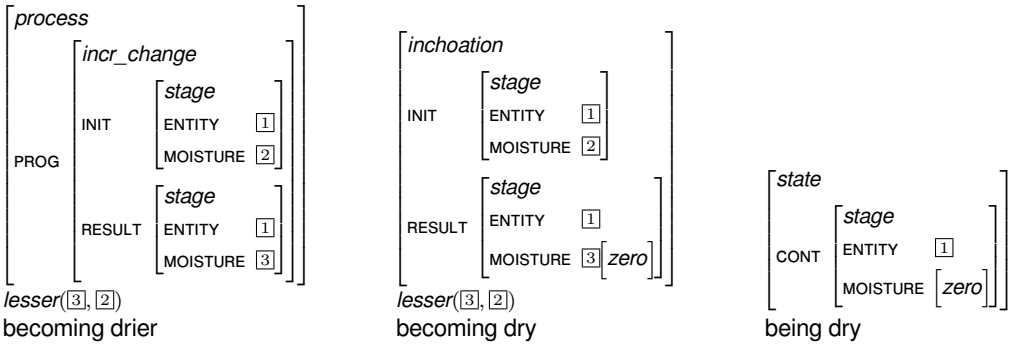


Figure 4: Representation of (non-causative) atelic, telic, and stative *dry*, from Osswald & Van Valin (2014)

An alternative modeling of such an incremental process is to represent only the initial and the result state as a frame and to understand the process itself as an operation on frames that changes them. This way of capturing dynamic change in frames is also pursued in the CRC; it allows for a more explicit modeling of the dynamic operation. In the modeling exemplified in Fig. 4 this is implicit in the types and attributes. Dynamic operations on frames require the development of new operations on attribute value structures (Naumann, 2013; Gamerschlag et al., 2014). Operations on frames of verbs that denote events which bring about changes in the world can be modeled by update operations that are part of the meaning of such a verb. These operations change the values of some attributes. Such updates also apply at the level of nominal concepts. An example is the combination of scalar modifiers like *at least* with bare numerals like *two* (Naumann & Petersen, 2014).

Although a large range of projects in the CRC is concerned with applying frame theory to representing concepts expressed in language, we also adopt frame representations in other areas of concept representation. One such example is the modeling of conceptual changes in science. The idea is that a scientific concept can be represented as a frame and revisions of the theory due to new findings can be translated into revisions of the frame. As an example for a frame representation of a scientific theory, consider the bird taxonomy developed by John Ray in 1678 for which Chen (2002) proposes the frame representation in Fig. 5, based on Barsalou (1992). Such a frame is actually a kind of “meta-frame” representing not an object or an actual predication but a more general concept that describes a whole class of objects and that links subordinate concepts to their common superordinate concept. In the CRC we call this a *classificatory frame*. Fig. 5 states that birds have a beak that is round or pointed and feet that are webbed or clawed and

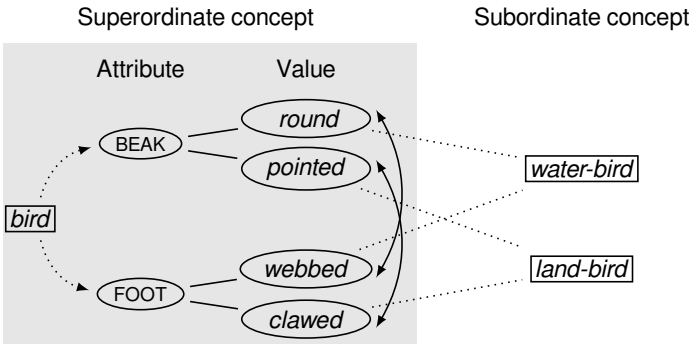


Figure 5: Frame representation of Ray's bird taxonomy, after Chen (2002)

(these are the bidirectional edges) a round beak comes with webbed feet and vice versa while a pointed beak comes with clawed feet and vice versa. Similar frames are used in Votsis & Schurz (2012) and Schurz & Votsis (2014) in order to represent scientific theory change. Such classificatory frames can be translated into descriptions of types, attributes and values, and constraints on paths (e.g., feature value identities or feature value incompatibilities) in the formal systems proposed within the CRC (Petersen, 2007; Kallmeyer & Osswald, 2013).

Operations on frames: shifts and frame composition
Besides the detailed investigation of the structure of predication and concept frames, an important topic of the CRC are various types of operations on frames. These are in particular frame composition operations and shifts. Let us illustrate this with an example from Schulzek (2014) involving both types of operations.

(2) a. Peter hat einen Lockenkopf.
Peter has a curls head
'Peter has curly hair'
b. Der Lockenkopf ist laut und nervig.
The curls head is noisy and obnoxious
'The curly-haired person is noisy and obnoxious.'

In (2-a), the German possessive compound *Lockenkopf* ('curly head') is used in its literal meaning whereas in (2-b), it is used metonymically. The literal meaning (2-a) arises from a unification of the two concept frames of *Locken* ('curls') and *Kopf* ('head') involved in this compounding operation. This unification does not identify the central nodes of the two frames but it identifies the *curls* node with the *hair* node of the *head* frame. This operation is shown on the left of Fig. 6, where the node labeling in the frame shows which nodes have to be identified during unification. From the literal meaning to the meaning in (2-b), a metonymical shift takes place. This shift moves the central node (i. e., the focus) from the *head* node to the *person* node. The shift operation is shown on the right of Fig. 6.

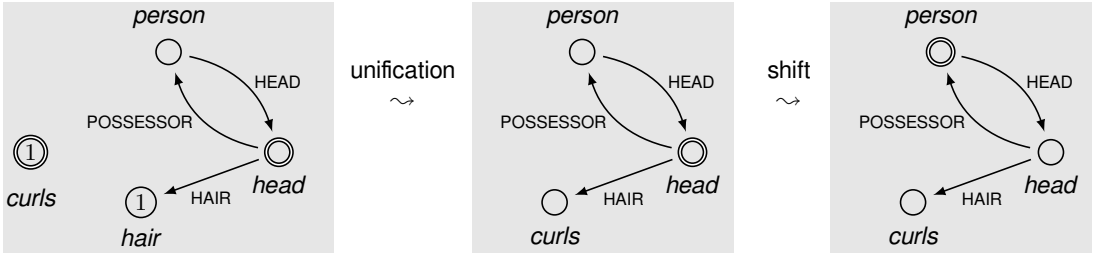


Figure 6: Unification and metonymical type shift: *Lockenkopf* (from Schulzek, 2014)

Various types of shifts and the constraints they are subject to are investigated in the CRC, including shifts between concept types, metonymical shifts, shifts between count and mass nouns and shifts arising from morphological derivation.

The investigation of frame composition in the CRC is by no means limited to word formation as in (2). Frame composition at the sentential level has already been important in the current funding period and will also be examined at the discourse level. Besides predicate-argument composition, which we already investigate now, modification will become a central issue in the next funding period. Modification requires a

particularly fine-grained frame structure since modifiers can target various embedded elements of the frame they attach to. In predicative frames, for instance, the modified element is often not just one of the event participants available via semantic roles.

(3) John walked along the brook.

(4) Er hat sehr geblutet. / Er vermisst sie sehr.
He has "very" bled. / He misses her "very".
'He bled a lot.' / 'He misses her a lot.'

As examples, consider (3) and (4). In (3), the prepositional phrase *along the brook* modifies the path of the event by specifiying that its region must be part of the region at the brook (see Kallmeyer & Osswald, 2013, for a frame analysis). In the degree modifications in (4), different scales are referred to by the modifier *sehr*: In the first example, the amount of blood involved is specified as being large, while in the second example, the modifier refers to the intensity of the feeling.

Several projects pursue the question of how frames compose with a focus on the interface between syntax and semantics. In other words, frame composition is considered as being triggered by syntactic composition and vice versa. The syntactic formalisms currently used in the CRC are *Lexicalized Tree Adjoining Grammars* (LTAG, Joshi & Schabes, 1997) and *Role and Reference Grammar* (RRG, Van Valin, 2005), two formalisms that share the idea of tree templates as syntactic building blocks, something that is also assumed in Construction Grammar (Goldberg, 1995) and that pairs quite well with frame-based semantic composition. See Kallmeyer & Osswald (2013) for a proposal of a syntax-semantics interface architecture that allows coupling syntactic trees with frames and syntactic composition with appropriate frame unifications. An implementation of a grammar engineering tool for this framework is on the way (Lichte & Petitjean, to appear). The frame semantics component of this tool can also be used on its own, which will be useful for several CRC projects.

Another type of frame composition investigated in the CRC is the *generalization* (or *overlap*) of two frames. Formal details are not fully specified yet, but, roughly, the generalization of two frames is their infimum with respect to the subsumption relation (Carpenter, 1992). In other words, it is the largest frame that contains only information that is present in both original frames. This operation comes into play in communication situations where two speakers have individual representations of some entity they are talking about and these individual represenations must be linked to some intersubjective public meaning of their utterances.

Besides composition and shift, a further operation that frames allow for is *zooming*. The idea is that a frame need not be fully specified but, if needed, one can zoom into its nodes and spell out their attributes and values. Such an activation of attributes and values can be triggered by a context that focusses on these attributes.

(5) a. Angela Merkel opens the meeting.
b. Angela Merkel is shorter than Helmut Kohl.

For instance, in (5-a), there is no need to activate the HEIGHT attribute of the *Angela Merkel* frame although we know, given that Angela Merkel is a *person*, that she has a HEIGHT attribute with a certain value. In (5-b) the HEIGHT feature gets activated but there is still no need to activate its specific value. The activation of a frame node only goes as far as needed in a certain context. Formally, zooming can be defined in different ways. Either it actually extends the frame (i. e., the frame is conceived of as an object) or it consists of just moving the focus in a (fully specified) frame to some new frame node and its attributes, or we operate with frame descriptions and zooming consists of adding constraints to the description of a frame. The frame activated so far would then be a minimal model of this frame description (see Kallmeyer & Osswald, 2013; Lichte & Petitjean, to appear, for a definition of frame descriptions and minimal models).

As has been sketched above, in the CRC, we pursue different ways to formalize frame theory including frame composition. In some cases, subsumption, unification and overlap seem to be appropriate notions while in other cases we need type shifts and maybe some form of functional application. This issue of formalization remains an important topic in the next funding period.

Frames and cognition

Feature structures/frames have been shown to be a mathematically well-understood representation format with well-defined operations. However, in our CRC, we take them to be more than that. Our hypothesis is that, at least in some areas, frames are cognitively "real", i. e., that the cognitive system actually operates with frames. This hypothesis is being investigated in several CRC projects.

Given this assumption, a frame theory of conceptual representations must be cognitively plausible and must be explicit with respect to the psycholinguistic processing properties of frames. The CRC provides

empirical evidence (a) with respect to the cognitive status of different kinds of attributes within frames and (b) with respect to how conceptual frame representations are activated and interact with preceding and subsequent processing stages in language production and comprehension. So far, psycholinguistic experiments in the CRC (Redmann et al., 2014) have shown that activating the concept of a depicted object in order to name it seems to also activate attributes of this concept that are represented in the concept's frame. However, this activation of an attribute does not seem to speed up naming by facilitating lexical access to the lemma of the corresponding concept, suggesting that (a) attributes are not themselves linked to the concept's lemma and (b) attributes within frames are not easily preactivated by primes. These findings are difficult to reconcile both with feature list models and non-decompositional network models of conceptual representation. They are, however, compatible with frame representations, because the frame may be seen as encapsulating the embedded attributes.

Besides gathering psycholinguistic evidence for the activation of frames and attributes in the brain, various types of conceptual shifts are another domain of psycholinguistic investigation in the CRC, complementing the linguistic projects working on such phenomena.

So far, experiments in the CRC have focused on concrete concepts. However, abstract concepts play a central role throughout human cognition, especially in social cognition and social interaction (Barsalou, 2008). In the next funding period, we plan to extend our research to concepts in social interaction, concentrating on non-human animals. Note that Barsalou proposed his account of frame structures as a theory of concepts not only in humans, but also in non-human animals (Barsalou, 2005).

In line with theories of grounded cognition (Barsalou, 2008; Kiefer & Barsalou, 2013), we assume that modal simulations, bodily states, and situated action underlie cognition. Following, e.g., Pulvermüller (2013), we take the representation of action verbs to be modality-specific and network-based. In the CRC, we elaborate on action verb processing investigating sensorimotor, visual motion and auditory brain areas regarding their local activations and functional connections in language tasks. In this domain, the collaboration between neuroscientists and linguists in the CRC is particularly fruitful (see for instance Klepp et al., 2014). Complementing this experimental research, frame theory as a representation tool has been applied to various forms of grounded concepts in Vosgerau et al. (to appear).

Related approaches

The CRC directly builds on Barsalou's frame theory (Barsalou, 1992, 2012), aiming at its formalization, further specification and application to various domains. This links us closely to its predecessors in cognitive science and artificial intelligence such as Marvin Minsky's frame theory (Minsky, 1975), which introduced the notion of a frame for the first time, and the earlier schema theory of Bartlett (1932) (see Busse, 2012, chapters 3 and 4 for overviews of Minsky's and Bartlett's work).

The application of frame theory to linguistics was initiated to a large extent by Fillmore's work on situation frames (Fillmore, 1982). In our linguistic projects, we build on this work while combining it with richer frame structures which provide a more explicit representation of event-internal components and integrate even dynamic aspects of event semantics into frames. In this respect, our approach is in line with the proposals of Bergen & Chang (2005) and Boas (2008).

Type Theory with Records (TTR) developed by Cooper (2005, 2012) synthesizes the ideas of frame semantics and Montague Grammar (Montague, 1973). In TTR, frames are represented as record types, which are objects with a structure close to typed feature structures. This is integrated in a lambda calculus allowing for abstraction and functional application. TTR is one of the ways explored in the second CRC funding period for bringing together cognitive approaches to semantics on the one hand and the field of formal semantics on the other hand. Another recent approach that relates truth-conditional semantics to frame-based lexical semantics and that was partly inspired by the work in the CRC, is proposed by Muskens (2013), using a version of Frank Veltman's Data Semantics (Veltman, 1984). The CRC holds intensive collaboration with both, Robin Cooper and Reinhard Muskens.

The relation of frames to non-symbolic models of concept formation such as Gärdenfors' conceptual spaces (Gärdenfors, 2000, 2014), which are based on gradual membership and family resemblance is not fully understood yet. In principle, frames could be augmented with weighted attributes, similarity measures on values and the like. In the second phase, such questions will be addressed in the CRC.

Leading research questions

Given the aims and research topics of the CRC as described so far, one can identify the following four leading research questions that the CRC addresses:

1. Assuming that concepts are best represented by frames, what is the concrete **structure of conceptual representations**?

2. How do frames interact with each other and how do we process them, i. e., how do we build **complex or derived conceptual structures**?
3. What is the **relation between the human conceptual system and natural language**?
4. How do **frames relate to other systems of representation**?

All these questions are addressed from a linguistic, cognitive, and philosophical perspective. The CRC is concerned with the structure of frames that represent linguistic concepts, for instance the meaning of natural language expressions, with the way these frames combine and with their relation to other systems of representation used in linguistics, in particular in semantics. On the other hand, these questions are also considered from the broader perspective of cognition and mental representations, including philosophical, psychological and neural investigations.

Project areas of the CRC

The CRC is structured into four project areas that are concerned with the following questions and topics:

- Area A: *General aspects of a theory of frames*
  This part addresses foundational issues concerning frames, ranging from formal properties of frames and frame composition to questions about frames being grounded in basic sensory-motor representations, psycholinguistic investigation of accessing conceptual information and an investigation into the history of the notion of frames in philosophy. These aspects, already relevant in the first CRC period, will now be complemented by an investigation of the relation between frames, logics and ontologies in the context of representing scientific theories.
- Area B: *Dynamic frames in language and science*
  This group of projects contributes exploratory work on the nature of frames in a broad range of applications such as frames in psychiatric classification, law and neural representations of actions. One uniting aspect of area B is the relevance of causal, temporal and aspectual information in the concepts they are dealing with. Several projects are in particular concerned with event frames. In area B, research will be intensified on frame composition and event modification, as well as on the representation of temporal dynamics in event frames and in representations of scientific concepts. Additionally, corpus-based investigations of event frames are planned for the second CRC phase.
- Area C: *Operations on frames*
  This group of projects mostly concentrates on nominal frames. In the first CRC period, the work pursued in this part of the CRC was largely based on the theory of concept types and determination developed in Löbner (2011). The projects explored type shifts in a cross-linguistic perspective, statistically and corpuslingustically, psycholinguistically and historically. Parts of the work in area C had already been started in the preceding Forschergruppe FOR 600 and has obtained satisfying results. For this reason, several of the C projects are ending and their lines of research will be continued under different perspectives. In the next funding period, the scope of this project group will be extended to shifts and operations on frames in general. Besides the continuation of previous topics, the application of frames will be extended to the complex of countability, to the semantics of nominal derivation, and to nominal modification. To reflect the extended focus of area C, the title has been changed from *Frames and concept types* to the broader title *Operations on frames*.
- Area D: *Extending the boundaries of frames*
  This project area is new in the second CRC phase. While in the first phase frames and frame composition in the CRC were mostly restricted to lexical frames and to predicate-argument relations, we will now extend this approach to cover more intricate cases, which in turn requires an extension of the frame models used so far. Area D covers philosophical research on prototype-based reasoning and probabilistic frames, and on the interplay of public versus private meaning representations. Furthermore, it extends linguistic research on frames beyond semantics and the syntax-semantics interface: We will investigate the role of information structure in concept composition, and we will pursue the representation of morpho-phonological paradigms within frames. Finally, area D extends the application of the frame approach to the domain of social cognition, which, for reasons of experimental controllability, will be mostly studied in animals.

Results of the current funding period

The multidisciplinary research of the CRC in the first funding period strongly corroborated the viability of the working hypotheses, in particular the “frame hypothesis”. In the linguistic projects, Löbner’s (2011) theory of nominal concept types and type shifts was strongly confirmed, and it was extended to encompass the dimension of countability (Löbner, to appear in 2015). The projects in group C produced robust typological

(C01), statistical (C02), and psycholinguistic (C03) evidence for the significance of the type distinction and the reality of shifts among the concept types.

Across the projects applying frames as a format of representation, the approach produced considerable progress in areas as different as lexical semantics (B01, B02, C05), philosophy of science (B04), law (B05), and psychiatry (B06). The application of frames to a growing variety of areas served as a driving force for pushing frame theory further, far beyond the limits of the original Barsalou approach. The frame representations developed in the CRC in law and psychiatry are the first formal concept representations in these disciplines.

The general theory of frames (A01, A02, B01) has been formalized and linked to concepts and techniques from formal logic and model theory. At the level of single event frames, we investigated ways to represent the internal temporal structure of events for various aspectual verb classes, along with causation (A01, A02, B01). Thus, the major properties of established verb classes can now be modeled. At the same time, the decompositional analysis of verb meanings was deepened, beyond the level of Fillmorean case frames, by investigating particular phenomena of verb semantics (A01, A02, B01, B02). Several projects were concerned with the grounding of frames in the sensorimotor system; these include the projects B03 (neurology), A03 (philosophy of mind), and C04 (historical semantics). They all produced evidence in favor of Barsalou's modal approach to cognition.

Another focus was on dynamic operations on frames: modification of frames, in particular by metonymical operations (C04, C05), frame composition as involved in compositional semantics and word formation (A02, C05), modeling constraints on frames (A01, B01), defining truth and reference of frames by relating them to ontologies (A01), employing frames at the interface of lexicon and syntax (A02).

The development of the frame theory of representation has been supported by the experimental projects (A04, B03 and C03) on the one hand, and by a thorough philosophical reflection of this format of representation and its emergence in the history of Western philosophy (A05) on the other hand.

The CRC contrasted, and connected, the domestic approaches to other theories and systems of representation, such as formal semantics, Construction Grammar, FrameNet, Gärdenfors' theory of Conceptual Spaces, to name only a few. The researchers of the CRC are aware that they are treading new paths of investigation and theorizing which need to be made accessible, and compatible, to other approaches of different orientation. Besides presenting and publishing their results and ideas, the CRC has been successfully using workshops and the biannual international conference 'Concept Types and Frames' for creating platforms of exchange between invited leading scholars, external contributors, and researchers of the CRC. As a result, the Düsseldorf frame approaches have achieved growing recognition in the scientific communities.

Aims and objectives for the second funding period

The second phase of the CRC is characterized by expanding on all four of the leading research questions listed above. The question of what conceptual representations look like, be it at the mental or the linguistic level, will be tackled in combination with questions of frame composition. At the linguistic level, so far, we have mainly considered cases of predicate-argument composition. In the second funding period, this will be extended to more subtle cases of composition, in particular to modification, ranging from event modifiers to nominal modification, which require a more fine-grained frame structure and more complex mechanisms driving the composition. Furthermore, semantic frame composition is considered in its interaction not only with syntax but also with morphology and information structure. This leads to more complex interfaces for frame composition (compared to the first funding period) that will be specified in the second CRC phase. Furthermore, evidence will be gathered from computational linguistics for frames and for concept composition, based on syntactic and lexical distributional information.

Concerning cognition, research on empirical evidence for frames will be continued and extended; besides the ongoing experimental research on psycholinguistic and neural evidence for frame structures in concept formation, the second phase will extend the domain of investigation to abstract social concepts in non-human animals. The question of what is the relation between the human conceptual system and natural language will be examined more closely, including aspects of determining how public (i. e., speaker-independent) meaning comes about and how this meaning, represented with frames, can be used to characterize specific situations. In this context, our frame-based research will be linked to notions of reference and truth conditions from the field of formal semantics. Related to the question of how we mentally represent concepts and how this links to situations is the investigation of how to represent abstract general concepts such as prototypes or theories we have about certain types of objects. These topics will play an important role in the second funding period.

On the methodological level, the second funding period will introduce weights and probabilities into frames, in order to capture notions of typicality and ambiguities in language-specific frame models. Finally, the next CRC period will lead to more intricate cases of dynamic operations on frames, for instance

in the context of dynamics in event semantics and of representing phonological processes within frames.

1.2.2.2 The four groups of projects: Results and objectives

Area A: General aspects of a theory of frames

Results of the first funding period
Dealing with general issues of a comprehensive theory of frames, the projects of this group have provided the foundations, and a driving force, for the CRC enterprise as a whole. The projects continued extending and further formalizing a precise and explicit theory of frames and their application. They compared this frame approach to alternative theories of cognitive representations (A01, A03, A04, A05) and reflected the emergence of the notion of frame in the history of philosophy and psychology (A05). As a result, the frame approach taken by the CRC was confirmed as a theory of representation that appears promising, and in good accordance with empirical findings. Beyond a mere comparison of theories, the frame approach was combined, and integrated, with existing other formalisms in computational linguistics (A02), grammar (A02 with B01), logics, database theory and formal semantics (A01).

The main contributions of the area A projects comprise the following:

- Frame theory: Development of a formal mathematical, logical, and semantic theory of frames that includes dynamic frames.
- Frame theory and language: Integration of a frame-based semantics in the computational formalism of Lexicalized Tree Adjoining Grammar (LTAG)
- Frame theory, cognition, and philosophy of mind: Exploration of the grounding of cognitive frames in sensorimotor representations, and the models of abstraction involved in concept formation.
- Frame theory and cognition: Empirical investigation of the role of attributes in semantic processing.
- Frame theory and philosophy: Reflection on the emergence of the modern conception of frames in the history of philosophy and psychology.

Project A01 “Mathematical modeling of frames” (Petersen) develops the mathematical foundations for a theory of frames. Providing the formal basis for the other projects within the CRC, it ensures consistency and adapts and expands the formal model in exchange with the other projects. Reflecting its central role in the CRC, project A01 had direct collaboration with A02, A03, A05, B01, B02, C01, and C02, in form of common publications, edited volumes, and jointly organized conferences. A01 played a leading role in bridging the frame approach with other approaches and exploring new fields of applying frame theory to problems of compositional semantics, including the semantic analysis and modeling of nominal concept types and nominal possession as well as stative and dynamic intensional verbs (with B02). Currently, the project is developing the integration of basic notions of truth and reference within frame theory, as well as negation, conjunction and other propositional connectives. At the formal level, the graph-based definition of frames in Petersen (2007) was adapted to Kripke structures. In addition, the definition of frames was extended to the notion of a team from dependence logic. These extensions made it possible to define nominal and action/event concepts in terms of structural properties of Kripke structures. This new extended definition of frames proved useful in a first approach to model quantifiers and phase quantificational expressions like *already*.

A02 “Argument linking and extended locality: a frame-based implementation” (Kallmeyer) aims at pairing LTAG with a frame-based semantics. The project mainly concentrated on (i) a detailed decomposition of the meaning of English verbal constructions into constructional and lexical meaning, and (ii) the morpho-semantic decomposition of the meaning of prefixed verbs in Russian. Russian is particularly challenging for frame semantics because of its rich system of aspectual prefixation. (i) has lead to an extensive collaboration with B01 while (ii) was pursued together with C09 and B01. From the analyses of the various constructions in English and Russian, certain requirements for the underlying notion of frames emerged. These considerations have led to the formal definition of frames as base-labeled feature structures, a work in collaboration with B01. Following this formalization, A02 extended the implementation framework XMG in order to be able to specify and compile frame descriptions. A02 furthermore achieved a better understanding of other syntactic formalisms with a so-called extended domain of locality (EDL), namely some variants of LTAG, Role and Reference Grammar (RRG) and certain flavors of Construction Grammar (CxG). This work led to the development of project D04.

A03 “Grounded cognition: Causal indexicals and affordances in frames” (Vosgerau) investigates the extent to which, and also the manner in which, concepts are ’grounded’ in basic sensorimotor representations. The focus of the project is on analyzing concepts that have direct implications for one’s actions, such as causal indexicals and affordances, in terms of frame theory. Frames have been compared and defended against other representational formats (e.g. mental files). An abstraction process has been described that

produces more general frames from simple action representations. Novel accounts were developed for action-related concepts (such as artefact concepts for tools); in particular, a comprehensive account of affordances has been formulated that preserves the explanatory value of affordances as introduced by Gibson (1979), on the one hand, but goes beyond the Gibsonian account by systematically integrating affordances into a representational theory. By relating concepts to action representations, the 'endpoints' of frames, i.e. the values of terminal attributes, were discussed in detail, paying special attention to empirical results from the cognitive sciences.

The role of A04 "Accessing conceptual information in language production and comprehension" (Indefrey) within the CRC is to provide empirical evidence (i) with respect to the cognitive status of different kinds of attributes within frames and (ii) with respect to how conceptual frame representations are activated and interact with preceding and subsequent processing stages in language production and comprehension. So far, research conducted in project A04 provided evidence against one type of competing accounts of conceptual representation, i.e. decompositional 'feature list' models. At the same time, our results suggest that conceptual attributes embedded in frames may contribute little to the activation of the lexical entry (lemma) of the embedding concept and hence to the speed of naming in language production. There are several possible accounts for the latter result and they are intrinsically related to (i) the nature of attribute representations in frames (is the color attribute of the LEMON frame an abstract yellow or the specific yellow of a lemon?) and (ii) the nature of the activation flow from a conceptual frame to its corresponding lexical entry (does only the central node of the frame have access to the lemma level or also the attribute value nodes?).

The main aim of A05 "Presuppositions of frame theory in the history of philosophy" (Kann) is to reflect and contextualize the notion of frames developed in the CRC by historical reconstruction and systematical comparison to important predecessors and related notions in philosophy or adjunct disciplines. Historically, there are not only several connections to philosophy mediated through early psychologists like Bartlett, Selz and James, especially to the epistemological tradition e.g. to the notion of schema in Kant, the notion of abstract ideas in the English Empiricism and the notion of a scheme in Whitehead, but there are also predecessors in the ontological tradition, e.g. the categorial scheme in Aristotle. Systematically, since frame theory has to be placed among theories of concepts, implications of recent trends such as pluralism and eliminativism have been discussed and analyzed as alternatives to describe concepts as mental particulars e.g. in a pragmatist account of concepts.

Plans for the second funding period

Except for A03, the area A projects will be continued in the second CRC phase; the results from A03 will feed into the new project D02. A new project on representing scientific theories with frames (A06) is added to area A, continuing the work of project B04 from a different perspective.

In the second funding period, both the theoretical and the empirical coverage of the Düsseldorf frame model will be extended by A01. "Mathematical modeling of frames" (Petersen). Parallel to the fourfold classification of nominal concepts, a hierarchical classification of attributes in terms of relations like 'part-of' will be developed. For action/event concepts, a classification in terms of temporal and causal relations between subevents will be investigated. If a term expressing a concept is used in a particular situation, a reference to objects in that situation is established. In order to arrive at a theory of reference for frames, Löbner's (to appear in 2015) onion-model will be used, which is based on a hierarchy of different layers to enrich a concept e.g. by establishing reference to objects. Concepts can be enriched by adding attributes expressed by adjectives or adverbs ('red apple, 'to drive carefully'). A theory of such modifications will be developed in close collaboration with projects B09 and C10. Besides modification, a major question concerns the integration of quantification. In particular the distinction between monontone increasing vs. monotone decreasing quantifiers as well as the topic of polyadic quantification will be investigated. Having integrated modification and quantification, a compositional and incremental model of sentence processing will be developed. A01 follows Baggio & Hagoort (2011) in assuming that language use builds upon a repertoire of stereotyped, non-novel utterances stored in the mental lexicon (cf. 'scenarios' in van Lambalgen & Hamm (2005)). In the Düsseldorf frame model, these sterotypes can be taken to be partially ordered sets of frames which define possible 'evolutions' (in the sense of dynamic epistemic logic or epistemic temporal logic) of the sentence-frame built up during sentence processing in the brain. Finally, in collaboration with project D01, the frame model will be extended by probabilistic and/or normalcy relations in order to capture typicality effects.

Project A02 "Argument linking and extended locality: a frame-based implementation" (Kallmeyer) adopts a computational linguistic perspective, coupling a syntactic framework with an extended domain of locality (EDL) with a frame-based semantics. The EDL formalism used in A02 is *Lexicalized Tree Adjoining Grammar* (LTAG). In the second funding period, A02 will extend the methodological approach of the first funding period from elementary pairs of syntactic building blocks and corresponding frames to more intricate cases of tree and frame composition. More concretely, the approach will be applied to different empirical domains, namely cross modification, modification of complex predicates, and idiomaticity in multi-word expressions.

These domains are chosen because they provide insights into the locality and accessibility of information within the syntax-semantics interface. The underlying hypothesis is that the required locality matches the one provided by the combination of EDL and frames, in other words, that the combination of EDL and frames comes with adequate empirical predictions concerning the scope possibilities of modifiers. Besides these empirical investigations, the project will also focus on issues of complexity and implementation. Here, our assumption is that the extended locality in the syntax allows a rather simple feature structure unification on frames as composition operation, which enables efficient parsing. In the second funding period, A02 will implement a parser that processes LTAG coupled with a frame-based semantics. As part of the grammar engineering framework (XMG) used in A02, the project provides a frame implementation tool for the CRC and will support the other projects in using it.

Project A04 “Accessing conceptual information in language production and comprehension” (Indefrey) will follow up on the results obtained in the first phase suggesting that frame-theoretic conceptual representations can be distinguished from alternative accounts with psycholinguistic and neurocognitive approaches. In particular, A04 will aim at finding convincing empirical support for the assumption that attributes in frames may be frame-specific and encapsulated, as such properties of attributes are difficult to account for in alternative theories of conceptual representation. Much of this research will involve experiments on the activation of color in high color-diagnostic concepts, because, so far, this has yielded the most promising results and there is an active research community interested in color processing. As intended from the start, however, A04 will continue to study a broader range of attributes, such as form (long, round etc.) and material (iron, glass, wood etc.) attributes, with the long-term perspective to better understand their status in conceptual frames. A04 will also continue to study the activation of these kinds of attributes in language comprehension.

Project A05 “Presuppositions of frame theory in the history of philosophy” (Kann) continues the historical and systematic investigations of frames in philosophy, focusing in the second funding period on the representational and closely related ontological assumptions of frame theory. The starting point is the observation that there are important structural similarities between frame theory and the ontological tradition of the Aristotelian categorial scheme. Aristotle ambiguously treats the categories as highest kinds of real entities, as highest classes of predicates, and as general forms of mental representations. Similar ambiguities concerning the subject and scope of theories of concepts and categorization recur throughout the history of philosophy up to contemporary psychology and cognitive science. Other ontological approaches differ from the Aristotelian substance ontology and subject-predicate scheme of representation in multiple ways. These alternative ontologies from the history of philosophy including its ancient and medieval traditions have to be considered. Bundle ontology (Hume), process ontology (Whitehead), functions/relations ontology (Cassirer), trope ontology (Husserl, Williams) etc. will be discussed, and their implications for a frame theory of concepts will be evaluated.

A06 “Logic and ontology of the cognitive representation of theories: Frames, sentences and models in comparison” (Schurz), a new project in area A, investigates frame-based methods of representing scientific theories, both from a logical and an ontological perspective. This comprises a formal definition of the notion of a classificatory frame and of its logical counterpart, i.e., its fomulation as a set of propositions. As a test case, (parts of) the theory of Role and Reference Grammar (RRG), the grammatical framework used in B01 and D04, will be represented with frames. Furthermore, frame-based approaches to scientific theory representation will be compared to two traditional representation methods in philosophy of science, namely the representation of theories (i) as sets of sentences (e.g., Carnap) and (ii) as sets of models (e.g., Sneed). This comparison will be carried out on the logical and on the ontological level.

Area B: Dynamic frames in language and science

Results of the first funding period

This area was united by several aspects of frame theory. (1) All projects dealt with aspects of dynamicity of frames, where dynamicity can refer to the frame content as well as to the dynamics of the development of frames in certain areas. All projects examined frames of dynamic content: B01, B02, and B03 frames – or mental representations (B03) – of verbs; B04 included frames for chemical reactions; B05 for criminal deeds; B06 considered cognitive processes. (2) B04, B05, and B06 dealt with the historical dimension of the concepts investigated, and how these changes can be properly represented, or possibly modeled, in frames. (3) B04, B05, and B06 developed frame representations in novel fields of application, investigating scientific (or more generally, institutional) categories and the respective frames, in law, natural sciences, and in psychiatry. (4) B04, B05, and B06 all examined hypercomplex frames, i. e. frames of considerably higher complexity than lexical frames.

The projects of area B have contributed to a theory of representations in all three areas, language, cognition, and science. The contributions concern the following aspects:

- Cognition: Distributed neural representation of verb concepts and the interaction of motor action and mental access to verb concepts.
- Language and frame theory: Frame models of verb concepts that incorporate not only the usual case frames but also dynamic concept components such as causation, change in time, and relation to scales.
- Language: Insights into the lexicalization of isolated (Löbner, 2014) conceptual dimensions and the division of labor between functional nouns, dimensional adjectives, and dimensional verbs.
- Science: Modeling of scientific concepts by means of hypercomplex frames, which requires an extraordinary effort in determining appropriate attributes and frame structures.
- Science: Exploration of complex concepts outside the usual domain of semantic investigation; concepts that are semantically controlled, and defined, in scientific and institutional discourse.
- Science and frame theory: modeling historical change in scientific theories in frame theory.

B01 “Verb frames at the syntax-semantics interface” (Van Valin) is working on a frame-based decompositional approach to the semantics of verbs and constructions, the modeling of the interaction between semantics and syntax in these constructions adapting the linking system of Role and Reference Grammar, and the analysis of the cross-linguistic variation in the packaging of the meaning components in these constructions. B01 demonstrated how decompositional event frames can overcome the limitations of Fillmore’s FrameNet approach with respect to deriving linking generalizations, and proposed a formally precise working definition of decompositional frames, where frames are defined as base-labeled feature structures with types and relations (this definition was provided in collaboration with A02). B01 also undertook a pioneer in-depth study on the gradation of verbs.

The other project on verbs, B02 “Dimensional verbs” (Löbner, Geisler), focused on verbs that isolate a single frame attribute (‘dimension’) of their theme argument, such as stative *kosten* ‘cost‘ and dynamic *verteuern* ‘raise [in price]’ (both relating to the dimension PRICE). These are the first classes of verbs that have been fully decomposed with frames, using the frame templates for aspectual classes of verbs developed in A01. The project investigated the division of labor, and the systematic derivational mechanisms, between these verbs, dimensional adjectives, and functional nouns, studying German, English, French, French creole languages, and Korean. B02 also dealt in depth with the intensional use of verbs such as *steigen* ‘rise’ with functional concept theme arguments (*the temperature is rising*), where the frame approach offers a deeper semantic analysis.

B03 “Neural representation of action-related concepts” (Biermann-Ruben, Schnitzler) investigated the distributed representation of action concepts in the human brain as regards localization and functional interactions in the framework of grounded cognition and frame representations. Neuronal sources representative of hand movement or foot movement preparation were specifically activated in the concordant verb reading condition. Additionally, B03 found rhythmical brain activity somatotopically modulated. Language-motor interference was further investigated in a competition task where subjects had to react with their right hands to concrete verbs only, but not to abstract verbs. Reaction times in this task showed an effect of interference when subjects had to react to hand action verbs, but only in case of high imageability. In three behavioral priming experiments B03 modulated the reaction time tasks. One of these tasks is applied in a current electrical stimulation study. From the beginning of the project on B03 collected measures that characterize the verbs used in the studies, e.g., imageability and familiarity. This was done in close collaboration with project C04.

B04 “A frame-theoretic investigation of unification and reduction in scientific theories” (Schurz) pursued three aims: (i) a frame-theoretic analysis of two central concepts in the philosophy of science, i.e. the concept of unification and the concept of reduction; (ii) application of this to understand to what extent scientific systems in natural sciences are reducible to other systems; (iii) extension of the formal theory of frames as to enhance its ability to represent dynamical relations between frames. Comparing existing accounts of reduction, the project came to the conclusion that neo-classical accounts go some way toward overcoming various objections raised against the classical account. The neo-classicists rightly liberalize the notion of reduction. The project made steps towards a further liberalization proposing several modifications. Currently, the accounts of unification and the modified version of the neo-classical notion of reduction are being modeled in frame theory.

Project B05 “A frame analysis of German legal terms” (Busse) aimed at the frame-semantic analysis of legal terms in German. A sample of terms of statutory law has been analyzed in depth on the basis of interpreting texts such as high court decisions and other judgments and legal commentaries. Detailed frame analyses were developed for the notion of *Diebstahl* ‘theft’ and the related concepts *Eigentum* (ownership) and *Besitz* (possession) that belong to the most important concepts in civil law. A further focus was on the notion *(mit) Gewalt* ([by] violence/force) and related concepts such as *Nötigung* ‘coercion’. In total, more

than 100 frames for legal notions have been constructed.

B06 “Frame analysis of mental disorders” (Zielasek, Vosgerau) developed the first systematic frame-based representations of mental disorders. Using the example of specific phobia, B06 showed how information from classificatory definition criteria and pathomechanisms can be integrated into a comprehensive Barsalou-type frame structure, to yield a complete picture of the complex interrelations between different pathogenic processes and their ensuing classificatory elements. The frame analysis of the concept of delusion highlighted the theoretical inadequacy of the DSM-IV and -V characterization of delusions. The review of the empirical literature concerning delusions led to a first application of frame theory to the inter-level relations characterizing neuropsychological explanations. The critical review of the literature devoted to inter-level explanations in cognitive neurosciences allowed the project to highlight overlooked theoretical difficulties in meta-theoretic accounts relying on interventionism and mutual manipulability. The project engaged in a general analysis of the concept of ‘mental disorder’, broadly construed, showing that classical forms of scientific essentialism are insufficient to address the issue of the nature of mental disorder and that mental disorders should be handled as theoretical entities.

Plans for the second funding period

Among the six projects of this area, three had predecessors in RU 600: B02 (A2, 2005-2011), B01 (A6, 2008–2011), and B04 (B6, 2008-2011). Of these, B02, after ten years of funding, will not be continued; the subject of scientific theories in B04 will be investigated in the new project A06 from a different angle; B01 is applying for continuation. Three projects started with the CRC: B03, B05, and B06. Of these, B03 and B06 are applying for continuation. Project B05 on the frame analysis of German legal terms will end with this funding period.

Two new projects will join area B: a project on probabilistic frame induction (B08), which builds considerably on the linguistic insights into event frames obtained in B01 and A02, and a project on event modification (B09) building on results on event structure from A01, B01 and B02.

Project B01 “Verb frames at the syntax-semantics interface” (Van Valin) is concerned with the interaction between morphosyntax and semantics in verb-based constructions. In the second funding period, the project aims at developing a systematic account of the syntax-semantics interface of event-integrating constructions, thereby extending and generalizing the results of the first funding period. Many complex scenarios that are conceived as coherent units are typically described in natural language by means of multiple predicates. A simple example is the sentence *Mary sat reading a book*, which describes a single scenario by the verbs *sit* and *read*. Tight syntactic patterns like *sit reading* cannot be interpreted as describing two temporally independent events. A different type of example is given by complement constructions involving implicative verbs (*manage/fail to open the door*), which come with presuppositions and entailments. B01 has three main objectives in its second period: (i) A systematic account of the meaning structures that underlie the class of scenarios which are conceivable as coherent events. To this end, B01 will extend and refine the relevant part of the interclausal semantic relations hierarchy of Role and Reference Grammar (RRG) by richer frame-semantic decompositions, which make explicit the relations between the subevents. (ii) A cross-linguistic analysis of the various ways of describing complex coherent events by tight syntactic constructions, and the extent to which these constructions inherently have the macro-event property. This analysis will build on and possibly extend the clause linkage templates developed in RRG. (iii) A compositional model of the syntax-semantics interface of coherent event descriptions, which is based on the formal framework developed in the first funding period.

B03 “Multimodal cerebral representation of action concepts” (Biermann-Ruben, Schnitzler) investigates the distributed representation of action concepts in the brain with respect to localization and functional interactions in the framework of grounded cognition and frame representations. In the second CRC period, B03 concentrates on multimodal cerebral representations of action verbs, i.e., on different qualities of actions concerning sound and visible motion and their relation to activation patterns of corresponding brain areas. To this end, stimuli and methods developed in the first project period will be used and enhanced. B03 will focus on hand-, foot- and mouth action and non-movement actions using behavioral experiments as well as magnetoencephalography (MEG) and transcranial current stimulation (tCS). In order to account for the new focus in the project aims, B03 has changed its title.

Project B06 “Frame analysis of mental disorders” (Zielasek, Vosgerau) is concerned with an application of frames in science, specifically in psychiatry. B06 develops frame analyses of mental disorders. The particular focus of the second funding period will be on the representation of more complex disorders such as schizophrenia that require the representation of continuous variables as values. In addition, the project aims at advancing the frame-based analysis and representations of mental disorders by taking a broader range of attributes and values into account. To that end, the frame analyses will be expanded to brain disorders with a clearly defined pathophysiology such as Parkinson’s disease or epilepsy, with the goal to develoop frame representations for genetic and other factors besides cognition. These broadened analyses

of specific mental disorders will provide the resources to conduct an analysis of the comorbidity of mental disorders by means of frames in relation to the Modular Psychiatry concept and to systematically analyze the classification systems of mental disorders (DSM-5 (APA, 2013) and ICD-11 (WHO, scheduled for 2017)) using the frame theoretical approach, including the search for paradigm shifts in comparison to previous versions.

The aim of B08 "Hierarchical frame induction via probabilistic models" (Kallmeyer), which is new to area B, is the unsupervised induction of frames for events described by verbs. To this end, B08 will develop probabilistic models and machine learning techniques for unsupervised and semi-supervised frame induction. In the unsupervised case, the input for frame induction consists of text documents with syntactic information. The outcome should not only identify predicate-argument relations but also provide a rich characterization of these relations via hierarchically ordered semantic roles. This allows then the induction of an event type hierarchy that will be checked against and provide evidence for the event types assumed in the linguistic CRC projects and in the literature, for instance in the Levin classes. In a second step, B08 also seeks to learn relations between the frames of verbs that are subject to alternations. This goal will be pursued in a semi-supervised approach where the learning algorithm will be fed with possible alternation patterns. Combining the two, B08 aims at identifying a hierarchical classification of event types and semantic roles and at learning complex frames with embedded event frames. In the context of the CRC, this project can provide additional empirical evidence for the existence and the nature of frames. Moreover, it can provide an automatically induced event type hierarchy to projects aiming at implementing their event frame analyses.

B09 "Modifiers as a probe into the frame structure of events" (Löbner, Petersen), also a new project, seeks to determine the architecture that is needed for frame representations of events by analyzing their interplay with adverbial modifiers, especially manner and agent-oriented event modifiers. B09 includes both work in the area of verb meaning, i.e., constructing frame-based representations of semantic traits that are available as targets of adverbial modification, and work in adverbial semantics, especially with respect to composition rules that show how the meaning of an adjectival lexeme (in adverbial use) can be brought to bear on the verb's representation to modify it — sometimes in different ways for one and the same adjectival lexeme. B09 will (i) develop a more fine-grained view on the delimitation of manner and non-manner adverbs, which has been a problem for existent approaches, (ii) develop a frame-based representation of the manner component of verb meaning that is detailed enough to account for manner modification phenomena, (iii) study the modification patterns against the backdrop of robustly defined verb classes, in order to assess the roles of lexical semantics and inferential processes as boundary conditions in the interpretation of verb-modifier combinations. B09 closely collaborates with C10, which is concerned with adjective-noun modification, relating adverbial verb modification to corresponding adjectival modification of deverbal nouns.

Area C: Operations on frames

Results of the first funding period

Area C (*Frames and concept types* in the first funding period) was based on the theory of nominal concept types and determination developed in the Research Unit RU 600 'Functional concepts and frames', with three out of the five CRC projects in area C being follow-ups to RU projects: C01, C02, and C04.

The projects of area C contributed to several aspects of the overall aim of studying and modeling cognitive representations in the realm of linguistic meanings. These aspects include:

- Language: Linguistic evidence for the distinction of the basic concept types of sortal, relational, individual, and functional concepts.
- Language and Cognition: Exploration of metonymy as a basic conceptual operation involved in historical semantic change, coercion, and various semantic mechanisms of word formation.
- Frame theory: Modeling metonymy as a basic operation on lexical frames that results in a shift of the central 'referential' node of the frame.
- Language: Interaction and combination of frames in mechanisms of nominal compounding as cases of 'close composition' of two lexical frames that combine directly.
- Cognition: Experimental evidence for conceptual shifts during the processing of NPs.
- Cognition: Location of brain areas involved in complex semantic processing.

Projects C01, C02, and C03 focused on the predictions of the CTD Theory of Concept Types and Determination (Löbner, 2011) from a typological (C01), statistical (C02), and psycholinguistic (C03) perspective. According to the theory, there are four basic nominal types that can be cross-classified by two features, inherent uniqueness and relationality (see Fig. 3, p. 13). Sortal nouns (*cow*, *snow*) are neither inherently unique nor relational; individual nouns (*pope*, *Mary*) are inherently unique and not relational; relational nouns

(in the narrower sense, *brother*, *baggage*) are relational and not inherently unique, while functional nouns (*mother*, *handle*, *size*) are relational and inherently unique. These four types correspond to four types of concepts, and these, in turn, to four different frame structures. Functional concepts are of particular interest in frame theory because attributes, the constitutive components of frames, are functional concepts. In linguistic semantics, the distinction between nonrelational and relational nouns is broadly accepted, but not so the distinction between inherently unique and non-unique nouns, in particular not for the distinction of functional nouns as a class of their own.

According to CTD, the standard types of determination immediately correspond to the two distinctions: (in)definite determination indicates an inherently (non)unique NP concept, possessive vs. absolute determination indicates a relational vs. nonrelational NP concept. Crucially, the conceptual type of the NP may be congruent or incongruent with the lexical concept type of the head noun. CTD predicts that (i) there will be languages that distinguish grammatically between congruent and incongruent determination; (ii) incongruent uses of nouns will be less frequent; (iii) incongruent uses cost more cognitive effort.

Project C01 “Conceptual shifts: typological evidence” (Löbner, Stassen) investigated splits in the grammar of determination, proving that they can be explained as immediately relating to the distinction of congruent and incongruent determination. The major lines of investigation addressed alienability splits (relating to the congruence of possessive determination), definiteness splits (relating to (in)congruent definiteness), and the historical emergence of definiteness marking in Uralic languages.

C02 “Conceptual shifts: statistical evidence” (Löbner, Petersen) undertook a large corpus study on German data, and a smaller one on Polish. The German corpus study involved the annotation of the lexical concept types and the grammatical determination types of more than 50,000 noun tokens in a balanced corpus. The statistical predictions of CTD were strongly corroborated; for example, it could be stated that roughly two thirds of inherently unique nouns are used with definite determination, while two thirds of inherently nonunique nouns carry indefinite determination; possessive uses of relational nouns are about five times as frequent as possessive uses of nonrelational nouns.

Project C03 “Conceptual shifts: psycholinguistic evidence” (Indefrey), in a series of six behavioral experiments on German and English (in collaboration with G. Thierry, Bangor University, UK), demonstrated the congruence effect predicted by CTD and clarified two important properties of this effect: (i) it arises post-lexically and (ii) it is a facilitation effect. In a second line of research, Indefrey (in collaboration with P. Hagoort, Nijmegen, NL) conducted a meta-analysis of more than 150 hemodynamic neuroimaging studies comparing the activations reported for sentences involving semantic shifts, semantic violations, and semantic ambiguities to those of sentences with increased syntactic demands due to syntactic operations, violations, or ambiguities. The main findings were that: (i) the neural correlates of semantic processes are distinct from those of syntactic processes and (ii) the neural correlates of different kinds of semantic processes share brain structures. The latter finding raises the question whether at a neural level but also functionally, there is a kind of general semantic processor involved in different kinds of semantic shift operations.

Project C04 “Conceptual shifts: their role in historical semantics” (Geisler) concentrated on the phenomenon of metonymy in historical change. Metonymy is a basic mechanism of conceptual shift. The research on this phenomenon has up to now been suffering from the lack of a precise definition of metonymy. Here, frame theory offers a breakthrough: metonymy can be understood as a mechanism that shifts the central node of the frame to the value of one of its attributes, where this shift underlies certain structural restrictions. The resulting notion of metonymy is much more precise than other existing notions and at the same time more comprehensive in accounting for a broader range of cases. The frame-based theory of metonymy was developed in close collaboration with project C05 (Frames and nominal word formation) and A01. C04 studied metonymies from a historical perspective on the semantic change of French nouns (along with other types of conceptual shifts, including metaphor).

C05 “Frames and nominal word formation” (Löbner) investigated mechanisms of German word formation in the framework of frame theory. Here, too, metonymy plays a central role, not only for analyzing metonymic uses of nouns as such. Many word formation processes, such as nominalizations, involve a shift of the central node and a subsequent adaptation of the resulting frame so as to meet well-formedness conditions for lexical frames. C05 came up with frame models of several major productive types of nominal compounds. These investigations resulted in first frame accounts of mechanisms of close composition, modeling modes of interaction of two nominal frames, or a verb frame with a noun frame. Close composition will be further studied in the second funding period in projects B09 on verb modification and C10 on noun modification.

Plans for the second funding period

By the end of the first funding period, the three lines of projects C01, C02 and C04 will have been funded for ten years each including their RU predecessors; they will not be continued but their results will be the basis for further research in the same domain.

While only one of the C projects, C03, is continued, the projects of area C in the first CRC phase have provided foundational work and results for the remaining and new projects C03, C08, C09, and C10. The methods developed in C03 will now be applied to new, but related phenomena. The models and results developed in C05 and C04, in particular the frame modeling of the semantics of word formation will be taken up and developed further in C08 and C10; the large database of annotated German NPs provided by C02, constitute a valuable resource for C10. Research on countability in C01 and C02 will be relevant for C09.

Compared to the first funding period, area C has broadened its range of topics and therefore has changed its title. The focus is now on operations on frames in general.

C03 “Conceptual Shifts: Psycholinguistic Evidence” (Indefrey) is the only continuing project in the C group. It will further pursue its psycholinguistic investigation of conceptual shifts. In the second period the successful paradigms developed in the first funding period will be applied to other types of conceptual shifts, in particular nominal mass/count shifts and verbal telic/atelic shifts. This research relies on a close collaboration with project C09. Based on work from the first period, C03 will furthermore start a new line of research with the aim to provide a neurocognitive theory of conceptual shifts in general. It will systematically investigate similarities and differences of the electrophysiological and hemodynamic signatures of a range of conceptual shifts including concept type shifts, mass/count shifts, telic/atelic shifts, and metaphoric shifts. The working hypothesis is that conceptual shifts of different kinds may arise at the same processing stages and may be subserved by at least in part overlapping neuronal populations. Evidence in favor of this hypothesis would strongly support a generalized view of conceptual shifts as operations on frame representations.

C08 “The semantics of derivational morphology: A frame-based approach” (Arndt-Lappe, Plag) is concerned with the operations on frames that are triggered by derivational morphological processes, more specifically by nominalizations. Many derivational processes in English (but also in other languages) are highly polysemous, often exhibiting a whole range of meanings. C08 deals with this central problem of derivational morphology, the polysemy of derivational processes and the compositionality of word-formation processes. It aims at describing and modeling the potentially diverse interpretations of derived words, addressing questions such as: What kinds of interpretation are principally possible given the meaning of the base and the affix? Is there a restricted set of semantic mechanisms that can account for derivational readings in a principled way? What is the role of world knowledge and how can it be integrated into a theory of derivational semantics? These questions will be tackled using frame semantics. Frames allow for the incorporation of semantic and conceptual knowledge into rich, but formally constrained, representations. Semantic operations in morphological categories can be conceptualized as operations on (or shifts within) frames, and the semantics of a derivational process is describable as its specific potential to perform specific operations on the frames of its bases.

The goal of project C09 “A frame-based analysis of countability” (Filip) is to develop a theory of countability in a frame-based theory. The emphasis is on (i) the fine-grained representation of units of counting and measuring in the semantic representation of nominal expressions, which motivates the count vs. mass distinction, and its extensions to the parallel event vs. process aspectual distinction in the verbal domain, and (ii) shifts of meaning between count and non-count interpretations. The novel feature of this theory is that it combines the fundamental insights of frame semantics with the current research in formal semantics (Montague Grammar) and closely related research in psychology and the philosophy of language. For this, the point of departure is Type Theory with Records (TTR, Cooper), a form of model theory in which frames (in the sense of Fillmore) are represented as record types. A record type (frame) is a typed recursive feature structure represented in a format akin to an attribute-value matrix. TTR offers the means to integrate a fine-grained account of mereological and aspectual properties, as possible in frame semantics, with a logic based on lambda abstraction and functional application.

C10 “A frame-based analysis of adjective-noun combinations” (Löbner, Petersen) aims at a semantic analysis of the compositional interaction of attributive adjectives with nouns in German and English. Rather than providing a classification of adjectives, the focus is on conceptual mechanisms of combining the frames of A and N into one. The application of frame theory opens new prospects for long-known semantic problems. In particular it ventures to analyze adjectival modification on the basis of decomposing the lexical meanings of both the adjective and the noun by representing the relevant aspects of lexical meanings in Barsalou frames. The project will transcend the present state of the art in several regards. (i) Based on the analysis of the lexical decomposition of noun and adjective meanings, it will be able to provide a more explicit picture of the mechanisms of composition, along with analyses for cases which hitherto lack a plausible treatment. (ii) Linking the research to previous frame analyses of the semantic mechanisms of nominal compounding will contribute a general picture of modification that also encompasses nominal compounds. (iii) Merging the analysis of adjective-noun combinations with the theory of nominal concept types will lead

to new questions and insights. The data to be analyzed will be provided by comprehensive statistical corpus investigations for German and English, starting with the determination of statistical clouds of adjectives and nouns in combination. In total, the approach will hopefully be able to arrive at a picture of the subcompositional nature of adjectival modification which is at the same time more differentiated, more explicit, and more comprehensive than other current approaches.

Area D: Extending the boundaries of frames

Results of the first funding period
Area D is a new project area in the second CRC funding period.

Plans for the second funding period
Compared to the domains of frame theory application considered so far in the CRC, the projects of area D extend the frame approach to more intricate cases, which often require an extension of the frame models used so far.

The aim of project D01 "Frame representation of prototype concepts and prototype-based reasoning" (Schurz) is to account for prototype concepts and reasoning, based on prototype frames. Prototype frames are frames which include information about the typicality and/or probability of the values of attributes and information about the diagnosticity of attributes. The project pursues the following three aims: (1) Modeling prototype concepts by means of prototype frames. This part of D01 seeks to integrate the concept of a prototype frame into the rich frame theory that has been developed in the CRC. (2) Investigation of the compositionality of prototype frames and ways to handle failures of compositionality. In this part of the project some prominent models of prototype combinations, in particular of adjective-noun combinations, will be analyzed focusing on their compositionality and their fit with empirical data. The typicality values predicted by the models will be compared with empirically observed typicality values. (3) Investigation of the rules of reasoning with prototypical properties and prototype frames. The focus of this part of the project is (i) the investigation of the predictive efficiency of reasoning with prototypes, and (ii) the logical and empirical study of rules of default inheritance of prototypical properties to different kinds of subclasses.

Project D02 "Individual psychology and public meaning: bridging the gap with frames" (Vosgerau) aims at clarifying the relation between the psychological level of describing the cognition of individuals and the intersubjective level on which language (and scientific understanding) operate. More concretely, it seeks to clarify the link between the individual mental representations of language users and the public meaning of linguistic expressions, which still represents an open problem in philosophy. The project aims at establishing this link by means of frames, in accordance with the hypothesis that frames are a universal format of different levels of concept representation. The recursive structure of frames allows the representation of one and the same thing at different levels of granularity. The underlying idea of D02 is to conceive public meaning as a generalization from individual mental representations. Furthermore, D02 assumes that these generalizations (or overlaps) are enhanced by different attunement mechanisms that reflect the influence of language use on concept formation. The overall aim of the project is to develop a first frame-work for a theory of communication that is able to systematically relate individual mental representations with public meanings. However, D02 will not provide a full-blown theory; rather, a "proof of concept" will be given by spelling out the most relevant generalization and attunement mechanisms for words expressing sortal concepts.

Project D03 "Conceptual representation in social cognition: frame-theoretical representation of 'social partner' " (Kalenscher) extends the CRC research on frame-based conceptual representation in two important directions by focusing on abstract concepts in social cognition and by investigating conceptual representations in animals. As the scientific study of conceptual representations often focuses on tangible concepts, remarkably little is known about the cognitive representation of abstract concepts, even from the perspective of traditional cognitive theories. However, abstract concepts play a central role in cognition, especially in social cognition and social interaction. We constantly classify people into social categories. From this classification, rich inferences (attributions) result about the causes of the person's behavior and their likely actions. D03 extends frame theory to social cognition, especially prosocial behavior. An agent may perceive someone else either as a social partner, as a competitor, or as a non-social object. D03 plans to investigate the conditions and consequences of the 'partner' frame representation on the attitude towards the partner, in particular with respect to choice behavior during social interaction. Because animal models allow for better standardization and thus more rigorous testing than human studies, D03 will use rats (rattus norvegicus) as model organisms. With the help of a rat model of prosocial choice, D03 plans to characterize the nature of the conceptual representation 'partner' during social interaction. The predictions of Barsalou's frame theory will be contrasted with the predictions of other accounts, in particular from flat feature list representations.

Project D04 “The role of information structure in sentence formation and construal: a frame-based approach” (Latrouite, Van Valin) extends frame theory to the information structure (IS) – morphosyntax interface and the common ground (CG), which is relevant to this interface. It adopts a typological approach and concentrates on four languages in which discourse-pragmatics is immediately reflected in the morphosyntax: three non-configurational languages, Lakhota, Tagalog and Kapampangan, and one discourse-configurational language, Hungarian. IS is understood as the grammatical devices used by a speaker in a discourse to structure an utterance with consideration of the shared common ground and discourse-specific purposes. Describing and capturing the structure-building aspect of IS as well as its effects on argument realization and constituent order in the target languages is the first objective of this project. The second objective concerns the modeling of the findings that relate to the syntax-semantics-pragmatics interface, especially aspects of CG content and management via frames. In line with Zeevat (2004) the representations are assumed to be part of a theory of informational updates producing an information state that puts constraints on morphosyntactic realization patterns and interpretation. D04 hypothesizes that frames are the appropriate representation format for modeling relevant aspects of the common ground, as they allow for a straightforward integration of lexical frames and their role in givenness evaluations.

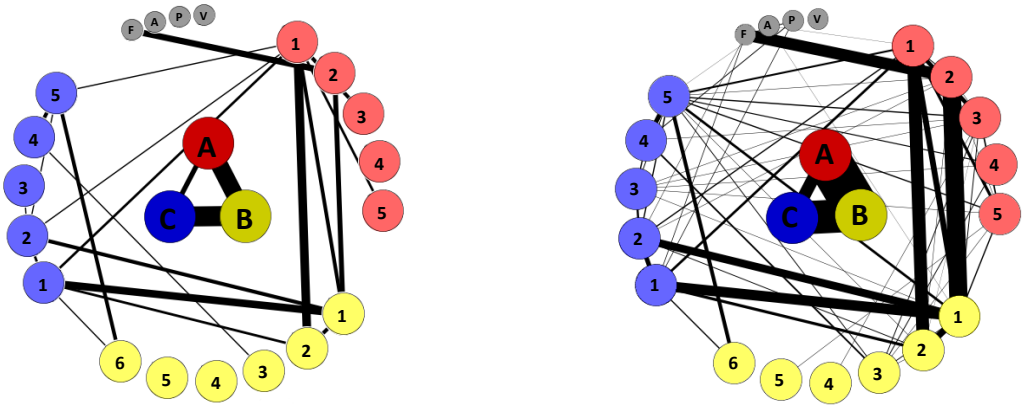
Project D05 “Frames in morphophonology: Modeling paradigms as frames” (van de Vijver) proposes to represent paradigms in morphophonology as frames. Paradigms are sets of word forms related to each other by shared meaning and phonology. There are several phonological and morphological processes that show the necessity of paradigms as a linguistic unit. Paradigms may consist of subparadigms and this structure is reflected in the intuitions of native speakers. In addition, word forms in a paradigm often resemble each another and phonological processes may be applied or may be blocked to apply to ensure this similarity. The similarity among the word forms often stems from one word form in the paradigm, which is thought to be the base of the paradigm. Despite the central role of paradigms in phonology their treatment in phonological theory raises various problems. D05 proposes that frames can be used to analyze paradigms and that doing so solves many issues surrounding the theoretical treatment of paradigms. Frames have been hypothesized to be a general format for cognitive representations. In a frame a referent is defined by its attributes and their values. Each value can potentially have further attributes with particular values. A paradigm is, therefore, hypothesized to consist of a referent, defined by its attributes and their values. The attributes can be morphological or phonological in nature, and, because of the asymmetric structure of a frame, a paradigm is hypothesized to be asymmetric; some, but not all, values have further attributes themselves. Furthermore, native speakers can form generalizations over similarities among frames in order to go beyond their lexical knowledge. These generalizations are frames themselves, in which the frequency of the frames over which they are generalizations is reflected. Representing paradigms as frames allows the theory to resolve problematic aspects of the treatment of paradigms and to shed light on aspects of frames that are ill-understood.

1.2.2.3 Collaboration within the CRC

Collaboration network in the first funding period

As can be seen from the different reports in section 3, there have been various collaborations between the CRC projects resulting in common workshops, talks and publications and also in joint supervision of PhD students by members from different projects. Figure 7 visualizes our CRC-internal collaboration in a graph. The outer ring of nodes shows the projects. The red nodes represent area A projects, the yellow ones area B and the blue ones area C where the node is labeled with the project number. The grey nodes are the associated projects by Hana Filip (F), Daniel Altshuler (A), Ingo Plag (P) and Ruben van de Vijver (V), which joined the CRC in the course of this funding period. The edges between nodes represent collaborations where the thickness of the edges corresponds to the intensity of the collaboration. This intensity is a sum of the following factors: (i) the number of joint publications (weighted with factor 3), (ii) the number of joint conference talks (weight 2), (iii) the number of conferences and workshops organized together (weight 1), and (iv) the number of the jointly supervised graduate students through the MGK’s advisory teams (weight 0.5). Finally, for the inner triangle the data of the research projects has been collocated to show the collaboration between the three large areas A, B, and C. The left graph shows only the publication output of CRC-internal collaboration across projects while the right graph represents all four of the forms of collaboration listed above. The graphs are based on a total of 28 joint publications, 35 joint conference talks, 10 jointly organized workshops/conferences and 24 PhD students supervised by members of different projects.

The two graphs illustrate that our CRC is much more than a sum of its projects. In particular the publication graph shows that a considerable part of our results would not have been possible without this collaborative research environment.



joint publications overall internal cooperations

Figure 7: Internal cooperations in phase 1. Vertices refer to projects, thickness of edges refers to intensity of collaboration, which is calculated from (i) joint publications, (ii) joint conference talks, (iii) jointly organized conferences/workshops and (iv) jointly supervised Phd-students.

Axes of collaboration planned in the second CRC phase

Besides smaller working groups within the CRC, the following axes of internal collaboration are planned/exist already:

Verbs, nouns and modification: Several projects are concerned with event frames, frames for deverbal nouns and with their modifications, namely the projects A01, A02, B01, B08, B09, C08, C09, C10. Some of these projects already collaborate actively (see above). In order to further foster exchange and joint work among these projects, we plan to organize a CRC research seminar on this topic in the winter term 2015/2016. Furthermore, we also plan a workshop on "Event semantics and modification" in the second half of 2016 followed by the publication of a high-quality peer-reviewed edited volume in the CRC series "Studies in Language and Cognition" published with Düsseldorf University Press. Besides this, there will be smaller working groups, as is already the case right now.

Empirical research on cognitive representations: An important aim of the CRC is to bring together the theoretical investigation of frames with empirical research on cognitive representations as pursued in projects A04 and C03 (Indefrey) on psycholinguistic evidence for frame-structured representations and conceptual shifts, in B03 (Biermann-Ruben, Schnitzler) on neural representation of action concepts and in D03 (Kalenscher) on social concepts in animals. Knowledge about the nature of concept frames and predicative frames developed in the linguistic projects (for instance B01, B09, C09, C10) and in the philosophical projects (in particular A05, D01 and D02) of the CRC feeds into these projects and their experimental set-up (see, e.g., Klepp et al., 2014). On the other hand, these projects provide important empirical evidence for the CRC hypothesis that frames are cognitively "real". In order to further promote this collaboration, we plan a workshop on "Frames and cognition" in 2016.

Representational and ontological structures: The question whether the structure of frames mirrors the structure of reality or whether the relation between mental representations such as frames and reality has to be conceived of differently will be a topic of collaboration for several of the philosophical projects in the CRC. Project A05 (Kann) will work out similarities and differences between the modern frame approach and classical ontologies proposed in the history of philosophy. Project A06 (Schurz), in turn, is concerned with the ontological presuppositions of frame theory within the domain of science, especially the question whether it implies a universalist or rather a trope ontology, while Project D02 (Vosgerau) discusses the relation between frames and public word meanings that are shareable among members of a community. We expect an intense collaboration between these projects in the second funding period.

Interfacing frame semantics with morphosyntax and pragmatics: So far, during the first funding period, A02 and B01, together with the SFF projects of Hana Filip and Daniel Altshuler, have been the only projects interested in the way in which syntactic and morphological composition triggers frame composition, also in interaction with pragmatic factors (including information structure). In the second funding period, the group of projects investigating the interface between frame semantics, morphosyntax and pragmatics will grow; we expect in particular a close and fruitful exchange between projects A02, B01, B08, C03, C08, C09 and D04. These projects investigate meaning composition and/or meaning shifts triggered by the morphological or syntactic context, in interaction with pragmatic factors.

Weights and probabilities in frames: One of the new aspects in the second funding period will be the integration of probabilities (or weights) into frames. This is pursued in a range of projects, with very different topics and aims: A01 (Petersen) is interested in a general definition of probabilistic frames, B08 (Kallmeyer) seeks to develop probabilistic models that appropriately describe the relation between morphosyntax and frames in a context of data-driven unsupervised machine learning, D01 (Schurz) introduces weights into frames in order to capture non-monotonic properties of frames and typicality, D02 (Vosgerau) makes a similar use of weights in frames, and D05 (Van de Vijver) uses frames to represent morphophonological paradigms with weights attached to the operations represented in these frames. Despite the different topics, there are common methodological questions that will be tackled in collaboration. We plan a workshop on weights and probabilities in frame-based representations.

Frames and scientific theory: Project A06 (Schurz) aims at examining the use of frames for representing scientific theories in a general way, investigating the specific frames and frame logics needed. B06 (Zielasek, Vosgerau), by contrast, uses frames to represent specific highly complex concepts in psychiatry. In both cases, appropriate frame definitions and appropriate constraint languages must be found, which links these topics to the foundational theoretical issues addressed by A01, A02, B01 and C09. We plan to collaborate in these areas, aiming at clarifying the way frames are used in science.

Implementing (constraints on) frames: The frame implementation tool developed within XMG in A02 (Kallmeyer) is intended to help the CRC projects implement their frame analyses and thereby test them. Possible users of this tool in the CRC are, besides A02 itself, A01, A06, B01, B06, B08, B09, C08, C10 and D04. On the one hand, the needs of these projects might have an impact on the frame definition adopted in the tool, and on the other hand, A02 will help these projects specify their frames and frame operations. To this end, we plan a tutorial on XMG's frame component in the second half of 2015, and a further workshop on frame implementation and XMG in 2016. These events will be organized together with the XMG development team from the Université d'Orléans.

1.2.2.4 The development of the CRC

From the first funding period to the second, the CRC undergoes a considerable change in its project composition. To a large extent, this is due to the fact that there was already a preceding DFG Research Unit (Forschergruppe) RU 600 "Functional Concepts and Frames" (2005/2 – 2011/1)[6]. Among the 8 scientific projects from the first period that will not be continued, the 5 projects B02 (Geisler, Löbner), B04 (Schurz), C01 (Löbner, Stassen), C02 (Löbner, Petersen) and C04 (Geisler) were already part of this research unit. They have obtained satisfying results (see also section 1.2.2.2 on results of the first funding period). Their lines of research, however, are continued under different perspectives in the planned projects of the second CRC phase: The results of project B02 are immediately relevant for project B09, insights from project B04 provide the starting point for project A06, and projects C01, C02 and C04 provide the basis for the new projects C09 and C10 on semantic analyses of various types of nouns.

Only A03, B05 and C05 will end after only one funding period. In the cases of A03 and C05, the results of the project feed immediately into some new project in the second CRC phase: Project A03 showed that sensorimotor values can be understood as playing a role both in (the frame representation of) motor/sensory processes and in (the frame representation of) some concepts. The question of abstraction and abstract concepts (which was planned to be tackled in the continuation of the project), is now framed in a different way and will be addressed as part of the new project D02. The results of project C05, which is also ending, immediately feed into the new project C10, which in some sense continues C05 but has a considerably broader scope. Project B05 (Busse) was planned from the beginning as a project for four years. Its main objectives will have been achieved by the end of its funding.

In the first funding period, the CRC includes a project INF. Besides setting up general infrastructure, INF was mainly concerned with developing database architectures for some of the projects, in particular C04 (ending), A04 and C03 and with implementing an annotation tool based on a project-specific database for C02 (ending). For A04 and C03, the database design and implementation will be finished by the end of the first funding period. INF, together with A02, is also involved in the development of a frame implementation tool. In the second phase, A02 will be responsible for maintaining and extending this tool. In addition, support may be needed when disseminating data in view of sustainability in the second funding period of the CRC; this can be provided by the Department of Computational Linguistics. Therefore, given that the CRC currently does not build resources on a larger scale, an INF project is not necessary in the second CRC phase (see also section 1.3.3).

In the second funding period, the CRC will extend its coverage in various aspects. This is reflected in the addition of a new project area, area D, and also in the extension of area C. The fact that the CRC can

[6] http://www.phil-fak.uni-duesseldorf.de/fff/

be extended in such a way is to a large extend due to the active promotion of the research environment in language and cognition at Heinrich Heine University. Various appointments of professorships in this area have taken place in view of the research domain of the CRC (see also section 1.3.1). Several new PIs have joined us in the course of the first funding period, namely Sabine Arndt-Lappe, Hana Filip, Tobias Kalenscher, Anja Latrouite, Ingo Plag and Ruben Van de Vijver. Some of them had a preparatory project financed by the university (Filip, Van de Vijver) or from the lump sums of the CRC (Arndt-Lappe & Plag, Filip), which allows for a smooth integration of these new projects. Except for Tobias Kalenscher, who has not joined the CRC with a project yet but who is already an active member of its research community, all PIs of the second funding period are already participating in the CRC with a project in the current phase.

1.2.2.5 Summary: The CRC as a whole

The research aim of the CRC as a whole is the interdisciplinary development of a universal theory of representation that covers a broad variety of types of concepts. The fundamental hypothesis that unites the CRC projects is that there is a uniform structure of representation underlying the neural level, the psychological level, the level of linguistic concepts, and the level of institutionalized conceptions such as those used in science. This uniform structure is frames (roughly) in the sense of Barsalou (1992).

The core of the CRC consists of its linguistic projects, i. e., a principal focus is on representing linguistic concepts, in particular meaning, with frames. From a broader perspective, as part of the general interdisciplinary enterprise of mind and brain research, the theory will unite research on representations at the neural, the cognitive, the linguistic, and the social level of concept formation.

In our first funding period, we have extended and further formalized our notion of frames, always in the light of the different frame theory applications pursued in the CRC. As a result, we have developed a specific frame model, that we call *Düsseldorf frames*. These frames are typed attribute-value structures where attributes are functional. These structures can be recursive and they allow for structure sharing (value identities of attributes). Düsseldorf frames can be formalized as a special kind of typed feature structures that have the following properties: (i) There need not be a unique root node. (ii) In some cases, we can have relations between nodes that are not functional. (iii) We can focus on internal nodes of a frame, i. e., have immediate access to them.

The CRC projects of the current phase compared our frame approach to other theories of cognitive representations and reflected the emergence of the notion of frame in the history of philosophy and psychology. As a result, the frame approach taken by the CRC was confirmed as a theory that is in good accordance with empirical findings. Beyond a mere comparison of theories, the frame approach was combined and integrated with existing other formalisms. The CRC projects are not only pursuing their own approach, but are also relating it to other frameworks, bridging in particular between work in formal and cognitive semantics (as being developed in the CRC).

A central concern of the CRC is to represent aspects of dynamicity within frames, where dynamicity can refer to the frame content as well as to the dynamics of the development of frames in certain areas. In the first phase, several CRC projects have modeled dynamic aspects of events within frames, a topic that will be further pursued in the second funding period. Several other types of concepts that involve dynamic frame components or operations on frames have been investigated, in particular frames for criminal deeds, frames for mental disorders, and frames for central concepts in the philosophy of science.

A large part of the CRC research in phase 1 centered around nominal concept types, investigating linguistic properties correlating with different concept types and exploring shifts between concept types along various dimensions (syntax, typology, psycholinguistic evidence, metonymical shifts).

The second CRC phase will put a stronger focus on the representation of dynamicity in frames such as dynamic temporal and causal components. It will also account for the dynamics within systems of frames, for instance frame composition, and for representing phonological processes within frames. On the linguistic level, so far, we have mainly considered cases of predicate-argument composition. In the second funding period, this will be extended to more subtle cases of composition, in particular to modification, ranging from event modifiers to nominal modification, which require a more fine-grained frame structure and more complex mechanisms driving the composition. Furthermore, semantic frame composition will be considered in its interaction not only with syntax but also with morphology and information structure.

Concerning cognition, research on empirical evidence for frames being cognitively 'real' will be continued and extended to abstract concepts and to new types of shifts. The question of the relation between the human conceptual system and natural language will be examined more closely, linking our frame-based research to notions of reference and truth conditions from the field of formal semantics. Related to the question of how we mentally represent concepts and how they are linked to situations is the investigation of how to represent abstract general concepts such as prototypes or theories we have about certain types

of objects. These topics will also play an important role in the second phase. On the methodological level, the second funding period will introduce weights and probabilities into frames, in order to capture notions of typicality in concept formation and of ambiguities in language-specific frame models.

1.2.3 Positioning of the Collaborative Research Centre within the academic field

The CRC focuses on a formal theory of conceptual representations by means of frames that claims to possess not only sufficient descriptive power, but first of all, cognitive plausibility (which, in turn, must be based on neurocognitive evidence). As a general model of conceptual representations, frame theory is immediately relevant for, and subject to, psychological, neurocognitive, philosophical, and semantic theories of concepts and of the way they are part of the organization of the brain, and related to the external world. This locates the CRC endeavor in the contexts of mind-and-brain research, philosophy of mind, cognitive psychology, neurology, theoretical semantics, and computational science.

Together with its predecessor research unit RU 600, the CRC is among the first research collaborations that focus on bridging the gap between formal and cognitive semantics by developing cognitively adequate representation formalisms – a trend that is now taken by several research clusters. One important example for this new research direction is the “Language in Interaction” Consortium, which brings together 50 researchers from eight Dutch universities. Several groups within the consortium aim at grounding formal linguistic theories in neurobiological reality. Therefore, they have established a strong collaboration between the ILLC in Amsterdam which focuses on logical approaches to language and the neurolinguistics group at the University of Nijmegen. The CRC has strong links to both institutes. Our designated Mercator fellow Henk Zeevat is a member of the ILLC and our PIs Robert Van Valin and Peter Indefrey are associated with the MPI at Nijmegen and the University of Nijmegen.

The various fields of application of the Düsseldorf frame theory link particular CRC projects to research in linguistics (lexical and compositional semantics, computational linguistics, syntax- semantics interface, morphophonology, discourse), philosophy (philosophy of mind, philosophy of language, philosophy of science, history of philosophy), experimental psychology, psycholinguistics and neurocognition, psychiatry, and law.

Philosophy In the philosophical discussion on concepts, recently pluralistic and even eliminativistic accounts try to capture the experimental success of different canonical theories of concepts. Frame theory might be a solution to this philosophical debate due to its flexibility. Moreover, frames promise to offer new, cognitively adequate answers to most perennial questions of philosophical epistemology and ontology, and philosophy of language concerning, e.g., the nature and acquisition of knowledge, the relation between linguistic and mental representations (D02), their relation to world structures, and the embodiment of cognition (A03). In particular, frame-based reconstructions have been proven to be a highly useful representation method in philosophy of science (B04). Among other things, frame-based reconstructions of scientific concepts have been developed for reconstructions of scientific theories, their interrelations, and of conceptual change within scientific revolutions. In the history of philosophy (A05), the comparison of classical philosophical approaches and modern approaches from cognitive science is still a largely underexplored desideratum that the CRC will address. A further contribution to this topic is project D01 integrating prototype theory into frame theory. Overall, by investigating these and related issues, frame theory even touches on the ultimate question about the viability of traditional conceptual analysis as the prime philosophical method for discovering truths, and hence on the question about the nature of philosophy itself.

Mathematical linguistics and logics Within and outside the CRC, project A01 plays a pioneer role in developing, and establishing in the field, a comprehensive theory of frames, which goes far beyond the state of the art in existing similar formalisms such as typed feature structures. It not only accounts for possible structures of frame representations of a richer diversity (including dynamic event frames or frames for different types of concepts), but is also developing a theory of second-order frame operations and relations between frames.

Linguistics The CRC may be said to be leading in lexical **semantics**, including stored linguistic meanings (B01, B02, C01, C04), compositional word formation semantics (C04, C05, C08), and lexical meaning shifts (C01, C02, C03, C04, C05, C09). This is due to the suitability of frames as a formal decompositional format that at the same time has the necessary expressive power and cognitive viability. The frame approach to decomposition succeeds where the logical analyses of formal semantics lack, not expressive

power, but a connection to theories of cognition. The frame approach is also working its way into compositional semantics (A02, B01, B09, C10), towards a theory of representation of sentence meanings as truly structured propositions that – unlike the propositions in possible-world semantics – fully preserve the semantic information of the elements they contain, and the way in which they are combined. The CRC is thus developing a formal semantic apparatus which, for the first time, will be able to explain and describe the *conceptual* level of meaning – a level bypassed in the dominant paradigm of model-theoretic semantics. It is also working towards a conceptual theory of compositions which former theories of cognitive semantics were not able to model. It is apparent from recent developments in formal semantics that attempts are being made to overcome the a-conceptuality of the formal semantics framework in one way or other, e.g. by resorting to 'kinds' in formal analyses; but these attempts are not informed by cognitive theories. The discipline is ready for bridging between formal semantics and *formal* cognitive / conceptual approaches to meaning, where the gap between formal semantics and earlier theories of cognitive semantics (e.g. prototype semantics) was too wide to be bridged. On the biannual CTF (Concept types and frames) conferences organized by the CRC at Düsseldorf (2007, 2009, 2012, 2014, to be continued) and various workshops, we were able to register a growing interest in the conceptual level of meaning on the part of formal semanticists, and increasing convergence of our approaches with others of different provenience, but similar aims. Some scholars outside of Düsseldorf have begun to adopt the Düsseldorf frame approach, e. g. Reinhard Muskens (Tilburg) or Henk Zeevat (Amsterdam).

A particular strength and an outstanding feature of the **computational linguistic** research (A02, B08) in the CRC is the close collaboration with the other linguistic projects. This enables the development of computationally sound and linguistically informed analyses, formalisms and implementations. The work on modeling constructional meaning and lexical meaning in Tree Adjoining Grammar (TAG) using frame semantics was fostered by this particular research environment. It has led to a series of invited talks and of papers at international conferences and in the Journal of Language Modelling (Kallmeyer & Osswald, 2013), a high-quality international open access journal. This work has carried frame semantics into the TAG community, where it has already inspired the integration of frames into state of the art grammar engineering tools for TAG.

A massive trend in computational linguistics is the application of statistical methods of analysis. Several CRC projects contribute to this development by applying these methods for the purpose of information retrieval (B08), automatic classification (C02), and semantic pre-analysis (C10). In its second phase, the CRC will integrate techniques from the area of semantic parsing and distributional semantics and thereby link to cutting-edge topics in natural language processing.

In **morphology**, the central problems of word-formation semantics, affix polysemy and meaning shifts in derived words, are still not satisfactorily solved. A representational framework is needed that can model the decomposition of the meaning of complex words and can access semantic information beyond argument structure in an explicit form. Frame semantics seems ideally suited for this, and initial results implementing this approach with *-ment* derivatives in English have been very well received. (C08)

Project D05 expands two trends in **morphophonological** research. One shows that paradigms have an internal structure. The other argues that morphologically complex words are stored in the lexicon. D05 broadens these trends by hypothesizing that the structure of a paradigm is a frame which is stored lexically.

Psycholinguistics and neuroscience The psycholinguistic and neurocognitive work of the CRC 991 is embedded in, and contributes to, at least three research fields that are highly active and have seen important developments in the last years. Firstly, there is the field of 'grounded cognition' research investigating the role of sensory and motor activations in conceptual representations. The main recent developments in this field are (i) a broadening of the scope of sensory modalities investigated and (ii) a shift of the focus of interest towards the precise circumstances under which sensorimotor activations may be observed. Both developments are well reflected in (B03). Focusing on neural representation of action verbs, project B03 addresses currently widely debated and highly relevant questions in the neuroscience fields of embodiment and human mirror neuron system. The international neuroscience community has shown increasing interest in these topics during the last decade. B03 is linked or collaborates with some of the leading researchers in these areas.

The second research field is psycholinguistic research on the processing of ambiguous words. This field has a long and continuous tradition of research on homonym processing on the one hand and metaphor processing on the other hand. With its investigation of concept type (CT) shifts, C03 has put a novel type of conceptual shift on the agenda.

Finally, research of the CRC aims to revive an interest in the exact format of conceptual representations in psycholinguistics. Current models still conceive of concepts as feature lists or in terms of classic non-decompositional networks and there still is little work on the role of conceptual attributes in lexical ac-

cess. Recently, there has been an increased interest in the role of conceptual components (e.g. 'part-of' words, such as bumper when naming car) as distractor words in picture naming. This research, however, has mainly been conducted to test different accounts of lexical selection rather than to investigate the status of attributes in conceptual representations and hence the format of concepts. Project A04 takes the innovative perspective that attributes of concepts may be concept-specific and require a frame-theoretic representation to be properly accounted for. Thus rather than contributing to an existing development in the field, A04 will have to start such a development.

Experimental psychology (D03) People are prosocial animals. The evolutionary roots and factors favoring prosocial choice, as well as its cognitive prerequisites are currently a hot topic of debate in economics, neuroscience and psychology. Gaining novel insights into the quintessence of social cognition – recognizing and representing a conspecific as a social being – has the potential to transform the field.

Psychiatry The field of psychiatry is currently characterized by the revisions of the classification systems for mental disorders. The publication of the revised classification criteria used in the U.S.A. in May 2013 (Diagnostic and Statistical Manual of Mental Disorders, 5th revision) by the American Psychiatric Association showed that research in neurobiology (including genetics) and psychology is now approaching a point where new concepts are needed to integrate the wealth of information and the increasing knowledge about the complex etiopathogeneses of mental disorders. This had led to a new research initiative by the National Institutes of Mental Health (NIMH) under the term "Research Domain Criteria", which aims at defining genes, neurocircuits, psychopathology and psychological mechanisms as the criteria for future classifications of mental disorders. The ensuing complex interrelationships need a unifying construct of mental representations, and frame analysis is suggested by project B06 to provide such a construct. The general interest by psychiatrists in the topic of frame representations is shown by the poster award 2012 received at the annual congress of the German Society of Psychiatry (DGPPN) and the prize for philosophy in psychiatry awarded to one of the project co-PIs (Vosgerau) by the DGPPN in 2014.

Law Project (B05) provides a new model of analysis to the problem of defining precisely the content (and historical change) of central terms of German law (such as *Diebstahl* 'theft', *Eigentum* 'property', or *Gewalt* 'violence'). More generally it contributes to the field of representing institutional concepts, a field shared with B04 on the philosophy of science, and B06 on psychiatry. Law and psychiatry are two fields where the Düsseldorf frame approach is the first to provide any formal representations at all.

International visibility of the CRC Members of the CRC have published/will publish during the current funding period in the following **peer-reviewed journals** (only published and accepted papers are considered, including preliminary work for the second phase): American Philosophical Quarterly; Brain; Brain and Language; Brain Research; Cognitive Science; Computational Linguistics; English Language and Linguistics; Erkenntnis; European Journal of Neuroscience; Facta Philosophica; Frontiers in Neuroscience; Frontiers in Psychology; Grazer Philosophische Studien; Journal for General Philosophy of Science; Journal of Language Modelling; Journal of Linguistics; Journal of Logic, Language and Information; Journal of Semantics; Kriterion; Journal for Philosophy; Laboratory Phonology; Language and Cognitive Processes; Lingua; Movement Disorders; NeuroImage; Neuron; Philosophica; Philosophical Studies; Philosophy of Science; PLoS One; Process Studies; Review of Philosophy and Psychology; Review of Psychiatry; Studies in History and Philosophy of Science; Studies in Language; Synthese; Theoretical Linguistics; THEORIA; The Review of Symbolic Logic; Zeitschrift für Dialektologie und Linguistik.

In order to enhance international visibility, the CRC initiated a book series Language and Cognition with Düsseldorf University Press, which pursues the policy of dual publication, i. e., print as well as open-access electronic publication. There are three subseries, *Studies in Language and Cognition* (high level, peer reviewed), *Proceedings in Language and Cognition* (proceedings of CRC workshops and conferences subject to the usual reviewing modalities for proceedings), and *Dissertations in Language and Cognition*. The first volumes appeared this year.[7]

Besides publications and conference talks (see individual project reports for further details), the CRC projects have participated in several large-scale international scientific events in the first funding period in order to intensify discussions and collaborations with other scholars and in order to further establish Düsseldorf in the community as a center for research on frames and cognitive representations.

The CRC was asked to host the 25th **European Summer School in Logic, Language and Information (ESSLLI)** in August 2013. Besides this, several other international conferences related to CRC topics

[7] http://www.uni-duesseldorf.de/home/universitaet/strukturen/duesseldorf-university-press-dup/dup3/geisteswissenschaften.html

have taken/will take place in Düsseldorf, namely the 18th Conference on Formal Grammar (2013), the 12th International Conference on Finite-State Methods and Natural Language Processing, FSMNLP 2015, and the Role and Reference Grammar Conference in 2015. Moreover, besides the biannual CTF conference mentioned above, Tobias Kalenscher has established the annual Düsseldorf Decision Neuroscience Symposium, which has attracted in the past scholars from, e.g., Cambridge University, Stanford University, Rutgers University, Harvard/MIT etc.

The CRC members have also carried their knowledge and their theories into the community via lectures at an international level. In particular, the following courses and tutorials have been/will be taught:

Lecturer(s)	Title	Event
Balogh (A02, D04), Lichte (A02)	Working with Tree-Adjoining Grammars	ESSLLI 2015
Filip (C09), Altshuler	Aspect: From Verb to Discourse	ESSLLI 2013
Filip (C09)	Course on formal semantics	2012 LOT Winter School
Löbner (B02, B09, C01, C02, C05, C10)	Lecture on Metonymy	Summer school "Non-compositionality and Figurative Speech", Jerusalem, 2013
Maier, Lichte (A02)	Introduction to Tree Adjoining Grammar	DGfS-CL Fall School 2011
Petersen (A01, B09, C02, C10), Balogh (A02, D04)	Introduction to Formal Language Theory	NASSLLI 2014
Petersen (A01, B09, C02, C10) , Balogh (A02, D04)	Formal Languages in Theory and Praxis	ESSLLI 2015
Van Valin (B01, D04)	Information structure at the syntax-semantics interface	Linguistic Society of America Summer Institute 2011
Van Valin (B01, D04)	Information structure and linking syntax and semantics	LOT Winter School, Leiden, 2013
Van Valin (B01, D04)	Introduction to Role and Reference Grammar	Symposium on Verbs, Clauses and Constructions, Rioja, 2014

1.2.4 Integrating the Collaborative Research Centre into the local research environment

The CRC 991 has considerably shaped both research and teaching at Heinrich Heine University. In the following, we describe how the CRC is embedded in the research environment of the university and how the teaching program has been enriched over the last three years thanks to the CRC.

1.2.4.1 Integration into the research profiles of the HHU

Research on representations in language, cognition and science is firmly anchored in the University Development Plan of Heinrich Heine University as one of its research priorities. The CRC 991 will further develop and extend this research area. It continues the collaborative projects FOR 600 "Functional Concepts and Frames" (DFG) and "Classification and Evolution in Biology, Linguistics and History of Science" (BMBF), which were already part of this priority. At the Institute for Language and Information, the main questions of the CRC are connected with research questions of computation and implementation of frame-based formalisms on the one hand, and with research on semantics, general linguistics, linguistic typology, and language processing on the other. These lines of research in turn enrich the CRC. The Collaborative Research Centre has led to an intensification of the research priorities on logic and philosophy of science at the Institute for Philosophy, investigating frames not only as cognitive representations, but also as tools for scientific theorizing. Moreover, research questions of the CRC, which connect questions of "classical" formal semantics and philosophy with cognitive approaches, have led to a unique series of collaborations between philosophers and psychiatrists, integrating researchers from clinical neurosciences and psychology, to scrutinize the cognitive and empirical side of the frame hypothesis. This tight collaboration between clinical researchers on the one hand and the humanities on the other, facilitated by the CRC, gives the HHU a strong profile in cognitive science in a very complete sense. Integrating researchers from the Institute for Experimental Psychology in the upcoming funding period will further expand the scope of cognitive science research in the CRC and underlines the importance of the CRC as a crystallization core for collaboration between the Faculty of Arts and Humanities, the Medical Faculty and the Faculty of Mathematics and Natural Sciences. Such collaboration is essential for the strategic development of Heinrich Heine University into a nationally and internationally recognized center of cognitive science research.

The HHU has actively supported the further development and extension of the university's research focus on language and coginition beyond direct support to the CRC. It has financed three further research projects in this area via the *Strategischer Forschungsfonds (SFF)*, namely the projects "A Frame-Based Analysis of Countability" (PI Hana Filip), "Frames in phonology: Paradigms as representations" (PI Ruben van de Vijver), and "Temporal constraints on discourse structure" (PI Daniel Altshuler). Furthermore, also via the SFF, a project for preparing the second CRC phase is currently funded.

1.2.4.2 Impact on teaching at the HHU

CRC-related topics are integrated into the curricula in linguistics and philosophy. This, in turn, makes it possible to integrate BA- and MA-students into the CRC with a team project or a BA- or MA-thesis. The following table lists the courses that have been taught by CRC members and that are immediately related to the CRC research topics.

Lecturer(s)	Sem.	Type	Title
Balogh (A02, D04)	S14	BS/MS	Discourse Representations
Balogh (A02, D04)	S12	BS/MS	Semantics and Pragmatics of Focus and Question
Bontcheva (INF)	W14	MS	Computational Tools for Corpus Linguistics
Busse (B05)	W11	MS	Frame-Semantik
Busse (B05)	S13	MS	Prädikation
Busse (B05)	W13	MS	Lexikalisch-semantische Felder
Filip (C09), Thomas	S14	RS	Countability
Filip (C09), Altshuler	S13	BS/MS	Speaking of Events
Filip (C09), Altshuler	W12	BS/MS	Aspect: From Verb to Discourse
Geisler (B02, C04)	S12	MS	Kognitive Semantik des Spanischen
Geisler (B02, C04)	S14	V	Einführung in die Kognitive Linguistik für Romanisten
Hommen (A05), Inderelst (A05)	W13	MS	Aristoteles: Kategorien
Hommen (A05), Sölch	S14	MS	Wittgensteins Philosophische Untersuchungen
Horn (C02)	S12	BS/MS	Semantische und pragmatische Analyse mit korpuslinguistischen Methoden
Indefrey (A04, C03)	S12	RS	Begriffsaktivierung
Indefrey (A04, C03)	W12	RS	Bedeutungsaktivierung im Satzkontext
Indefrey (A04, C03)	W13	RS	Polysemie
Kallmeyer (A02), Lichte (A02)	W12	BS/MS	Lexicalized Tree Adjoining Grammars
Kann (A05)	S13	V	Ontologie und Metaphysik
Latrouite (B01, D04)	S13	SK	Tagalog
Latrouite (B01, D04)	S14	BS/MS	Diskurs- und Informationsstruktur
Latrouite (B01, D04)	W14	MS	Information Structure and Morphosyntactic Change
Lichte (A02), Balogh (A02, D04)	W14	BS/MS	Tree Adjoining Grammars
Petersen (A01)	S12	MS	Frame Theory
Petersen (A01)	S13	MS	Begriffsstrukturen
Petersen (C10)	S14	RS	Distributionale Adjektivsemantik
Plag (C08)	W14	MS	Word-formation Semantics
Schulzek (C05)	S13	RS	Metonymische und metaphorische Prozesse in der Wortbildung
Soom (B06)	W12	MS	Mental Causation
Soom (B06)	S13	MS	Scientific classifications, the case of psychiatry
Vosgerau (A03, B06, D02)	W11	MS	Embodiment: Körper und Geist
Vosgerau (A03, B06, D02)	S14	MS	Begriffstheorien

(S = summer term, W = winter term, RS = research seminar, MS = master seminar, BA = bachelor seminar, V = Vorlesung, SK = Strukturkurs)

1.2.5 National and international cooperation

The following is only a selection of the most important collaborations established between the CRC and other research institutes.

1.2.5.1 National Cooperations

Klinische Kognitionsforschung, RWTH Aachen Katrin Sakreida has worked on the embodiment of concrete and abstract noun-verb combinations together with Ferdinand Binkofski using the fMRI-technique. Project B03 has already consulted her concerning stimulus material and will continue to do so. Furthermore Sakreida has expertise concerning stimulation studies aiming at language functions. B03 plans regular discussions with her to benefit from each other concerning experimental procedures.

Department of Philosophy, University of Bochum Project D01 will cooperate with Markus Werning. Werning works at the interface of philosophy and cognitive science. He was a former collaborator of the the PI of D01, Gerhard Schurz. Schurz and Werning have co-edited several books. A joint experiment with Markus Werning is planned on the role of pragmatic implicatures in reasoning with prototypes.

Goethe-Universität Frankfurt am Main There is an ongoing collaboration of A02 with Frank Richter on quantification in frames and the link from frames to truth-conditions (see common publications listed in the A02 report). A02 further collaborates with Manfred Sailer on multi-word expressions. This collaboration has started in the European Research Network COST Action IC1207: PARSEME: PARSing and Multi-work Expressions.

Max Planck Institute for Evolutionary Anthropology, Leipzig Project D02 will collaborate with researchers at the MPI in Leipzig who are working on language acquisition and communication. The collaboration will be coordinated with the managing director of the institute, Micheal Tomasello.

Munich Center for Mathematical Philosophy, Ludwig Maximilians University Munich Project D01 will cooperate with Hannes Leitgeb and Niki Pfeifer on uncertain reasoning and reasoning with prototypes. The PI of D01, Gerhard Schurz, has co-edited with Hannes Leitgeb a volume of the Journal Synthese on non-mono-tonic and uncertain reasoning, and has co-published with him an article on non-standard probability measures. Schurz and Niki Pfeifer have co-organized joint symposia and are in the process of co-editing a volume on paradigms of cognition. **Institute of Statistics, Universität Ulm** Markus Pauly was in Düsseldorf before taking up a position in Ulm and he was intended to be a co-PI of project B08. He will continue to work with B08 on mathematical aspects of probabilistic frame models.

1.2.5.2 International Cooperations

Brazil

Pontifícia Universidade Católica do Rio de Janeiro Hana Filip (C09) will continue to collaborate with Guillaume Thomas, who worked at Heinrich Heine University previously and who has helped developing the research program of C09.

Canada

Department of Philosophy, University of British Columbia, Canada: Project A06 will cooperate with Holger Andreas on the representation of theories in structuralist philosophy of science and its relation to theory representations by means of frames. Holger Andreas is a renowned expert in structuralist philosophy of science. The PI of A06, Gerhard Schurz, has contributed to a volume of the journal 'Erkenntnis' on structuralist philosophy of science that was guest-edited by Andreas Holger.

McGill University, Montreal B08 has an ongoing collaboration with Jackie Cheung on probabilistic models of frames and on frame induction. Jackie Cheung stayed for a research visit at the HHU from 28.10.–07.11.2014, during which he already started running experiments with B08. This will be continued, taking his work as a starting point for the work planned in B08.

France

Université de Lille 3, France: A01 collaborates with Christopher Piñón on questions concerning a dynamic frame theory, in particular the relation between actions and events as well as the topic of modality. Both A01 and B09 will collaborate with Piñón the topic of adverbial modification. Piñón and Naumann have a long-standing cooperation starting in the time when Piñón worked in Düsseldorf.

Inria Nancy - Grand Est In September 2014, Sylvain Pogodalla has joined the Department of Computational Linguistics (Laura Kallmeyer) as a long-term visitor for an entire year, funded by an Inria grant. He is collaborating with A02 and also with other CRC projects (A01 and D04) on aspects of frames and truth conditions and on discourse semantics.

Université d'Orléans Projects A02, B08 (Laura Kallmeyer, Timm Lichte) have a long-term collaboration with Yannick Parmentier and Denys Duchier on the development and use of metagrammar frameworks for grammar implementation (see common publications in the A02 proposal). In particular the frame component of XMG is developed in cooperation with Orléans.

Institut Jean Nicod, Paris The collaboration with the Institut Jean Nicod (especially with the director François Recanati) was established by project A03 and will be continued by project D02 (Gottfried Vosgerau). Recanati is an internationally leading philosopher of language and cognition and works on the relation between mental representations and linguistic meaning.

Israel

Bar Ilan University, Israel There is a collaboration between the event semantics projects of the CRC, in particular C09, and Susan Rothstein consisting of regular ongoing discussions and exchanges.

Tel Aviv University Project C09 (Filip) has an long-term collaboration with Fred Landman consisting of regular meetings and discussions of issues related to event semantics and the mass/count distinction.

Italy

Department of Medical and Surgical Science, University Magna Gaecia, Catanzaro and IRCCS Neuromed, Pozzilli Project B03 successfully collaborated with Giovanni Buccino during the first phase of the CRC and plan to continue the collaboration. We jointly conducted one experiment during the first phase (interference paradigm), the results of which were already presented at conferences. The journal publication is currently under review. We plan to conduct a follow-up experiment in the second phase.

Institute of Cognitive Sciences and Technologies (ISTC), Laboratory for Applied Ontology, Trento, Italy An invitation of Nicola Guarino to the 2017 Düsseldorf CTF conference led to cooperation on frames and formal ontologies.

Japan

Kwansei Gakuin University, School of Humanities, Department of Literature and Linguistics, Nishinomiya, Japan C10 collaborates with Hiroyuki Miyashita on German adjective semantics by jointly working with a visiting Ph.D. fellow.

Meisei University, Tokyo; Tokyo University of Foreign Languages Anja Latrouite (D04) participates in an ongoing collaboration on "Information structure in Austronesian languages" with Atsuko Utsumi (MU) and Asako Shiohara (UFL) plus 17 joint researchers from different countries (Anja Latrouite receives travel & housing funds for the yearly international workshop).

Tokyo University, Graduate School of Arts and Sciences: There is a collaboration between A01 and Yoshiki Mori on questions concerning the application of a dynamic frame theory to Japanese, in particular with respect to questions relating the dynamic dimension of frames to the temporal domain. In addition, A01 will collaborate with Y. Mori on the topic of phase quantification. Mori and Naumann have a long-standing cooperation starting in the time when Mori worked in Düsseldorf.

The Netherlands

Institute for Logic, Language, and Computation (ILLC), Universiteit van Amsterdam The CRC and the ILLC (contact person: Paul Dekker) have agreed to collaborate on the basis of regular in- and outgoing research visits. Furthermore, in the second phase, Henk Zeevat from the ILLC will spend half of his time throughout the first two years in Düsseldorf.

Donders Institute for Brain Cognition and Behaviour and Max Planck Institute for Psycholinguistics, Nijmegen Peter Indefrey has a long-term collaboration on the neurocognition of language processing with Peter Hagoort. Joint work on sentence-level semantic processing has been conducted in the first funding period (project C03) and will be continued in the second funding period.

Tilburg University, The Netherlands A01 cooperates with Reinhard Muskens on questions concerning

the mathematical modeling of frames, in particular on the relation between frame theory and Montagovian type theory. Muskens and Petersen (A01) meet regularly since several years to discuss frame topics.

Utrecht University, Department of Languages, Literature and Communication, Utrecht Institute of Linguistics OTS, Utrecht, The Netherlands C01 and B09 have a collaboration with Henriette de Swart and Joost Zwarts on NP semantics and the semantics of modification; joint work with a visiting Ph.D. Fellow.

Norway

University of Oslo Regarding information structural annotation and the argument structure-information structure interface, project D04 collaborates with Hanne Martine Eckhoff.

South Korea

Chungnam National University, College of Humanities/Linguistics, Daejeon/South Korea B02 has continued the existing long-term collaboration with Byong-Rae Ryu on Korean linguistics. Ryu stayed for a research visit at the HHU in August/September 2013, where he worked on double case marking in Korean.

Spain

Universitat Autònoma de Barcelona A05 collaborates (since 2011) with Thomas Sturm on the history of philosophy, especially on Kantian epistemology, and on the philosophical presuppositions of scheme and frame theories. Kann and Sturm had meetings in Barcelona and discussed issues related to A05, Sturm held CRC-related lectures in Düsseldorf. Kann and Sturm contracted common supervision for the PhD thesis of Lara Scaglia (SToRE-fellow).

Sweden

University of Gothenburg, Sweden Projcet C09 has established a cooperation with Robin Cooper concerning the relation between frame semantics and Type Theory with Records.

Universität Linköping Project A02 has a long-term collaboration with Marco Kuhlmann on mildly context-sensitive grammar formalisms and their link to dependency grammar, including research on TAG and on the formalization of RRG (see the common publication in the A02 proposal).

Department of Philosophy, Lund University Project A06 will continue its cooperation with Frank Zenker and Peter Gärdenfors on systems of cognitive representation, in particular on the relation between conceptual spaces and frames. Peter Gärdenfors has given an invited lecture at the 2009 CTF conference and Frank Zenker contributed to the proceedings of this conference.

United Kingdom

School of Psychology, Bangor University, Bangor, U.K. Peter Indefrey (C03) started a collaboration with Guillaume Thierry on the neurocognition of conceptual shifts. A joint experiment on concept type shifts in native English speakers was conducted in the first funding period. The collaboration will be continued in the second funding period.

Institute of Neuroscience and Psychology, University of Glasgow Project B03 collaborates with Joachim Gross. In the last third of the first phase, the CRC hosted Liyu Cao, an international fellow of Professor Gross' institute, collaborating on an experiment investigating the impact of the verb contents, movement energy and sound on auditory hearing performance. Conference presentations and publication of this study will exceed the first phase of the CRC. Additionally we would like to continue the collaboration with Professor Gross by hosting another international fellow in the second CRC phase.

Department of Philosophy, London New College of the Humanities, London Project A06 will cooperate with Ioannis Votsis. He is a former collaborator of the PI of A06, Gerhard Schurz, and was a postdoc in the project B04 of the first 4 years period of the CRC. Together Votsis and Schurz have co-organized several workshops, guest-edited several Journal volumes; in particular they have co-published two articles on the applications of frame theory in the philosophy of science. This cooperation will continue in the second 4-year phase of the CRC.

The United States of America

Emory University, Department of Psychology, Atlanta, USA Lawrence Barsalou is a regular invited speaker at the CTF conferences; he gave talks at CTF07, CTF09, and CTF12, and will contribute to the CTF14 volume of selected talks, planned with CUP. Phil Wolff from the same department was invited speaker at the CTF14.

Department of Linguistics, University of Texas, Austin: A02 plans a research visit of Julia Zinova (the doctoral student in A02) at the University of Texas, Austin, in order to collaborate with John T. Beavers on lexical aspect, motion verbs and scalar semantics.

University at Buffalo, New York Regarding information structure and syntactic theory/RRG, Project D04 is collaborating with Mitsuaki Shimojo, who has been working on information structure in Japanase within Role and Reference Grammar. Project B01 is collaborating with Jürgen Bohnemeyer on the semantics and typology of event-integrating constructions.

Institute for Slavic Languages and Literatures, University of Kansas A02 has a collaboration with Stephen Dickey on aspect and motion verbs in Slavic languages, planning a research visit of Julia Zinova, the doctoral student in A02, to Kansas University.

University of New Hampshire, College of Liberal Arts Project C08 will be carried out in collaboration with Rochelle Lieber, who is among the most distinguished experts on word-formation semantics internationally. Lieber and one of the PI's have collaborated successfully on several previous occasions, including the research for and writing of "A Reference Guide to English Morphology" (OUP 2013, with Laurie Bauer as additional author).

Brandeis University, Department of Computer Science, Waltham MA, USA James Pustejovsky and Sebastian Löbner started a collaboration on the interplay of linguistic semantics with Distributional Semantics at a 2013 Dagstuhl seminar, to be continued at a symposium "Meaning in Context: Models of Computation and Representation" 2015 at Munich. Pustejovsky also was invited speaker at CTF09 and CTF14.

World Health Organization Jürgen Zielasek (B06) has an ongoing collaboration with G. Reed as rapporteur/consultant to the WHO ICD-11 Working Group on Psychotic Disorders and consultant to the Field Study Coordination Group.

References

Baggio, G. & P. Hagoort. 2011. The balance between memory and unification in semantics: A dynamic account of the N400. *Language and Cognitive Processes* 26(9). 1338–1367.

Barsalou, L. W. 1992. Frames, Concepts, and Conceptual Fields. In A. Lehrer & E. F. Kittay (eds.), *Frames, Fields, and Contrasts* New Essays in Semantic and Lexical Organization, chap. 1, 21–74. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Barsalou, L. W. 2005. Continuity of the conceptual system across species. *Trends in Cognitive Science* 9. 309–311.

Barsalou, L. W. 2008. Grounded cognition. *Annual Review of Psychology* 59. 617–645.

Barsalou, L. W. 2012. The Human Conceptual System. In M. J. Spivey, K. Mcrae & M. F. Joanisse (eds.), *The Cambridge Handbook of Psycholinguistics*, chap. 12, 239–258. Cambridge University Press.

Bartlett, F. C. 1932. *Remembering. A study in experimental and social psychology*. Cambridge University Press.

Bergen, B. K. & N. Chang. 2005. Embodied Construction Grammar in simulation-based language understanding. In J.-O. Östman & M. Fried (eds.), *Construction Grammars. Cognitive Grounding and Theoretical Extensions*, 147–190. Amsterdam: John Benjamins.

Boas, H. 2008. Towards a frame-constructional approach to verb classification. *Revista Canaria de Estudios Ingleses* 57. 17–47.

Busse, D. 2012. *Frame-Semantik. Ein Kompendium*. De Gruyter.

Carpenter, B. 1992. *The Logic of Typed Feature Structures*. Cambridge: Cambridge University Press.

Chen, X. 2002. The 'platforms' for comparing incommensurable taxonomies: A cognitive-historical analysis. *Journal for General Philosophy of Science* 33. 1–22.

Cooper, R. 2005. Records and Record Types in Semantic Theory. *Journal of Logic and Computation* 15(2). 99–112.

Cooper, R. 2012. Type Theory and Semantics in Flux. In R. Kempson, N. Asher & T. Fernando (eds.), *Handbook of the Philosophy of Science*, vol. 14: Philosophy of Linguistics, 271––323. Elsevier BV.

Fillmore, C. J. 1982. Frame Semantics. In *Linguistics in the Morning Calm*, 111–137. Seoul: Hanshin Publishing Co.

Gamerschlag, T., W. Geuder & W. Petersen. 2014. Glück auf, der Steiger kommt: a frame account of extensional and intensional *steigen*. In D. Gerland, C. Horn, A. Latrouite & A. Ortmann (eds.), *Meaning and Grammar of Nouns and Verbs*, 115–144. Düsseldorf University Press.

Gärdenfors, P. 2000. *Conceptual Spaces: On the Geometry of Thought*. Cambridge, MA: MIT Press.

Gärdenfors, P. 2014. *The Geometry of Meaning*. Cambridge, MA: MIT Press.

Gibson, J. J. 1979. *The Ecological Approach to Visual Perception*. Houghton Mifflin Company.

Goldberg, A. E. 1995. *Constructions. A Construction Grammar Approach to Argument Structure*. Chicago, IL: University of Chicago Press.

Horn, C. & N. Kimm. 2014. Nominal Concept Types in German Fictional Texts. In T. Gamerschlag, D. Gerland, R. Osswald & W. Petersen (eds.), *Frames and Concept Types. Applications in Language and Philosophy*, vol. 94 Studies in Linguistics and Philosophy, 343–362. Dordrecht: Springer.

Joshi, A. K. & Y. Schabes. 1997. Tree-Adjoining Grammars. In G. Rozenberg & A. Salomaa (eds.), *Handbook of Formal Languages. Vol. 3: Beyond Words*, 69–123. Berlin: Springer.

Kallmeyer, L. & R. Osswald. 2013. Syntax-Driven Semantic Frame Composition in Lexicalized Tree Adjoining Grammars. *Journal of Language Modelling* 1(2). 267–330.

Kiefer, M. & L. W. Barsalou. 2013. Grounding the human conceptual system in perception, action, and internal states. In W. Prinz, M. Beisert & A. Herwig (eds.), *Action science: Foundations of an emerging discipline*, 381–407. Cambridge: MIT Press.

Klepp, A., H. Weissler, V. Niccolai, A. Terhalle, H. Geisler, A. Schnitzler & K. Biermann-Ruben. 2014. Neuromagnetic hand and foot motor sources recruited during action verb processing. *Brain and Language* 128(1). 41–52.

van Lambalgen, M. & F. Hamm. 2005. *The proper treatment of events*. Blackwell Publishing. Explorations in semantics series, edited by Susan Rothstein.

Lichte, T. & S. Petitjean. to appear. Adding semantic frames to XMG. *Journal of Language Modelling* .

Löbner, S. 2011. Concept types and determination. *Journal of Semantics* 28. 279–333.

Löbner, S. 2014. Evidence for Frames from Human Language. In T. Gamerschlag, D. Gerland, R. Osswald & W. Petersen (eds.), *Frames and Concept Types. Applications in Language and Philosophy*, vol. 94 Studies in Linguistics and Philosophy, 23–67. Dordrecht: Springer.

Löbner, S. to appear in 2015. The semantics of nominals. In N. Riemer (ed.), *The Routledge Handbook of Semantics*, Routledge.

Minsky, M. 1975. A framework for representing knowledge. In P. Winston (ed.), *The psychology of computer vision*, 211–277. New York: McGraw-Hill.

Montague, R. 1973. The Proper Treatment of Quantification in Ordinary English. In J. Hintikka, J. Moravcsik, & P. Suppes (eds.), *Approaches to Natural Language: Proceedings of the 1970 Stanford Workshop on Grammar and Semantics*, 247–270. Dordrecht: D. Reidel Publishing Company.

Muskens, R. 2013. Data Semantics and Linguistic Semantics. In M. Aloni, M. Franke & F. Roelofsen (eds.), *The dynamic, inquisitive, and visionary life of ϕ, $?\phi$, and $\diamond\phi$. A festschrift for Jeroen Groenendijk, Martin Stokhof, and Frank Veltman*, .

Naumann, R. 2013. An outline of a dynamic theory of frames. In G. Bezhanishvili, S. Löbner, V. Marra & F. Richter (eds.), *Logic, Language, and Computation. 9th International Tbilisi Symposium on Logic, Language, and Computation, TbiLLC 2011, Kutaisi, Georgia, September 26-30, 2011, Revised Selected Papers*, vol. 7758 Lecture Notes in Computer Science, 115–137. Springer.

Naumann, R. & W. Petersen. 2014. Frame theory, dependence logic and strategies. Submitted to *Proceedings of the 10th international Tbilisi symposium on language, logic and computation*.

Ortmann, A. 2014. Definite Article Asymmetries and Concept Types: Semantic and Pragmatic Uniqueness. In T. Gamerschlag, D. Gerland, R. Osswald & W. Petersen (eds.), *Frames and Concept Types. Applications in Language and Philosophy*, vol. 94 Studies in Linguistics and Philosophy, 293–341. Dordrecht: Springer.

Osswald, R. & R. D. Van Valin. 2014. FrameNet, Frame Structure, and the Syntax-Semantics Interface. In T. Gamerschlag, D. Gerland, R. Osswald & W. Petersen (eds.), *Frames and Concept Types. Applications in Language and Philosophy*, vol. 94 Studies in Linguistics and Philosophy, 125–156. Dordrecht: Springer.

Petersen, W. 2007. Representation of Concepts as Frames. In F. T. Jurgis Skilters & G. Stemberger (eds.), *Complex Cognition and Qualitative Science*, vol. 2 The Baltic International Yearbook of Cognition, Logic and Communication, 151–170. University of Latvia.

Petersen, W. & T. Osswald. 2014. Concept Composition in Frames: Focusing on Genitive Constructions. In T. Gamerschlag, D. Gerland, R. Osswald & W. Petersen (eds.), *Frames and Concept Types. Applications in Language and Philosophy*, vol. 94 Studies in Linguistics and Philosophy, 243–266. Dordrecht: Springer.

Pulvermüller, F. 2013. How neurons make meaning: brain mechanisms for embodied and abstract- symbolic semantics. *Trends in Cognitive Science* 17. 458–470.

Redmann, A., I. FitzPatrick, F. Hellwig & P. Indefrey. 2014. The use of conceptual components in language production: an ERP study. *Frontiers in Psychology* 5. 363.

Rounds, W. C. 1997. Feature Logics. In J. van Benthem & A. ter Meulen (eds.), *Handbook of Logic and Language*, 475–533. Amsterdam: North-Holland.

Schulzek, D. 2014. A Frame Approach to Metonymical Processes in Some Common Types of German Word Formation. In T. Gamerschlag, D. Gerland, R. Osswald & W. Petersen (eds.), *Frames and Concept Types. Applications in Language and Philosophy*, vol. 94 Studies in Linguistics and Philosophy, 221–242. Dordrecht: Springer.

Schurz, G. & I. Votsis. 2014. Reconstructing Scientific Theory Change by Means of Frames. In T. Gamerschlag, D. Gerland, R. Osswald & W. Petersen (eds.), *Frames and Concept Types. Applications in Language and Philosophy*, vol. 94 Studies in Linguistics and Philosophy, 93–109. Dordrecht: Springer.

Van Valin, R. D., Jr. 2005. *Exploring the Syntax-Semantics Interface*. Cambridge: Cambridge University Press.

Veltman, F. 1984. Data Semantics. In J. Groenendijk, T. Janssen & M. Stokhof (eds.), *Truth, Interpretation, and Information; Selected Papers from the Third Amsterdam Colloquium*, 43–63. Dordrecht: Foris.

Vosgerau, G., T. Seuchter & W. Petersen. to appear. Analyzing Concepts in Action-Frames. In T. Gamerschlag,

R. Osswald & W. Petersen (eds.), *Meaning, Frames, and Conceptual Representation* Studies in Language and Cognition, Düsseldorf: Düsseldorf University Press.

Votsis, I. & G. Schurz. 2012. A Frame-Theoretic Analysis of Two Rival Conceptions of Heat. *Studies in History and Philosophy of Science* 43(1). 105–114.