Functional Concepts and Frames

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Abstract

The central point of this paper is the observation that attributes in Barsalou frames are functional concepts. If Barsalou is correct in assuming that frames in his sense constitute the universal format of human cognitive representations, the observation means that human conceptualization is entirely in terms of functional concepts. This raises interest in this particular type of concept. Functional concepts appear in natural language mainly in the form of functional nouns. This type of noun did not get much attention in semantics. The paper therefore first reviews the notion of individual and functional nouns in formal semantics, departing from Barbara Partee's *rising temperature* puzzle. The second part turns to a general definition of Barsalou frames as recursive attribute-value structures with functional attribute and identifies functional concepts as their basic components. It is argued that the functional concept vocabulary is a recent development in natural language lexica which is closely related to scientific evolution.

1 Introduction

It is the aim of this paper to argue that functional concepts are of fundamental importance for semantic analysis and for cognitive theory. They are important for semantics because they constitute a logical and grammatical type of nouns of its own. They are important to cognitive theory because of the fundamental role they play in categorization. Following Barsalou (1992a, 1992b), I hypothesize that frames in Barsalou's sense constitute the universal format of concepts in human cognition; i. e. the universal format for the representation of arbitrary objects and categories. Frames in the sense of Barsalou's are recursive attribute-value structures, similar to those used e. g. in HPSG[1] and other formalisms. What

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[1] Head-Driven Phrase Structure Grammar, initiated by Pollard & Sag (1994).

constitutes the connection between frames and functional concepts is the fact that the attributes in Barsalou frames are functional concepts which assign values to their arguments. If the hypothesis is correct, it follows that all representations of objects and categories in human cognition are exclusively in terms of functional concepts.

When I refer to "functional concepts", I do not mean words, but cognitive structures of representation, ultimately implemented in neuronal structures of the brain. Languages may have lexical expressions for some of these functional concepts, e. g. words such as English *name*, *size*, *shape*, *color*, *meaning*, *head*, *bottom*, *root*, *mother*, or *cholesterol level*. But languages differ widely in this respect. In those languages that exhibit a rich vocabulary of terms for functional concepts, many of these expressions are relatively young. It will be argued below that functional concepts play a key role in scientific theory. The repertory of functional concept terms in a language to a good deal reflects the stage of development of scientific reasoning. This holds in particular for abstract functional concepts. Nouns that carry the meaning of a functional concept will be referred to as "functional nouns". Functional concepts are not necessarily expressed by nouns. There are also verbs that immediately express functional concepts, e. g. *cost* or *weigh*, corresponding to the functional nouns *price* and *weight*, respectively (for a survey article see Gamerschlag 2014).

In the following, I will introduce the notion of functional concepts from a semantic point of view, by recalling and analyzing Partee's famous *rising temperature* paradox (§ 2). The discussion of functional nouns will then be embedded into the distinction of a system of four basic types of nouns, including in addition sortal, individual, and relational nouns (§ 3). In § 4, I will introduce Barsalou frames, showing that they essentially are networks of functional assignments in terms of attributes. This provides the crucial link between functional concepts and frames. § 5 will briefly discuss the role of frames, functional concepts, and functional nouns in science. § 6 will formulate the conclusions of the discussion.

2 Partee's paradox recalled

2.1 The temperature is rising

Montague (1973) cites an example of Barbara Partee's that constitutes an apparent paradox: The sentences in (1a) and (1b) do not entitle the inference of (1c).

(1)   (a)   The temperature is rising.
       (b)   The temperature is ninety.
       (c)   Ninety is rising.

The example appears to contradict a fundamental law of predicate logic, ascribed to Leibniz: If a predication P is true of an individual a, and a is identical with b, then P is also true of b.

(2)   **Leibniz' Law**
       P(a)   a predication about some individual a
       <u>a = b</u>   identity of individuals a and b
       P(b)   the same predication about b

   Partee's example is not free of problems. It has been objected (cf. Jackendoff 1979) that (1b) does not constitute an identity statement but rather is used to express the location of the temperature value on a scale. According to Thomason (1979), the predication in (1c) constitutes a category mistake.[2] Also it may be objected that the expression *ninety* does not refer to the same object in (1b) and (1c). While these objections are justified from a linguistic point of view, they can be avoided in several ways (cf. Löbner 1981, Löbner 1979:23f, Lasersohn 2005). One way to save the argument intended by Partee is to consider examples such as the following:

(3)   (a)   The US president will change.
       (b)   The US president is Barack Obama.
       (c)   Barack Obama will change.

Assume we relate these sentences to some time when Barack Obama is in office as US president. Assume further that *change* in (3a) means 'be replaced'[3]. Obviously, (3a) and (3b) do not entail (3c) if *change* is taken in that meaning, which of course is necessary if (3) is taken to represent an instance of Leibniz' Law. In fact, it can be argued that (3c), with that reading of *change*, not only does not follow from the two premises, but in fact is semantically abnormal. A remaining problem with

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[2]   This fact does not really show that the argument is wrong. Whether (1c) is logically possible and does not follow from the two premises or whether the conclusion is necessarily false, or altogether senseless – the fact remains that the entailment is invalid.

[3]   Single quotes are used for representing meanings and the contents of concepts.

(3) is the fact that sentences (3a) and (3c) both have another reading with *change* construed as 'become different'. With this reading of *change*, (3) does constitute a valid instance of Leibniz' Law. This problem does not arise in the German equivalents of the three statements if *change* is translated as *wechseln* which has the reading 'be replaced' but not 'become different':

(4)   (a)   Der US-Präsident wird wechseln.
       (b)   Der US-Präsident ist Barack Obama.
       (c)   Barack Obama wird wechseln.

What is expressed in (4), and was intended in (1), is the following. The referent of the subject NP varies with the time of reference: there is a temporal sequence of US presidents as there are temperatures varying in time. For the nouns *US-Präsident* and *temperature*, there are functions from times to persons and temperature values, respectively, which yield for every time the current referent of the noun. Note that for these nouns there is necessarily at most one referent at every time and in a given context.[4] In sentences like (5a,b), the NPs refer just to the actual values at the given time of reference, and the predications expressed by the respective VPs take these as their arguments.

(5)   (a)   The temperature is low.
       (b)   The US president is married.

Consequently, no paradox like that in (4) will arise with the sentences in (5); consider the valid inference in (6).

(6)   (a)   The US president is married.
       (b)   The US president is Barack Obama.
       (c)   Barack Obama is married.

Crucially, the predications in (4a) and (1a) express a change in time of what the subject refers to: the referent of *der US-Präsident* is replaced, as is the referent of the subject NP *the temperature* if the temperature rises. The first premise, therefore, is a statement of the type $p(f, t_e)$ where p represents the predication

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[4]   Uniqueness of reference here is not due to the definite article, but a fact inherent to the meanings of the nouns *US-Präsident* and *temperature*. The definite article is redundant. See Löbner (1985) and Löbner (2011) for the role of definiteness marking with functional nouns.

'change/wechseln' or 'be rising' and f represents the function from times to entities which assigns a US president, or a temperature, respectively, to every time; t_e is the implicit time of reference, or evaluation time, which the statement relates to. Roughly, (4a) says that there is a time $t > t_e$ where $f(t) \neq f(t_e)$; (1a) states that $f'(t_e) > 0$, where f' is the first derivative of f with respect to t, i. e. $df(t)/dt$. Thus, the content of (1a) and (4a) is a predication of the type:

(7)   (a) $p(f, t_e)$ where f: TIME $\longrightarrow$ E (E some appropriate set of entities)

The second premise in (4) and (1) states that the value of f for the time of reference t_e is a particular one. In (4), the second premise constitutes an identity statement, in (1) it can at least be taken as an equivalent of an identity statement.

(7)   (b) $f(t_e)$ = Barack Obama
              $f(t_e)$ = 90°

In Leibniz' Law, the second premise states that the argument of the predication in the first premise is identical with some object b. The two statements in (7b) are identity statements about $f(t_e)$, i. e. about theindividual that constitutes the value of the function f for the time of reference. This, however, is not the argument of the predication in (7a). p in (7a) has two arguments, the function f and the time t_e, and the two-place predication cannot be reduced to a one-place predication about $f(t_e)$: *der US-Präsident wird wechseln* is not a predication that just concerns the president of the US at time t_e; the analogue holds for the rising temperature statement.

Consequently, the apparent paradox can be resolved by observing that the second premise does not constitute a relevant identity statement for the Leibniz entailment.

2.2   The nature of the example

Partee's paradox is cited by Montague as an instance of an intensional subject construction in the first premise, something originally assumed not to exist (Lewis 1970). To see what an intensional construction is, let us first define the notion of an extensional construction. In the framework of Montague's[5], the extension

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[5]   Montague (1973)

of a noun is the set of its potential referents in a given context of utterance. (Montague would talk of a possible world index instead of a context of utterance.) For example, the extension of *cow* in a particular context of utterance would be the set of all cows given in that context of utterance. The extension of *US president* would be the (one and only) US president, the person in office, in that context. A sentence construction is extensional with respect to a certain NP position, if the NP can be replaced by any other NP with the same extension without changing the truth-value of the sentence. For example, the valid entailment in (6) shows that the sentence in (6a) (*the US president is married*) is extensional with respect to the subject position: Let (6b) (*the US president is Barack Obama*) be true; it then follows that the NPs *the US president* and *Barack Obama* have the same extension. Consequently, (6c) is true because the construction NP *is married* is a predication about the extension of the subject NP.

A construction is intensional, if it is not extensional. In Montague's terminology, the intension of an expression is a function that returns for every possible context of utterance the extension of the expression. In the case of *US president* and *temperature*, the intension returns the current US president and the temperature, respectively, for a given context of utterance. The sentences in (1a) and (4a) are intensional since the VP predicates about the extensions of the subject NP at more than one time, i. e. in different possible contexts of utterance. In intensional constructions, the truth value may change, if the NP is replaced by another NP with just the same extension. For example, if in a given context of utterance the US president is Michelle's husband, and the US president changes, it does not follow that Michelle's husband changes. Intensional constructions represent a predication about the intension of the NP which cannot be logically reduced to a predication about its extension (otherwise, the construction would be extensional).

Although (1a) is clearly not extensional, Partee's example met some opposition as an instance of a construction with intensional subject position. Examples of intensional (or 'opaque') constructions known in the historical context of the early 1970s were sentences such as the following, with an intensional object NP:

(8)   (a)   Hank is seeking a unicorn.

There are two readings to the sentence, one in which it entails (8b), and the crucial, opaque one, in which it does not.

(8)   (b)   There is a unicorn that Hank is seeking.

The source of intensionality here is different from the 'rising temperature' cases. The verb *seek* in its relevant reading does not express a predication about the extension of the object NP at all. The actual extension of the object NP does not matter. Hank may seek a unicorn even if no unicorns exist, in fact, even if Hank does not believe in the existence of unicorns himself. The object NP renders a description related to the intention of the seeker rather than to some object in the world. Because of the different nature of intensionality in the classical examples of the type in (8a), the rising-temperature examples were considered not intensional proper (e. g. Dowty, Wall & Peters 1981:279-286), although the non-extensional character manifest in the apparent failure of Leibniz' Law was mostly acknowledged.[6]

A further fundamental difference between the two types of intensionality concerns the logical type of noun involved. The construction in (8a) is possible with special verbs such as *seek*, *design*, *imagine*, *expect* and almost all types of nouns, including sortal nouns, relational nouns, proper names and functional nouns (see the next section for the distinction). The Partee example, by contrast, requires a special type of noun for its intensional NP argument, as we will see now.

3   Types of nouns

3.1   Individual nouns and concepts

The rising-temperature, or changing-president, construction represents a predication about the changing referent of the subject NP. The meaning of the noun must be such that it yields for every appropriate context of utterance a particular object as the unique referent. If the predication of the construction concerns variation in time, the subject noun has to define a function from times to an appropriate type of entities, e. g. persons or temperature values. Such nouns are of a particular logical type. They are inherently unique. The concept they express

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[6]   Jackendoff (1979) argues for an extensional analysis of *the temperature is rising*; see Löbner (1981) for a reply.

defines a function that returns a unique referent to every appropriate context of utterance.[7] In former publications I therefore referred to this type of nouns as "functional nouns", and the corresponding type of concepts as "functional concepts" ("FC1" in Löbner 1985, 1998) or "Funktionalbegriffe" in German ("FB1" in Löbner 1979). To avoid confusion, and join established terminology, e. g. in Janssen (1984), I will use the terms *individual concept* and *individual noun* here, as I did in Löbner (2011). Thus *temperature* and *US-Präsident* are **individual nouns**, and their meanings are individual concepts.

The subject terms of the rising-temperature or changing-president construction need not only express an individual concept that assigns referents to times. In addition, the underlying functions must be able to return different values at different times. Otherwise the predication about the temporal variation of the value of the function would be inapplicable for logical reasons. The latter requirement for the nouns in subject position is responsible for the awkwardness of the sentences in (1c) and (4c): NPs such as *ninety* or *Barack Obama* do not have different referents at different times.

The type of intensionality observed with (1a) and (4a) is also possible with transitive verb constructions such as:

(9)   (a)   The coach replaced the goalkeeper.
      (b)   The government raised the exchange rate.

To see the difference between these intensional constructions and ordinary extensional ones, consider the verb *grow*. If I say, for example, the sentence in (10), I refer to a particular child now and the same child some time ago, when her height was measured the last time.

(10)   The child has grown 2 centimeters.

Contrary to predications such as *wechseln* in (4a), *grow* here requires that the referent of the subject NP remains identical over time. It would be a joke playing with this logical requirement if I would use (10) for a situation where the child has been replaced by some other child which happens to be 2 cm taller than the

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[7]   Quite generally, there will be contexts where a given inherently unique noun fails to refer; every functional noun presupposes certain general conditions, or "appropriate context", for successful reference. For example, *US president* fails to refer if the time of reference is in the 16th century, or *husband of Amy* lacks reference if Amy is not married.

former one. The required constancy of the argument over time is what makes the verb *grow* in (10) an extensional predicate term.

Not incidentally, the verb *grow* can also be used in the intensional construction, similarly to *rise* in (1a), if the subject noun is an abstract individual noun:

(11)   The gross national product grew 0.3 per cent.

The GNP is an abstract figure; the noun refers to whatever is the current GNP value. If the GNP grows, the noun changes its referent. This is not true of persons, or trees. If they grow, it is only one attribute, among many, that changes; the growing organism remains the same organism.

The particular logical character of the constructions in (1a), (4a) and (9a,b) is veiled by the fact that the constructions not only use the same syntax as their extensional counterparts, but they also use the same vocabulary. First, the individual nouns occurring here can also be used as the heads of argument terms for extensional constructions (cf. (5a,b)); in fact they mostly are. Second, the predicate terms, mostly verbs, usually have extensional uses as well, which are more frequent, more basic and older. For example, *rise* can also be used extensionally as in (12a), and *wechseln* as in (12b):

(12)   (a)   The mercury is rising.
        (b)   Hans wechselt auf die andere Straßenseite.
              'lit. Hans changes to the other side of the street.'

In English or German, there do not seem to be many verbs that occur exclusively in the VP position of the rising-temperature construction. English *vary* and its German equivalent *variieren* are among the rare examples. The existence of pairs such as extensional *the mercury is rising* vs. intensional *the temperature is rising*, or the extensional vs. the intensional reading of *the president has changed* is rather typical.

Partee's paradox did not have too much impact on the intensionality debate in early formal semantics. Its importance lies in the fact that Partee came across a linguistic construction specific for individual nouns. The discovery of inherently unique nouns, and its significance, was not immediately recognized. In fact,

intensional constructions of this type were widely ignored[8] and the relevance of the subcategory of individual nouns for other constructions was not realized[9].

3.2   Functional nouns and concepts

The noun *temperature* is used in (1) without a possessor specification and given that the example is to be interpreted out of any special context, no implicit possessor specification is presupposed to be provided. In this use, *temperature* means 'temperature of the air'. In general, however, the notion of temperature is a relational concept: temperature <u>of</u> some physical entity, be it a gas, a liquid or solid, or light.[10] Relational nouns like *temperature* – e. g. *size*, *weight*, *speed*, *color*, *shape* – denote a certain conceptual dimension of some object. The object is usually specified by means of a possessive construction. The whole denotes the unique value in that dimension of the 'possessor' object.

Similarly, the component *president* of the term *US president* is a relational noun, since a president, due to the underlying concept, is always the president of something, a country, some institution, society etc. In the compound *US president*, the modifier *US* specifies the possessor institution. A specification of a (non-relational) possessor for some relational noun combines with the originally relational concept to form a non-relational concept – such as *US_president* or *temperature_of_the_air* – which integrates the possessor concept into the relational concept.

Nouns which are both inherently unique and relational are **functional nouns**. English grammar allows for the omission of a possessor specification, but if unspecified the possessor has to be determined otherwise.[11] There are three major classes of functional nouns.

- **Role terms** for unique roles related to the possessor, where the possessor may be a person (*father*), an institution (*king*), an event (*speaker*), an ob-

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[8] For exceptions see Janssen (1984) and Löbner (1979).

[9] These other constructions include "concealed questions" (see § 1.6 below).

[10] The special absolute use of the relational noun *temperature* is probably due to the fact that the modern notion of temperature derived from the historical meaning 'mixture'. The word *temperature* acquired its present meaning first in its application to the air (the temperature of the air was apparently considered resulting from a mixed composition of the air).

[11] There are many languages which require either an explicit possessor specification or some derelativizing morpheme for relational nouns. See Ortmann (to appear) for a general discussion and examples.

ject (*inventor*) etc. Examples are kinship terms for unique relatives such as mother, father, husband, or wife (in monogamous social systems), but also role terms for all sorts of other persons that stand in a unique relationship to somebody (*boss, best friend, landlord*). Many role terms relate their referent to an institution: terms for presidents, monarchs, and all the countless offices in public life.

- **Terms for unique parts** of the possessor play a central role in mereologies. They include body part terms for unique body parts such as *head, mouth, stomach*, or terms for parts of artefacts: *handle, keyboard, mouthpiece*, etc. or physical objects in general: *surface, top, tip, core* etc.

- **Terms for attributes (aspects, dimensions)** of the possessor: terms for scalar attributes such as *size, weight, temperature, price, value*, but also for nonscalar dimensions: *color, shape, meaning, name, function* etc.

There are, of course, also terms for nonunique roles such as *neighbor, friend, colleague*, or nonunique kinship terms: *son, sister, aunt* etc. Also many part-terms denote parts that may occur more than once, for example *eye, leg, bone, tooth*. These terms are all relational nouns in the narrower sense to be introduced in the next subsection.

NPs are primarily used referentially, i. e. as argument terms of a predication, for instance as subject or object NP. In referential use, functional and relational nouns are in need of saturation of their open possessor argument. This constitutes what I have called the "absoluteness constraint" on referential NPs.[12] Otherwise NPs with relational head nouns could not be interpreted in context because their reference cannot be resolved. One option of saturating the possessor argument is by explicit specification, e. g. in *temperature of the air* or *president of the US*. Alternatively, the specification of the possessor can, in many languages, be omitted and left to inference from the given context.[13] For example, *price* in (13) would be construed as referring to the price of something which is uniquely determined in the context:

(13)   The price is rising.

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[12] Löbner (2011:299).

[13] For further ways of dealing with an open possessor argument of functional and relational nouns see Löbner (2011, § 5.3, § 6.2).

If a functional noun is combined with a possessor specification of the individual concept type, the result is an individual concept.[14] This follows from the fact that functional nouns determine their referent uniquely relative to a possessor. If the possessor itself is uniquely determined, so is the value of a functional concept for this possessor. Thus, functional nouns may yield NPs that constitute individual concepts. This is the case if the possessor is specified by means of a definite NP or if an implicit unique possessor is retrieved from the context.

For this reason, it is not only individual nouns[15] that enter the subject and object positions of intensional verbs, but very often functional nouns with an explicit or implicit unique possessor specification. In fact, I assume, functional nouns are even more frequent than individual nouns in these constructions. In this sense, the rising-temperature construction and its transitive counterpart are characteristic of inherently unique nouns in general, individual or functional.

(14) (a) *individual noun*   The temperature is rising.
      (b) *functional noun, implicit unique possessor* The price is rising.
      (c) *functional noun, explicit unique possessor* The price of the ticket is rising.
      (d) *individual noun*   The US president will change.
      (e) *functional noun, implicit unique possessor* The president will change.
      (f) *functional noun, explicit unique possessor* The president of the US will change.

3.3   Sortal and relational nouns and concepts

Functional nouns are distinguished by two properties which set them apart from ordinary common nouns: inherent uniqueness and inherent relationality. Individual nouns are inherently unique, but not relational. Naturally, there are two more basic types of nouns.

Relational nouns in the narrower sense are relational, but not inherently unique. Nouns of this type include terms for potentially multiple roles such as

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[14] See Löbner (2011, § 4) for the compositional semantics of relational and functional nouns with possessor specifications, and in particular for the "transparency property" of functional nouns which makes them inherit the conceptual type from their possessor argument. The transparency property is first mentioned in Löbner (1998).

[15] Talking of nouns rather than NPs (or DPs) here is rather sloppy, although harmless. Of course, it is NPs (or DPs) rather than nouns that fill the subject and object positions of the constructions discussed. The difference can be neglected here, because in the examples we need to discuss, the NPs consist of just the noun, or the noun with a possessor specification, plus a definite article. In the cases discussed, the nouns are inherently unique. The definite article is redundant under these conditions. The whole NP then expresses the same concept as does the bare noun. (See Löbner 2011 for this account in the framework developed there.)

brother, neighbor, friend, colleague, contemporary etc. or multiple parts of objects. There are also a large number of relational nouns derived from verbs, such as *predication*, *use*, *statement*, *expression* and so on. Depending on the underlying verb, deverbal relational nouns may have more than one additional argument. For example, nominalizations from transitive verbs like *discovery* in *discovery of X by Y* have two additional arguments.

Sortal nouns constitute the great majority of "common nouns"; they are neither inherently unique nor relational. They specify their potential referents by means of characteristic properties. Thus they describe a sort (or category, or kind) of objects. Since the number of objects that meet the description may happen to apply in zero, or one, or more cases, sortal nouns are not inherently unique. Sortal nouns are very numerous; they include terms for natural kinds as well as for classes of artefacts or any other concrete or abstract objects.

			inherently unique	
	sortal nouns		**individual nouns**	
	dog table noun water		*Paula pope weather*	
	relation: –		relation: –	
	logical type: ⟨e,t⟩ unary pred. term		logical type: e individual term	
relational	**relational nouns**		**functional nouns**	
	part brother property		*mother death age meaning*	
	relation: to possessor		relation: to possessor	
	logical type: ⟨e,e,t⟩ binary pred. term		logical type: ⟨e,e⟩ unary function term	

Table 1: Types of nouns

The distinction in terms of inherent uniqueness and relationality gives rise to a system of four logical noun types (Table 1). The system is not complete as there are types of relational and functional nouns with more than one relational argument. The type distinction corresponds to basic types distinguished in first-order predicate logic: individual nouns are of type e (individual terms), sortal nouns of type ⟨e,t⟩ (one-place predicate terms), relational nouns of type ⟨e,⟨e,t⟩⟩ (two-place predicate terms), and functional nouns of type ⟨e,e⟩ (one-place function terms). As I argued in Löbner (2011:283-286), the type distinctions for nouns (in a given lexical reading) are lexical, i. e. really inherent.

3.4 Two characteristic constructions for individual and functional nouns

Abstract functional nouns can be considered to correspond to attributes (or conceptual dimensions) of their "possessors", in the widest sense. For a given possessor, in a given context of utterance, the functional noun denotes the actual value that this attribute adopts. Like the "temperature of the air", the "price of a barrel oil", the "size of the pupil", the "meaning of *temperature*", "your cell-phone number" or the "speed of the rocket", the value of such an attribute is, or may be, variable over time and dependent on circumstances. Consequently, languages may provide intensional constructions such as in (1a) and (9) for the description of the variation of the attribute values.

Abstract individual and functional nouns, with a few exceptions such as terms meaning 'name', 'shape' or 'color', are comparatively young in English, German, and other European languages. Most of them are lexical innovations of the last three centuries. The verb vocabulary for predications about such abstract things as temperature, weight, price, stock exchange rate, voltage etc. was recruited from extensional-verb vocabulary. This development in lexicon and grammar is responsible for the co-existence of extensional and intensional uses of the same verbs.[16] Intensional verbs of the relevant type mostly denote movements and similar changes in their extensional uses, while their application to things like prices and temperature is metaphorical and/or metonymical. Not before the 18th century, the German verb *steigen* 'rise' for upward motion could be used to form a sentence that literally expressed 'the temperature rises'.[17] Apparently the modern construction in (15c) is built on the predecessors (15a) and (15b). (15a) is metonymical for the change of temperature indicated. Note that the mercury columns of traditional thermometers were vertical; it was not the whole column of mercury that rose, rather its tip. Thus, even (15a) involves a pars pro toto metonymy. The derived way of expression in (15b) metonymically abstracts from the mercury column, but still the subject is not the abstract notion of temperature. The thermometer itself, however, did not move anymore. Thus, this construction abandons the literal meaning of *steigen* 'rise'.

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[16] For a collection of about three hundred relevant verbs see Löbner (1979:114-124).

[17] Evidence is provided by the entries in Grimm's dictionary, Grimm (1854/1984).

(15)   (a)   Das Quecksilber steigt.   'The mercury is rising.'
       (b)   Das Thermometer steigt.   'The thermometer is rising.'
       (c)   Die Temperatur steigt.   'The temperature is rising.'

   Variability is accompanied by uncertainty. Thus a second type of construction deals with the possibility of different alternative values for a given functional concept. The corresponding verbs include epistemic predications like *know*, *estimate*, *guess*, *determine*, *be interested in*, *remember*, *tell* along with other verbs that presuppose alternatives, such as *choose*, *influence*, *control*, *delimit*, or *constrain*, predications of evaluation: *appreciate*, *discuss*, *fear*, or of co-variation *depend on*, *follow* etc.

(16)   (a)   Do you know the price of the download?
       (b)   The number of victims cannot be determined yet.
       (c)   The price depends on the exchange rate of the British pound.

In this type of constructions, the functional NP can be replaced by an interrogative clause, e. g. *Do you know what the price of the download is?* For this reason, these constructions were called "concealed questions". Concealed question constructions are not restricted to abstract functional nouns.

(17)   (a)   Bill does not know the capital of Belgium.
       (b)   His mother could not be determined.

   Similar to the rising-temperature construction, concealed questions borrow their syntax from ordinary predication formats, but exploit the concept type of individual and functional concepts for a different type of predication. Löbner (1979:129-141) contains a collection of about 1000 German verbs that can enter the concealed question or similar constructions.[18]
   I mention these two types of constructions – the rising-temperature type and concealed questions – because they play a crucial role in scientific discourse. There are more constructions that require functional or individual concepts. One such construction in Russian is investigated in Partee & Borschev (2012).

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[18] The notion of concealed question was introduced in Baker (1968); for a survey see Nathan (2006).

4   Frames in cognition

4.1   Barsalou's notion of frames

Among the various notions of frames and schemata defined and used in cognitive psychology, artificial intelligence, social interaction theory, and linguistics, the frame definition of Barsalou (1992a, b) is the most explicit, precise, and elaborate definition of this type of structure. According to Barsalou, a frame is a concept representation that is recursively composed out of attributes of the object to be represented, and the values of these attributes. In addition to the specification of attributes and their values, a frame may contain various kinds of constraints that restrict the values an attribute may adopt or define relations between the values of different attributes.

Barsalou represents frames with directed labeled graphs. A central node represents the object, or category of objects, which the frame represents; arcs connect nodes to further nodes. In Barsalou (1992a,b), the complex consisting of the possessor of an attribute, the attribute, and the value it adopts is graphically represented as in Figure 1:
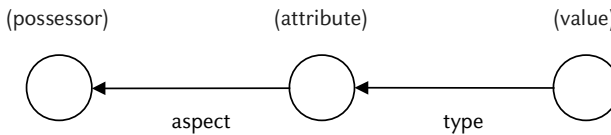

Figure 1: Possessor-attribute-value complex in Barsalou (1992a, 1992b)

The arc labeled "aspect" stands for "is an aspect of". The arc labeled "type" means "is of type". For example, if the three nodes in Figure 1 were taken to represent (from left to right) a tomato, the attribute COLOR[19], and its value red, the right arc would mean that red is of the type color. The label "type" is the same for all value-attribute connections.

Barsalou "define[s] an attribute as a concept that describes an aspect of at least some category members" (Barsalou 1992b:30). Values of attributes are defined as "subordinate concepts of an attribute" (Barsalou 1992b:31). This view of the relation between value and attribute focuses on a certain aspect of the relation between an attribute and the values it adopts. For every attribute there is the range of values which it can possibly adopt; it constitutes a space of alternatives.

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[19] In this article, small caps are used for attribute terms.

Thus, an attribute-as-function essentially corresponds to the set of values it can adopt. In the sense of Carpenter (1992), the set of all possible values forms an ordered hierarchy of types.

The general correspondence between attributes and sets of values has been observed, among others, by Guarino (1992). The correspondence is reflected in a systematic ambiguity of linguistic expressions for attributes. A noun like *color* can be used both as a functional noun and as a sortal noun. This ambivalence is systematic[20]. An example of the functional, attribute use of the noun would be (18a). (18b) illustrates the sortal use; the statement is of the type represented by the central and the right nodes in Figure 1 and the "type" link between them.

(18)   (a)   The color of the potato is red.
         (b)   Red is a color.

In (18b), the subject NP *red* refers just to a color as such, not to a color as a color of something. In (18a), however, *color* is an inherently relational noun. I consider the functional meaning as basic, because the sortal meaning can be easily derived from it, but not vice versa. In his definition of an attribute, Barsalou relates to the functional concept variant. But when he defines values as subordinate concepts of attribute, he conceives of attributes as sortal concepts for the possible values.

Complex frame elements such as in Figure 1 can be recursively connected by unifying a value node with another possessor node (an example is given in Figure 3 below), resulting in a subordinate specification of the value by another attribute and its value. Barsalou (1992b:33) discusses recursive attribute specification in terms of direct connections from attribute nodes to attribute nodes. For example, he remarks that the frame for 'vacation' may exhibit an attribute COMPANION which in turn has its own attributes such as AGE, FREE TIME, and PREFERRED ACTIVITIES. The chain VACATION – COMPANION – AGE is graphically represented as in Figure 2.

This representation, however, is a simplification of the relations involved. Regarding the example in Figure 2, COMPANION is an aspect, or attribute of a vacation. However, AGE is not an attribute of the attribute (for example, the attribute COMPANION is not an old or young attribute), but an attribute of the *value* of the attribute COMPANION, i. e. an attribute of the companion: the companion is of a

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[20] In Löbner (2011:310) I called the shift from the functional reading to the sortal reading "Guarino shift", relating to the observation of the underlying ambivalence in Guarino (1992).
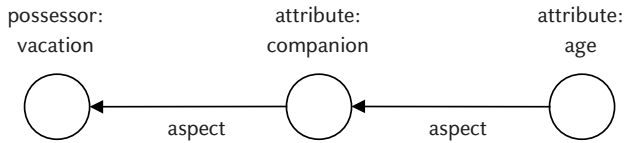
Figure 2: Attribute chain in Barsalou (1992a, 1992b)

certain age. Disentangling the ambiguity, the state of affairs depicted in Figure 2 would have to be represented as in Figure 3, in order to be in accordance with Figure 1.
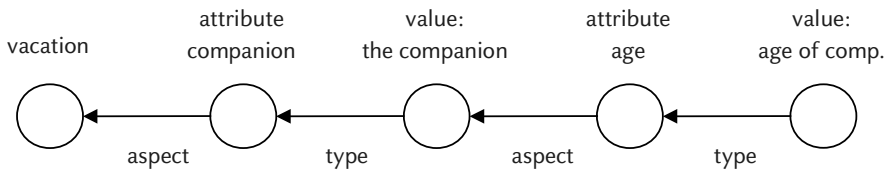

Figure 3: Attribute chain of Figure 2 revised

Barsalou does not explicitly state what kind of relation between possessor and value is established by an attribute. Obviously, different possessors can have the same value for a given attribute. The crucial question is, if an attribute may relate more than one value to a possessor at the same time. If not, the attribute constitutes a function. Implicitly, Barsalou appears to presuppose that attributes are functions. This is evident from the choice of examples for attributes he cites as well as from the fact that he talks of attributes "adopting values". The very use of the term *value* with respect to attributes would be inappropriate for nonfunctional relations. Still, the possibility would remain that some node might have the same attribute assigned to it more than once, e. g. two color attributes, representing an assignment of more than one color value.[21] Such a constellation, however, never occurs in Barsalou's frame examples.

It is therefore assumed (cf. Löbner 1998, Petersen 2007/2015) that the attributes in Barsalou frames constitute functions (to be precise, partial functions) that return one value for every possessor of the relevant type. This basic assumption allows a less complex way of graph representation, than the one depicted in Fig-

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[21] There are, of course, multicolored objects, such as the Union Jack. But the Union Jack does not simply have the color red and at the same time the color blue and the color white. Rather, it consists of parts of homogeneous color, and it is these parts to which their respective color attribute assigns a value.

ure 1. The basic unit of such graphs is a complex of two nodes, representing the possessor and the value, connected by an arc that connects the former to the latter. The arc represents the attribute as a function and is labeled accordingly.[22]

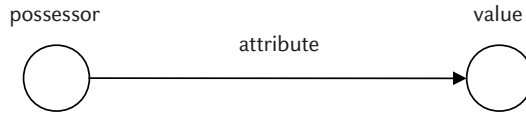possessor · attribute · value

Figure 4: Possessor-attribute-value configuration revised

Unlike Barsalou's frame graphs, this design implements the fundamental distinction between functions and objects[23], or in this case, between attributes and values. Nodes represent objects. Attributes, being funtions and not objects, are not represented by nodes.

Figure 5 displays a partial frame for a car, in the revised graph notation, with similar attributes as the example frame in Barsalou (1992b:30).
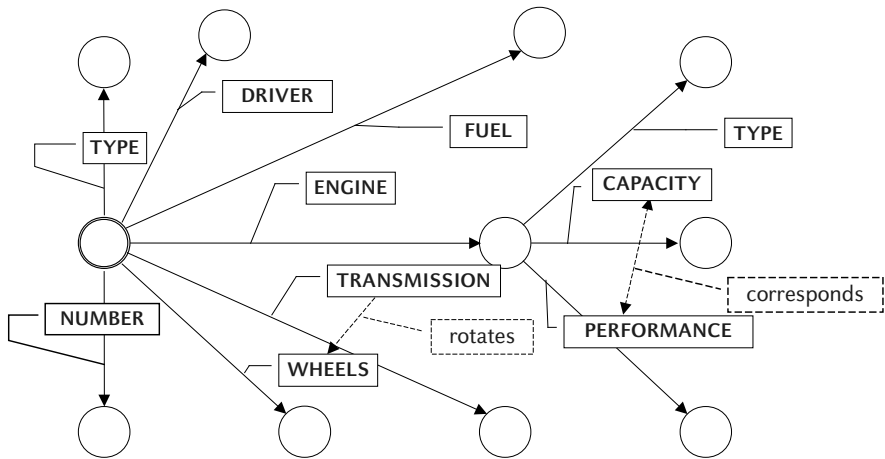
Figure 5: A frame for a car

The frame represents the values of the attributes by nodes not further specified. The broken-line elements represent two types of constraints. "Structural

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[22] For a deeper and more formal treatment of the issues of Barsalou frames discussed here, see Petersen (2007/2015).

[23] See (Frege 1891).

invariants" represent constitutive relations between (the values of) attributes: the transmission rotates the wheels; similarly, the engine rotates the transmission, the driver operates the engine, the engine consumes the fuel. "Attribute constraints" capture global dependencies between the values of attributes: the greater the capacity of the engine, the higher its performance (as well as the consumption of fuel and the production of CO_2).[24]

Barsalou (1992a:§ 7) assumes that frames constitute the general format of concept representation, and hence of categorization, in human cognition. Frames can be used for modeling the structure of concepts as well as what Barsalou calls "conceptualizations", i. e. ad-hoc modifications of concepts in actual contexts.

4.2   Frames and functional concepts

The fact that attributes in Barsalou frames can be considered functions that assign a value to objects of appropriate type has a very important consequence: Attributes in Barsalou frames are functional concepts. This is of utmost importance for Barsalou's conception of categorization: **We categorize exclusively in terms of functional concepts**. Functional concepts constitute the representational "vocabulary" of categorization—where the notion "vocabulary" is meant metaphorically. It is not to be taken in the sense that cognitive categorization is verbal. To the contrary, it is to be expected that most of the attributes used in human cognition did not make their way as functional nouns into the lexica of human languages. But conversel, if a language does possess functional nouns, it may be safely assumed that they correspond to attributes in cognitive frames. There is no other motivation for this untypical type of nouns.

There is psychological evidence that in first language acquisition children assign meanings to nouns that favor concrete sortal or individual concepts, while suppressing attribute concepts: "One way children initially constrain the meanings of terms is to honor the whole object assumption and thereby assume that a novel label is likely to refer to the whole object and not to its parts, substance or other properties." (Markman 1990:58f). In addition to the "whole object assumption", the "taxonomic assumption" causes children to establish labels that "refer to objects of the same kind rather than to objects that are thematically related."

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[24] There are further types of constraints (cf. Barsalou 1992a:37-40); for the present purpose it is not necessary to go deeper into the matter here.

(Markman 1990:59) Thus relational meanings for nouns are dispreferred. This does not mean, of course, that children are completely unable to learn relational or functional nouns, but the two strategies mentioned clearly establish sortal and individual nouns and the corresponding types of categorizations as the paradigm cases. The bias against relational and functional nouns corresponds to the fact that the referents of relational and functional nouns, for example roles, properties, and parts of objects do not exist independently; the cognitive isolation of such aspects requires abstraction.

4.3 General properties of frames

The first thing to observe about Barsalou frames is the fact that they represent sortal concepts. The attributes they employ are functional concepts but the whole frame is sortal: a concept that describes what it refers to in terms of certain properties, leaving open how many, if any, objects might satisfy this kind of characterization. A frame might contain specifications that narrow down the possible number of objects that meet them to one, but there is nothing in the structure of a frame telling that it is meant to represent exactly one object. For example, passports contain a perfect frame description of their respective bearers; the attributes they make use of are chosen in order to uniquely identify the bearer, but in principle they are still sortal frames: they might happen to describe no person at all, or exactly one person, or more than one if there happen to be two or more persons that meet the same description.

Given this observation, it is obvious that in addition to the frames Barsalou describes, one needs frames for types of concepts other than sortal. For relational and functional nouns, one needs frames with empty slots for the relational arguments. For individual and functional concepts, the structure of the frame must provide for unique reference. Still, these frames too will provide a mental description in terms of attributes, their values and constraints and relations correlating the values of attributes. Petersen (2007/2015) introduces frames of slightly different structures for the representation of relational, individual, and functional concepts.

One of the fundamental properties of frames is their flexibility. Frames can be reduced or enriched, by removing or adding attributes, or by changing the specification of attribute values. Attributes can be bundled into complex attributes; for

example, the attributes LENGTH and WIDTH in a rectangle frame can be combined into SIZE. Conversely, attributes with complex values such as COLOR can be split into components. A further way of combining attributes is functional composition: the attribute EYE COLOR of a person is the composition of the attribute EYE and its subattribute COLOR.

Frames for concrete real objects are principally incomplete. A real object, such as a person, or a tree, can never be completely described. The human mind chooses frames of a composition, complexity, and specificity that are adapted to the needs of particular situations.

4.4 Restrictions on attributes and the embodiment of frames

If frames constitute the general format of knowledge representation in the human cognitive system, the question arises as to how this format is grounded, or embodied.[25] One general aspect is the question: What does constitute a possible attribute in human cognition? Obviously, the set of all values which an attribute may adopt must form a natural space: the cognitive system will not employ attributes which may adopt values out of an arbitrary set of entities including, say, colors, shapes, prices, fingers and ancestors. Rather the set of values which a given attribute may adopt must be composed of mutually exclusive alternatives; colors and shapes are not mutually exclusive (they can be freely combined), but different colors are. Also, it appears reasonable to maximize those spaces, making them encompass all alternatives rather than a subclass. The completeness requirement can be subjected to constraints in particular frames; for example the frame of a mouse will restrict the values of the attributes SIZE, WEIGHT, or LIFESPAN to ranges of values possible for mice. In addition, further constraints have been proposed. In his work on conceptual spaces, Gärdenfors (2000) argues for a general constraint that restricts the space of possible values of an attribute in a concept to be convex: if two values are within the attribute space, then the values between them are, too. Gärdenfors & Wargien (2012) extend the conceptual-spaces approach to concepts for actions and events. Jäger (2012) addresses a similar question. He applies statistical methods to the data of the World Color Survey[26] in order to investigate constraints on the composition of the extension

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[25] For an extensive discussion of the psychological aspects of this issue, see Barsalou (1999).

[26] The WCS collects data on the use of basic color terms for a sample of 110 unwritten languages from an average of 24 speakers each. See Cook, Kay & Regier (2005) for details.

of color categories. The result is largely in accordance with Gärdenfors' convexity conditions; there are, however, exceptions: some speakers seem to have nonconvex color term extensions, for example one term covering black and white, but not the shades of grey between.

5   Frames and functional concepts in science

Frames and functional concepts play a central role in scientific thinking. Sciences in general deal with particular classes of objects, e. g. physical objects, living organisms, chemical substances, languages, human subjects, works of art etc. The objects of science are investigated in terms of their relevant attributes, where sciences differ in which attributes they address. For example, psychology, medicine, sociology, and economics are concerned with human individuals under various perspectives, dealing with different sets of attributes of the individual.

Together, the attributes constitute the, more or less, abstract objects of a science. For example, merely two attributes, MASS and LOCATION, constitute the mass point in physics. A chemical element is constituted by a small set of attributes, including its atomic number. Scientific theorizing investigates possible values of the attributes, possible combinations of the values of different attributes, correlations of values etc. These aspects are captured by different types of constraint in Barsalou's frame theory. To give an example from linguistics, a lexeme is defined by a frame such as in Figure 6; general constraints would capture the correspondence between phonological form and spelling of lexemes, or the dependence of word inflection on the part of speech that a lexeme constitutes.

Attribute terms play a central role not only in scientific terminology, but also in the very evolution of science. The notion of atomic number in chemistry evolved with the theory of atomic structure, and with it today's notion of a chemical element. Frames can be shown to underlie the conception of scientific classifications, as well as of types of processes such as chemical reactions; these underlying frames can, in turn, be used to analyze paradigm shifts in scientific evolution (see Chen & Barker 2000, Schurz & Votsis 2014).

The two typical constructions for functional nouns mentioned in § 3,4 directly correspond to needs of scientific discourse. The rising-temperature construction meets the need of being able to verbally describe changes of the values of attributes and correlations between them. Concealed questions are involved in
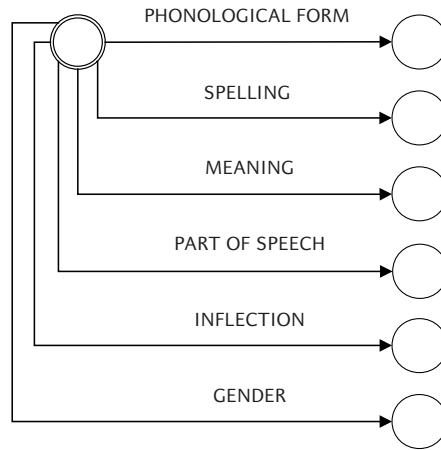
Figure 6: Frame for a lexeme

talk about possible values of attributes. Thus it appears plausible that abstract functional nouns and the characteristic constructions they figure in emerged in co-evolution with scientific theory and practice.

6   Conclusion

The discussion aimed to show that the distinction of conceptual types of nouns is of fundamental importance for understanding not only the semantics of nouns, but human cognition in general. Among conceptual types of nouns, functional nouns are of particular interest. From a linguistic point of view, functional nouns constitute a rather marginal class in grammar, as witnessed by their late emergence in natural language vocabularies and, concomitantly, by the parasitic character of the constructions they are used in. In linguistic theory, too, they have been enjoying little attention, sharing their fate of disregard with individual concepts. The distinction between inherently relational and non-relational nouns (see Table 1) is generally acknowledged. However, the fact that there are types of nouns that are inherently unique, namely individual and functional nouns, is rarely recognized, except for the inherent uniqueness of proper names and personal pronouns.[27]

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[27] Matushansky (2008) even denies inherent uniqueness of proper names, arguing for a sortal concept, type $\langle e,t \rangle$, analysis.

When Janssen titled his 1984 paper "Individual concepts are useful", this was a reaction to the disregard of inherently unique concepts in the development of Formal Semantics following Montague (1973). From the perspective of this article, Janssen's statement is actually an understatement. The immediate connection between functional concepts and frames shows that functional concepts figure most fundamentally in human concept formation. If Barsalou is correct in assuming that the basic structure of all concepts in human cognition is frames, then functional nouns represent the type of concepts which our entire cognition is based on. Attribute concepts, i.e. instances of functional concepts, form the structure of the mental representations in our cognitive system: we categorize whatever we categorize in terms of functional concepts. The relatively complex logical type $\langle e,e \rangle$ of functional concepts is the elementary unit of concept formation, while the logically elementary type e of individuals corresponds to concepts of unlimited complexity.

One has to assume that the mental representations of the meanings of linguistic expressions are of the same structure as concepts in general. Consequently, propositions and lexical meanings basically have the structure of frames, if Barsalou is right. This observation might pave the way for a unified theory of decomposition and composition that conceives of meanings as represented by frames. Such a perspective would offer a basis for integrating the results of formal semantic research with those of cognitive psychology and neuroscience.

Acknowledgments

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