Focused Spatial Attention and Spatial Semantics: The Case of *to follow*

Attention Focalisée Spatiale et Semantique Spatiale: Le Cas du Verbe *suivre*

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Abstract

In this paper, an interdisciplinary approach to the relation of language and space is presented which ultimately aims at the identification of cognitively relevant properties of spatial representations. This goal will be motivated by a semantic analysis of the German verb folgen (to follow). It will be shown that approaches in spatial semantics which lack a cognitive foundation of their basic entities are not able to offer a complete explanation of the pertinent linguistic data. Taking both linguistic aspects and current psychological findings into consideration, focused spatial attention is proposed to be a dimension that may serve as an interface between language and perception. According to this proposal, representations of corresponding focus changes can be regarded as providing the skeletal structure of indirect, but explicit mental representations of space.

Résumé

Dans cet exposé, nous presentons un modèle interdisciplinair que vise à l´identification des qualités cognitives de la representation spatiale. Ce but de recherche sera motivé au moyen d´une analyse semantique de l´allemand verbe folgen (suivre). Nous ne considérons pas seulement des informations linguistiques mais aussi des informations psychologiques, et nous établissons l´hypothèse suivante: la dimension de l´attention focalisée spatiale est

importante pour la representation spatiale indirecte, mais en même temps explicite.

1. Introduction+

An important aspect of developing theories of spatial representation and spatial semantics is the choice of a spatial ontology, the set (of sets) of basic entities for modelling spatial knowledge. Due to the inherent differences of the disciplines involved (linguistics, artificial intelligence, psychology etc.) and criteria applied (e. g., explainability of linguistic or psychological data, ontological adequacy, inferential capability, suitability for specific tasks), the theories might diverge on this point. Therefore, interdisciplinary work is useful here on principle: evidence gained from different perspectives on the spatial domain can be used as constraints in the process of theory building. An example would be an interdisciplinary cognitive science approach to the relation of language and space combining insights from linguistics and psychology in order to arrive at hypotheses about mental spatial representations (Miller/Johnson-Laird 1976, Landau/Jackendoff 1993, Logan 1994).

In this paper, a specific analysis in line with such an approach is presented. In general, it is concerned with the question of whether spatial knowledge can be described in purely spatial terms or whether aspects of the *perception* of space have to be taken into account, too. With respect to the semantics of spatial prepositions, it is argued in Carstensen (to appear) that for both theoretical and empirical reasons, the assumption that spatial representations as well as spatial semantics can be characterized by "purely spatial information" (in that case, the localization of the place of the object to be located (LO) in a certain region of the reference object (RO); cf. Wunderlich/Herweg 1991) is seriously flawed. Not only does it pose an ontological problem (leading to the "what are regions"-question), it also leads to problems in providing explanations for some of the linguistic data. As an alternative, I propose to look for cognitively based and psychologically founded basic constructs in order to avoid these problems. This is for the most part in agreement with (and presumably even goes beyond) the conclusion Habel (1989) arrives at in his analysis of abstract paths:

> "A formal theory of cognitive processes in spatial reasoning will be based on the mathematical theories of topological, metrical and geometrical spaces, *but has to respect the specific constraints of finite size and limited granularity of local regions in mental models*" (Habel 1989: 22, my emphasis).

Here, a (further) restriction will be proposed: Not only do the properties of "purely spatial" information have to be analyzed more closely, it is also necessary to take into account non-"purely spatial" information for achieving an adequate model of spatial knowledge. To substantiate this claim, the role of focused spatial attention for the representation and processing of this knowledge will be examined with respect to the

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+ This is a revised and translated version of a paper presented at the 16th Annual Conference of the German Society of Linguistic Science (Münster, March 1994). I´d like to thank Heike Tappe for numerous comments and many stimulating discussions. Thanks also to two anonymous revievers for some helpful and critical remarks.

semantics of the German verb folgen (to follow)[1]. On the whole, the point of view taken in this paper can be characterized as adressing the question of "how language relates to space" (see Talmy 1983) with the goal of "modelling spatial knowledge on a linguistic and psychological basis" (see Lang/Carstensen/Simmons 1991).

2. Abstract Paths

In his definition of abstract paths, Habel (1989) starts out from the domain D (the set of spatial objects), and the domain LR (the set of spatial regions). He then defines a place function REG (a mapping from D to LR), and a localization relation LOC (LR x LR). On this basis, he introduces *parametric paths* as in (1).

1. φ: I -> LR is a *parametric path*, iff φ is continuous wrt. the topology of LR with I denoting the interval [0, 1] ⊂ **R**

While parametric paths contain information about the locations traversed, an orientation (beginning and end of the path), and the velocity of traversal (all of which are necessary to represent the movement of objects), there may be cases in which one wants to abstract from certain aspects (for example, velocity might not always be relevant) or in which less information is needed for the description of linear spatial entities (path-like objects). In order to account for this, Habel shows how such abstractions can be formally described as equivalence classes of parametric paths (for details, see Habel 1989: 13ff). He calls the class of parametric paths in which information about velocity (but not orientation and location) is neglected a *path*, and the one which also abstracts from orientation a *spur*. This yields a natural "hierarchy" of abstract paths or path concepts: a spur is always a path, and a path is always a parametric path, but not vice versa. With respect to a specific problem in spatial semantics regarding the representation of linear entities, one thus has to decide which of the levels in this hierarchy to choose.

3. Basic Analysis of folgen

As Habel shows, the basic inventory of abstract paths can be used in different ways for the interpretation of spatial expressions. In his analysis of the German preposition zwischen (between), he refers to BETWEEN-regions which he defines as topological deformations of paths connecting two objects. As a further case he shortly discusses the significance of abstract paths with respect to the semantics of to follow. According to Hays (1990), three use types of this verb (listed in (2)) can be distinguished.

2. a. Er folgte ihm nach Venedig
   He followed him to Venice
   [both subject (LO) and objekt (RO) are moving]
   b. Wir folgten dem Fluß
   We followed the river
   [LO is moving, RO is stationary]

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[1] In this paper, I might use English translations of this verb and of some of the examples. It should be noted, however, that the present analysis is restricted to German in the first place.

c. Die Grenze folgt dem Rio Grande
The border follows the Rio Grande
[LO and RO are both stationary]

With the three-fold distinction of abstract paths, a uniform treatment both of "movements" and of "linear objects" is made possible. Due to the availability of the concept 'spur', a common property of the follow-situations can be identified: Looking at the spurs of each LO-RO-pair, it turns out that a however-to-be-exactly-characterized notion of *parallelism* applies to them. Therefore, it could be argued that this parallelism of the spurs of LO and RO can be taken as an abstract semantic property of the verb to follow, leading to the hypothetical (and simplified) semantic entry (3). Following this line of reasoning[2], the differences of how the spurs are induced and which restrictions hold between them (both depending on the type of the objects), might be put aside to the conceptual interpretation, where more information about paths, parametric paths, and the constraints imposed on them can be exploited.

3. folgen/to follow: λy λx [PARALLEL(spur(x), spur(y))]

4. Problems of the basic analysis

Habel himself questions the descriptive adequacy of the direct application of his abstract paths. He poses the following three questions:

- Why does the potentially possible use type "LO stationary and RO moving" seem to be non-existent in German?
- Can LO and RO be exchanged in sentences of type (2c), i.e., is there a symmetry?
- Can every pair of "spur-like" form be described by to follow? Why is the verbal description in (4) for the situation depicted in fig. 1 inacceptable?

4. *Ein Streichholz folgt dem anderen
*One match follows the other one

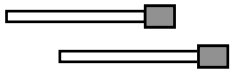

fig. 1

Interestingly enough, Habel hypothesizes that a conceptualization of LO has to be present which induces a moving (or movable) object, "e.g. the moving focus [!] of vision in a mental image" (Habel 1989:22), where LO must be "at least as movable with respect to the follow-situation" as RO. He assumes that the inacceptability of (4) can be explained by a failure of establishing such a conceptualization, which is caused by aspects of granularity and size of a mental image: "the objects in question are so small that scanning along the object´s shape is unnatural" (ibid.). From these considerations, he concludes that a a 'spur'-analysis (in my terms, a "purely spatial" one) does not suffice to explain the semantics of to follow and that – even for static configurations! –

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2 which by the way does not match exactly Habels argumentation.

other aspects of abstract paths have to be taken into account. Of course, this specific conclusion generalizes to the whole field of spatial semantics.

Although Habel´s proposal of different abstract paths clearly shows the necessity of going beyond "purely spatial" aspects, it nevertheless provides only a very general framework, which is furthermore still *rooted in* "purely spatial" notions. In the following, I will show that a further step has to be made in order to arrive at a sufficiently adequate analysis.

5. *Die Bahnstrecke Marseille-Lyon folgt dem Nil
   *The railway Marseille-Lyon follows the Nile

6. Die Seefahrer folgten dem Nordstern, bis sie endlich die Küste Grönlands erreichten
   The seamen followed the north star until they finally reached the shore of Greenland

7. Die Straße folgt dem Fluß bis zum Rand der Hochebene
   The street follows the river to (as far as) the border of the plateau

As a first example, (5) shows – similar to (4) – the overgeneralization of (3) and, accordingly, the requirement of constraints qualifying the notion of 'parallelism of spurs': Although the spurs are roughly parallel in some (mathematical) sense, the sentence is inacceptable. In the case of sentences like (6), the question of how to justify a local spur with respect to a stationary and point-like RO arises, thus challenging the necessity of spurs.

Examples like (7) show that even the use types denoting purely static configurations are not captured by (3). According to an analysis of Wunderlich/ Kaufmann (1990), the German preposition bis indicates the endpoint of a continuously changing, homogeneous situation (that is, of a process). Processes in turn may be characterized by a recurrent instantiation of a non-homogeneous situation type (e.g., PUT_A_CHAIR_TO_SOME_PLACE, cf. Moens/ Steedman 1988). A relevant contrast can accordingly be exemplified by (8) - (11). While (8) and (10) express a simple change of the LO´s location (single object and group of objects, respectively), (9) is inacceptable because of an apparent the violation of the process condition (namely that there is no recurrence). For (11), however, an interpretation can be generated (the chairs are placed one after another, with the last one put near the window). As regards (7), it remains unclear how its acceptability (the fulfilment of the process requirement of bis) can be explained by (3), which denotes a static state of affairs (the parallelism of two spurs).

8. Sie stellte den Stuhl ans Fenster
   She put the chair to the window

9. *Sie stellte den Stuhl bis ans Fenster
   *She put the chair to (as far as) the window

10. Sie stellte die Stühle ans Fenster
    She put the chairs to the window

11. Sie stellte die Stühle bis ans Fenster
    She put the chairs to (as far as) the window

A final problem emerges from a comparison of to follow with its *converse* lexeme führen (to lead) (e.g., (12), (13)). To account for the conversity, a plausible solution would be to simply exchange the argument positions of the underlying semantic relation. With the proposed semantic entry in (3), however, no real distinction can be expressed because of the (presumed) symmetry of the PARALLEL-relation.

12. Wir folgen der Straße nach Norden
    We follow the street in a northwardly direction
13. Die Straße führt uns nach Norden
    The street leads us in a northwardly direction

These examples show that analyses which are ultimately based on or rooted in reference to locations ("purely spatial information") fail to provide a complete account of the phenomena. In accordance with Habel, I suggest that it is also necessary to take properties of the *perception* and *imagination* of space into consideration. Most importantly, these properties have to be *represented* in order to be available for a theory of spatial representation and spatial semantics.

Aiming at a characterization of relevant properties for the analysis of to follow, the characteristics and problems of the basic analysis adressed in the previous discussion are summarized as follows:

i. The relation between theme (LO) and relatum (RO) is established only *indirectly* via relating their spurs (-> problem of overgeneralization, see (4), (5); question of how the spurs are induced, see (6))
ii. The functional distinction between theme and relatum (RO acts as a reference object) is not represented, that is, the relation between LO and RO is symmetric (-> problem of missing stationary/moving-combination; problems of conversity and asymmetry)
iii. The inherent process condition is not represented (see (7))

These results can be contrasted with the following proposed requirements:

I. There must be an abstract dimension on which a relation between theme and relatum can be established *directly*
II. Theme and relatum must be explicitly distinguished in that the relatum takes the function of a reference object
III. The fact that (I) and (II) apply iteratively (characterizing a homogeneous type of situation which satisfies the process condition) must be made explicit

Apparently, linguistic considerations point to the necessity of assuming a dimension that has not been considered before in this theoretical context. Yet within the realms of linguistics, the question as to what this dimension should be cannot be resolved. Thus, one has to look elsewhere for an answer.

5. Focused spatial attention and spatial representation

5.1 The role of focused attention in visual perception

One of the central topics of investigation in cognitive science is to characterize the mapping from external to cognitive space. Undoubtedly, visual perception is involved in this task to a larger part (but not exclusively, of course). It therefore seems reasonable to look for some results of research done in this field that may help identifying the needed dimension.

What is known about how we arrive at a coherent, structured, categorical description of the world, given the vast amount of sensory input data? How do we *select* data for processing, distinguishing them from data not to be processed? Which conclusions can be derived from these considerations for the nature of spatial representations?

Current approaches in visual perception which strive to provide answers to these questions seem to converge on the point that for selecting information from a visual field, *focused attention* to this information is of utmost importance (cf. Treisman 1988, Theeuwes 1993). At the heart of what can now be regarded as a paradigm, there are two basic observations: On the one hand, single items "pop out" of a homogeneous field of type-different items (e. g., a circle in a field of squares). This effect appears independently of the number of the distractor items, which points to massively parallel processing. On the other hand, reaction times of searching items of a certain type within an inhomogeneous display increase with the number of distractors, which is taken as evidence for serial processing. For the explanation of these phenomena, that is, as an answer to the question of *when* and *how* an object is selected for identification, the following (simplified) stages of processing in this part of visual information processing are currently assumed:

S1 parallel processing of visual stimuli in separate modules (colour, orientation, size, direction of movement; each feature of one of these modules is assigned its position in a module of locations, the so-called "map of locations", Treisman 1988);
computation of differences between features; the more a feature differs from others, the higher activation it gets (compare the "odd-man-out"-principle of Ullman 1984)

S2 shifting of attention (like a "beam" or "spotlight") to the highest activated item on the "map of locations" (-> selection); integration of the features (-> object identification), possibly creation of a temporary, time- and place-specific representation of the object (so-called "object file", Kahneman/Treisman 1992)[3]

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[3] The simplification of the description of this processing model mainly results from disregarding some of the aspects that are still controversially discussed, for example, the number of processing stages (cf. Trick/Pylyshyn 1993), the types of operations performed on each stage and the corresponding characteristics of 'selection' ("early" vs. "late"), the involved types of attention (object-based vs. location-based, cf. Vecera/Farah 1994), how spatial attention operates ("spotlight-" vs. "zoom-lens-"metaphor), divisibility of attention, and the direction of processing ("bottom-up" vs. "top down" (influences)). For a general criticism of this field see Allport (1989).

According to Theeuwes, the engagement of attention happens automatically (that is, it is not controllable), while the amount of attention allocated (usually considered to be limited) is variable. Attention can be distributed or else in a state which is called "focused attention". As a first (and admittedly partial) answer to the questions above, the following conclusion can be derived from these results: There are specific mechanisms of the perceptual system which make a selection of the incoming perceptual data in order to pass them to central processing. The construct 'focused attention' (which by the way is not specific to the perceptual system) can be regarded as playing an important role in this process.

5.2 The role of focused attention in the representation of space

From the results just discussed, some further conclusions concerning the representation of space can be drawn:

First, 'focused attention' obviously has to be regarded as an intermodal construct. Therefore, it is in principle relevant for questions concerning mental representation; at the same time, it has a concrete impact on *spatial* representation (see S2).

Second, due to the serial processing in S2, the mental capturing of space evidently happens *in time* (in a non-trivial sense), which, most importantly, also holds for *static* states of affairs. This is one important aspect that warrants and supports a criticism of approaches proposing spatial representations that are based on "purely spatial" information.

Third, the sequence of engagements of focused attention constitutes an abstract dimension of change which both for empirical[4] and principled reasons suggests itself for conceptual categorization.

As a consequence of these observations it will be proposed in this paper that the changes of (engagements of) focused attention are indeed conceptually categorized. According to this view, focused attention defines a cognitive featural dimension whose set of values may consist of spatial reference objects (the 'object files' of Kahneman and Tversky). This is most explicitly stated in the title of a paper by George Sperling and Stephen Wurst (presented at the 32st Annual Meeting of the Psychonomic Society, San Francisco, 1991): "Selective Attention to an Item is stored as a Feature of the Item" (for details, see Sperling et. al. 1992). Obviously, spatial objects are related to one another along this dimension. It can therefore reasonably be assumed that focused attention serves to establish spatial relations between objects which are not defined in "purely spatial" terms. This assumption is in agreement with ideas developed within the paradigm of image processing:

> "The basic idea is that when *sequentially* fixating different objects, the change in fixation provides a direct encoding of the desired spatial relationship" (Ballard 1987:192).

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[4] Empirical support derives from research showing "top down"- or, in Posner´s (Posner 1980) terms, endogenous, influences (cf. Theeuwes 1993, Sperling et al. 1992).

However, 'focused attention' is distinct and provably independent of 'fixation' (although strongly related to it). Besides this, focused spatial attention should not be regarded as being confined to the visual system. For example, spatial information can also be acquired through haptic experience (there even seems to be no functional difference in the spatial representations of sighted and blind people, Haber et al. 1993). Because of this transmodality, a distinct but rather unspecified spatial representation system has been proposed recently (cf. Bryant 1992).

If it is assumed that changes of spatial attention are associated with proprioceptive movement information originating from different levels and different systems, the resulting structures may serve to constitute (or be a constitutive part of) such a spatial representation system. According to this view, space is for the most part represented *indirectly*, which is far remote from a conception like a monolithic 'cognitive map' (see, e. g., Kuipers 1982 for a criticism of this notion).

In addition to that, a contrast to *analogical* representations of space like, for example, concrete visual images is established. In these representations, each part is spatially related to each other part (cf. Kosslyn et. al. 1978). Note, however, that the relations are given only *implicitly*. It has been argued that in order to be available for being named by a linguistic expression, spatial relations must be made *explicit* (cf. Olson/Bialystok 1983). Yet ironically, while linguists use to disregard psychological adequacy of their proposed spatial relations, psychologists seem to ignore linguistic (especially cross-linguistic) evidence for the most part. As a result, one often finds "spatial relations" corresponding to the prepositions in a certain language (ABOVE, BELOW etc.). The recent work of Logan (in press) can be viewed as an exception in this respect. Interestingly, he investigates spatial relations within the paradigm of visual spatial attention thus highlighting the internal structure and explicit character of these relations, which provides further evidence for the proposal made in this paper.

With the annotated focus structures, there is a *qualitative*, explicit level of spatial representation that seems suitable for defining the spatial concepts adressed by linguistic expressions.[5] However, pieces of these structures may be activated in working memory leading to the instantiation of a mental image or, more abstractly, to a spatial mental model in order to allow for drawing inferences with respect to a certain spatial configuration (cf. Taylor/Tversky 1992). This *constructive* aspect of spatial representations (not to mention partiality, hierarchical structure and other aspects, cf. Tversky 1981) is another reason for rejecting analyses based on "purely spatial" information. To summarize, with this view of explicit spatial representations based on structures of changes of focused spatial attention, it is now possible

- to represent external space not by mirroring its properties but by qualitative aspects of *experiencing* space (where the notion of "experiencing" can be given a fairly concrete interpretation).
- to specify what is meant by "purely spatial information": If one accepts the distinction between explicit and implicit spatial representations I have drawn, it seems to be exclusively the latter that is adressed by this description; in the foregoing discussion, I have shown that this restriction is untenable for the characterization of (the varieties of) spatial knowledge; in the following section, I

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[5] According to this assumption, it is not necessary to examine the neuropsychological level for constraints on possible spatial concepts (e. g., the 'what'-'where'-distinction) as is suggested in Landau/ Jackendoff (1993).

will show that an analysis based on explicit spatial representations is better suited to specify the semantics of to follow.

- to assign a motivated temporal structure (necessary for inducing a certain ordering, see above) to static spatial situations by referring to the inherently temporal perception of space.
- to further elucidate hierarchical structure in spatial representation (cf. Hirtle/Jonides 1985, McNamara 1986, Carstensen 1991) taking into account the processes of selecting a next focus of attention (see S1).

5.3 The role of focused attention for spatial semantics

The analysis of folgen proposed here is crucially based on the following assumption (IV), which is derived from the previous considerations:

IV. The relevant dimension looked for is the one constituted by changes of engagements of focused spatial attention. The relation of LO and RO can be identified as a *change of focused spatial attention* from one to the other

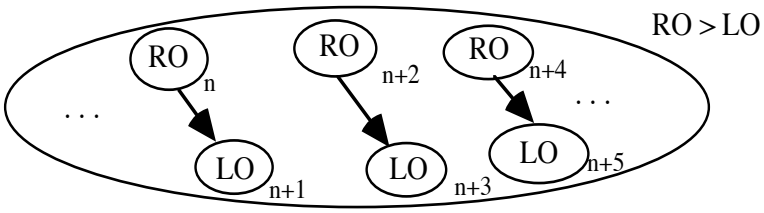

fig. 2

expression	constancy	variance
We follow the man (RO is moving)	type, ref(erence)	loc(ation)
We follow the torchbearer to Olympia (RO is moving)	type	ref, loc
We follow the markings/the marking (RO is stationary)	type	ref, loc
We follow the river (RO is stationary)	type, ref, loc	part
The seamen followed the northstar (RO is stationary, LO is moving)	type, ref, loc	

fig. 3

The conceptual conditions central for the treatment of folgen and führen can be illustrated on the basis of fig. 2, which exhibits the following properties:

- Within this schema, only a constancy of the focused entities (LO, RO) on a certain level of conceptual specification is demanded. Therefore, the variance in the

extension of the respective object expressions (see fig. 3) can be captured and explained by the possible variability *within* the rather rigid structural frame.

- It illustrates the existence of a level of representation that is orthogonal to representing objects and movements: due to the inherent temporality of focus sequences, their conceptual categorization allows to characterize as different entities as moving objects (man), stationary linear multiplexes (markings), and object form (river).

- It generalizes a set of similar conceptual schemata which are not only *based* on perceptual experiences of the environment, but also require the *relevance* of these experiences for our behaviour. As to the former aspect, it explains the inacceptability of expressions like (5) in which there is no experience available. It is simply not possible for the railway and the Nile to be perceived in a way that corresponds to the schema in fig. 2. As regards the latter aspect, although it is possible in this case to view the matches in (4) according the follow-schema, it is by no means relevant for our behaviour to do so.[6] Instead, typical perception of these objects (in my terms, presumably via a simple change of focused attention, if at all) will prevent the application of the schema, which requires a multiplicity of focus changes.

- It expresses a *direct* relationship between RO and LO. Thus, spurs can be legitimately regarded as secondary to the analysis of to follow, and furthermore neither necessary ((6)) nor sufficient ((4), (5)).

- It refers to changes of focus thus expressing an inherent asymmetry in the relation of RO and LO, as opposed to the symmetry of the PARALLEL-relation. Because of this, a treatment of the conversity of to follow and to lead is possible in principle.

- It contains an additional asymmetry of RO and LO (represented as 'RO > LO') which can be attributed to general differences of these entities with respect to figure/ ground-assignment. It therefore represents the fact that LO is related to another entity which is selected as a *reference object* for some context dependent reason. This functional difference can be viewed as the reason for the exclusion of examples of the type 'LO stationary, RO moving': they do not satisfy the principle underlying this asymmetry and hence cannot instantiate the above schema.

- It differs from representations of simple spatial relations in the structured multiplicity of focus changes. Thus it characterizes – as has been demanded above – an underlying process that can be modified by bounding expressions like bis ((7)).

In taking into account the dimension of focus changes for the analysis of the linguistic data, a qualitative change in the treatment of the phenomena occurs: While restrictions have to be imposed externally on a representation that is based on "purely spatial" information (for avoiding overgeneralization and for the explanation of how the spurs are induced), they are inherent to a representation that is based on the assumptions (I)-(IV) or can be derived from them in combination with the pertinent world

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6 On the contrary, smaller animals like ants might rate (4) as perfectly acceptable, due to the possible significance of the matches for their behaviour.

knowledge. As has been described, they *follow* from the interaction of the postulated constructs, general cognitive representations, processes, and principles of our species, and our specific perceptual experiences of the world. As a result, (4) is inacceptable because matches lying close to one another are typically experienced in one single glance; (5) is inacceptable because due to their spatial relation in the world there are no external representations (maps) or, as a consequence, internal representations (mental images) in which railway and river can be related according to the schema in fig. 2.

6. Formal aspects

As a result of the present analysis, and in contrast to (3), (14) and (15) shall now be proposed as simplified semantic entries of to follow and to lead, respectively ('*' denoting the multiplicity of the annotated property). Observe that the conversity actually is obtained by simply changing the arguments of the semantic structure.

14. folgen/to follow:
λRO λLO [[CHANGE(FOCUSED(RO), FOCUSED(LO))]*, RO > LO]

15. führen/to lead:
λLO λRO [[CHANGE(FOCUSED(RO), FOCUSED(LO))]*, RO > LO]

This proposal can be further refined in providing definitions for CHANGE and FOCUSED (as used in this context), respectively. This requires a closer view at the spatio-temporal aspects of focused spatial attention. Recently, elaborated formal theories of space-time for natural language semantics have been developed (Aurnague/ Vieu 1994, Asher/Sablayrolles in press). In those works, functions yielding spatio-temporal referents (STrefs) of entities are used for modelling their spatio-temporal extent, their trajectories, and their orientation along some dimension. STrefs are therefore quite similar to what is referred to with "FOCUSED(X)".

However, note that the latter designates aspects of mental representation and processing, which has to be made explicit. Therefore two separate functions will be introduced: *FSref(x)*, which yields a mental spatial referent in a state of focused attention, and *IT(fsref)*, which maps fsrefs on their corresponding temporal interval of internal processing. Focused spatial attention to an entity of type X then is defined as in (16).

16. $\text{FOCUSED}(X) \equiv_{\text{def}} \text{IT}(\text{FSref}(X))$

On the basis of this definition, focus *changes* can be modelled by interval relations. More specifically, what is needed in the context of this paper, is the BEFORE-relation of Allen ($<_t$), giving rise to the definition in (17).

17. $\text{CHANGE}(\text{IT}(\text{FSref}(X)), \text{IT}(\text{FSref}(Y))) \equiv_{\text{def}} <_t (\text{IT}(\text{FSref}(X)), \text{IT}(\text{FSref}(Y)))$

With (17), the central point of this paper has been made explicit (space is not only represented in spatial terms, but –even for static configurations like (2.c)– also in terms of the inherently temporal perception of space). However, there is another important difference between the proposals in (3) and (14): while the predicate in (3) describes a

static unbounded situation (the parallelity of spurs) denoting a *state*, according to (III) follow has to be analyzed as a *process*(a *dynamic* unbounded situation). Although this information is implicit in (14) by way of "*" as an indicator for multiplicity, the difference in situation type can be explicitly represented on the one hand with an iterativity operator ITER (mapping bounded predicates to unbounded predicates) and on the other hand with sortal predicates applying to situation arguments. With these explications, (3) and (14) can be finally rewritten as (3') and (14').

3'. folgen/to follow:
λy λx λs [instance(s, [PARALLEL(spur(x), spur(y))])
& State(s)]

14'. to follow:
λRO λLO λs [instance(s,[ITER([CHANGE(FOCUSED(RO), FOCUSED(LO))]),
RO > LO])
& Process(s)]

7. Final remarks

Based on a discussion of the semantics of to follow, I have argued that finding adequate basic constructs is an important task in the fields of spatial representation and spatial semantics. It has been shown that it is not sufficient to propose such constructs only for the sake of linguistic analyses but that it is also necessary to clarify the role of these constructs in an overall cognitive system. In this respect, it turned out that proposals relying on what was called "purely spatial information" are neither able to give a complete account of the linguistic data, nor relate adequately to cognitive representations of space.

It was suggested that the "purely spatial information" used in some current semantic theories only refers to aspects of implicit spatial representations, that is, to properties of analogical representations like mental images (thus neglecting explicit spatial representations). It was then shown that the dimension of focused spatial attention not only is relevant for characterizing these explicit representations but that it is also essential for specifying the semantics of to follow.

I hope that with the results achieved in this paper (by taking a cognitive science perspective), I have demonstrated the usefulness and, ultimately, the necessity of interdisciplinary work for the investigation of spatial knowledge.

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