Understanding Radio Broadcasts On Soccer:

The Concept 'Mental Image' and Its Use in Spatial Reasoning

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Abstract

Most cognitive theories agree that a listener of a sports broadcast on radio usually imagines the scene described; the concept 'mental image' appears in a specific sort of explanations. In contrast to this conception, it is argued that this concept should rather be understood as part of a certain kind of *grounding* explanations of the radio listener's understanding. This particular conception is based on the distinction between 'specification' and 'implementation' as found in the theory of abstract data types. Its application to the field of spatial concepts leads to a computational system (ANTLIMA) which exemplifies how the expression 'mental image' could be used while explaining a speaker's ability to control the resolvability of ambiguities in an objective report of what the speaker sees.

Extended Version with three addenda

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Zusammenfassung

Die meisten Kognitionstheorien stimmen darin überein, daß ein Hörer einer Radioreportage sich die beschriebene Szene oft bildlich vorstellt; der Begriff 'mentales Bild' tritt in einer bestimmten Form der Erklärung auf. Im Gegensatz dazu wird argumentiert, daß man diesen Begriff besser verstehen sollte als Teil einer *Begründung* von Erklärungen, die das Verstehen des Radiohörers betreffen. Dieses Verständnis leitet sich von der Unterscheidung zwischen 'Spezifikation' und 'Implementation' aus der Theorie der Abstrakten Datatypen ab. Seine Anwendung auf das Feld der räumlichen Begriffe führt zu einem Computersystem (ANTLIMA); es demonstriert, wie der Ausdruck 'mentales Bild' benutzt werden kann, wenn die Fähigkeit eines Sprechers erklärt werden soll, die Auflösbarkeit der in einem Bericht über Gesehenes verwendeten Ambiguitäten zu kontrollieren.

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1 Introductory Remarks on Mental Images

"We do not have to ask what mental representations are, or what happens when we imagine something, but how the expression 'mental representation' is used."[1] This remark of Wittgenstein holds for 'mental images' (or 'pictorial mental representations') in particular. That is, we should ask: How and under what circumstances do we speak meaningfully while using the expression 'mental image' or one of its synonyms? A particular type of such a context of use is given by the situation of a person listening to radio sportscasts, for example about a soccer game. This case, especially objective parts of the report concerning the observed spatial configurations on the soccer field, may serve as a paradigm for a more general group of uses of the expression 'mental image'.

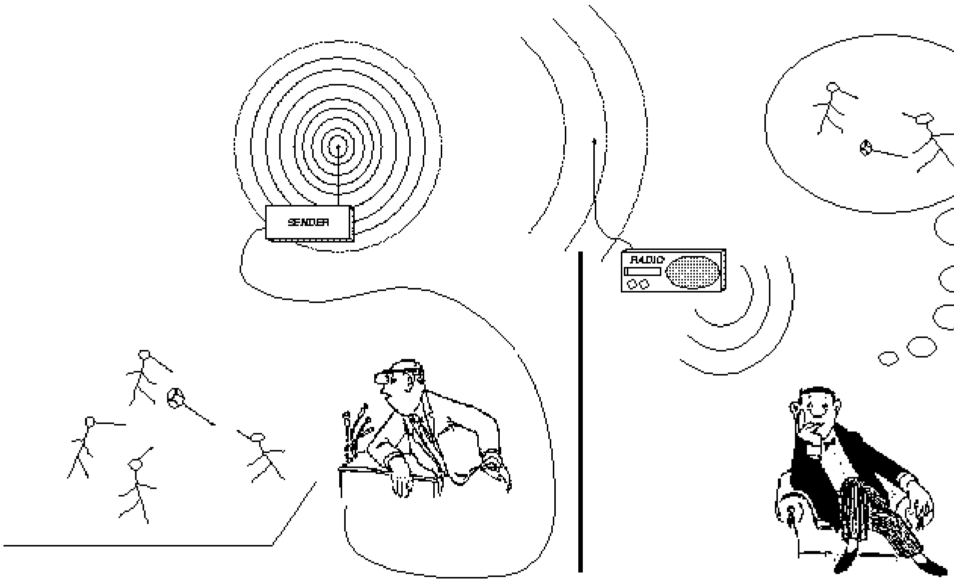


Figure 1: Mental images as explanations

Most contemporary cognitive theories[2] agree that a listener while concentrating his attention on a sportscast on radio, usually imagines the described spatio-temporal configurations. More precisely: the concept 'mental image' appears in a specific sort of explanations of an aspect of what happens cognitively 'in' the hearer of a radio report: it is proposed that, in order to understand the description, the listener would have to re-present, i.e., to bring to his presence, *in a concrete, quasi 'sensible' form* what is described. Since the description is primarily anchored referentially in something seen, it is assumed that the listener imagines the scene in a form which substitutes a corresponding visual perception (cf. Fig. 1). Exactly in this sense, Dankert – a German linguist concerned with the pecularities of sports reports – described as the criterion of success for reporting in radio: *"the radio reporter has solved his task only if he describes the reality of a sports event so vividly and obviously to the listener that the listener believes he sees that reality."*[3]

[1] cf. [Wittgenstein, Ludwig: Philosophische Untersuchungen. Frankfurt/M. 1969, §370 (transl. J.S.).];

[2] cf., e.g., [Johnson-Laird, Philip N.: Semantic primitives or meaning postulates: mental models or ixupropositional representation. In: B. G. Bara & G. Guida (eds.): Computational Models of Natural Language Processing. Amsterdam 1984.];

[3] cf. [Dankert, H.: Sportsprache und Kommunikation. Untersuchungen zur Struktur der Fußballsprache und zum Stil der Sportberichterstattung, Tübingen 1969, p. 94 (transl. J.S.).];

The essential claim of those theories is such that the implications concerning spatial information that the listener is able to draw from the reporter's descriptions can simply be *'seen'* in these visual pseudopercepts: after receiving a corresponding initial part of a report which forms the actual context of understanding, the listener would, for example, be able to 'see in his mind's eye' that a particular player of whom he recently was only told the locational restriction *'to be beside the penalty area'* in fact stands *'to the left of the opponent penalty area'*. He should be able to do that concretization because that particular understanding is the only consistent way for him to continue the mental image, i.e., his understanding of the contextual scene relative to the newly communicated 'being beside': he resolves ambiguities in both the meaning of 'being beside' and in the reference of 'the penalty area'.

In contrast to this conception of the relation between referential semantics and spatial reasoning (Sec. 2), I shall argue in Section 5 that the concept '(pictorial) mental image' and its synonyms should be understood rather as part of an attempt to *justify* (or *'ground'*) explanations of the radio listener's understanding. This particular conception is based on the distinction between *specification* and *implementation* as found in the theory of abstract data types: the application of this distinction to the theory of concepts and reasoning is given in Section 4 after a brief examination of the question whether mental images exist (cf. Sec. 3). Before we come to the conclusion (Sec. 7), a complex computational system designed in accordance with those theoretical arguments is sketched (Sec. 6).

2 'Referential Sematics' and 'Spatial Reasoning'

(a) Referential and intra-lexical semantics: Although often appearing under different names, one rather stable distinction in semantics is that between *referential* and *intra-lexical semantics*: whereas researchers in the latter framework concentrate their efforts on circumscribing the uses and meanings of verbal expressions – and thus, stay in the medium of language, always facing the inevitability of circular or open-ended definitions – the former try to escape these traps by stepping *outside* of language to ground semantics. Since at least those terms dealing with concrete, spatio-temporally extended and localizable affairs are anchored in non-verbal experiences, such an approach does not seem impossible, at first. Assumedly, the reference relation which associates each expression with its (usually) non-verbal 'thing', is mediated mentally. Essentially, it is perception that supplies the needed referents. By and large, visual perception is used as a paradigmatic case for studying referential semantics.

Since aspects of perceptibility do not play a crucial role in intra-lexical semantics, such approaches have little difficulty with objects that are actually (or even generally) not perceptible. However in the framework of referential semantics, an elaborated answer to that question is required: if the meaning of (some) verbal expressions is based on the reference relations of those expressions, then in each use of these expressions, their meaning should be 'cashable' in corresponding referents.[4] If however the referents are mediated by perception, the 'cashing' cannot happen if no corresponding percepts can be obtained. But percepts are set up mentally: there apparently is no reason for assuming that *autonomously created* mental structures of the same type as percepts may not serve the same functions as percepts in cases where the latter are not available. This is seen as the major theoretical motivation for the concept 'mental image' in semantic theories.

[4] cf. [Kaufman, Geir: Imagery, language, and cognition. Toward a theory of symbolic activity in human problem-solving, Bergen, Oslo, Tromsø 1980, p. 15.];

How is understanding explained in the two frameworks? Such an explanation would have to describe how an utterance changes the listeners' ability to handle a subsequent verbal interaction, for example, the understanding of the following utterance of the report, or the answer to a question concerning the report. Therefore, explaining how to understand an assertion is explaining how the sentence used in the assertion changes the context, or more formally, how the sentence relates two contexts.[5] We shall see in the following argument that intra-lexical semantics concentrates on one particular type of context-to-context relation, whereas theories of perception elaborate a completely different type. Referential semantics finally combines the two types of relations considered between contexts on a higher theoretical level.

(b) The image of perception: a short example: To referential semantics, the underlying conception of perception is crucial; therefore, the current understanding in AI of the origin of

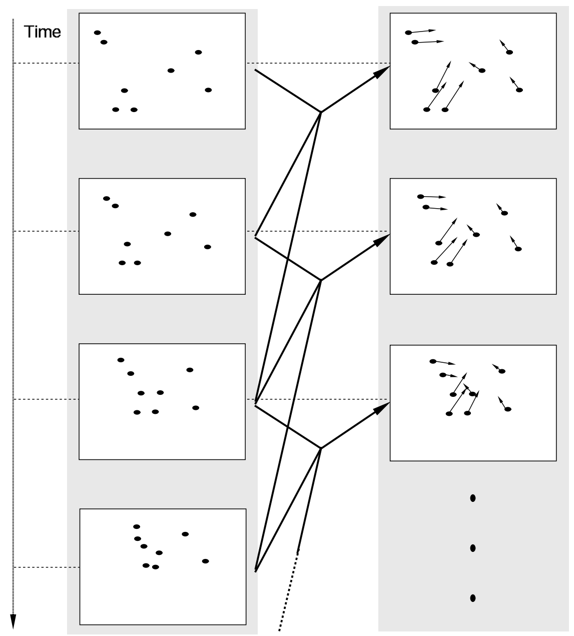


Figure 2: First grouping

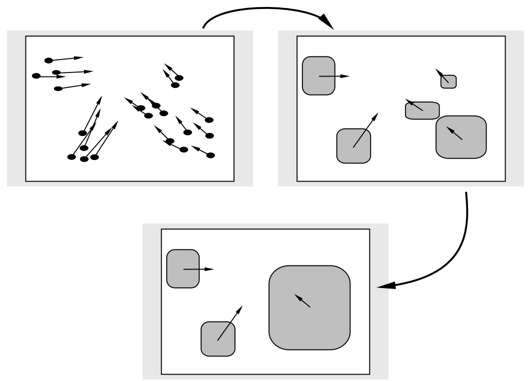


Figure 3: Second grouping

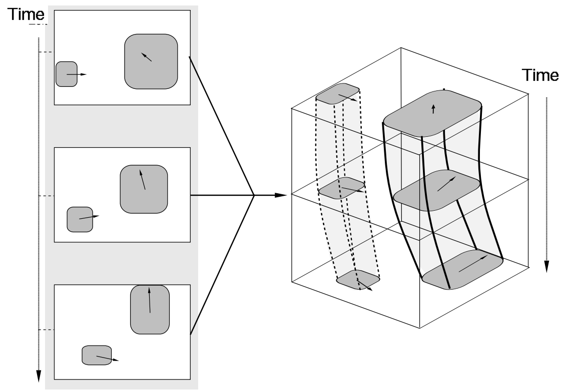


Figure 4: Third grouping

Sketch of the 'bottom-up' part of ACTIONS: First, extrema of the intensity field at consecutive instants are grouped to instantaneous (velocity) vectors, if they are of the same kind and at almost the same position (Fig. 2); then, closely positioned similar vectors at one instant are grouped to spatially extended entities; if several of these still instantaneous entities happen to be close to each other and have a similar velocity vector, they are merged (Fig. 3); finally, another temporal grouping of the development of those entities is applied (Fig. 4);

[5]cf. [Kamp, Hans: On the representation and transmission of information. Sketch of a theory of verbal communication based on Discourse Representation Theory. In: E. Klein & F. Veltman (eds.): Natural language and speech. Berlin 1990, p. 135–158.], [Schirra, Jörg R.J.: Sprachliche Bildbeschreibung als Verbindung von visuellem und sprachlichem Raum. Eine interdisziplinäre Untersuchung von Bildvorstellungen in einem Hörermodell, St. Augustin 1994, Sec. 3.3.];

the referents for spatial relations is sketched by means of an example in computer vision: the perception of spatial objects by motion as by the systems ACTIONS and XTRACK.[6]

In most computational approaches to object recognition, the signal of a video camera, i.e., essentially a sequence of matrices of intensity values, stands at the beginning. On a general level, two structurally different phases of subsequent processing can be distinguished: in the lower phase, the primary data is processed 'bottom up' (data-driven): the results depend essentially on that data alone. In the higher phase, intermediate data is related to other sources of information, an integration which usually is performed 'top-down' (goal- or expectation-driven). On the lower level of our particular system (cf. Fig. 2 to 4), candidates of spatio-temporally extended objects are calculated by means of several layers of grouping criteria depending on similarity of the grouped entities (including spatial and temporal closeness). However, these candidates are not yet spatial objects in the usual sense: this can be seen clearly in situations like that shown in Fig. 5. The pure 'bottom up' grouping has to be complemented by additional 'teleological' knowledge providing the conditions under which deformations, loss or exchange of parts and substance, occlusions, etc. do or do not alter the identity of an instance.

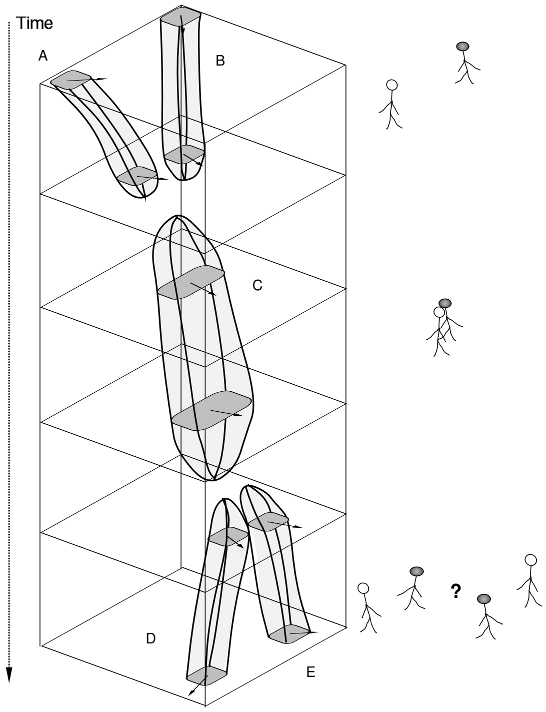


Figure 5: Problem of identity for bottom-up processing: five candidates for two objects

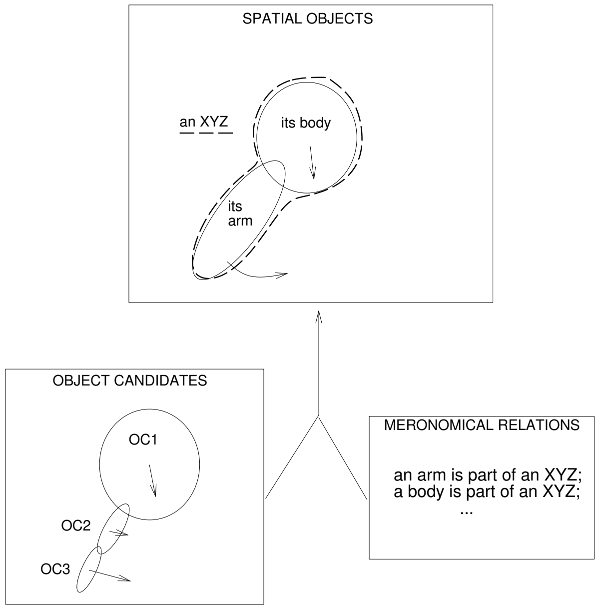


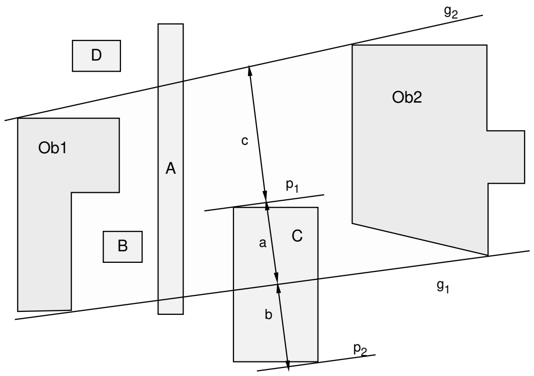
Figure 6: Sketch of object constitution by relating perceptual geometrical and functional part-whole relations

The established way to do this is using 'object models':[7] they essentially describe which configurations of parts form an instance of a particular type of object. The projection of the object models to the perceived object candidates finally establishes the perception of spatio-temporally extended, persistent, and localizable entities – exactly the type of objects involved

[6] cf. [Koller, Dieter: Detektion, Verfolgung und Klassifikation bewegter Objekte in monokularen Bildfolgen am Beispiel von Straßenverkehrsszenen. St. Augustin 1992.]; an elaborated description and further references are to be found in [Schirra, 1994, *op. cit.*, Chap. 9.];

[7] cf., e.g., [Marr, David: Vision. A computational investigation into human representation and processing of visual information, New York, San Francisco 1982.];

in spatial relations. The largely geometric information about the *actual* configurations from the bottom-up phase is combined with information about part-whole relations governing the *possible* range of configurations (cf. Fig. 6). The resulting set of instances of such objects may be used as the referential context for the experiential anchoring of the use of locative prepositions (as in Fig. 7), verbs expressing spatio-temporal events, and even terms for higher concepts.[8] In general, the constructed descriptions of what is seen form distinct contexts on different levels; perception can be conceived of as the systematic relation between these contexts.



Algorithm for 'x is between Ob1 and Ob2':

1. Calculate the tangents g_1 and g_2 of Ob1 and Ob2;
2. If:

   A: both tangents hit object x:
   $\rightarrow$ degree of applicability := 1.0;

   B: Ob1, Ob2, g_1 and g_2 enclose x entirely:
   $\rightarrow$ degree of applicability := 1.0;

   C: only one tangent hits x:
   $\rightarrow$ degree of appl. := $max\,(\frac{a}{a+b}, \frac{a}{a+c})$;

   D: else: $\rightarrow$ degree of applicability := 0.0;

Figure 7: An example: algorithm for recognizing simple instances of 'being between'

(c) Conceptions of Spatial Reasoning: The changes induced in a context by a sentence are often called the (semantic and pragmatic) *implicatures* of the assertion.[9] The implicatures we are mainly interested in in our example are essentially conclusions to be gained by means of what has been called *Spatial Reasoning* in AI. In order to better understand the relations between the concept 'spatial reasoning' and the implications of an approach using referential semantics, we have to examine the nature of reasoning and of the utterances involved. Two rather simple but nevertheless typical examples of spatial reasoning are given in schemata (a) and (b):

	(a)	(b)
if we already know that:	*Miller is to the right of Smith.*	*Your apple is in your bag.*
and:	-	*Your bag is in my kitchen.*
we can deduce that:	*Smith is to the left of Miller.*	*Your apple is in my kitchen.*

These examples of spatial reasoning can be described on a formal basis as a deduction of almost classical type depending on the logical structure of the singular assertions used. Following the constructivist analysis of logic,[10] singular assertive utterances are logically divided into four parts: one is called the involved set of singular terms, or *nominators*, which refer to some given (i.e., already mutually known) individual objects, like 'your apple', 'my kitchen' or 'Smith' in the examples above. The second part is called the general term, or *predicator*. The function of predicators is to introduce a standard gauge with respect to which the considered

[8] cf. [Herzog, Gerd & Sung, C.-K. & André, E. & Enkelmann, W. & Nagel, H.-H. & Rist, T. & Wahlster, W. & Zimmermann, G.: Incremental natural language description of dynamic imagery. In: W. Brauer & C. Freksa (eds.): Wissensbasierte Systeme. Berlin 1989, p. 153–162.] and [Schirra, 1994, *op. cit.*, Chap. 9.];

[9] cf. [Grice, Herbert P.: Logic and conversation. In: P. Cole & J.L. Morgan (eds.): Syntax and semantics. vol. 3, New York 1974, p. 41–58.];

[10] cf. [Kamlah, Wilhelm & Lorenzen, P.: Logische Propädeutik. Vorschule des vernünftigen Redens, Mannheim, Wien, Zürich 1973.];

objects are rated: a dimension of distinction to be communicated. In the examples above, we employ the predicators 'to be to the left of', 'to be to the right of', and 'to be in'.[11] A *logical copula* is the third part of any assertion: it carries the function of binding the nominators as arguments of the predicator and of performing the act of assertion.[12] Traditionally, two copulae are studied in logic, corresponding to the two sides of a (binary) distinction; they are formally expressed by the symbols ε for ascribing the predicator to that set of nominators, and ε' for denying it. Finally, assertions are uttered in a particular *situational context* that determines their meaning: the nominators in particular cannot be understood without a context: following Strawson's explications of the reference relation, a nominator does not simply represent an object by means of a one-to-one relation, but it *picks out* an object from a certain given finite contextual domain of discourse objects, therefore conceptually requiring a one-to-many relation.[13] We use scheme (1) to explicate the functional structure of a singular assertion (with nominator variables n_i, a predicator variable P, a copula variable κ, and a context variable Δ).

$$(\{n_1,\ n_2,\ \ldots n_j\} \ \ \kappa \ \ P)_\Delta \tag{1}$$

Understanding an assertion transforms its context to the context which has to be used for any subsequent utterance. If we are not interested in distinguishing between synonymous expressions, this analysis of an assertion is called the corresponding *proposition*: in our example (a), the first assertion corresponds to the proposition $(\{\mathit{Miller},\ \mathit{Smith}\}\ \varepsilon\ \ \textit{to be to the right of})_{\Delta_1}$ (for some particular context Δ_1 which may remain unspecified here).

(d) Meaning and methodological utterances: In order to explain the use of a verbal expression, generally the *meaning* of the expression is mentioned: the meaning of a predicator is called a *concept* – an assumed interpersonally accessible abstract reference point which allows the one who has it to rate (and argue about) the validity of the communicated distinction.[14] Assertions are called '*empirical* with respect to a concept' if that concept is expressed by the predicator; assertions which are used to *talk about* the concept are called '*methodological* with respect to that concept'. Methodological statements thus are statements about the meaning of expressions in predicative use.[15] Definitions, for example, are a well-known partial class of methodological sentences. If we discuss the meaning of locative prepositions in predicative use, we have to employ corresponding methodological assertions: we can perform the conclusion of example (a) if we know that 'being to the right of' and 'being to the left of' are converse (anti-symmetric) with respect to their meanings (cf. proposition (2)); and we can perform the conclusion of example (b) if we know that 'being in' is a transitive concept (cf. proposition (3)).[16]

[11] In comparing the logical and the linguistic terms, the nominators correspond mainly to the definite noun phrases of the sentence; predicators are given mostly by means of the predicates (verbs, adjectives, adverbs, indefinite NPs and PPs);

[12] cf. [Kamlah & Lorenzen, 1973, *op. cit.*, I.4, and p. 90.]. The logical copulae have to be distinguished from the linguistic copula, which essentially has the function of a non-specific verb binding adjectives as predicates to a subject; the logical copulae correspond to Frege's '$\vdash$', but carry in addition a polarity correlated to truth values; cf. [Schirra, 1994, *op. cit.*, Chap. 6.];

[13] cf. [Strawson, Peter F.: Logico-linguistic papers. London 1971, p. 17ff.] and [Tugendhat, Ernst: Traditional and analytic philosophy. Lectures on the philosophy of language, Cambridge 1982, Sec. 21ff.]. Logical copulae and contexts may remain implicit in an utterance;

[14] cf. [Ros, Arno: Begründung und Begriff. Wandlungen des Verständnisses begrifflicher Argumentationen, Hamburg 1990, Vol. III., Chap. 1.]; this definition of 'concept' does not imply that concepts have to be mental;

[15] cf. [Ros, 1990, *op. cit.*, Vol. I, p. 192.] and [Schirra, 1994, *op. cit.*, Chap. 2.]; (cf. also addendum 1, p. 22)

[16] The similarity of these relational implications to the classical attributional deductions of the form: *'As Socrates is human and 'to be human' involves 'to be mortal', therefore Socrates is mortal.'* should be obvi-

$$\begin{array}{rc} \text{empirical:} & (\{\mathit{Miller},\ \mathit{Smith}\}\ \varepsilon\ \textit{to be to the right of})_{\Delta_1} \\ \text{methodological:} & \underline{(\{\textit{`to be to the right of'},\ \textit{`to be to the left of'}\}\ \varepsilon\ \textit{to be converse})_{\Delta_1}} \\ \text{deduced empirical:} & (\{\mathit{Smith},\ \mathit{Miller}\}\ \varepsilon\ \textit{to be to the left of})_{\Delta_1} \end{array} \tag{2}$$

$$\begin{array}{rc} \text{empirical (a):} & (\{\textit{your apple},\ \textit{your bag}\}\ \ \varepsilon\ \ \textit{to be in})_{\Delta_2} \\ \text{empirical (b):} & (\{\textit{your bag},\ \textit{my kitchen}\}\ \ \varepsilon\ \ \textit{to be in})_{\Delta_2} \\ \text{methodological:} & \underline{(\{\textit{(the concept) `to be in'}\}\ \ \varepsilon\ \ \textit{to be transitive})_{\Delta_2}} \\ \text{deduced empirical:} & (\{\textit{your apple},\ \textit{my kitchen}\}\ \ \varepsilon\ \ \textit{to be in})_{\Delta_2} \end{array} \tag{3}$$

So far, we know a form of spatial reasoning that seems to be completely independent of referential semantics: if only we have the corresponding methodological assertions, i.e., a description of the meaning of the involved spatial concepts, we are seemingly able to draw all possible implicatures from a given set of spatial empirical assertions.[17] This, evidently, is the view in intra-lexical semantics: the meaning of predicators is essentially given by means of sets of corresponding methodological sentences. Note that relations to referents are not involved: percepts or mental images need not be mentioned. After all, we may be able to explain the understanding of a listener of a radio sports report without using any conception of visual mental representations of the scenes described. Thus, do mental images exist at all?

3 Concerning the Existence of Mental Images

(a) Statements on existence: Questions concerning existence must always be handled carefully since it must be clear whether the existence of particulars is considered or whether, in a metaphorical sense, the 'existence' of a concept is what is being discussed. The difficulty is essentially based on the close relation between utterances with *general empirical* sentences and *singular methodological* utterances, together with a common misunderstanding of the use of methodological sentences.[18] Compare, for example, the following four sentences (as uttered in the same context Δ_3), especially with respect to their verification strategies:

S 1 *There is a unicorn.*

S 2 *Today, there is a unicorn in this circus.*

S 3 *Somewhere, there is a unicorn possible.*

S 4 *The concept 'unicorn' is possible.*

$$(\exists\, x,\ (???) :\ (\{x\}\quad \varepsilon\quad \textit{being a unicorn}))_{\Delta 3} \tag{4}$$

ous: combining $(\{\mathit{Socrates}\}\ \varepsilon\ \textit{to be human})_{\Delta_3}$ with $(\{\textit{`to be human'},\ \textit{`to be mortal'}\}\ \varepsilon\ \textit{to involve})_{\Delta_3}$, i.e., an empirical with a methodological assertion, leads to the empirical assertion $(\{\mathit{Socrates}\}\ \varepsilon\ \textit{to be mortal})_{\Delta_3}$; the methodological interpretation of a general statement like 'all humans are mortal' is discussed in Sec. 3;

[17]A typical example for such a collection of methodological sentences concerning locative prepositions can be found in the form of combination tables and compatibility tables in [Hernández, Daniel: Qualitative representation of spatial knowledge. München 1992.] Contexts are viewed as complete in the following sense: they correspond to the deductive closure of the communicated assertions under the 'closed world assumption'; this completeness may be restricted (or 'focused') by pragmatic factors, cf. Sec. 6;

[18]cf. [Kamlah & Lorenzen, 1973, *op. cit.*, III.4ff & V.5.] and [Ros, Arno: Reduktion, Identität und Abstraktion. In: D. Gerhardus (ed.): Festschrift für Kuno Lorenz, (to appear), Sec. 2 & 3.];

The use of a sentence like S 1 is unclear, since the domain of the quantifier remains unspecified (cf. propositional scheme (4) which follows Frege's 'classical' analysis of such general sentences): is it the context of the utterance that is meant, as indicated in sentence S 2?

$$(\exists\, x,\ x \in \Delta_3 :\ (\{x\} \quad \varepsilon \quad \textit{being a unicorn}))_{\Delta_3} \tag{5}$$

With this interpretation (cf. scheme (5)), we deal essentially with the short form for the conjunction of singular empirical assertions : $((\{o_1\}\, \varepsilon\, P)_{\Delta_3} \vee \ldots \vee (\{o_n\}\, \varepsilon\, P)_{\Delta_3})$. Obviously, the validity of such a general assertion can be determined by proving each of the corresponding singular empirical assertions. In the exemplary case: we have to take every object that is on that day in the circus mentioned and decide whether it is a unicorn or not. The general statement is true if at least one object found in the domain also happens to be a unicorn: a clear case of a compound *empirical* assertion.

Or should we interpret an assertion with sentence S 1 in the sense of an assertion more clearly expressed by means of S 3? An interpretation which after more careful analyses (employing a Leibnizian view) can be described as a nested quantification (cf. scheme (6)): first a quantification about contexts (or 'possible worlds'[19]) which binds an implicit context variable (δ); and embedded in it a second quantification which binds a nominator variable to that context variable. The intention of the utterance is to state that its propositional core holds in at least one *possible* context: past, present, or future. How would we proceed to prove the validity of such a statement? Here, we run into a problem, since the unbound number of possible contexts we would have to consider can never be examined in an exhaustive manner. Although an utterance with a sentence like S 3 seems to be empirically provable just as the one with S 2, we have to abandon that view since we have not defined how such a proof could actually be done.[20]

$$\begin{aligned}(\breve{\exists}\, \delta,\ (\delta\ \textit{context},\ \textit{reachable from}\ \Delta_3) :& \\ (\exists\, x,\ x \in \delta :\ (\{x\} \quad \varepsilon \quad \textit{being a unicorn}))_{\delta})_{\Delta_3}&\end{aligned} \tag{6}$$

But is it really an empirical fact that is to be stated by an utterance using sentence S 3? Let us look for a moment at a corresponding universally quantified statement, e.g., 'all swans are necessarily white.'[21] Effectively, we understand this utterance as a *rule*, the rule prescribing that 'if something is a swan, than it also has to be white' – a rule like the one determining how to continue a certain given sequence of numbers which is supposed to be part of an infinite sequence, e.g., $0 \rightarrow 10 \rightarrow 1110 \rightarrow 3110 \rightarrow 132110 \rightarrow 1113122110 \rightarrow$ etc. Such a rule fixes the *criteria*, not the instances: without a problem, it is able to cover an unbound, open number of particular cases since it concerns the concepts – the reference points – involved.[22] In the case of existence, the corresponding criterial view is not so directly visible: as indicated in S 4, the methodological reading has to be conceived not as a relation between concepts, but as the proposal of what should be a useful and well-formed ('proper', for short) reference point for

[19] cf. [Kripke, Saul A.: Naming and necessity. In: D. Davidson & G. Harman (eds.): Semantics of natural language. Dordrecht 1972, p. 253–355 & 763–769.];

[20] In order to express its different character, the context quantification is marked: '$\breve{\exists}$';

[21] i.e., $(\breve{\forall}\, \delta,\ \textit{Reach}\,(\delta,\ \Delta_3) :\ (\forall\, x,\ x \in \delta :\ (\{(\{x\}\ \varepsilon\ \textit{being a swan}),\ (\{x\}\ \varepsilon\ \textit{being white})\}\ \ \varepsilon\ \ \textit{implies}))_{\delta})_{\Delta_3}$

[22] Stated as a rule, we consider the methodological proposition $(\{\textit{'to be a swan'},\ \textit{'to be white'}\}\ \ \varepsilon\ \ \textit{implies})_{\Delta_3}$;

distinguishing objects in future uses (cf. proposition 7). Correspondingly, somebody doubting the validity of such a statement of existence tries to tell us that he does not want to use 'to be a unicorn' as a standard gauge in discussions concerning the validity of empirical statements since he observes methodological problems he would like to clarify first. (addendum 2)

$$(\{\textit{`to be a unicorn'}\} \quad \varepsilon \quad \textit{being a proper concept})_{\Delta_3} \tag{7}$$

(b) The meaning of 'Mental images exist (not).': In this section, we are mainly interested in the consequences of these considerations on assertions with general sentences equivalent to S 5. Formalized in the naïve way, we first may try on proposition (8).[23]

S 5 *Mental images do not exist.* $$(\forall x, (???) : (\{x\} \ \varepsilon' \ \textit{being a mental image}))_{\Delta_4} \tag{8}$$

Corresponding to the above considerations, we should ask whether an utterance with such a sentence is meant to express

1. an empirical result concerning some (possibly only implicitly given) particular context, e.g., a certain experimental session;

   in particular: is it meant that in a particular psychological experiment (Δ_4), a particular person or finite group of persons did not have any instances of the type 'mental image'?

   $$(\forall x, \ x \in \Delta_4 : (\{x\} \ \varepsilon' \ \textit{being a mental image}))_{\Delta_4} \tag{9}$$

2. an empirical result concerning *all possible contexts*: 'mental images do not exist in general.' (though again, how should such a sentence be proven?);

   in particular: is it stated that it is or may be empirically proven that under no circumstances could any instance of 'mental image' be found?

   $$\begin{aligned}(\breve{\forall}\,\delta, \ (\delta \ \textit{context, reachable from}\ \Delta_4) :& \\ (\forall x, \ x \in \delta : (\{x\} \ \varepsilon' \ \textit{being a mental image}))_{\delta})_{\Delta_4}&\end{aligned} \tag{10}$$

   As in the first case, this interpretation of course implies that it is clear how we can identify such instances.

3. a methodological statement, i.e., an assertion concerning our criteria;

   in particular: is it stated that the concept 'mental image' (as proposed somewhere) is contradictory, non-functional or similarly ill-formed, and hence should not be used in scientific discourse, either to set up empirical experiments, or to interpret empirical findings?

   $$(\{\textit{`being a mental image'}\} \ \varepsilon' \ \textit{being a proper concept})_{\Delta_4} \tag{11}$$

   Note that this interpretation in fact questions the precondition of the two former cases.

The most interesting case, also forming the base of the imagery debate, is the last one: can cognitive scientists, in the light of the apparently sufficient explanation of spatial reasoning by intra-lexical semantics, find a convincing method to introduce a proper concept 'mental image' reflecting the naïve conception of Fig. 1? And more generally, what could be a useful method of introducing new concepts? (cf. addendum 3)

[23] with the usual transformation: $(\neg\exists x : (\{x\} \ \varepsilon \ P))_{\Delta} \equiv (\forall x : (\{x\} \ \varepsilon' \ P))_{\Delta}$;

4 Fields of Concepts and Implementation

(a) Necessary attributes and substantial concepts: Why are there no green dreams? Some predicators can only be used in combination with some other concept: the latter *provides* the kind of things to be distinguished by the former. *'Substantial'* concepts (forming an 'ontology' in the terminology of AI) have to be distinguished from *'attributive'* concepts (associated 'features'): instances of substantial concepts carry properties or stand in relations which are expressed by attributive predicators. For example, we cannot speak about spatial relations without thinking of spatial objects that may enter in such relations: the concept of spatial objects is substantial to the attributive concepts of spatial relations.

A serious consideration of a substantial concept has to refer to all the *essential* attributive concepts that may be applicable to the instances, and thereby distinguish them from *arbitrary* attributes or relations, i.e., those attributive concepts that are not related in a systematic way to the substantial concept in question. That a certain instance of triangle is made of iron is not an attribute this object has due to its being a triangle. Triangles do not have this attribute necessarily; though they necessarily are planar, have three corners, and at least one of their inner angles must not be smaller than $\pi/3$. Triangles may be either right or oblique, either equilateral, isosceles or scalene. Such ranges of mutually exclusive attribute values are called *incompatibility areas.*[24] In the following, we mean by a *field of concepts* the methodological structure of one substantial concept – the central concept of the field – and all the associated ('necessary') attributive concepts and incompatibility areas.[25] Arbitrary attributes occur if something that is currently viewed as an instance of the substantial concept of one field happens to be viewed additionally as an instance of the substantial concept of another field, e.g., a triangle as a material object. The introduction of new concepts always concerns whole fields, not isolated concepts.

The theory of abstract data types and their specification[26] provides a good way to understand the concept of a field of concepts and its relation to intra-lexical semantics: the specification of a data type describes a certain type of entities (e.g., 'stacks', 'sets', 'integers') together with all the incompatibility areas of necessary attributes (e.g., 'empty' and 'not-empty' for stacks), the relations between the instances of the central data type (e.g., 'pop'), and those to some auxiliary data types (e.g., 'push' between two stacks and an element). Imagine, for example, the data type 'hotel room' which might be needed in a hotel management software system; together with the possible attributes and their ranges of values, and the relations which define what can be done with corresponding instances, etc., this specification firstly and completely determines the concept 'hotel room' to be used in that system.

With such a specification, one can indeed calculate *symbolically* assuming representatives of instances of the central concept have certain attributes or relations. It is also possible to examine the effects that one particular attribute value may impose on the ascription of the values of other incompatibility areas (e.g., for triangles the effects of being equilateral to the possibility of being right). And in combination: one can – just as in intra-lexical semantics – explain how the context of an utterance ascribing an attributive concept to an instance of the central concept is changed to include all the corresponding implicatures: this is why that hotel management software is usable in a hotel.

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[24] cf. [Strawson, Peter F.: Introduction to logical theory. London 1952, §1–8.] and [Tugendhat, Ernst & Wolf, U.: Logisch-semantische Propädeutik. Stuttgart 1983, Sec. 4.];

[25] cf. [Ros, 1990, *op. cit.*, Vol. I, p. 134.];

[26] cf. [Ehrig, Hartmut & Mahr, B.: Fundamentals of algebraic specification. Berlin 1985.];

However, two basic questions remain unanswered: how can objects that are instances of this concept (not just plain, unconnected 'symbols') be found? And how could the 'meaning postulates' of the specification be grounded, in the case somebody doubts that this specification is sound (i.e., that such a concept 'exists' in the criterial view of the previous section)? The relations between the concepts of one field are seemingly overloaded with those tasks. We have to consider relations *between different* fields; particularly, those corresponding to the relation 'implementation' between data types can be used to answer our questions.

(b) Field-external relations and 'implementation': Let us assume that we have the specification of, for example, the data type of the rational numbers with its central concept *RAT*. One of the internal rules of that field would be that a particular rational number, let us symbolize it with ONE, interacts in a very special manner with the relation called MUL – namely as its neutral element. Furthermore, we consider the data type of integers *INT* with its internal relations SUCCESSOR, PREDECESSOR, ADD, and TIMES, all based on the only elementary integer ZERO. The well-known schema (12) establishes a relation between the two data types – it *implements* the rationals on the integers. This relation external to the two fields makes it possible to *ground* the basic relations of *RAT* as in (13) and (14): the attributes of the internal relations of the rationals now become consequences of this particular coordination of integers.

$$\begin{aligned}
&\forall\, r:\ r \in RAT: \qquad\qquad\qquad\qquad (12)\\
&\quad \exists\, x,\ y:\ x,\ y \in INT \ \wedge y \neq \textsc{Zero}:\\
&\qquad\qquad \forall\, a:\ a \in INT \ \wedge a \neq \textsc{Zero}:\\
&\ r \ \equiv_{def}\ \textsc{Div}\,(\textsc{times}\,(a,\ x),\ \textsc{times}\,(a,\ y))
\end{aligned}$$

$$\forall x,\ y,\ u,\ v:\ x,\ y,\ u,\ v \in INT \wedge x,\ y \neq \textsc{Zero}:$$

$$\textsc{One} \Longleftarrow \textsc{Div}\,(x,\ x) \tag{13}$$

$$\textsc{Mul}\,(\textsc{Div}\,(u,\ x),\ \textsc{Div}\,(v,\ y)) \Longleftarrow \textsc{Div}\,(\textsc{Times}\,(u,\ v),\ \textsc{Times}\,(x,\ y)) \tag{14}$$

For example now, ONE is not simply the neutral element for rational multiplication by definition (as in the field-internal view), but *because* the rationals have been based by means of that schema relation on the integers with their particular internal structure (cf. deductions (15) to (18)).[27] We have an external foundation for the internal determination of a field of concepts, a justification of the methodological assertions about the rationals, that is.

$$\forall\, r:\ r \in RAT:\ \ \exists\, x,\ y,\ z:\ x,\ y,\ z \in INT \wedge x,\ z \neq \textsc{Zero}:\ \ \forall\, a:\ a \in INT \wedge a \neq \textsc{Zero}:$$

$$\begin{aligned}
\textsc{Mul}\,(\textsc{One},\ r) &= \textsc{Mul}\,(\textsc{Div}\,(x,\ x),\ \textsc{Div}\,(\textsc{Times}\,(a,\ y), \textsc{Times}\,(a,\ z))) && (15)\\
&= \textsc{Div}\,(\textsc{Times}\,(x,\ \textsc{Times}\,(a, y)), \textsc{Times}\,(x,\ \textsc{Times}\,(a, z))) && (16)\\
&= \textsc{Div}\,(\textsc{Times}\,(\textsc{Times}\,(a, x),\ y),\ \textsc{Times}\,(\textsc{Times}\,(a, x),\ z)) && (17)\\
&= r && (18)
\end{aligned}$$

Does the implementation also provide us with an access to instances? Assume that we have got (a) a specification S of a field of concepts F' and do not know how to find instances to the abstractly defined concepts; (b) a set of fields of concepts G_1 to G_m with a set of procedures for recognizing corresponding instances, and (c) a schema Σ, which implements S

[27] Step (15) by (12) and (13); (16) by (14); (17) by transitivity of integer multiplication TIMES (internal to *INT*); and (18) again by the inversion of (12) with respect to (15); note that no rule of *RAT* has to be used;

on G_1 to G_m. Thus, Σ constitutes A', the central concept of F', as a coordination of the substantial concepts of the implementing fields; if the corresponding identification procedures all apply simultaneously (or better: coordinated in that particular manner of Σ), not only are instances of those implementing concepts found (which would simply lead to a bag of arbitrary attributes): this combined procedure has indeed *identified an instance* of A', as well, with all its 'emergent' attributes.[28]

In summary: the implementation of a specification (α) *provides* us with *instances* of the specified field of concepts, just as the schema (12) sets up a way to find instances of rationals by means of two independent instances of integers now playing the coordinated roles of counter and divisor. It furthermore allows us (β) to *ground* the internal *rules* of a field which, as methodological sentences, are used to explain reasoning concerning the instances.[29]

5 Transfer to the Spatial Field

For considering spatial reasoning, a particular field of concepts is used: its central concept is that of spatial objects, and part of its specification determines symbolically how the relations between such objects interact. These are precisely the methodological statements on locative prepositions used in the example of section 2 to define their intra-lexical semantics and to mediate spatial reasoning: e.g., anti-symmetry ('conversity') of 'being to the right' and 'being to the left', or transitivity of 'being in'. This specification cannot be grounded inside the spatial field; nor does that field as such make clear what are instances of spatial objects, or how to find out about the validity of an (empirical) assertion stating relations between instances. To that purpose, an implementation of the spatial field is needed.

(a) An implementation of spatial objects: Spatial objects are essentially viewed as instances of 'sortal concepts':[30] those concepts subsume the kind of object we usually have in mind when we use the expression 'concrete object' in the strict sense: perceptible, countable entities that are persistent over time even if they are not perceived, and that may even change their appearance during their lifetime. Sortal concepts like 'chair', 'car', or 'human being' are distinguished from concepts like 'fog', 'shadow', 'red', 'water', or 'gold'. They characteristically contain a criterion to identify and distinguish different individual objects of the same sort, and thus enable us to point to one such individual *as an individual*, or to count several of them: sortal concepts *individuate* their instances (cf. again Fig. 5, p. 4).

In analytic philosophy, a schema for sortal concepts is offered: they are conceived as a particular form of coordination between (a) configurational 'Gestalt' entities (of a 'geometrical field'), and (b) objects involved in part-whole relations which make it possible to assign functions to those objects (of a 'functional field').[31] The field of objects with the functional

[28]The attributive concepts are implemented analogously;

[29]Kant's understanding of 'synthesis' and 'transcendental schemata' is closely related to the idea of implementation as a field-external relation, and also centers around the question how a concept can be related to its 'intuitions' (mental representations of its instances); cf. [Ros, Arno: Kants Begriff der synthetischen Urteile a priori. In: Kant-Studien 82(2) (1991), p. 146–172.], [Schirra, 1994, *op. cit.*, Chap. 4f.], and [Schirra, Jörg R.J.: Connecting visual and verbal space. Preliminary considerations concerning the concept 'mental image'. In: M. Aurnague & A. Borillo & M. Borillo & M. Bras (eds.): Semantics of time, space, and movement. Toulouse 1993, p. 105–121.]. Note that the implementation relations have to be *internal* to the field determining the concepts 'concept' and 'field of concepts', i.e., the field which centers around the concept of 'rational argumentation';

[30]cf. [Strawson, 1971, *op. cit.*], [Tugendhat, 1982, *op. cit.* Sec. 26.], [Tugendhat & Wolf, 1983, *op. cit.*, p. 158.], and [Schirra, 1994, *op. cit.*, Sec. 4.3.];

[31]cf. [Tugendhat, 1982, *op. cit.*, Sec. 26.], and for the formal modeling especially [Vieu, Laure: Sémantique

part-whole relations, abstract as it is, does not restrict in any manner the geometrical relations between an object and its parts. It only allows us to state that there are such parts, and that without this or that part, the whole object would be something different. The schema of sortal objects leads to entities that have not only parts, but also a geometrical shape and a location; and additionally, all the parts *also* have shapes and locations – the whole object is a configuration of the shapes of its parts. This has an interesting effect on the ability to identify instances: similar to two red objects which are not distinguishable by their being red alone, the functional parts of a car, for example, do not distinguish one car clearly from another one of the same type, since they both have the same functional structure, and are therefore functionally undistinguishable. Only the different geometrical components of two instances of 'car', their different *histories*,[32] allow us to distinguish both. On the other hand, it is not the mere configuration that makes something a car, but the functional restrictions between the configurational parts. Furthermore, it is not possible to distinguish purely by geometrical features between an object and its material, e.g., a ring and the gold making it up: these two different objects, which stand in a particular functional relation, are involved by means of their geometric projection in the very same geometrical relations. Spatial relations also depend on both components, as many linguists have observed:[33] although spatial relations often correspond quite directly to relations of the mere geometrical field of concepts, their application to spatial objects implies operations of idealizations and conceptualizations. These operations most prominently project to the parts or constituents of an object in focus in the relation: 'the flowers are in the vase' exemplifies a rather obvious case, but the complicated part-whole relations needed to reach the 'touching surfaces' relevant in the case of 'the cup is on the table' are another example. Spatial relations are an integral part of the spatial field mirroring its implementation; they are not simply inherited from the geometrical field alone.

What does that mean for the conception of mental images? Recall Fig. 6 (p. 4): in the usual description of the referential anchoring of the semantics of spatial expressions in perception, the constitution of the spatial field as a synthesis of a geometrical field directly connected to vision and an abstract field covering the functional part-whole relations plays a major role. As we anticipated at the end of the previous section: the reference relation established by perception can be conceived as a relation that *implements* the field of spatial objects on other (simpler) fields of concepts. From this structural point of view, it does not matter whether it is instances for rational numbers that have to be provided, or instances for spatial objects. Obviously, the above schema of the spatial field matches the goal-driven phase of the perceptual processing described in Section 2. In fact, perception in this sense can be seen in general as a cascade of implementation relations between several fields of concepts.[34] With each grouping step of the data-driven level, and also especially in the combination step of the goal-driven phase, it is the kind of object together with the associated attributes that changes: from instantaneous points

des relations spatiales et inférences spatio-temporelles. Une contribution à l'étude des structures formelles de l'espace en Langage Naturel, Toulouse 1991.], [Aurnague, Michel & Vieu, L.: A three-level approach to the semantics of space. In: C. Zelinsky-Wibbelt (ed.): The semantics of prepositions. From mental processing to natural language processing, Berlin 1993, p. 393–439.];

[32]cf. [Hayes, Patrick J.: The second naive physics manifesto. In: J. Hobbs & R. Moore (eds.): Formal theories of the commonsense world. Norwood/NJ 1985.];

[33]cf., e.g., [Herskovits, Annette: Language and cognition. An interdisciplinary study of the prepositions in English. Cambridge 1986.], [Aurnague & Vieu, 1993, *op. cit.*] or [Habel, Christopher & Pribbenow, S. & Simmons, G.: Propositional and depictional partonomies: a hybrid approach. Report MMDP 1, ZIF, Universität Bielefeld 1993.];

[34]This theme is more extensively elaborated in [Schirra, 1994, *op. cit.*, Chap. 5, 6, and 9.];

attributed with only location and intensity to extended and persistent spatial objects with parts and a spatio-temporal history, able to enter in spatial relations and even to participate in events like 'following' or 'passing' (non-intentional readings). The representation of each of the levels concerned is governed by a particular field of concepts with its internal rules. With this relation between specification and implementation, that is, between the rules *in one* field of concepts, and the rules *between several* such fields, we can finally bring together in a coordinated manner the ideas behind intra-lexical and referential semantics. As a consequence precisely in the spirit of Wittgenstein's remark cited above, referential semantics in this reading does not jump outside of language, as is meant in the more naïve interpretations (cf. Sec. 2), but changes the explanatory level from merely explaining to grounding explanations.

(b) Understanding in referential semantics: At this point, we are finally able to present a more clearly elaborated version of the conception of understanding in the framework of referential semantics: the revision of the context by means of the predicator's concept – e.g., 'to be in' – is now partitioned into three steps (cf. Fig. 8): first, the proposition of the utterance (including the context) is transformed by following the schema of the spatial field into a corresponding structure of sets of propositions on the lower fields (1a & b).

Second, the revision of the context by means of the spatial concept (communicated by the predicator of the utterance) takes place on the lower fields (2a & b): coordinated by the schema, the corresponding projections of the spatial context are revised by those concepts of the geometrical and functional fields implementing the spatial concept in question – a revision on the experiential level of the instances, so to speak.

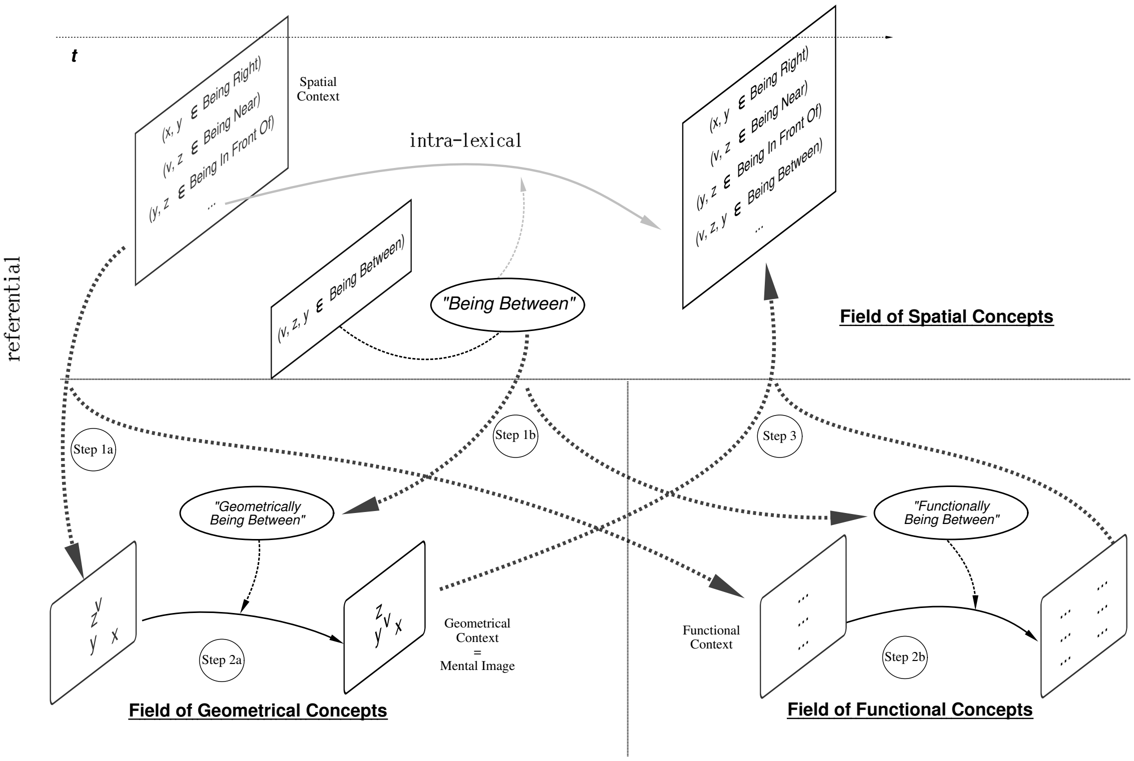

Figure 8: Grounding the explanation: sketch of 'understanding' in referential semantics

Third, the resulting partial understandings – especially the derived context of the geometrical field – are synthesized back to form the spatial context for the subsequent utterance (3);

the resulting context includes the spatial implicatures of the utterance in question. This step is equivalent to the goal-driven phase of perception and may be directed, like perception, by pragmatically motivated focusing strategies.

Just as in the explanation of intra-lexical semantics, the relation between the context of a locative utterance and the context corresponding to the understanding of that utterance is mediated by the internal rules of the spatial field, especially by the methodological assertions with respect to the relevant spatial relations ('horizontal' relation between contexts). As was the case for the internal rules of the field of rational numbers, these methodological assertions cannot be grounded within the spatial field, since the latter is originally constituted by those rules. However, we have seen that the rules of the field of rational numbers can be grounded by means of the field-external relation of implementation. We particularly demonstrated this grounding for the postulate that ONE is the neutral element of MUL: the postulate was shown to be valid *because* of the given schema of the rational numbers on the base of the integers *and* the internal rules of the integers, particularly the transitivity of integer multiplication. Correspondingly in the considerations of referential semanticists, the methodological sentences concerning spatial relations are justified by means of their implementational introduction on the geometrical and functional field. Their use in spatial reasoning is viewed as mediated by changes particularly in the geometrical part of the context – said to be a 'mental image' closely related to perception.

Thus, integrating into the consideration an implementation of the spatial field not only provides us with an explanation of the nature of mental images and more generally the reference relation in referential semantics approaches ('vertical' relation between contexts in Fig. 8); its main effect is a *shift of the level of explanation* considered. Intra-lexical semantics approaches could explain that the implicatures of an utterance can be deduced by following the methodological structure of the spatial field: as was shown before, example (b) in Section 2 works, because the considered predicator 'to be in' happens to be transitive by its concept (cf. again proposition (3)). These rules, however, had to remain 'god-given'. Referential semantics approaches also try to tell *why* this transitivity does (or possibly does not) hold.[35]

The intra-lexical explanation of the (horizontal) transformation of a context by a new predication is now *grounded* by a set of associated (horizontal) transformations in the implementing fields of concepts and the corresponding (vertical) shifts between the implemented and the implementing fields. The concept 'mental image' as we understand it only comes into the explanatory picture if the field of concepts we are investigating is *viewed as* implemented using an equivalent of the geometrical field of concepts, or, in more general words, if we are interested not only in explanations but also in their foundation (or justification), a change in perspective simultaneously focusing on the connection to referents.

(c) Referential semantics and 'hybrid reasoning': The geometrical field contributes some particularly interesting features to the spatial field. Only one is to be considered here: the geometrical field's incompatibility area of locations is *syntactically dense*, an attribute that Goodman suggests taking as a necessary and for our purpose (though not generally) sufficient criterion for pictorial systems: an incompatibility domain is called syntactically dense *"if it provides for infinitely many characters* [i.e., predicators] *so ordered that between each two is a third"*.[36] Therefore, vectors based on the syntactically dense rational numbers usually form

[35]In this sense, Vieu ([Vieu, 1991, *op. cit.*]) gave a paradigmatic study of referentially grounding the complicated behavior of 'to be in' (in French) with respect to transitivity;

[36]cf. [Goodman, Nelson: Languages of art. An approach to a theory of symbols, Indianapolis 1968, p. 136.]; Scholz ([Scholz, Oliver R.: Bild, Darstellung, Zeichen. Philosophische Theorien bildhafter Darstellung,

a very good model for the incompatibility area of locations. Correspondingly, the deductions of the geometrical field concerned with locations need not be performed in analogy to the *modus ponens*-like examples of spatial reasoning given in Section 2: our culture provides more efficient implementations of 'calculating' with rational numbers, which of course may be used for considerations of reasoning in the geometrical field as well. This is especially important in the context of computational approaches, where propositions on numbers are easiest to handle.[37]

AI-oriented approaches to spatial language understanding often do not bother with the more complicated background of referential semantics unfolded above. Essentially motivated by intuition, they assume the mere coexistence of two representation formalisms: beside a 'propositional' part, reflecting the immediately logic-based perspective of intra-lexical semantics, an allegedly non-deductive 'depictional' part is imagined which should be able to handle 'mental images' in the direct manner sketched in Section 2.[38] The characteristics of the depictional part of representation usually correspond closely to the properties of the geometrical field of concepts: especially, a syntactically dense incompatibility area of locations is considered. Such approaches are said to demonstrate 'hybrid reasoning'. The above argument indicates that there is in fact a good reason to speak in the elaborated framework of referential semantics of 'hybrid' reasoning since the reasoning mechanisms may be concieved as quite different in the two fields: in one of them, propositions with spatial predicators are combined with methodological assertions on those predicators; in the other, rational arithmetic takes place. However, a sophisticated understanding of the connections between hybrid reasoning, the consideration of the referents in reasoning, and the level of argumentation of referential semantics, as sketched in this section, are usually not explicated.

6 A Glance at ANTLIMA

How can we make practical use of this understanding of the expression 'mental image'? Can we apply it to the example scene described at the beginning and gain an operational model of the theory of the radio listener's understanding in referential semantics? As a test case, we consider the resulting explanation of the understanding of an underspecified utterance, like 'Miller is beside the penalty area'. Note that an operational model of the conception of 'mental image' given above would be the implementation of an implementation relation. The basis is the field of concepts provided by a programming language, CLOS in the case of ANTLIMA.[39]

ANTLIMA is essentially based on the model of visual perception of moving objects sketched in Section 2: for the sake of simplicity, the mobile objects are furthermore conceived as mere

Freiburg/München 1991, p. 97.]) remarks that it only is necessary that the field provides the potential of an unrestricted number of densely ordered attributive concepts; any single context of such a field may merely contain a finit number of propositions (and thus, of distinct predicators); a similar result is mentioned in [Vieu, 1991, *op. cit.*, p. 130f.];

[37]We here are concerned with possible implementations of the geometrical field (the 'medium' of mental images), i.e., implementations of a field used to implement the spatial field; evidently, the mentioned 'arithmetication' of geometry reminds of Descartes' answer to Euclid. The interaction of the methodological feature of density with the finiteness of available representation formalisms (esp. in neurophysiology, and comparably, in connectionism) is problematic and relates to the problem of scaling in mental images; a separate paper is to be dedicated to that theme and neurophysiologically plausible solutions; cf. the remarks to that theme given already in [Schirra, 1994, *op. cit.*, Sec. 15.5f.]

[38]cf., e.g., [Habel & Pribbenow & Simmons, 1993, *op. cit.*];

[39]The particular semantics of spatial prepositions used in the following example is not intended to be adequate with respect to ordinary language, since the nature of the relation between 'mental image' and spatial reasoning was focused in ANTLIMA; the system exemplifies the chains of arguments a referential semanticist could use;

points moving in a two-dimensional plane – the soccer field from a bird's eye view.[40] Due to these simplifications, we can largely ignore more complicated influences of the functional field: only the static objects forming the soccer field have (or are) parts. Given a contextual situation and an utterance with a locative preposition as predicator: can we implement the referential grounding of the intra-lexical explanation of the context change induced by the utterance? Does the implementation allow us to further clarify the use of 'mental image' in linguistics?

(a) **Building mental images in ANTLIMA:** The understanding of the audience is modeled following the three steps described in Section 5.b:[41] first, the proposition of the utterance is projected to the lower levels implementing the spatial field: i.e., from stating spatial relations between spatial objects to restrictions of the *locations* of (*parts* of) the objects; concerning the spatial-relational concept involved, this transformation is mediated in ANTLIMA by means of certain recognition functions: the concepts of spatial relations are *graded*, i.e., although an unbounded number of locational propositions is associated with one spatial proposition, they are not all associated in the same strength. Some locations are more typical with respect to a spatial relation than others, or viewed from the other direction: the spatial description is better applicable to some locational descriptions than to others (cf. again Fig. 7). For each spatial-relational concept, a *typicality potential field* – for short: *TyPoF* – projects from a given geometrical configuration of the parts of the objects involved to a value of typicality ($\in [0 .. 1]$).[42]

Fig. 9 illustrates a comparison of the essential regions of the TyPoFs of a player 'being near' and 'being at' a certain line by means of grey values. Both spatial relations are based on distance – a purely geometric concept: in this simplified model, part-whole relations play only a minor role, but they have to be considered when the extended constituents of the soccer field are concerned. In a geometrically more precise sense, a player being near a side line is actually near one point which is part of that line. The selection of the appropriate point depends on the types of the objects in question.[43] Correspondingly, TyPoFs are implemented as a combination: a core called 'typicality schema' (cf. Fig. 10), which is independent of the objects involved in the relation; and a mainly object-dependent modification of that core which *idealizes* the extended objects to the geometric projections of their relevant parts, like closest points, as in the case of the side line in Fig. 9, or centroids in other cases.

In the second step, the context of the utterance is revised on the lower levels, essentially in the contextual geometric 'mental image': the locations of the objects (or their relevant parts, respectively) are chosen by means of a hill-climbing algorithm guided by the TyPoFs (cf. Fig. 11). Here, the gradation of the spatial-relational concepts with respect to the geometric field opens an interesting access to pragmatic implicatures by means of a selection criterion

[40]Although the structure of the soccer field does not move and therefore cannot be perceived by means of the algorithm sketched, we assume that it is seen, as well; the data format described here corresponds exactly to the 'percepts' of the system SOCCER, the 'speaker system' in which ANTLIMA is embedded; cf. [Schirra, Jörg R.J. & Stopp, E.: ANTLIMA – A listener model with mental images. In: R. Bajcsy (ed.): Proc. IJCAI-93. Chambéry 1993, p. 175–180.];

[41]Details of the image construction algorithm, its extension to spatial events, and the data types involved are described in [Schirra, 1994, *op. cit.*, Chap. 10f.], [Schirra, Jörg R.J.: A contribution to reference semantics of spatial prepositions: the visualization problem and its solution in VITRA. In: C. Zelinsky-Wibbelt (ed.): The semantics of prepositions. Berlin 1993, p. 471–515.], and [Schirra, & Stopp, 1993, *op. cit.*];

[42]TyPoFs mediate the perception of spatial relations; the typicality values can be conceived as an extended set of logical copulae used in propositions with spatial-relational predicators as in ($\{Smith, Ball\}$ $\kappa_{0.8}$ *being close*) ("Smith is relatively close to the ball."); cf. [Schirra, 1994, *op. cit.*, Chap. 6.];

[43]The predicators of locative assertions in most cases include parts of the nominators' descriptive components: instead of simply studying 'being in' in the abstract, the compound predicators 'a hole being in a wall', 'a bird being in a tree', etc. need to be distinguished;

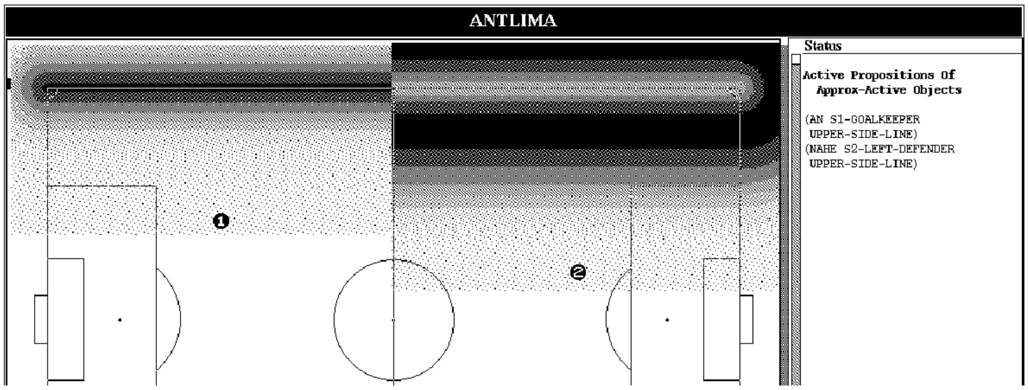

Figure 9: Graphical representations of the TyPoFs for 'being at' and 'being near' a line

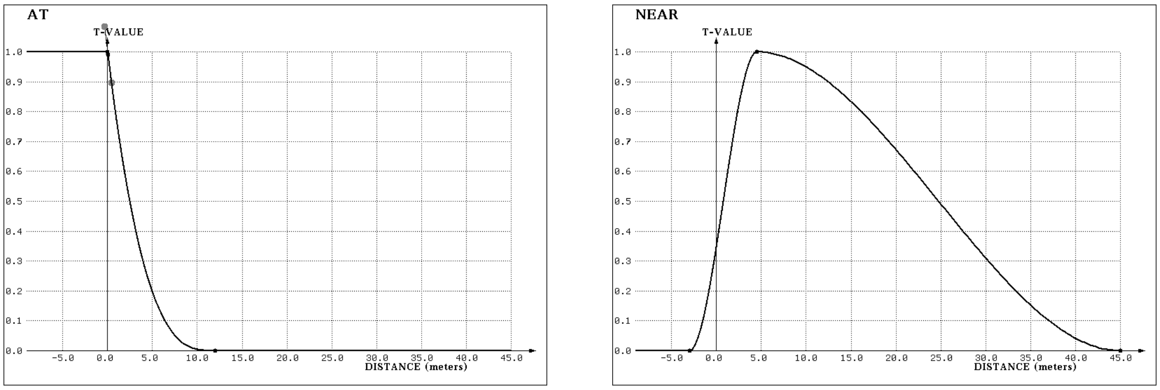

Figure 10: Typicality Schemata for 'being at' and 'being near'

which directs the communication between the speaker and his audience: both seemingly expect that the *contextually most typical interpretation* of an utterance is intended; discrepancies to the typical cases must be mentioned explicitly.[44] The hill-climbing procedure of stepwise approximation based on the gradedness of the spatial relations enables the model to find for each located object a 'best' (most typical) location which also depends highly on the contextual positions. Following this conception, a listener prefers in a particular context to pick out either the left or the right side of a 'being beside' (cf. Fig. 12), as long as counter-evidence is not explicitly given.

Thus, the pragmatic restriction mentioned provides the background for the mysterious concretization which should allow the listener to complete spatially underspecified utterances. The completion, however, has to take place on the level of the utterance, the spatial level, that is: the third step of the conception of referential semantics in Section 5.b has to be considered, as well. The schemata of the spatial relations – the TyPoFs – are applied again to construct the resulting context with respect to the spatial field explicitly containing the implicatures: this step corresponds exactly to the explanation of the speaker's perceiving of spatial relations in referential semantics. In this context, it makes sense to use the metaphor that the listener 'looks'

[44]Using the interpretation of typicality values as copulae, and the association between copulae and truth values, the pragmatic postulate mentioned can be seen as Grice's maxim of truth generalized to graded concepts; cf. [Grice, 1974, *op. cit.*] and [Schirra, 1994, *op. cit.*, Chap. 6.];

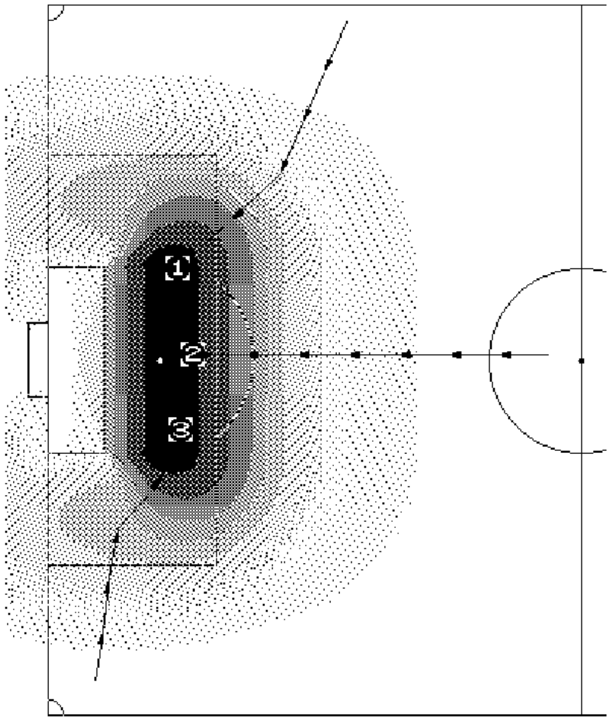

Figure 11: Search paths and contextually best positions of three objects located 'in front of' the right goal area

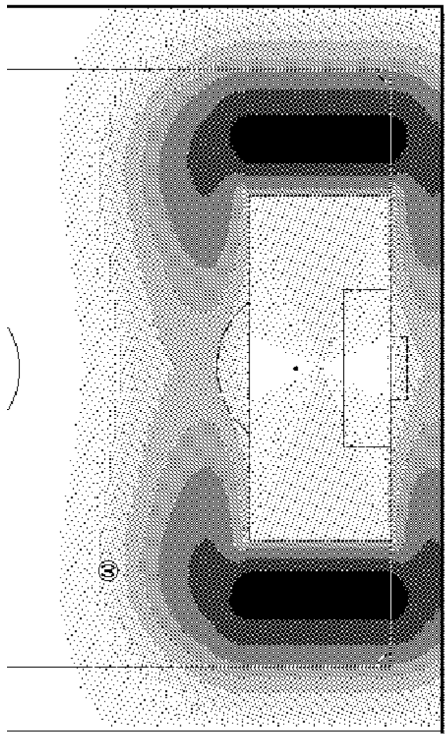

Figure 12: The two maxima of the TyPoF for 'beside a penalty area'

at the resulting mental image, and can 'see' there the effects of the communicated proposition, including the concretizations following the selection of the contextually most typical locations. In the case of Fig. 11, for example, the 'being in the right penalty area' might be 'seen'.

(b) And using them in referential linguistics: There is an elegant way of demonstrating the capability of this model: we have to take into account that the speaker directs his utterances at an audience. Why is it that the speaker can use underspecified utterances without having to be afraid of being misunderstood? In AI, the concept of listener models has been introduced to that purpose: the speaker is assumed to anticipate the understanding of his audience which enables him to select adequate utterances in a feedback loop.[45] In referential semantics, the explanation has to conceive the speaker precisely as anticipating the listeners' ability to resolve underspecifications by means of mental images.[46]

Let us imagine an example at the beginning of a description: without preceding utterances specifying the current context, the listeners would have to use their *a priori* knowledge about the standard strategic positions of the players involved. For example, the goal keepers typically stand in their goal. While anticipating the listeners' understanding, the speaker may construct according to the algorithm described above an imaginative geometric context that is rather different from his percept, as in the case shown in Figs. 13 and 14: the former shows the

[45]cf. [Kobsa, Alfred & Wahlster, W. (eds.): User models in dialog systems. Berlin 1988.]; some critical remarks are given in [Schirra, 1994, *op. cit.*, Sec. 4.4.5.];

[46]Correspondingly, 'ANTLIMA' is an acronym of '*ANTicipation of the Listeners' IMAgery*'; concerning the use of mental images in the listener model: cf. also [Schirra, 1994, *op. cit.*, Chap. 12f.];

speaker's percept to be communicated by the predicator 'a player passing a ball to another player' with the receiving player standing in the upper part of the field; the latter shows the image constructed by that predicator using the players' standard positions.[47]

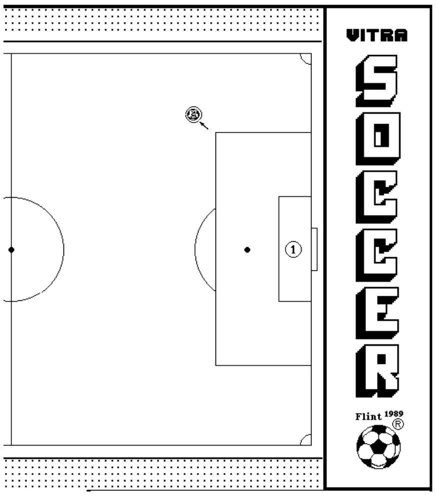

Figure 13: What is seen and ...

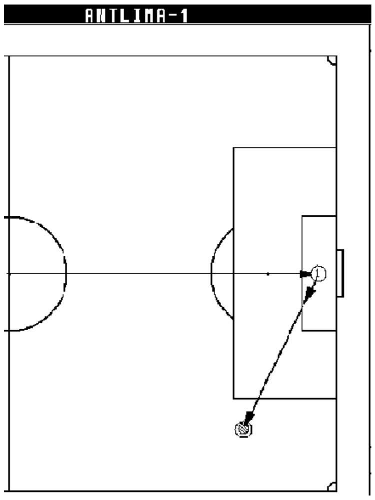

Figure 14: ... what is imagined

In order to find the relevant differences between the percept and the anticipated pseudo-percept, a focusing mechanism has to be considered during the third step. This mechanism forms the imaginary pendant of the visual focus in perception.[48] The speaker is mostly interested in the spatial relations of the objects he is going to mention in the planned utterance; he therefore concentrates on the regions around these objects and the relations to other objects within the focused region. The speaker thereby gains the relevant spatial implicatures of the planned utterance the listeners are most likely to deduce. Differences between these implicatures and the propositions grounded in the speaker's percept mark precisely the violations of the pragmatic principle cited above: deviations from the contextually most typical interpretation. Such deviations need to be prevented explicitly, e.g., by communicating additional spatial modifications of the predicator by means of optional locative expressions. In the example illustrated in Fig. 14, ANTLIMA associated the following two propositions as relevant differences: ($\{$*Miller*, *back side line*$\}$ ε *being near*) with high typicality value in the percept, and ($\{$*Miller*, *front side line*$\}$ ε *being near*) with high typicality value in the imagined scene. The actually perceived proposition is used to modify the utterance by an additional locative expression: 'The goal keeper passes the ball to Miller *near the back side line*'.

The use of underspecified definite descriptions, like 'the penalty area' can be motivated, as well: in general, the speaker can (and should) use a definite description that is ambiguous in the discourse universe in question if the object actually meant is in focus and the alternatives are not. The paradigmatic case for such a focusing occurs if the intended object has already been referred to in earlier utterances. ANTLIMA demonstrates a different type of focusing not depending on previous mentioning and particularly connected to referential semantics. The imaginative visual focus of an utterance introduced above contains exactly the implicatures the listener was presumably able to draw; these implicatures in turn form the context of the next utterance. Therefore, the speaker can use the expression 'the penalty area' without lack of understanding, even if the penalty area intended was never explicitly mentioned before, as long as this particular penalty area is the single penalty area in the imaginative visual focus

[47]In both cases, the icon of the ball covers the receiving player's icon; the arrows in the imagined scene indicate the search paths of the ball constructed by the hill-climbing algorithm;

[48]In SOCCER, the corresponding perceptive focus is essentially bound to the ball's surrounding, cf. [André, Elisabeth & Herzog, G. & Rist, T.: On the simultaneous interpretation and natural language description of real world image sequences: the system SOCCER. In: Proc. ECAI-88, London 1988, p. 449–454.];

ascribed to the listener in determining the best predicator of the previous utterance (especially if modifications of the predicator as above have not been necessary).

7 Conclusion

In this article, the use of the concept 'mental image' in spatial reasoning was clarified. It should be particularly noted that the conception of mental images presented is embedded in the theory of argumentation, not merely the theory of meaning. In the spirit of Wittgenstein's quote in Section 1, it was not our subject to ask what happens in the mind of some radio listener, but what happens between two cognitive scientists who try to find a consensus about what happens in a radio listener's mind while understanding a sportscast on radio – i.e., what is the structural essence of their explanations and especially of the justification one of them may use to convince the other that the explanation he proposed works. Mental images play a role if one tries to ground rationally the implicatures that should explain the understanding of spatial utterances by means of corresponding methodological rules. Concerning that use of methodological rules, the same conception of explanation already appears in intra-lexical semantics; but that framework is too narrow to also provide a foundation of the explanation. Furthermore, intra-lexical semantics in general does not offer any clear conception of the relation connecting verbal expressions to their referents. Both difficulties are closely related to the problem of introducing newly specified fields of concepts in a methodological argument: the class of field-external relations equivalent to implementations of data types was proposed as a solution to all three questions. Applied to the problem of spatial reasoning, that solution clarifies what is actually meant in referential semantics. It thereby justifies the referential semanticists' intuition about 'pseudopercepts': the field of spatial concepts can be implemented by means of a field of geometrical concepts with a syntactically dense incompatibility area of locations ascribed to a lower level of perception. Due to the properties of this field, particularly efficient reasoning methods can be employed in arguments on spatial reasoning.

The sketch of the ANTLIMA system illustrated how the implementation relation of the spatial field can be implemented and utilized in computational linguistics. The sketched schema of spatial objects could be used to construct algorithms for both identifying spatial-relational propositions in percepts, and constructing mental images to given spatial restrictions. Both capacities were employed in a listener model. The resulting system is not the answer to the question of what happens when we imagine something visually; it exemplifies how a referential semanticist could use the expression 'mental image' in an argument about explaining a speaker's ability to control the resolvability of ambiguities, with respect to both the predicators and the nominators the speaker employs in an objective description of what he sees.

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For Fig. 1, two drawings of Loriot were used;
Jerry Feldman, David Bailey, and Ellen Hays have to be heartily thanked for their constructive comments to earlier versions of this paper;

Three Addenda

The following paragraphs were ommitted in the version published in Sachs-Hombach's book due to spatial restrictions; however, they may be quite helpful for clarifying a bit further some of the rather complicated methodological points from the first part of the paper.

Addendum 1 to the distinction between empirical and methodological assertions in Section 2.d:

It is important to note at this point that methodological assertions, i.e. assertions concerning our criteria, cannot be examined in a 'realistic' way: criteria are not simply found in *'the nature'*, so one would only have to look carefully enough (be it to the outside world, or in one's consciousness) to get them and to verify any ascription of properties by means of a methodological statement. Indeed, methodological sentences are often even used not only to state, but to clarify formerly not completely regulated (i.e., 'open') properties of concepts; more precisely: they are used as *proposals* for the future common use of the expressions the meaning of which is discussed.[49] Wittgenstein's note concerning the length of that special object in Paris called 'standard meter' brings this observation to the point: *"Man kann von* einem *Ding nicht aussagen, es sei 1 m lang, noch, es sei nicht 1 m lang, und das ist das Urmeter in Paris"*.[50] Of course, a sentence like 'The standard meter in Paris has the length of 1 meter' in fact has a meaningful use – but precisely not the one as a statement: whereas it is possible (at least in principle) to prove a statement about its length in meters for every other concrete object by means of applying a meter rule to that object, this certainly cannot work so easily for the standard meter.

As is well-known, the standard meter indeed consists of several sticks of a particular blend of platinum and iridium, all constructed in the same way; they are saved at different places in Paris, and, in a way, *control mutually* their length and thus, what it means to be one meter of length; this obviously is something different compared to the simple application of a standard meter to an object in order to determine the object's length. The standard meter was introduced by an international conference which, in doing so, established an interpersonally accessible standard gauge for proving the validity of predications concerning the lengths of objects – i.e., a concept.[51]

Addendum 2 to the different possible interpretations of existential assertions in Section 3.a:

The argument may become even clearer if we look at some examples from physics (which, at a time, in fact were used to develop modern physics):

S 6 *Neutrinos exist.*

S 7 *Atoms exist not.*

S 8 *Absolute time exists.*

S 9 *N-rays exist not.*

The interpretations to be distinguished, are again:

1. an empirical result concerning some (possibly only implicitly given) particular context, e.g., a certain experimental session; i.e., it is meant that in particular physical experiments, instances of the concept of neutrino or absolute time (well-known to all participants of the argument) have been identified or, respectively, that no instance of the (similarly well-known) concepts of atom or N-rays has been proven;
2. the extensional reading with its unclear justification strategy: an empirical result concerning all possible contexts; i.e., it is stated that there are some contexts (or none, respectively) with provable instances of neutrinos, absolute time, N-rays, or atoms;

   as in the first case, this interpretation of course implies that it is clear how such instances can be identified – the corresponding concepts must be accepted by the participants of the argument;

[49] cf. [Ros, 1990, *op. cit.*, Vol. III, esp. Sec. 2];

[50] cf. [Wittgenstein, 1969, *op. cit.*, §50]; (*"There is exactly* one *thing of which one cannot state that it is one meter long, nor that it is not one meter long; that is the standard meter in Paris."* – transl.: J.S.);

[51] Recently, the function as a gauge has been replaced by other procedures (multiples of the wave length of certain quantum transitions given in a particular physical experiment); with respect to that reference point, the length of those sticks in Paris, now taken as ordinary objects without their traditional use, can be stated just as of every other object (with the only new exception of that particular wave length, of course);

3. a methodological statement, i.e., an assertion concerning the usability of the concepts 'atom', 'absolute time', 'N-ray' or 'neutrino';

Rather obviously in the history of physics, the most prominent use of such sentences was the latter one: the statement 'neutrinos exist', for example, was used first to *postulate* that the use of a certain concept of a new type of microphysical entity consistently fits in some theory under consideration, and there may be used to explain some otherwise unexplained phenomena – the 'real proof' of an instance, i.e., the justified positive assertion of a corresponding empirical sentence, did not happen until several years later; similarly, a sentence like 'atoms do not exist' was used for quite a long time as a directive for setting up and interpreting physical experiments, i.e., a methodological statement motivated by some theoretical considerations (which finally came out themselves as not being very well-formed). In all the cases, empirical considerations may be very helpful for developing and testing (especially falsifying) concepts and theories; but the relation between concept formation and empirical research is much more complicated than naïve empiricist theories imagine (cf. sect. 4.b);

Addendum 3 to the discussion of the existence of mental images in Section 3.b:

Whether 'mental image' *exists* or not in explanations of Spatial Reasoning is primarily not an empirical decision. That some empirical findings can very well be interpreted by means of one or the other proposal for a concept 'mental image', this fact alone does not already prove that this candidate for a concept indeed satisfies methodological needs. And especially does the successful application of such a candidate in a particular empirical case prove nothing about an instance being there – since the proposed conception of 'mental image' very well may come out as ill-formed after more severe methodological investigation.

During the 1970's, the well-known 'imagery debate' in cognitive science essentially circled around the question of the existence of mental images:[52] however, applying the analysis of statements of existence as given in section 3.a., we obtain a disappointing image. Whereas the 'imaginists' (or 'iconophiles') essentially pretended to have found instances of mental images in a lot of experimental settings, their opponents, the 'propositionalists' (or 'iconophobes'), defended precisely assertion S 5 above: 'mental images do not exist'.[53] In the whole context of discussion, it is rather obvious that the iconophobic position aims at a statement that should hold *in general*, not just in one or the other experimental setting: 'there is no context ever, in which any instance of that concept can be found', i.e., an assertion which is intended to be proven empirically, and which may only be used under the precondition that the predicator's concept is accepted. They thus claim precisely the extensional case distinguished above at second position. In this case, the iconophilic position is seemingly in advantage as soon as one psychological experiment identifies an instance of mental image – and the debate should have been finished immediately.

However, as we have argued earlier, the extensional reading of the negated existential assertion involves principal pragmatic difficulties: if an assertion with sentence S 5 is not interpeted in the sense of the first case described above, i.e., interpreted as a compound empirical assertion bound to a particular context, it in fact is meant to be a methodological criticism that already turns against the preconditions of empirical research as performed by the iconophiles. Viewed from this perspective, the iconophiles completely missed the point when they referred in that argument to some experiments that they believed to show instances of mental images.

The crucial question of the *traditional* conception of mental images is the *privacy* ascribed to them. In fact, they share it in that framework with all other mental phenomena, including concepts. The most obvious consequence of the assumed privacy of mental representations is, that there is no way to determine whether or not an instance of some sort really is present ('in some other mind') or not. *"Clearly, there indeed is no way at all to know for certain whether a cognitive theory describes what is actually going on inside. (...) we cannot know whether it accurately describes the internal processes."*[54] *"If you claim that your thinking resembles the interior monologues that James Joyce and Virginia Woolf*

[52] To mention just a few of the enormous literature involved in the imagery debate: cf. [Morris, Peter E. & Hampson P.J.: Imagery and consciousness. New York, 1983] and [Sterelny, K.: The imagery debate. In: Philosophy of science 53:560–585, 1986];

[53] The names 'iconophile' and 'iconophobe' have been introduced in [Dennett, Daniel C.: Two approaches to mental images. In: Dennett, D.C. (ed.): Brainstorms. Philosophical essays on mind and psychology, Cambridge, 1978, p. 174–189];

[54] cf. [John R. Anderson: Cognitive psychology and its implications. San Francisco, 1980, p. 17];

put into the minds of their characters, and I claim that I never think in this way (...), then there is no way to decide whether one or the other of us is deluded."[55] In consequence, such a conception would have to be ill-formed from the very beginning: a concept that does not allow to rate the validity of corresponding empirical statements (and that always means: to rate the validity *interpersonally*) cannot serve its very function.

But let us recall at this point Wittgenstein's note starting this paper: *"We do not have to ask what mental representations are, or what happens when we imagine something, but how the expression 'mental representation' is used."*.[56] We may very well look at the *uses* of the expression 'mental image' (especially the uses by cognitive scientists in their arguments). We thereby may obtain a non-mentalist kind of concept avoiding the disadvantages of strict privacy associated to the older conception.[57] The transition from the problem 'what are mental representations' to the question 'how is the expression "mental representation" used', primarily corresponds to a shift between the types of entities examined: whereas in the former case, we direct our attention to certain subjects P whose mind assumedly 'contains' some (private) mental representations of a particular kind, the latter task directs us to examine the scientists S studying the subjects P; then, especially the structural properties and the pragmatic embedding of the dialogs they use to that purpose lay in the focus of our interest. The privacy of instances of 'mental representations' those scientists may assume does not interfere with any communicated – hence not private – determination of their concept of such mental representations. Although there remain some rather complicated problems, especially with respect to the adaptation of this understanding to self-referencing psychological utterances, it is sufficient for our discussion (i.e., the search for a clearer conception of the use of 'mental image' in cognitivist theorizing).[58]

Postscriptum:
the sequence of numbers used as an example in the third section continues as follows: (... $\rightarrow$ 1113122110) $\rightarrow$ 311311222110 $\rightarrow$ 13211321322110 $\rightarrow$ 1113122113121113222110 $\rightarrow$ 31131122211311123113322110 $\rightarrow$ etc. Can you continue? The simple rule belongs to the scheme $x_0 \rightarrow f(x_0) \rightarrow f(f(x_0))$.

[55] cf. [Philip N. Johnson-Laird: The computer and the mind. An introduction to cognitive science, London, 1988, p. 16];

[56] cf. [Wittgenstein 1969, *op. cit.*, §370] (*"Nicht, was Vorstellungen sind, oder was da geschieht, wenn man sich etwas vorstellt, muß man fragen, sondern wie das Wort 'Vorstellung' gebraucht wird."*);

[57] For a more general discussion of this 'new way of concepts', cf. [Ros 1989f., *op. cit.*, esp. Vol. III]; an extended discussion of the mentalist conception and its difficulties is to be found in Vol. II of that opus;

[58] cf. also the considerations in [Schirra 1994, *op. cit.*, Sec. 4.4]; for an elaborated discussion of a more general solution, cf. [Ros 1989f., *op. cit.*, Vol. III, Sec. 1.3] and [Ros, Arno: Bemerkungen zum Verhältnis zwischen Neurophysiologie und Psychologie. In: Zeitschrift für allgemeine Wissenschaftstheorie (1994)];

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