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THE DOUBLE DYNAMICS OF DEFINITE DESCRIPTIONS

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1 INTRODUCTION

The overall question of this volume, whether meaning is dynamic or not, is investigated in this paper with respect to the interpretation and representation of texts and discourses. Their coherence crucially depends on reference, coreference and anaphoric reference, as illustrated in the fragment (1), which is from Hemingway's novel *The old man and the sea* (1925, 28).

(1) **A small bird** came toward the skiff from the north. **He** was a warbler and flying very low over the water. The old man could see that **he** was very tired. **The bird** made the stern of the boat and rested there. Then **he** flew around the old man's head and rested on the line where **he** was more comfortable.

The indefinite description *a small bird* is the antecedent for the different occurrences of the anaphoric pronoun *he* and the anaphoric definite description *the bird* in the subsequent sentences. The coherence of the small fragment can only be established if we can assign the same referent to the antecedent and its anaphoric expressions. Thus, discourse semantics has to explain the anaphoric linkages by assigning the right reference to the anaphoric expressions.

The initial problem that motivated discourse semantic theories is the interpretation of nominal and temporal anaphora in discourse. The phenomenon of cross-sentential anaphora forces a semantics to extend its limits from the sentence to the discourse. The key idea in the approach to the semantics of discourse, exemplified in Heim (1982), Kamp (1981) and later in Groenendijk & Stokhof (1991), is that each new sentence or phrase is dynamically interpreted as an addition or 'update' of the context in which it is used. This update often involves connections between elements from the sentence or phrase with elements from the context. Anaphoric relations and definite expressions are captured by links between objects in this representation.

Dynamic semantics reconstructs anaphoric relations by two interacting operations: the context change potential of indefinite descriptions, and the context dependent interpretation of anaphoric pronouns. The indefinite description *a small bird* in (1) changes or updates the context in such a way that the anaphoric pronoun *he* in the next sentence can be linked to the antecedent. Discourse semantics generally assumes that one type of expression has either a context change potential or its interpretation is context dependent, but not both. I argue that this is coincidence: Indefinite descriptions are not context dependent because it is their primary function to introduce new discourse items. Anaphoric pronouns cannot update the context since they do not contain descriptive material.

I argue that definite descriptions have both dynamic aspects: Their interpretation depends on the given or updated context, and at the same time this context is changed by their interpretation. This thesis extends the dynamicity claims of dynamic semantics, which assumes definite description to be purely static expressions in the sense of Russell's classical Theory of Descriptions. In order to show the double dynamics of definite descriptions we have to deviate from the Theory of Descriptions in at least three aspects: (i) definite descriptions refer to the most salient element of the set that is expressed by their descriptive content, rather than to the unique element of that set. Thus the Russellian uniqueness condition is replaced by a more flexible salience ranking, which is necessarily context dependent. (ii) The interpretation process of a definite description updates the context, which consists of salience hierarchies for each introduced set. If, however, the definite description is already the most salient referent of the set, it only trivially updates the context by making this referent the most salient one for that set. Therefore, we have to assume (iii) that the update does not only affect the set that is defined by the descriptive material, but also some supersets of it. This is illustrated by the anaphoric linkage in (1) between the antecedent *a small bird* and the anaphoric *the bird*. Birds are supersets of small birds. Furthermore, the anaphoric chain *a small bird ... he ... he ... the bird ... he... he* has a very typical shape: First an indefinite description introduces the new referent, which is picked up by anaphoric pronouns, but only once or twice. Then a definite description has to be used to refer to the antecedent *and* to make the referent salient again, which then can be referred to by another one or two pronouns. This schema vindicates the view that definite descriptions can raise a referent to salience, but anaphoric pronouns cannot.

The paper is organized as follows: In section 2, I present the Theory of Descriptions by Russell (1905) and the representation of definite descriptions with the iota-operator. I dispute the three main assumptions: (i) The assumption that the uniqueness condition is part of the lexical

semantics of the definite article, (ii) the assumption that definite descriptions are context-free, and (iii) the assumption that they cannot change the context. In section 3, I develop the alternative reconstruction of definite descriptions by means of a salience structure, epsilon terms, and their interpretation in terms of choice functions. First Lewis' (1979) idea of a salience structure is presented, which is reconstructed by Egli & von Heusinger (1991/1995) with epsilon terms. Finally context dependent epsilon terms and their interpretation as choice functions are given. In section 4, I informally develop a new dynamic semantics with choice functions, where definite descriptions receive the double dynamics: They are interpreted depending on the context and at the same time they update the context. A formal account is given in the appendix.

2 THE STATIC VIEW OF DEFINITE DESCRIPTIONS

2.1 Russell's Theory of Descriptions

Russell (1905) distinguishes between referring terms, like proper names, and denoting expressions, like quantifiers. Contrary to Frege, he assumes that definite descriptions are denoting expressions, rather than referring terms. He develops his Theory of Descriptions in order to show that definite descriptions are quantifiers, but still refer to a unique referent, like referring expressions. The descriptive material of a definite description denotes just a singleton set of that element that the whole definite description refers to. Russell argues that this uniqueness condition is part of the lexical semantics of definite descriptions.

He builds his theory of a particular type of definite descriptions – Those that denote exactly one individual due to the lexical meaning of the descriptive content, as in (2) and (3). He also discusses problems with the existence condition on examples like (3). But he rarely notes that there are many more types of definite descriptions whose descriptive content refers to a set with more than one element, as in (4).

  (2) the center of mass of the Solar System
  (3) the present king of France
  (4) the bird

He accounts for the meaning of definite descriptions only in the context of a sentence. Like other quantifiers such phrases do not refer by themselves, but contribute to the meaning of the whole sentence. Russell translates a definite description into a complex quantifier consisting of a uniqueness condition and an existence condition. This quantifier binds a variable in an argument position of the predicate. In a sentence like (5) the definite description *the father of Bertrand Russell* expresses the existence of a father of Bertrand Russell, the uniqueness condition, and then the predication that this individual is English. Thus (5) is represented as (5a), or shorter, but equivalent, as (5b). Russell abbreviates this complex formula by (5c), which mirrors the predicate-argument structure of the surface sentence (5). He understands the iota-operator as a contextual abbreviation for the existence and uniqueness condition of the definite description, but not as an operator with its own semantics.

(5)   The father of Bertrand Russell was English.

(5a) $\exists y$ [(Father-of(b, y))   existence
       & $\forall x$ (Father-of(b, x) $\rightarrow$ x = y)   uniqueness
       & English(y)]   predication

(5b) $\exists x$ [$\forall y$ (Father-of(b, y) $\leftrightarrow$ x = y) & English(x)]

(5c)   English(ιx Father-of(b, x))   iota-operator

For indefinite descriptions, Russell only demands the existence condition, but rejects the uniqueness condition, explaining the difference between definite and indefinite descriptions with uniqueness. He translates (6) into (6a) with the existence condition for *a bird* and the predication. Russell himself saw no necessity to abbreviate this form, but Reichenbach (1947, 265) uses the eta-operator as an abbreviation for the existence condition. Thus, (6b) reflects the surface argument structure of the original sentence (6).

(6)   A small bird came.

(6a) $\exists x$ [Small-Bird(x) & Come(x)]   existence + predication

(6b)   Come(ηx [Small-Bird(x)])   eta-operator

Russell's theory gives us a static view of definite (and indefinite) descriptions, which is also mirrored in the universal quantification of his contextual definition (5a,b). His theory of definite and indefinite descriptions was the base for most semantic theories. Even though dynamic theories deviate in their interpretation of indefinite descriptions and anaphoric pronouns (but see Neale, 1990, for a defense of Russell), they still keep to the Russellian semantics of definite descriptions (Groenendijk & Stokhof, 1991, Kamp & Reyle, 1993, van Eijck, 1993). I argue that the Russellian analysis fails in at least the following assumptions: (i) the uniqueness condition is part of the lexical semantics of the definite article, (ii) definite descriptions are context-free, and (iii) definite descriptions cannot change the context.

2.2 The non-uniqueness of definite descriptions

Russell assumes that the reference of definite descriptions is determined by the uniqueness of the descriptive material, and he therefore builds the uniqueness into the lexical semantics of the definite article. However, he misunderstood the 'unique availability' of the referent (cf. Peregrin, 2000) of a definite description as part of its lexical meaning. It is uncontroversial that definite descriptions refer to one (unique) referent (such as indefinite descriptions), but it is controversial how this unique reference is established. The way definite descriptions refer to their referents is determined by at least two parameters: the descriptive material and the function of the definite description. We can distinguish different kinds of definite descriptions with respect to the type of descriptive material they contain:

(7)   Types of definite descriptions
(i)   superlatives   *the first man on the moon, the highest mountain*
(ii)   unique concepts   *the Earth, the Pope*
(iii) functional concepts   *the sun, the president, the father*
(iv)   sortal concepts   *the bird, the cat, the paper*

Since there is only one person who has been the first man on the moon, the definite description *the first man on the moon* refers to exactly that man. Definite descriptions based on unique concepts, like *Earth*, refer to that unique element, while definite descriptions with functional concepts refer to a unique element depending on the argument for the associated function: The sun of our solar system, the president of the United States, the father of Bertrand Russell. This behavior of definite descriptions caused their use in mathematics and epistemology for definitions. In the context of a definition, a definite description refers to the unique object that satisfies the descriptive material. Russell's Theory of Descriptions is based on such cases and, therefore, entails the uniqueness condition for definite descriptions. However, in normal natural language discourse we find definite descriptions based on sortal concepts, like *the bird, the cat, the paper*. Such descriptions are sometimes called incomplete definite descriptions. They refer uniquely to one object due to their descriptive material and other information, like hidden parameters and their function.

Definite descriptions can take different functions in a discourse, as listed in (8) and illustrated with example (9), which is from the beginning of Umberto Eco's novel *The name of the rose* (1994, 21).

(8)   Functions of definite descriptions
(i)   situational salience   *the steep path, the mountain*
(ii)   anaphoric relation   *the abbey, the mountain*
(iii) functional dependency   *the walls that girded it, the plateau*
(iv)   uniques and proper names   *the Christian world, the City of God*

(9)   While we toiled up **the steep path** that wound around **the mountain**, I saw **the abbey**. I was amazed, not by **the walls that girded it on every side**, similar to others to be seen in all **the Christian world**, but by **the bulk** of what I later learned was **the Aedificium**. This was an octagonal construction that from a distance seemed a tetragon (a perfect form, which expresses **the sturdiness** and impregnability of **the City of God**), whose southern sides stood on **the plateau of the abbey**, while **the northern ones** seemed to grow from **the steep side** of **the mountain**, a sheer drop, to which they were bound.

The definite descriptions *the steep path* and *the mountain* indicate the situational salience of that path and that mountain. Since the abbey was already mentioned in the text, the two occurrences here are used anaphorically, like the second occurrence of *the mountain* in the last sentence. The definite description *the walls that girded it* and *the plateau* are functionally dependent on their arguments, which is already determined by their descriptive material. Finally, we also find definite descriptions that express unique entities, referred to by proper

names, as *the Aedificium, the City of God* or expressions that come close to it, like *the Christian world*. With uniques the function does not play any role since they always refer to the one referent. However, with definite descriptions based on sortal concepts, the function crucially decides if the expression is used as a definite description or as an indefinite description.

This short discussion can be summarized by the following two points: The uniqueness condition, that is, the claim that the descriptive content may only be true for one individual, is a useful property, but it is not a necessary property of descriptions. From the supposed fact that a description denotes exactly one individual, Russell concluded that the uniqueness presupposition was a valid restriction of the descriptive content within the description. However, we assume instead that the 'unique availability' is introduced via the context and only shown by use of the article and that the descriptive content can indeed be true for more than one individual. Russell's assumption, then, is a special case, describing exactly that situation where the descriptive content is true for only one individual.

2.3 Context dependency of descriptions

In the last section we have seen that the 'uniqueness'-flavor of definite descriptions is determined by their lexical material and their function. We now look closer at the function, namely the anaphoric use in the next section, and the situational use in this section. The referent of a definite description used as indicating situational salience, like *the mountain* or *the steep path*, indicates that the referent is situationally salient among other referents with the same property. In other words, the definite description refers to the first element of an ordered set that is denoted by the descriptive material. The order, however, is context dependent. In a different story, we could refer to a different mountain and a different path by the same definite descriptions as in (9).

To illustrate this with another example (Egli & von Heusinger, 1991/1995), let's assume that there are three islands on the Lake Constance: the Mainau, the Reichenau, and the Lindau. They have all the same property of being an island, however they are located in different parts of the lake. So, for example, the description *the island*, used in a situation like standing on the terrace of the University of Konstanz (looking down at the island of Mainau) will probably denote Mainau. In the same situation, I could possibly utter that we do not see *the other island* referring to Lindau. Thus, we have established an order in which Mainau is the first element. A different situation, like strolling on the island Reichenau, will establish a different order where Reichenau is the first element and the description *the island* denotes Reichenau. Despite the effects of context dependency, an individual can be specified independently of particular situations or locations. So, for instance, even while walking on Reichenau, we could refer to Mainau simply as *the island* by invoking such an order by other means.

2.4 Definite descriptions and context change

The context can also be constituted by the linguistic environment. The interaction of the context change potential and the context dependent interpretation of definite descriptions establishes anaphoric relations, as already illustrated by the fragment (1) above. Lewis (1979, 179) makes the same point with a text in which two occurrences of the same definite description *the cat* refer to two different cats.

(10)   Imagine yourself with me as I write these words. In the room is **a cat, Bruce**, who has been making **himself** very salient by dashing madly about. **He** is the only cat in the room, or in sight, or in earshot. I start to speak to you:
The cat is in the carton. **The cat** will never meet **our other cat,** because **our other cat** lives in New Zealand. **Our New Zealand cat** lives with the Cresswells. And there **he**'ll stay, because Miriam would be sad if **the cat** went away.

This very natural text illustrates how definite descriptions change the context *and* are context dependent in their interpretation. Lewis explains the shift of reference for the definite description *the cat* by the general principle of salience, rather than by Russell's uniqueness condition. The indefinite description *a cat* in the first sentence introduces a new cat, Bruce, and makes him salient. The subsequent definite description *the cat* in the third and fourth sentence refers to that cat Bruce. However, the definite descriptions *our other cat* and *our New Zealand cat* not only introduces a second cat (Albert), but also makes him the most salient cat such that the last occurrence of the definite description *the cat* now refers to Albert (and not to Bruce).[1] Lewis replaces the uniqueness condition of Russell by the principle of salience. However, he does not give any formal reconstruction of this observation. In the following I assume that the contextual information essentially consists in a salience structure.

A salience structure assigns to each of the introduced sets a ranking among its elements. A definite description refers then to the most salient or highest ranked element of the set described by its descriptive material. The indefinite description *a cat* introduces a new referent and changes this structure in that it assigns its referent to the set of cats as being the most salient one. The subsequent definite description *the cat* refers to that most salient referent. The definite description *our New Zealand cat* updates the context in the following way: First it trivially updates the set of New Zealand cats with its referent (which is already the most salient one). Second it updates also some supersets, e.g. the set of cats, such that its referent becomes the most salient referent of the supersets. In this way we can account for the salience change of the set of cats from one cat (Bruce) to another cat (Albert) by the definite expression *our New Zealand cat*.

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[1] Interesting enough, Lewis (1979, 178) gives a hypothetical continuation of that conversation that allows for a shift back of the salience structure between the two introduced cats: "One rule, among others, that governs the kinematics of salience is a rule of accommodation. Suppose my monologue has left Albert more salient that Bruce; but the next thing I say is 'The cat is going to pounce you!' If Albert remains most salient and 'the cat' denotes the most salient cat, then what I say is patently false."

3 SALIENCE STRUCTURE, EPSILON TERMS, CHOICE FUNCTIONS

In this section, I present an alternative analysis of definite descriptions that is based on a contextually given salience structure. Starting with Lewis' (1979) idea of a salience hierarchy as the relevant contextual structure for the 'unique availability' of the referent of a definite description, I introduce Hilbert's epsilon operator as the semantic representation for the definite article. The epsilon operator is interpreted by a choice function, which selects one element out of the set denoted by the descriptive material, thus dismissing the uniqueness condition of Russell. In a further step, the operator is made dependent on a contextual variable mirroring the dependency of definite descriptions from the context. This extension of the formalism allows us to represent indefinite descriptions by the same representation, but with different contextual restrictions.

3.1 The concept of salience

The concept of salience was first discussed in the semantics of definite descriptions in the seventies. Lewis (1979, 178) uses it in order to replace Russell's problematic uniqueness condition for definite descriptions: "The proper treatment of description must be more like this: 'the F' denotes x if and only if x is the most salient F in the domain of discourse, according to some contextually determined salience ranking." The notion of salience itself seems to be influenced by the analysis of demonstrative expressions. A demonstrative like *this man* refers to the most prominent object in the physical environment of the speaker and hearer. Salience, however does not depend only on the physical circumstances, or any other single cause. Rather it is a bundle of different linguistic and extra-linguistic factors, as noted by Lewis (1970, 63): "An object may be prominent because it is nearby, or pointed at, or mentioned; but none of these is a necessary condition of contextual prominence. So perhaps we need a prominent-objects coordinate, a new contextual coordinate independent of the other."

The concept of salience also plays an important role in the Prague School, which has developed a dynamic view of the information expressed in a sentence. In this approach, the 'stock of shared knowledge' (Sgall et al., 1973, 70) constitutes the common background of the speaker and the hearer. It is the set of potential referents for definite expressions. This set is further divided into background and foreground information, which depends on encyclopedic knowledge, context information and thematic structure of the sentence. Besides this dichotomy, there is a further structure which is described in the following way (Sgall et al., 1973, 70f):

> There is no clear-cut dichotomy in the stock of shared knowledge, and it would be, probably, more adequate to work here with a kind of ordering than with two subclasses. Let us remark that the mentioning of an element of the stock of shared knowledge brings this element into the foreground of the stock, and, in some respects, it is possible to conceive the last mentioned element to be more foregrounded than the elements mentioned before, the foregrounding of which already shades away step by step, if it is not supported by some specific moments due to the given situation.

Finally, there is a recent interest in salience in computational linguistics analyzing anaphoric relations in large corpora (see for example Poesio & Stevenson, to appear).

In the following, salience is understood as the property of a context that assigns to each introduced set one of its elements. So the definite description *the cat* in (10) refers to the (most) salient cat – first to Bruce, and then after the salience has shifted to Albert. This means salience is not a static notion, but a notion that crucially depends on the dynamics of the interpretation process.

3.2 Hilbert's epsilon operator

Egli & von Heusinger (1991/1995) use Hilbert's epsilon operator as the semantic representation of the definite article. The epsilon operator corresponds to a selection function that assigns to each nonempty set one element of this set. An empty set will be assigned an arbitrary element. Thus it is guaranteed that the epsilon term ε*x (Fx)* under all circumstances denotes something and that there are no cases where it has no reference as in Russell's system. Like the iota operator, the epsilon operator forms a term from a sentential form. Unlike the iota operator, it carries with itself no existence or uniqueness presupposition. The main difference may be shown by the formalization and the paraphrase of the description *the cat*, as given in (11) and (12):

    (11) ιx cat(x)   the **unique** x, such that x is a cat
    (12) εx cat(x)   the **selected** x, such that x is a cat

Hilbert & Bernays (1939) replaced the existential and universal quantifiers by epsilon terms for metamathematical reasons. They use the epsilon operator as a generalized iota operator without the uniqueness and the existential condition. The epsilon operator is used to replace the existential and universal quantifier, according to the two epsilon rules (13) and (14). The latter one can be inferred from the former by substitution of ¬*F* for *F*, contraposition and replacement of the existential quantifier by the universal in (14).

    (13) ∃x Fx ↔ F(εx Fx)
           ∃x ¬Fx ↔ ¬F(εx ¬Fx)   [substitution of ¬*F* for *F*]
           ¬∃x ¬Fx ↔ ¬¬F(εx ¬Fx)   [contraposition]
    (14) ∀x Fx ↔ F(εx ¬Fx)   [replacement of the existential quantifier]

According to these syntactical definitions for the epsilon operator, the following interpretation becomes most natural: An epsilon term ε*x Fx* is interpreted in a model *M*, consisting of an individual domain *D*, an interpretation function *I,* and a choice function *Φ*, as that individual that is assigned to a set *F* by the choice function *Φ*. A choice function is generally defined as a function that assigns to each non-empty set *s* one of its elements, and an arbitrarily chosen element to the empty set.

(15) $\|\varepsilon x\ F\|^{M,g} = \Phi\|F\|^{M,g}$, with Φ as the function given by $M = \langle D, I, \Phi\rangle$

(16) $\Phi(s) \in s$ if $s \neq \emptyset$ and $\Phi(s) \in D$ if $s = \emptyset$

In this way, the universal and existential quantifiers can be replaced. In the following, we will concentrate on the representation of definite descriptions. But first we have to extend the formalism by the context parameter.

3.3 Context dependent epsilon terms and indefinite descriptions

Since Hilbert applied his epsilon terms only to the domain of numbers, a naturally ordered set, no determined choice function was necessary. However, in natural language the objects we refer to are not naturally ordered; rather, the order depends on a particular context. Thus, most attempts to introduce the epsilon operator into linguistic analysis have failed since they did not consider this context dependency. Egli & von Heusinger (1991/1995) approached this problem by assuming a family of choice functions for representing definite descriptions and indefinite descriptions. Each context c has its own choice function Φ_c, such that the definite descriptions *the F* can be represented as the indexed epsilon term $\varepsilon_c x\ Fx$, which can be paraphrased with *the selected x in the context c such that x is F* or *the most salient x in c such that x is F*. It is interpreted as the element that results from applying the choice function Φ_c to the set of all Fs. The contribution of the context to the interpretation of the definite descriptions consists in an ordering of the elements of each set described in that context. In this – preliminary – view definite descriptionss are interpreted similarly to deictic expressions. The 'unique availability' of the referent (see section 2.2) is warranted by the definition of the choice function, which assigns one element to a set.

Egli & von Heusinger (1991/1995) and von Heusinger (2000) generalize this semantics of definite descriptions to indefinite descriptions. Indefinite descriptions are also represented by indexed epsilon terms, but here the index is not determined by the context, but free.

(17)   the F: $\|\varepsilon_c x\ Fx\| = \Phi_c(\|F\|)$ with c contextually determined

(18)   an F: $\|\varepsilon_i x\ Fx\| = \Phi_i(\|F\|)$ with i free

Like free variables for individuals in Lewis-Heim-Kamp theories, the free index of the epsilon operator can be bound by operators in its environment or it can be existentially closed by some existential text operator. Thus, the contrast between definite and indefinite descriptions roughly corresponds to the familiarity condition of Heim (1982) (see von Heusinger, 2000, for discussion). The advantages of using choice function variables instead of individual variables are the following: (i) the epsilon term corresponds to the syntactic constituent of a definite or indefinite description, and the descriptive material of the indefinite is not treated on par with the main predicate in the sentence. Thus we can distinguish the identification of the referent from the assertion in the sentence. (ii) Indefinites need not be moved or raised for expressing different dependency behaviors. They remain *in situ*, whereas the choice function variable can be bound by other operators. (iii) This view clears the way for a dynamic semantics, in which the context change potential is expressed in updating choice functions. This is informally described in the next section, while the appendix gives the formal account.

4 DYNAMIC SEMANTICS WITH DEFINITE DESCRIPTIONS

4.1 The common picture of dynamic semantics

Dynamic semantics, like Dynamic Predicate Logic (DPL, Groenendijk & Stokhof, 1991), assumes an update function of indefinite expressions and a context dependent interpretation of pronouns. This is illustrated by the analysis of the small text fragment (1), repeated as (19), with the quasi logical representation (19a), which does not correspond to any dynamic formalism in detail, but it provides a good illustration for the basic mechanisms to be discussed.

(19)   **A small bird₁** came toward the skiff from the north. **He₁** was a warbler and flying very low over the water. The old man could see that **he₁** was very tired. **The bird₁** made the stern of the boat and rested there. Then **he₁** flew around the old man's head and rested on the line where **he₁** was more comfortable.

(19a)   [Small(x) & Bird(x) & Came(x)] & [Warbler(x) & Fly(x)] & ...
         & [Rest(ιy [Bird(y)])] & [Fly(x)] & [Rest(x)]

The expressions in (19) are translated into (19a): indefinite descriptions into predicates and a new variable, pronouns into simple variables, and definite descriptions into iota-expressions. The indexing in (19) determines the choice of variables in (19a): the anaphoric pronouns are represented by the same variable as their coindexed antecedent expression: the indefinite description *a small bird*. The quasi formula (19a) is true if there is an assignment function g that assigns an element to the variable x such that it is in the extension of all the predicates. The indefinite description *a small bird* introduces the new variable x and at the same time changes the context by updating the assignment function g to an assignment function h that differs at most in the value for x: $h[x]$. This update of the first sentence is passed on to the second sentence encoding that the value for x must hold of the predicates *small bird* and *come*. Since the pronoun in the second sentence was translated into the variable x (due to the coindexing), it is assigned the same value, thus reconstructing the anaphoric relation. The pronoun itself cannot update the assignment function, nor the definite description, which is interpreted as static expression.

This common picture of dynamic semantics assumes (i) a context change potential of indefinite descriptions, (ii) a context dependent interpretation of anaphoric pronouns, (iii) a static interpretation of definite descriptions (i.e. neither context change potential nor context dependent interpretation) and (iv) coindexing in the syntactic form.

4.2 The problem of coindexing

There is a major problem of this approach, which can be illustrated with (10), repeated as (20): The pronoun *he* in the last sentence has two potential antecedents: the cat Bruce or the cat Albert. Dynamic semantics cannot tell which is the more appropriate one, but has to rely on extra-linguistic knowledge, which is built into the syntactic representation as coindexing. Without this coindexing, we do not know in which variable we must translate the last

occurrence of the pronoun *he*. (See for the complete argument Peregrin & von Heusinger, 1995/2002.)

(20) "the cat" (Lewis, 1979, 179)

Imagine yourself with me as I write these words. In the room is **a cat, Bruce**, who has been making **himself** very salient by dashing madly about. **He** is the only cat in the room, or in sight, or in earshot. I start to speak to you:

The cat is in the carton. **The cat** will never meet **our other cat,** because **our other cat** lives in New Zealand. **Our New Zealand cat** lives with the Cresswells. And there **he**'ll stay, because Miriam would be sad if **the cat** went away.

Another problem is of course the interpretation of the different occurrences of the definite description *the cat*. Even if we would allow coindexing, the uniqueness condition of the Russellian description blocks reference at all.

4.3. Dynamic semantics with choice functions

Problems like these motivated an extension of dynamic semantics by Peregrin & von Heusinger (1995/2002). They implemented the idea of choice functions (see section 3) into the framework of Dynamic Predicate Logic of Groenendijk & Stokhof (1991). They assume that the context is represented by choice functions, rather than by assignment functions. The indefinite description *a cat* updates the value for the choice function applied to the set of cats. In other words, the update effects the ordering in the set of cats. Anaphoric expressions like *the cat* refer to the highest ranked element of the set of cats. However, the ranking in the set can be changed again. So if there is a second cat introduced, this cat becomes the highest ranked, and the last occurrence of the definite description *the cat* refers to the second (or last) introduced cat. Therefore, no coindexing is necessary, and definite descriptions can be interpreted even if there are more than one cat in the minimal context.

This approach differs from other dynamic frameworks in that it uses choice functions instead of assignment functions. This means it keeps track of the order in all sets which have been introduced so far. Linguistic expressions can change the context by modifying this order for a given set. In the original Peregrin & von Heusinger (1995/2002) framework, definite descriptions are interpreted as context-dependent. Yet they do not show a context change potential. Even if they update the current choice function for the set they describe, the order would not change, since they are already the first ranked element – so they only 'trivially' update.

This simple update mechanism can account for anaphoric chains of the sort given in (21a), but not the ones in (21b).

(21a) *a cat – the cat;*   *a small bird – the small bird*
(21b) *a New Zealand cat – the cat – he;*   *a small bird – the bird – he*

Therefore, Peregrin & von Heusinger (1995/2002) assume that the update potential of an indefinite description does not only update the set that is denoted by the descriptive material, but also some supersets, as illustrated in (22). The indefinite description *a small bird* updates the set of small birds, the set of birds and the set of (male) animals. With this extended update potential we can account for the anaphoric chains in (21b).

(22) Extended update potential of indefinite descriptions

indef. description	corresp. set	superset	superset
a small bird	*small birds*	*birds*	*(male) animals*
a New Zealand cat	*New Zealand cats*	*cats*	*(male) animals*

4.4 The dynamics of definite descriptions

Once we have introduced the extended update potential for indefinite descriptions, we can also assign it to definite descriptions, which now not only (trivially) update the set their descriptive material denotes, but they can also update the order in some supersets. With this mechanism we can account for the anaphoric relations and the shift of salience structure in (23), which is from the short story *A clean, well-lighted place* by Hemingway (1925, 380).

(23) It was late and everyone had left the café except an old man who sat in the shadow the leaves of the tree made against the electric light. [...] **The two waiters** inside the café knew that the old man was a little drunk [...]. "Last week he tried to commit suicide," **one waiter** said. "Why?" [...] **The younger waiter** went over to him. [...] The old man looked at **him**. **The waiter** went away. [...] **The waiter who was in a hurry** came over. "Finished," **he** said [...]. "Another", said the old man. "No, finished." **The waiter** wiped the edge of the table with a towel and shook **his** head. The old man stood up [...]. "Why didn't you let him stay and drink?" **the unhurried waiter** asked.

The extended update potential allows that the definite description *the younger waiter* not only updates the set of younger waiters, but also the set of waiters, and the set of all (male) humans. Thus we can account for the anaphoric chains in (25).

(24) Extended update potential of definite descriptions

def. description	corresp. set	superset	superset
the younger waiter	*younger waiters*	*waiters*	*(male) humans*
the waiter who was in a hurry	*waiters who were in a hurry*	*waiters*	*(male) humans*

(25) *the younger waiter – he – the waiter*
the waiter who was in a hurry – he – the waiter

This dynamic semantics with choice functions can account for the anaphoric relations between a definite antecedent and an anaphoric term by going dynamic not only for indefinite but also for definite descriptions.

Still there are many open problems which will demand a refinement of this semantics. One extension should try to capture the different anaphoric relations listed in (26) (it does not play a role regardless of whether the antecedent is definite or indefinite).

(26)   Anaphoric relations and the relations between the denoted sets

example	relation	set theoretical operations
a bird – the bird	identical sets	$\|bird\| = \|bird\|$
a small bird – the bird	superset	$\|small\ bird\| \subseteq \|bird\|$
a small bird – the small animal	intersection	$\|small\ bird\| \cap \|small\ animal\| \neq \emptyset$
a bird – the small bird	subset	$\|bird\| \supseteq \|small\ bird\|$

The current version (see Appendix) is able to describe a relation between the antecedent and the anaphoric term that consists in the identity relation or in the superset relation. However, the formalism given so far does not account for the intersection relation or a subset relation. It is, however, not clear to me, if the latter two relations are triggered by particulur pragmatic conditions. Still, this aspect has to be investigated.

Another very interesting problem is that the salience of an object is 'fading away' if this object is not referred to regularly. We have already seen that a typical anaphoric chain consists of a full description as antecedent, one or two pronouns, and then of another full description, like in (27) from example (19):

(27)   *a small bird ... he ... he ... the bird ... he... he*

So far, there is nothing in this semantics that can control such 'fading'. Other approaches have built in a rule that lowers all elements in their salience by one rank when a sentence terminates (cf. Hajičová, Hoskovec & Sgall, 1995). Highly ranked elements must be made salient again by a full description after one or two sentences, as illustrated in the anaphoric chain in (27).

5 SUMMARY

The interpretation of texts and discourses must link the reference of expressions to each other in order to reconstruct the coherence. Dynamic semantics presents a mechanism to do so, which consists of the interaction of the context change potential and the context dependent interpretation. This *double dynamics* is generally illustrated by the context change potential of indefinite descriptions and the context dependent interpretation of anaphoric pronouns. In this way, intersentential anaphoric relations are reconstructed. Theories of dynamic semantics treat definite descriptions, however, as static expressions in both aspects: They neither change the context nor does their interpretation depend on the context change of other expressions.

In contrast to this commonly held view, the paper has shown that definite descriptions are dynamic in both aspects of dynamic semantics: They do change the context and they do depend on the updated context. Definite descriptions are translated into epsilon terms that are interpreted by choice functions, while the context is modeled by a salience structure that is continuously updated. Finally, a semantics with choice functions has been presented, which reconstructs the double dynamics of definite descriptions. Once we have shown that even one of the most 'static' expressions, namely the definite description, has a dynamic meaning (in at least two aspects), how can we then dispute that meaning in general is dynamic?

APPENDIX: DYNAMIC SEMANTICS WITH CHOICE FUNCTIONS

Let us assume the non-empty universe U of individuals. An epsilon function (or a choice function) e is a partial function from the power-set of U into U such that $e(s) \in s$ for every $s \subseteq U$ for which e is defined. This means that the class EPS_U of all epsilon functions based on U is defined as follows (where $D(e)$ and $R(e)$ denote the domain and the range of e, respectively):

DEF1. $EPS_U = \{e \mid D(e) \subseteq Pow(U)$ and $R(e) \subseteq U$ and $e(s) \in s$ for every $s \in D(e)\}$

We further introduce update functions for epsilon functions, or epsilon updates in short. An epsilon update is a function that takes three arguments: an epsilon-function, an element of the universe, and a subset of the universe; it yields a new epsilon function.

DEF2. $UPD = \{e \mid D(e) = EPS \times U \times Pow(U)$ and $R(e) \subseteq EPS\}$

The basic epsilon-update upd_1 applied to an epsilon function e, an individual d, and a set s, yields the epsilon function e' which is identical with e except for the assignment d for the set s.

DEF3. upd_1 is the element of UPD defined as follows:
$upd_1(e,d,s)(s') = d$ if $s'=s$ and $d \in s$
$\qquad\qquad\quad = e(s')$ otherwise

The extended update potential of descriptions is described in the next definition, where not only the given set, but also some supersets are updated:

DEF4. upd_1 is the element of UPD defined as follows
$upd_1(e,d,s)(s') = d$ if $s' \subseteq s$ and $d \in s$
$\qquad\qquad\quad = e(s')$ otherwise

We use $e'=e^s$ as an abbreviation for $\exists d.e'=upd_1(e,d,s)$. If $e_2=e_1{}^s$ and $e_3=e_2{}^{s'}$, then we also write $e_3=e_1{}^{s,s'}$. upd_1 can be seen as the first approximation to the salience change potential of an indefinite description: The indefinite description *a man* selects an arbitrary man and changes the actual choice function such that this arbitrarily chosen man becomes the current representative for the class of men. In the following, a formal fragment will be defined illustrating how choice functions act in a dynamic semantics. I do without quantifiers, since

they play no role in the argument. However, for a detailed treatment of quantifiers in this framework see Peregrin & von Heusinger (1995/2002).

> DEF4a. (lexicon)
> 1. sentences
> 2. terms (constants **he, she, it**)
> 3. *n*-ary predicates for *n*>0 (constants **man, walk, whistles, farmer, boring, woman, thing**
>   for *n*=1; **own, beat** for *n*=2)
> 4. determiners (constants **a, the**)
> 5. *n*-ary logical operators for *n*=1,2 (the constant ¬ for *n*=1; **&, ∨** for *n*=2)

> DEF4b. (syntax)
> 1. If *P* is a unary predicate and *D* a determiner, then *D(P)* is a term.
> 2. if $T_1,...,T_n$ are terms and *R* an n-ary predicate, then $R(T_1,...,T_n)$ is a sentence.
> 3. If *S* is a sentence and *O* a unary logical operator, then *OS* is a sentence.
> 4. If S_1 and S_2 are sentences and *O* a binary logical operator, then S_1OS_2 is a sentence.

> DEF4c. (semantics)
> A model is a pair $<U,\| \|>$, where *U* is a set and $\| \|$ is a function such that (i) if *T* is a term, then $\|T\| \in U$; (ii) if *R* is an n-ary predicate, then $\|R\| \in U^n$. If *T* is a term and $e \in EPS_U$, then we define the value $\|T\|_e$ in the following way:
>> $\|T\|_e = \|T\|$ if *T* is a constant term
>> $= e(\|P\|)$ if *T* is *D(P)* for a determiner *D* and a predicate *P*

The function $\| \|$ is extended to the categories of terms and sentences so that if *E* is a term or a sentence, then $\|E\| \subseteq EPS \times EPS$. In the original Peregrin & von Heusinger (1995/2002) framework, the interpretation of the definite description is static ($\|\textbf{the}(P)\| = \{<e,e'>| e'=e$ and $e'(\|P\|)$ is defined$\}$). However, as argued above, definite descriptions do change the context. Therefore, they receive the same (extended) update potential as indefinite descriptions (the difference between definite and indefinite description is that the latter introduce a new referent, while the former refer to an old one, i.e. to one that is already raised to salience).

> 1a. $\|\textbf{a}(P)\| = \{<e,e'>| e'=e^{\|P\|}\}$
> 1b. $\|\textbf{the}(P)\| = \{<e,e'>| e'=e^{\|P\|}\}$
> 1c. $\|\textbf{he}\| = \|\textbf{the}(\textbf{man})\|$
> 1d. $\|\textbf{she}\| = \|\textbf{the}(\textbf{woman})\|$
> 1e. $\|\textbf{it}\| = \|\textbf{the}(\textbf{thing})\|$
> 2. $\|P(T_1,...,T_n)\| = \{<e,e'>|$ there exist $e_0,...,e_n$ so that $e=e_0$ and $e'=e_n$ and $<e_0,e_1> \in \|T_1\|$ and
>   ... and $<e_{n-1},e_n> \in \|T_n\|$ and $<\|T_1\|_{e_1},...,\|T_n\|_{e_n}> \in \|P\|\}$
>
> 3. $\|\neg S\| = \{<e,e'>| e=e'$ and there is no e'' such that $<e,e''> \in \|S\|\}$
> 4a. $\|S_1 \& S_2\| = \{<e,e'>|$ there is an e'' such that $<e,e''> \in \|S_1\|$ and $<e'',e'> \in \|S_2\|\}$ $(= \|S_1;S_2\|)$
> 4b. $\|S_1 \vee S_2\| = \{<e,e'>| e=e'$ and there is an e'' such that $<e,e''> \in \|S_1\|$ or $<e,e''> \in \|S_2\|\}$

An indefinite description *a P* is taken to express an epsilon-update, i.e. its function is taken to be the updating of the actual epsilon function *e* to a new epsilon function *e'*. *e'* then differs from

e at most in the representative of the set of *P*; the description refers to this representative. We write $e^{\|P\|}$ for an *e'* resulting from the evaluation of *a P* with the input *e*. A definite description *the P* denotes the representative of the set of *P*'s according to the current epsilon function and it updates this current epsilon function. There is no uniqueness condition, since it is replaced by the condition that there exists the representative of the set of *P*'s. A pronoun is defined to be semantically equivalent to the impoverished definite description expressing merely the corresponding gender.

The atomic sentence is semantically characterized in 2 via its potential to change the current epsilon function *e* to the updated function *e'* by way of the subsequent application of the updates expressed by its terms. Thus, *e* and *e'* must be connected by a sequence of epsilon functions such that the adjacent pairs of the sequence fall into the respective updates expressed by the terms; and the referents of the terms must fall into the extension of the predicate. Here we differ essentially from usual dynamic logic in that we consider atomic sentences as internally and externally dynamic. The logical operators ¬ and ∨ are static (they act as tests); they are in fact the classical operators only formally dynamized. **&** is the dynamic conjunction suitable for conjoining subsequent sentences.

I illustrate this mechanism by analyzing a simple atomic sentence with an indefinite description. Sentence (28) is assigned the formula (28a); this formula is then interpreted as (28b) according to the definitions given above. As we have noted, a pair of epsilons $<e,e'>$ falls into the update expressed by an atomic sentence iff *e* and *e'* are connected by a sequence of epsilons such that the adjacent pairs of the sequence fall into the respective updates expressed by the terms and the referents of the terms fall into the extension of the predicate. Since we have only one term in (28), this reduces to the condition that $<e,e'>$ falls into the update expressed by **a(man)** and that the referent of **a(man)** falls into the extension of **walk**. This yields $e'=e^{\|man\|}$ and $e'(\|man\|)\in\|walk\|$. The resulting set of pairs is clearly non-empty just in case $\exists d.d\in\|man\|\&d\in\|walk\|$ (i.e. if the intersection of $\|man\|$ and $\|walk\|$ is nonempty); and our formula (28b) is thus in this sense equivalent to the classical formula $\exists x(man(x)\&walk(x))$.

(28) A man walks
(28a) **walk(a(man))**
(28b) $\|\textbf{walk(a(man))}\| = \{<e,e'>|\ <e,e'>\in\|\textbf{a(man)}\|$ and $\|\textbf{a(man)}\|_{e'}\in\|\textbf{walk}\|\}$
$= \{<e,e'>|\ e'=e^{\|\textbf{man}\|}$ and $e'(\|\textbf{man}\|)\in\|\textbf{walk}\|\}$

Sentence (29) with the definite description *the man* is represented and interpreted similarly to (28). The only difference is the condition on the epsilon function – the interpretation of the definite description is static. In both cases, the referent of the description is yielded by the actual epsilon function.

(29) The man whistles
(29a) **whistle(the(man))**

(29b)$\|\textbf{whistle(the(man))}\|$

$\quad = \{<e,e'>| <e,e'>\in \|\textbf{the(man)}\|$ and $\|\textbf{the(man)}\|_{e'}\in \|\textbf{whistle}\|\}$

$\quad = \{<e,e'>| e=e'$ & $e'(\|\textbf{man}\|)\in \|\textbf{whistle}\|\}$

The analysis of the conjunction (30) of (28) and (29) shows how the referent of the anaphoric description *the man* gets identified with that of its antecedent *a man*.

(30) A man walks. And the man whistles

(30a)$\textbf{walk(a(man))}\&\textbf{whistle(the(man))}$

(30b)$\|\textbf{walk(a(man))}\&\textbf{whistle(the(man))}\|$

$\quad = \{<e,e'>|$ there is an e'' such that $<e,e''>\in \|\textbf{walk(a(man))}\|$

$\qquad$ and $<e'',e'>\in \|\textbf{whistle(the(man))}\|\}$

$\quad = \{<e,e'>|$ there is an e'' such that $<e,e''>\in \{<e,e'>| e'=e^{\|\textbf{man}\|}$ and $e'(\|\textbf{man}\|)\in \|\textbf{walk}\|\}$

$\qquad$ and $<e'',e'>\in \{<e,e'>| e=e'$ and $e'(\|\textbf{man}\|)\in \|\textbf{whistle}\|\}\}$

$\quad = \{<e,e'>|$ there is an e'' such that $e''=e^{\|\textbf{man}\|}$ and $e''(\|\textbf{man}\|)\in \|\textbf{walk}\|$ and $e''=e'$

$\qquad$ and $e'(\|\textbf{man}\|)\in \|\textbf{whistle}\|\}$

$\quad = \{<e,e'>| e'=e^{\|\textbf{man}\|}$ and $e'(\|\textbf{man}\|)\in \|\textbf{walk}\|$ and $e'(\|\textbf{man}\|)\in \|\textbf{whistle}\|\}$

$<e,e'>$ falls into the update expressed by (30b) if and only if there is an epsilon function e'' such that $<e,e''>$ falls into the update expressed by (28b) and $<e'',e'>$ falls into the update expressed by (29b). Using the results of the above analyses and eliminating redundancies, we reach the result that $<e,e'>$ falls into the update expressed by (30b) iff e' differs from e at most in the representative of the class of men and this representative is a walker and a whistler.

In the same way we can now represent the small fragment from (23), repeated as (31) (*the old man* is taken as proper name in this story, the pronoun *him* is interpreted as *the man*):

(31) **The younger waiter** went. [...] The old man looked at **him**. **The waiter** went away.

(31a)$\textbf{go(the(younger-waiter))}\&\textbf{look(the-old-man, the(man))}\&\textbf{go(the(waiter))}$

(31b)$\|\textbf{go(the(younger-waiter))}\&\textbf{look(the-old-man}, \textbf{the(man))}\&\textbf{go(the(waiter))}\|$

$\quad = \{<e,e'>|$ there are e'', e''' such that $<e,e''>\in \|\textbf{go(the(younger-waiter))}\|$

$\qquad$ and $<e'',e'''>\in \|\textbf{look(the-old-man}, \textbf{the(man))}\|$ and $<e''',e'>\in \|\textbf{go(the(waiter))}\|\}$

$\quad = \{<e,e'>|$ there are e'', e''' such that $<e,e''>\in \{<e,e'>| e'=e^{\|\textbf{youger-waiter, waiter, man}\|}$

$\qquad$ and $e'(\|\textbf{younger-waiter}\|)\in \|\textbf{go}\|\}$ and $<e'',e'''>\in \{<e,e'>| e=e'$

$\qquad$ and $<e'(\|\textbf{the-old-man}\|), e'(\|\textbf{man}\|)>\in \|\textbf{look}\|\}$

$\qquad$ and $<e''',e'>\in \{<e,e'>| e'(\|\textbf{waiter}\|)\in \|\textbf{go}\|\}\}$

$\quad = \{<e,e'>| e'=e^{\|\textbf{youger-waiter, waiter, man}\|}$ and $e'(\|\textbf{younger-waiter}\|)\in \|\textbf{go}\|$

$\qquad$ and $<e'(\|\textbf{the-old-man}\|), e'(\|\textbf{man}\|)>\in \|\textbf{look}\|$ and $e'(\|\textbf{waiter}\|)\in \|\textbf{go}\|\}$

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