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Choice Functions and the Anaphoric Semantics of Definite NPs

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Abstract. This article argues that definite NPs are interpreted depending on *contextual salience*, rather than on the uniqueness condition of their descriptive content. The salience structure is semantically reconstructed by a global choice function that assigns to each set one (most salient) element. It is dynamically modified by the context change potential of indefinite *and* definite NPs. The anaphoric potential of definite NPs can be accounted for by the interaction of the context change potential and contextual salience structure.

Key words: anaphora, choice functions, context change, contextual salience, definite NPs, semantics

1. Introduction

Since Russell's (1905) seminal paper on definite descriptions, definite NPs are interpreted as complex quantifiers that determine their referents by the uniqueness of their descriptive content. This semantic representation has not been changed, even though recent theories have developed new ways of analyzing the semantics of indefinite NPs, such as using choice functions or assigning context change potentials to indefinite NPs.

Choice functions are commonly used for representing indefinite NPs in LF for reasons of scope behavior, while definite NPs are analyzed according to Russell's classical theory. This view, however, is restricted to sentence semantics and, therefore, assumes static meanings of definite and indefinite NPs. Once we extend our analysis to (small fragments of) discourses, the picture changes dramatically – indefinite expressions receive a context change potential, while anaphoric definite expressions must be interpreted according to the updated context. This is the approach of dynamic semantics, such as File Changes Semantics, Discourse Representation Theory, or Dynamic Predicate Logic. Despite the "dynamic turn", definite descriptions aren't given interesting context change potentials. All dynamic theories give Russellian treatments of definite descriptions, which requires that the descriptive content determines uniqueness in a model. This won't work and

we need to get an account of definite descriptions which is consistent with non-uniqueness in a world but uniqueness within a (fine-grained) discourse context.

This paper extends a dynamic theory by a choice function approach for definite and indefinite NPs. Thus we will restore the parallelism between definite and indefnite NPs by analyzing both as having choice functions as their content and giving both similar (but distinct) context change potentials in terms of *contextual salience*. The motivation for such an extended semantic framework can be best illustrated by the discourse behaviour of definite descriptions as illustrated by Lewis.

1.1. Lewis's argument against Russellian uniqueness

Lewis (1979, p.179) shows that the Russellian view of definite NPs cannot account for the different reference of the two occurrences of the definite NP *the cat* in (1) (indices are inserted by the author):

(1) "the cat"
- i Imagine yourself with me as I write these words. In the room is **a cat**$_1$, Bruce$_1$,
- ii who has been making **himself**$_1$ very salient by dashing madly about.
- iii **He**$_1$ is the only cat in the room, or in sight, or in earshot.
- iv I start to speak to you:
- v The **cat**$_1$ is in the carton. **The cat**$_1$ will never meet **our other cat**$_2$,
- vi because **our other cat**$_2$ lives in New Zealand.
- vii **Our New Zealand cat**$_2$ lives with the Cresswells.
- viii And there **he**$_2$'ll stay, because Miriam would be sad if **the cat**$_2$ went away.

What is important to notice here is that this narrative contains two occurrences of the NP *the cat* which have different denotations. The situation being presented contains two individuals with the property of being a cat. While the first occurrence of the definite NP *the cat* in (1i) and in (1v) might be felicitously interpreted by a Russellian definite description, the last occurrence of the definite NP *the cat* in (1viii) shows that this cannot be the correct analysis. Still, the phrase occurs felicitously and refers to the second cat. Intuitively, this reference to the second cat is licensed by the fact that the second cat was introduced by the phrase *our other cat* and then made salient by talking about this second cat in (1vii–viii). The referent of the definite NP *the cat* is uniquely identifiable because it is the most salient cat, and not because it is the unique cat. Salience is understood as a property of the discourse that gives us for each set one (most salient) element of that set, rather than just a relation between discourse referents. Salience is not just created by talking about a certain individual, but by using definite NPs, and

the descriptive material of these definite NPs change the salience structure of the discourse.

We can account for the different denotations of the two occurrences of *the cat* in (1) by assuming the following context changes: The indefinite NP *a cat* in (1i) updates the context such that the subsequent term *he* in (1iii) and *the cat* in (1v) refer to that cat (let's call him Bruce). The second cat, let's call him Bobby, is introduced by the context change associated with the phrase *our other cat*. This new salient cat is available for further reference by the definite term *our New Zealand cat* in (1vii), which updates the context again: it makes the cat Bobby the most salient New Zealand cat, the most salient cat and the most salient (male) individual. Therefore, the definite pronoun *he* and the definite NP *the cat* in (1viii) refer to that cat Bobby in virtue of the assumption that they refer to the most salient object which meets their descriptive content.

1.2. Structure of the argument

In the analysis presented below, both definite and indefinite descriptions will be interpreted via choice functions. Their analyses will differ in three important respects, however. First, indefinite NPs are represented by local or "minimalized" choice functions, while definite NPs are represented by global choice functions. Second, each indefinite NP introduces a new local choice function, while all definites are interpreted according to one global choice function. Third, the local choice functions for indefinite NPs are static, while the global choice function for definite is dynamic, i.e. it is updated in the discourse.

The values of all definite descriptions can be determined by a single choice function which is defined for many predicates. This single choice function serves simultaneously as a model of discourse salience and insures that the context-change potentials of all types of descriptions interact with each other. In this way, the global choice function can serve some of the functions that assignment functions do in other dynamic accounts. This global choice function as a contextual parameter is one principal innovation of this analysis. It is supplied from a global parameter of discourse. Thus definite NPs appear to take widest possible scope, rather than showing the interaction with other operators typical of the local choice functions which interpret indefinites. As a part of discourse context, the global choice function which fixes the interpretations of definite descriptions will be updatable. We discuss the context change potentials of all types of descriptions in terms of their update to the structure of salience in the discourse. A second principal innovation of this paper is to the context change potential of definite descriptions.

The paper is organized as follows: In section 2, I argue that we need global choice functions for the representation and interpretation of definite NPs. Definite NPs can only be interpreted according to the salience structure provided by the context. A global choice function stands for this salience structure. In section 3, I present some arguments for the use of local choice functions for indefinite NPs. These choice functions are only defined for the predicate by which they are locally introduced. This kind of choice function is discussed in the recent literature on choice function in natural language semantics. Furthermore, I motivate the assumption that both definite and indefinite NPs have the same context change potential. In section 4, I present a dynamic semantics based upon global choice functions and update functions of indefinite NPs, following Peregrin and von Heusinger (1995, 2004). In section 5, I extend this dynamic semantics by introducing update functions for definite NPs as well, which allows us to capture the semantics of anaphoric definite NPs.

2. Definite NPs and Global Choice Functions

2.1. The concept of salience

The concept of salience was introduced into the discussion of the semantics of definite NPs in the seventies (Lewis 1970, 1979). Lewis (1979, p. 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, p. 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.

In the following, salience assigned in a particular discourse context is assigned to one object relative to each set (or to each predicate).[1] The object so designated is the most salient or most prominent object of the extension of the predicate. We can therefore speak of 'the most salient *F*' in the context.

The present approach treats salience as a primitive which will not be analyzed further. The idea of salience was often criticized because of its pragmatic nature (cf. Heim 1982), however, an explicit formal account of salience and Lewis "prominent-object coordinate" was never seriously attempted, even though there are many different approaches towards the concept of salience [e.g. Sgall 1984 or Poesio and Stevenson (to appear)].

Here we propose to follow Lewis's salience solution to the problem posed above by the multiple cats by treating definite descriptions as terms, implementing a choice function analysis with epsilon operators.

2.2. Syntax and semantics of Hilbert's epsilon operator

The epsilon operator corresponds to a selection function that assigns to each non-empty set one element of this set.[2] Like the iota operator, the epsilon operator forms a term (constant) from a sentential form. Unlike the iota operator, it carries with it no existence or uniqueness presupposition as a condition of its reference. This is the key to solving Lewis's multiple cat problem. The main difference may be shown by the formalization and the paraphrase of the description *the island*, as given in (2) and (3):

(2) ιx [island(x)] the **unique** x, such that x is an island
(3) εx [island(x)] the **selected** x, such that x is an island

To introduce epsilon terms into a first-order predicate logic, we will adopt the axiom (4) by Hilbert and Bernays (1939, p.15), which they call the *epsilon formula*. From each formula of the form *Fa*, we can go directly to the corresponding formula F(εx [Fx]). The only new constant that has to be introduced is the symbol ε

(4) epsilon formula: Fa $\rightarrow$ FεxFx

Hilbert and Bernays did not give a semantic interpretation of their epsilon symbol, leaving this task for others. Schröter (1956) proposed interpreting the epsilon operator by a choice function. Asser (1957) then formulated this idea with the necessary detail. Following Asser we will interpret the epsilon operator by a (partial) choice function Φ, which assigns one of its elements to each set.[3]

We assume that models are pairs $\langle D, I\rangle = M$ with the domain of discourse D, an intepretation I of the constants. Denotations of expressions in the model are assigned relative to an assignment g of individuals to the variables as usual and in addition relative to a choice function Φ. The interpretation of an epsilon term $\varepsilon x\ \alpha$ is given by the following rule: $\|\varepsilon \mathrm{x}\ \alpha\|^{M,g,\Phi} = \Phi(\mathrm{s})$, where s is the set of individuals $\{a : \|\alpha\|^{\mathrm{M,g^{x/a}}} = 1\}$. An epsilon term is interpreted by applying the choice function Φ to the set of elements with the property $\lambda x\, \alpha$.

(5) $\|\varepsilon \mathrm{x}\ \alpha\|^{\mathrm{M,g},\Phi} = \Phi(\{a\colon \|\alpha\|^{\mathrm{M,g^{x/a}}} = 1\})$

To illustrate this, let us assume a domain of discourse, called "Lake Constance", and three objects in this domain, called "Mainau", "Reichenau", and "Lindau". All three individuals have the property of being an island. Let Φ be the choice function that assigns an arbitrary individual to the set of islands.

(6) $\Phi(\{\text{Mainau, Reichenau, Lindau}\}) \in \{\text{Mainau, Reichenau, Lindau}\}$

We only know that this element must be in the set of islands, but we do not know which island it is. This observation is often taken as argument for the "indefinite" character of epsilon terms, thus interpreting them as representing indefinite NPs. It is true that in the original epsilon theory, the choice of an element is arbitrary, but once the choice is made it is fixed for all subsequent expressions, which is the "definite" aspect of the classical epsilon calculus. This very general characterization makes epsilon terms and choice functions as their interpretations an attractive and flexible semantic tool that can reconstruct different linguistic categories. The operation of selecting one element out of a set (i.e. assigning one of its elements to a set) is common to all uses of the epsilon operator. This function very well captures the basic semantics of definite and indefinite NPs in their guise as terms. It corresponds to the assumptions of traditional grammar that the definite and indefinite article have an "individualizing" function. In order to distinguish between indefinite and definite NPs, we must modify the classical calculus.[4]

2.3. Context dependent epsilon terms

Since Hilbert applied his classical 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. Egli (1991) approaches this problem by assuming a family of choice functions for representing definite NPs. Each context c has its own choice function Φ_C and the definite NP *the F* is represented as the epsilon term $\varepsilon x\ Fx\ (in\ the\ context\ c)$, 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 "uniqueness commitment" of a definite NP is not understood as the uniqueness of the associated set, but as the "unique availability" of the referent (cf. Peregrin 2000). This is warranted by the definition of the choice function, which assigns one element to a set, independently of the size of this set.

Let us illustrate this point with our model "Lake Constance"; the property *island* is common to three objects: Mainau, Reichenau, and Lindau. The definite description *the island* is represented as the epsilon term $\varepsilon x\ [island]$. It

denotes different islands according to different situations. If we hear the expression from a Reichenau fisherman, he probably means the island Reichenau; if we encounter the same sentence during a guided tour through Lindau it will rather be the island Lindau that is meant; however, uttered by the Earl, owner and occasional inhabitant of Mainau, the sentence is sure to be about the island Mainau. We can assign one choice function Φ_c to each of these situations, representing the salience structure of that particular context c.

(7) *the island*
(8) $\|\varepsilon x\ [\text{island}]\|^{M,g,\Phi^{\text{fisherman}}} = \text{Reichenau}$
(9) $\|\varepsilon x\ [\text{island}]\|^{M,g,\Phi^{\text{tourist-guide}}} = \text{Lindau}$
(10) $\|\varepsilon x\ [\text{island}]\|^{M,g,\Phi^{\text{earl}}} = \text{Mainau}$

Thus we can conclude that the most appropriate representation for a definite NP *the F* is the epsilon term $\varepsilon x\ Fx$, which denotes that individual with the property F that is selected in a situation c, as in (11):

(11) the F: $\|\varepsilon x\ \text{Fx}\|^{M,g,\Phi_c} = \Phi_c(\|F\|^{M,g,\Phi_c})$

To summarize: We represent definite NPs by epsilon terms which are interpreted by a global choice function representing the salience structure of the discourse. Thus we subsume the anaphoric use under the situational or salience use of definite NPs. Uniqueness is understood as "unique availability" of the referent rather than as a requirement that the corresponding descriptive material have a singleton set.

3. Indefinite NPs and Local Choice Functions

Recent work in linguistic semantics has explored the analysis of indefinites as terms rather than quantifier phrases as a response to concerns about constraining scope construal and systematic ambiguity of type. In this section I will add two further observations about the semantics of indefinites: First, the observation that indefinite NPs often behave like terms, and second the observation that indefinites and definites behave very similar with respect to their context change potential.

3.1. Choice functions and movement

One of the most celebrated arguments for using choice functions rather than existential quantifiers is based on a conflict between three principles of LF-representation: (i) scope ambiguities are reconstructed by movement, (ii) indefinite NPs are represented as existential quantifier phrases, and (iii) there are scope islands such as that-clauses. Fodor and Sag (1982) observe that (specific) indefinite NPs do not obey scope islands, as illustrated in (12b). Sentence (12) can receive a reading where the indefinite NP *a student* receives

wide scope over *the rumor* while the universal term *each student* in (13) cannot since the that-clause constitutes a scope island for quantifier phrases.

(12) John overheard the rumor that a student of mine had been called before the dean.
(12a) the rumor > there is a student
(12b) a certain student > the rumor
(13) John overheard the rumor that each student of mine had been called before the dean.
(13a) the rumor > each student
(13b) *each student > the rumor

One way to account for this ''exceptional'' scope behaviour is to assume that the indefinite is interpreted by a choice function. This can be illustrated on the example (14), where the indefinite NP *a girl* is represented by *f*(*girl*) with f being a choice function: *ch*(*f*)(cf. Reinhart, 1992; Winter, 1997; Kratzer, 1998; von Stechow, 2000; among others).

(14) Every boy dates a girl.
(14a) $\forall x$ [boy(x) $\rightarrow \exists$ f [ch(f) & date (x, f(girl))]]
(14b) $\exists$f [ch(f) & $\forall x$ [boy(x) $\rightarrow$ date (x, f(girl))]]

The two readings of the example (14) are represented both with the indefinite *in situ,* while the existential binder of the choice function variable *f* appears at different locations resulting in the narrow scope reading (14a) and the wide scope reading (14b).[5]

3.2. Indexed epsilon terms

Egli (1991), Egli and von Heusinger (1995), Meyer-Viol (1995), von Heusinger (2000) argue that indefinite NPs often behave like terms. Therefore, they represent indefinite NPs as epsilon terms, rather than as quantifier phrases. Epsilon terms reconstruct the assumption that the indefinite article ''picks up''one element of the set which is formed by all elements that fit the description in the NP. Thus an indefinite NP is of type *e*, rather than of the quantifier type ((et)t). This assumption about ''selecting one element'' is reconstructed by the interpretation of the epsilon operator by a choice function, which takes a set and yields an element of this set, as we have seen above. Other than definite NPs, each indefinite NP introduces a new choice function. This is represented in this framework by indexed epsilon terms which are interpreted by different choice functions, which are only defined for the descriptive content of the indefinite NP by which they are introduced. In contrast, all definite NPs are interpreted according to the one global choice function which stands for the salience structure of the context. This can be formalized as in (11), repeated as (15), and in (16):

(15) the F: $\|\varepsilon x\ Fx\|^{M,g,\Phi_c} = \Phi_c(\|F\|^{M,g,\Phi_c})$
(16) an F: $\|\varepsilon_i x\ Fx\|^{M,g,\Phi_c}$ = there is an Φ_i such that $\Phi_i(\|F\|^{M,g,\Phi_c})$

Here it also becomes obvious that the choice function for indefinites need not be defined for all sets, but only for the set that is associated with the descriptive material of the indefinite, thus we speak of ''minimalized'' or ''local'' choice functions.

To sum up: definite and indefinite NPs can be both represented by epsilon terms, which are interpreted by choice functions. They differ in that definite NPs are interpreted by the global choice function representing the salience structure, while indefinite NPs are interpreted by local and ''minimalized'' choice functions. Thus we use choice functions in two ways in representing definite and indefinite NPs.

3.3. Context change potential of definite and indefinite NPs

Definite and indefinite NPs exhibit another interesting common property: Their context change potential is identical, as it can be illustrated at the following examples. The anaphoric definite NP *the donkey* in the second sentence of (17) and (18) refers to its antecedent *a donkey* and *the donkey* in the same way.

(17) John owns *a donkey*. He beats *the donkey*.
(18) John owns *the donkey*. He beats *the donkey*.

The indefinite NP *a donkey* in (17) updates the given salience structure in such a way that the subsequent *the donkey* refers to the same object thus establishing the anaphoric reference by coreference. One could say that the indefinite updates the salience structure while the definite does not (since it already refers to the most salient donkey). Both definite NPs *the donkey* in (18) refer just to the same individual due to the uniqueness condition. However, in the presented theory, both definite NPs refer to the same individual due to the salience structure and establish coreference due to the same contextual parameters.

The structure of the contextual salience allows to account for coreference in examples (19) and (20) and illustrate an additional observation. Intuitively, in (19) the indefinite NP *a donkey* refers to a particular donkey that not only becomes the most salient donkey but also the most salient animal. This means that the indefinite not only updates the global choice function for the set that corresponds to the descriptive material by which it is introduced but also for some supersets of it. This also holds of definite NPs: *the donkey* in (20) not only (trivially) updates the global choice function for the set of donkey but also for some supersets (such as animals).

(19) John owns *a donkey*. He beats *the animal*.

(20) John owns *the donkey*. He beats *the animal*.

Therefore, I assume that both definite and indefinite NPs have the same context change potential (even though in simple cases it is invisible for definite NPs).

4. Dynamic Semantics with Choice Functions

Dynamic semantic theories like Discourse Representation Theory (DRT) (Kamp, 1981; Heim, 1982) or Dynamic Predicate Logic (DPL) (Groenendijk and Stokhof, 1991) take the following stand on the context dependent nature of interpretation. They assume that the meaning of a sentence is identified with its context change potential. Contexts are taken to be information states. Meanings are updates of such information states and interpretation of sentences creates context. Information states contain two kinds of information: information about the world, and discourse information. The information about the world is relevant for the truth conditions, while the information about the discourse restricts anaphoric relations. However, dynamic semantic theories only provide sets of accessible discourse referents, but no further ranking among them.

In a dynamic semantics with choice functions, the information states are sets of choice functions, rather than sets of assignment functions as in ordinary dynamic semantics. The discourse meaning of linguistic expressions (not only sentences) updates this information, which means that it potentially restricts the set of (possible) choice functions, which stand for the (possible) discourse structures. Here we model the discourse information of information states at an additional dynamic mechanism, which will developed below.[6]

4.1. The problem of coindexing

Dynamic approaches like Discourse Representation Theory (DRT) or Dynamic Predicate Logic (DPL) primarily investigate cross-sentential anaphoric pronouns. There is one problem of these approaches, which can be illustrated with our initial example (1): the pronoun *he* in line (viii) has two potential antecedents or already established discourse referents: the discourse referent for the cat Bruce and the discourse referent for the New Zealand cat Bobby. DRT cannot tell which is the more appropriate one, but must rely on additional knowledge, which is indicated by co-indexing the anaphoric term with its antecedent. However, it is the anaphoric relation that the theory should explain and not rely on.

(1) ''the cat''
 i Imagine yourself with me as I write these words. In the room is **a cat**$_1$, Bruce$_1$,
 ii who has been making **himself**$_1$ very salient by dashing madly about.

iii **He$_1$** is the only cat in the room, or in sight, or in earshot.
iv I start to speak to you:
v The **cat$_1$** is in the carton. **The cat$_1$** will never meet **our other cat$_2$**,
vi because **our other cat$_2$** lives in New Zealand.
vii **Our New Zealand cat$_2$** lives with the Cresswells.
viii And there **he$_2$**'ll stay, because Miriam would be sad if **the cat$_2$** went away.

It seems very obvious from the discourse structure that the pronoun *he* can only refer to the New Zealand cat Bobby and therefore must be linked to that discourse referent. Therefore, I assume that the anaphoric link should follow from the theory and not be part of the input. This restriction of dynamic theories like DRT and DPL is described by Muskens and et al (1997, p. 606):

> Discourse Representation Theory models the way in which anaphoric elements can pick up accessible discourse referents, it tells us which referents are accessible at any given point of discourse, but it tells us little about the question which referent must be chosen if more than one of them is accessible. There are of course obvious linguistic clues that restrict the range of suitable antecedents for any given anaphoric element (...).

In the following we will concentrate on the information that is supplied by the descriptive material of definite and indefinite NPs, which updates the salience structure of the discourse. And the salience structure crucially contributes to the interpretation of definite anaphoric expressions. Peregrin and von Heusinger (1995, 2004) developed a dynamic semantics with choice functions in order to modell this linguistic information that is relevant for resolving the anaphoric reference. The context change potential of an expression is seen in its potential to update the global choice functions in the sense of section 2 consistent with discourse. The dynamic semantics with choice function is an extension of classical DPL: the dynamism of the salience structure is modeled in parallel to the information states that encodes the increasing information of the discourse.[7] In the following we concentrate on the context change potential. The context change potential of definite and indefinite expressions updates the context by changing the (global) choice function Φ_c. An indefinite NP introduces a discourse referent, which then becomes then the most salient of its kind. Hence, the global choice function is updated with respect to the set described by the indefinite. This set is assigned the referent of the indefinite. A definite NP refers to the most salient of its kind. The context change potential is generalized and therefore represented as a relation between two (potential) global choice functions.

4.2. Choice functions and dynamic interpretation

In the remainder of this section I present the dynamic choice functions approach of Peregrin and von Heusinger (1995, 2004): let us assume the non-empty universe U of individuals. A choice function (or "epsilon function" in Peregrin and von Heusinger) f is a partial function from the power-set of U into U such that f(s) $\in$ s for every s $\subseteq$ U for which f is defined. This means that the class CH_U of all choice functions based on U is defined as follows (where D(f) and R(f) denote the domain and the range of f, respectively):

$$\text{DEF1 } CH_U = \{f | D(f) \subseteq \text{Pow}(U) \text{ and } R(f) \subseteq U \text{ and } f(s) \in s \text{ for every } s \in D(f)\}$$

We further introduce update functions for choice functions, or choice function (cf-) updates in short. A cf-update is an operation that takes three arguments: a choice function, an element of the universe, and a subset of the universe; it yields a new choice function. The basic cf-update upd_1 applied to an choice function f, an individual d, and a set s, yields the choice function f′ which is identical with f except for the assignment d for the set s.

DEF2 upd_1 is defined as follows

$$upd_1(f,d,s) = f' \text{ such that } \quad f'(s') = d \text{ if } s' = s \text{ and } d \in s$$
$$\text{and} \quad f'(s') = f(s') \text{ otherwise}$$

We use $f' \approx f^s$ as an abbreviation for $\exists d.f' = upd_1(f,d,s)$.[8] If $f_2 \approx f_1^s$ and $f_3 \approx f_2^{s'}$, then we also write $f_3 \approx f_1^{s,s'}$. Thus upd_1 can be seen as the first approximation to the salience change potential of an indefinite NP. The indefinite NP *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. We do without quantifiers, since they play no role in the argument. However, for a detailed treatment of quantifiers in this framework see Peregrin and von Heusinger (1995, 2004).

DEF3a. (lexicon)

1. sentences
2. terms (**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; **&, v** for n=2)

In the syntax DEF3b we first define the operation of forming a term *D(P)* with a determiner *D* (i.e. with the definite or indefinite article) and an open sentence *P*. Here we differ from other dynamic approaches, which interprete definite and indefinite NPs as quantifier phrases. The other clauses are as in other dynamic frameworks, they determine the construction of an atomic sentence in (2) and of complex sentences in (3) and (4):

DEF3b. (syntax)
1. If P is a unary predicate and D a determiner, then D(P) is a term.
2. if $T_1, \ldots, T_n$ are terms and R an n-ary predicate, then $R(T_1, \ldots, T_n)$ 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 $S_1 o S_2$ is a sentence.

DEF3c recalls the static interpretation of terms we have used in section 3. A term is interpreted in a model that consits of a domain *U* and an interpretation functions *I* and according to a choice function f. The interpretation of a constant term (such as proper names) does not depend on the choice function *f,* while the interpretation of a complex term of the type *D(P)* crucially depends on the given choice function, as in 1b. Here *he, she, it, the* P and *a* P play the role of variables: they do not have a lexical meaning but only a meaning relative to the contextual choice function. The rule 2 for predicate constants is as usual.

DEF3c. (static semantics)
A model is a pair $\langle U, I| \rangle$, where U is a non-empty set and I is a function such that

1a. $\|T\|^{M,f} = I(T)$ if T is a constant term
1b. $\|T\|^{M,f} = f(\|P\|)$ if T is D(P) for a determiner D and a predicate P
2. $\|R\|^{M,f} = I(R) \subseteq U^n$ if R is an n-ary predicate

This static semantics determines the interpretation of terms, but does not show the update function of linguistic expressions. In order to model the context change potential of linguistic expression we have to assume that meaning is an update of information states. As noticed above, information states contain knowledge about the world and information about the discourse. In the following we are only concerned with information about the discourse, in particular with the salience structure of the discourse. We assume that the (discourse) meaning of linguistic expressions is their update function of choice functions (which stand for the salience structure). Information states can be modeled as sets of choice functions that are potentially changed by the salience change potential of the linguistic expression. We therefore define the dynamic semantics in the following way: The function $\| \ \|$

is extended to the categories of terms and sentences so that if E is a term or a sentence, then $\|E\| \subseteq CHxCH$:

DEF3d. (dynamic semantics)
1a. $\|\mathbf{a}(P)\| = \{\langle f, f'\rangle | f' = f^{\|P\|}\}$
1b. $\|\mathbf{the}(P)\| = \{\langle f, f'\rangle | f' = f$ and $f'(\|P\|)$ is defined$\}$
1c. $\|\mathbf{he}\| = \|\mathbf{the}(\mathbf{man})\|$
1d. $\|\mathbf{she}\| = \|\mathbf{the}(\mathbf{woman})\|$
1e. $\|\mathbf{it}\| = \|\mathbf{the}(\mathbf{thing})\|$
2. $\|P(T_1, \ldots, T_n)\| = \{\langle f, f'\rangle |$ there exist $f_0, \ldots, f_n$ so that $f = f_0$ and $f' = f_n$ and $\langle f_0, f_1\rangle \in \|T_1\|$ and ... and $\langle f_{n-1}, f_n\rangle \in \|T_n\|$ and $\langle \|T_1\|_{f_1}, \ldots, \|T_n\|f_n\rangle \in \|P\|\}$
3. $\| \neg S\| = \{\langle f, f'\rangle | f = f'$ and there is no f'' such that $\langle f, f''\rangle \in \|S\|\}$
4a. $\|S_1 \& S_2\| = \{\langle f, f'\rangle |$ there is an f'' such that $\langle f, f''\rangle \in \|S_1\|$ and $\langle f'', f'\rangle \in \|S_2\|\} (= \|S_1; S_2\|)$
4b. $\|S_1 v S_2\| = \{\langle f, f'\rangle | f = f'$ and there is an f'' such that $\langle f, f''\rangle \in \|S_1\|$ or $\langle f, f''\rangle \in \|S_2\|\}$

The (discourse) meaning of an indefinite NP *a P* is an choice function update, i.e. it updates the input choice function f to the output choice function f′ (here "the input choice function" means "whatever choice function from the set of choice function is taken"). f′ differs from *f* at most in the assignment for the set of P, which is the denotation of the indefinite NP. We write $f^{\|P\|}$ for an f′ resulting from the evaluation of *a P* with the input f. Clause (1b) describes the salience change potential of definite NPs: A definite NP *the P* denotes the representative of the set of P's according to a choice function f; it is taken to express the trivial cf-update. Further, it is required that there be at least one P – this expresses the existential presupposition of definite NPs. There is no uniqueness condition, since it is replaced by the condition that there exists the representative of the set of P's. The pronouns in (1c-1e) are taken to be semantically equivalent to the impoverished definite NP expressing merely the corresponding gender.

The atomic sentence is semantically characterized in (2) via its potential to change the input choice function f to the updated function f′ by way of the subsequent application of the updates expressed by its terms. Thus, f and f′ must be connected by a sequence of choice 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 internally and externally dynamic.[9] The logical operators ¬ and v 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.

Let us illustrate this mechanism by analyzing a simple atomic sentence with an indefinite NP. Sentence (21) is assigned the formula (21a) which is then interpreted as (21b) according to the definitions given above. As we have noted, a pair of choice functions $\langle f, f' \rangle$ falls into the update expressed by an atomic sentence iff f and f′ are connected by a sequence of choice functions 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 (21), it is reduced to the condition that $\langle f, f' \rangle$ falls into the update expressed by *a(man)* and that the referent of *a(man)* falls into the extension of walk. This yields $f' = f^{\|man\|}$ and $f'(\|man\|) \in \|walk\|$. 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 non-empty) and our formula (21b) is thus in this sense equivalent to the classical formula $\exists$ x(man(x)&walk(x)).

(21) A man walks
(21a) walk(a(man))
(21b) $\|walk(a(man))\|$
$= \{\langle f, f' \rangle | \langle f, f' \rangle \in \|a(man)\| \text{ and } \|a(man)\|_{f'} \in \|walk\|\}$
$= \{\langle f, f' \rangle | f' = f\|man\| \text{ and } f'(\|man\|) \in \|walk\|\}$

Sentence (22) with the definite NP *the man* is represented and interpreted similarly to (21). The only difference is the condition on the choice function – the interpretation of the definite NP is static (in the formalism developed so far). The only condition is that the referent of the NP, determined by the current choice function, falls within the extension of the predicate. The difference between the definite and the indefinite NP thus lies in their different behaviors with respect to the choice function — the indefinite NP updates it, whereas the definite NP acts merely as a test.[10] In both cases, the referent of the NP is yielded by the input choice function

(22) The man whistles
(22a) whistle(the(man))
(22b) $\|whistle(the(man))\|$
$= \{\langle f, f' \rangle | \langle f, f' \rangle \in \|\rangle(man)\| \text{ and } \|the\ (man)\|f' \in \|whistle\|\}$
$= \{\langle f, f \rangle | f' = f'\|man\| \,\&\, f'(\|man\|) \in \|whistle\|\}$

The analysis of the conjunction (23) of (21) and (22) shows how the referent of the anaphoric NP the man gets identified with that of its antecedent a man.

(23) A man walks. And the man whistles
(23a) walk(a(man))&whistle(the(man))
(23b) $\|walk(a(man))\&whistle(the(man))\|$
$= \{\langle f,f' \rangle |$ there is an f″ such that $\langle f,f'' \rangle \in \|walk(a(man))\|$ and $\langle f'',f' \rangle \in \|whistle(the(man))\|\}$.

$= \{\langle f,f'\rangle |$ there is an f'' such that $\langle f,f''\rangle \in \{\langle f, f'\rangle |\ f' = f\|man\|$ and $f'(\|man\|) \in \|walk\|\}$ and $\langle f'',f'\rangle \in \{\langle f, f'\rangle |\ f = f'$ and $f'(\|man\|) \in \|whistle\|\}\}$

$= \{\langle f,f'\rangle |$ there is an f'' such that $f'' = f\|man\|$ and $f'(\|man\|) \in \|walk\|$ and $f'' = f'$ and $f'(\|man\|) \in \|whistle\|\}$

$= \{\langle f,f'\rangle |\ f' = f\|man\|$ and $f'(\|man\|) \in \|walk\|$ and $f'(\|man\|) \in \|whistle\|\}$

$\langle f,f'\rangle$ falls into the update expressed by (23b) if and only if there is an choice function f'' such that $\langle f,f''\rangle$ falls into the update expressed by (21b) and $\langle f'',f'\rangle$ falls into the update expressed by (22b). Using the results of the above analyses and eliminating redundancies, we reach the result that $\langle f,f'\rangle$ falls into the update expressed by (23b) iff f' differs from f at most in the representative of the class of men and this representative is a walker and a whistler.

5. The dynamics of definite descriptions

5.1. Projecting the salience change

Using this formalism, we can give a first analysis of the variety of anaphoric relations in (1) above. The meaning of the first sentence in (1i) – (1v) consists of the pairs of choice functions f and f' such that f' is like f with the single possible exception that f' chooses a new representative for the class of cats, namely Bruce. Furthermore, the chosen representative must be in the extension of the predicate be in the room. The definite expression the cat in (1v) then refers to this chosen individual, namely Bruce. Thus, the anaphoric relation is not explained in terms of binding or by means of a Russellian description, but rather in the interaction of the context change potential of the antecedent together with the context dependent interpretation of the anaphoric term. However, this basic picture can only account for the anaphoric link between *a cat* and *the cat*, but not for the anaphoric link between *a cat* and *he* in (1iii) or the anaphoric link between *our New Zealand cat* in (vii) and *the cat* in (viii):

In order to account for an anaphoric relation between the indefinite NP *a cat* and the pronoun *he*, Peregrin and von Heusinger (1995, 2004) modify definition DEF 2 to DEF 2′. An indefinite NP *an F* does not only change the representative of the class of Fs, but also the representative of (certain) supersets. Hence, the anaphoric expressions *he* (as short for *the (male) object*) refers back to the mentioned representative.

DEF2 upd_1 is defined as follows

$$\text{upd}_1(f,d,s) = f' \text{ such that } \quad f'(s') = d \text{ if } s' \subseteq s \text{ and } d \in s$$
$$\text{and} \quad f'(s') = f(s') \text{ otherwise}$$

This modificaton can not only handle the coreference between a pronoun and its antecedent, but also between an anaphoric definite NP and its antecedent if the antecendent is more specific, such as in (24) and (25):

(24) John is looking at a collie. The dog barks.
(25) John is looking at a small white dog. The dog barks.

Still, this modification does not explain the anaphoric link between the definite NP *our New Zealand cat* and the definite NP *the cat*. An even more flexible account of salience change potential is necessary.

5.2. The dynamics of definite descriptions

Lewis' example ''the cat'' illustrates that different occurrences of the definite NP *the cat* can refer to different referents, contrary to the classical assumption of Russell, which are also held in contemporary theories. The example rather shows that the context can change in a way that the second occurrence of the cat refers to a different object. The question I address in this subsection is what the contribution of other definite NPs to this context change is – we have already seen that an indefinite changes or updates an input choice function. Before we analyze the context change potential of a definite NP, I present another text in which we have more than one occurrence of one definite NP with different referents. The fragment is from the short novel ''A clean, well-lighted place'' from Ernest Hemingway ([1925] 1966, p. 379):

(26) **A clean, well-lighted place**
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 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.

In this fragment the two occurrences of the definite NP *the waiter* refer to different waiters – both refer to the last mentioned one. We can then extract the following anaphoric chains from this example:

(27) Anaphoric chains of definite NPs in (26)
the younger waiter ... him ... the waiter
the waiter who was in hurry.... he ... the waiter

It is obvious that the definite NP *the younger waiter* changes the context in a way that its referent is not only the most salient younger waiter (trivially), but also that its referent is the most salient waiter (at all). In order to implement this, we change the interpretation rule for the definite NP (1b) to (1b') by accommodating it to the one of indefinite NPs (1a) – the original rules are repeated below:

1a. $\|\mathbf{a}(P)\|=\{\langle f,f'\rangle \mid f'=f^{\|p\|}\}$
1b. $\|\mathbf{the}(P)\|=\{\langle f,f'\rangle \mid f'=f \text{ and } f'(\|P\|) \text{ is defined}\}$
1b′. $\|\mathbf{the}(P)\|=\{\langle f,f'\rangle \mid f'=f^{\|p\|}\}$

In the original rule (1b), the definite character of the NP was warranted by its static (i.e. non-updating) behavior, while in the new interpretation rule the definite NPs is also assigned an update function. However, this update function can only change the context if we allow for the more flexible updating function DEF2′, otherwise it would trivially update the given global choice function only for the set associated with the descriptive material. This rule makes the definite and indefinite article synonymous with respect to their discourse meaning, i.e. to the salience change potential. This matches the intuition that both definite and indefinite NPs change the salience structure.

The difference between an indefinite and a definite NP is not the dynamic vs. static behavior, but the way they find their referents. An indefinite NP refers to an arbitrarily selected element (by way of an existential quantifier or by a local choice functions), while a definite NP refers to its referents due to the global choice function (standing for the salience structure of a discourse). With these two modifications of the original dynamic semantics with choice functions, we can account for the example (1) of Lewis, the fragment from Hemingway (26) and many more natural language discourses with more than one occurrence of one and the same definite NP.

6. Summary

It was shown that definite descriptions exhibit two functions: (i) they are interpreted depending on the context and establish in this way anaphoric links by coreference, (ii) they change the context by raising new referents to the most salient ones for the set they describe as well as some supersets. Furthermore, it was argued that the most appropriate representation for definite descriptions are context dependent global choice function terms. These terms refer to the most salient object of the class of objects that fall under the descriptions and the referent of the term becomes the most salient element of the set, as well as some supersets. Indefinites are represented by local choice functions. Both NPs change the context by updating the global choice function, which represents the salience structure of the discourse.

Notes

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[1] In the remainder of this paper I discuss choice functions that take sets as their arguments, rather then predicates. This approach has to be modified to choice functions that take predicates in order to get a more adequate picture.

[2] Hilbert's original proposal assumed that the selection function was total and assigned an arbitrary object to the empty set. In this paper, I assume that the choice function which represents the global salience parameter is a partial function, excluding the empty set from its domain. For the purposes of modeling salience, partial choice functions are more intuitive. I will continue to use the epsilon operator to highlight the parallel treatment of indefinite and definite descriptions in our analysis.

[3] Partial choice functions will do for the reconstruction of the semantic behavior of definite and indefinite NPs. If we would use total choice functions we have to take care of the "empty set problem" (see Winter, 1997). There are several possible solution for this problem (see Asser, 1957).

[4] Slater (1986) uses the classical epsilon calculus in order to describe E-type pronouns. He substitutes the iota-operator by the epsilon-operator and can therefore avoid the problematic uniqueness condition of the iota-term. Meyer-Viol (1995) develops such full epsilon calculus and applies it to semantic problems such as E-type and Bach-Peter pronouns. A variant of Meyer-Viol's calculus is used in Dynamic Syntax (e.g. Kempson et al. 2000; Kempson & Meyer-Viol, 2003).

[5] Kratzer argues that the choice function variables remain free at LF and that the context specifies their values. This makes the choice functions for indefinites similar to the global choice function we have employed for definite NPs. This reflects Kratzer's view that choice functions represent specific indefinites, i.e. indefinites that have some characteristics of definite expressions such as their wide scope. However, Kratzer's choice functions still differ considerably from the global choice functions for definite NP. They are only defined for the set by which they are introduced ("minimalized" choice functions), each indefinite introduces a new choice function variable, and their referent must not be mentioned in the discourse before (novelty condition).

[6] The original idea was developed in Egli and von Heusinger (1995) and formalized in Peregrin and von Heusinger (1995, 2003). Groenendijk et al. (1997) discuss this idea in detail and compare it with their own version of DPL.

[7] We need two levels of dynamic procedure: The one that keeps track of the (denotational) information in the discourse, and the other that models the salience structure. While the denotational component is montone increasing, the structural component is not. See also for a similar distinction von Heusinger (1997, chapt. 8).

[8] Here it is assumed that the referent for the indefinite is found by interpreting the indefinite as an existential operator (at least at the meta-language). This corresponds to the classical approach to indefinites. According to the choice function approach of section 3, we can modify this by saying that the referent is found by applying a local choice function to the set described by the descriptive material of the NP. For the argument in this section this does not make any difference, since we do not deal with scope interactions. Thus, in the remainder of the section

we use the classical view. However, for a more comprehensive account one would like to follow the indexed epsilon approach.

[9] Since each of the arguments of an atomic sentence potentially updates the given choice function, we have to account for different interpretations of one sentence depending on the order of its arguments.

[10] At this stage a context change potential of a definite NP would trivially update the given choice function – it would make the most salient referent most salient. See, however, section 5 for a revision of this position.

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