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ANAPHORA, ANTECEDENTS, AND ACCESSIBILITY*

In this paper I discuss the notion of accessibility in dynamic semantics and develop a refinement of the accessibility relation, which pays special attention to the description expressed in the anaphoric expression and the progression in a discourse. Anaphoric expressions are interpreted as referring to the most-accessible item of their kind. I employ choice functions as the formal means to represent this accessibility relation. Choice functions are functions that assign to a set one of its elements. This element represents the most-accessible of its kind in a particular discourse. Linguistic expressions do not only depend in their interpretation on the accessibility structure of a discourse, they also change this structure. The referent of an indefinite NP becomes the most-accessible item of its kind. This change of the accessibility is modeled by updates of choice functions at an additional level of meaning. It will be shown that this extended formalism yields not only a more adequate representation of discourses, but also solves the problem of how to establish anaphoric links and supplies a uniform representation of definite and indefinite expressions with respect to their potential to change the accessibility structure of the discourse.

1. Introduction

The concept of accessibility plays an important role in text coherence, in particular in the relation between antecedent and anaphoric term. The anaphoric term refers to an accessible entity that was introduced or activated

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by the antecedent. Several factors determine the accessibility structure of a discourse. In this paper, I investigate the aspect of accessibility that depends on the descriptive content of the expressions used in a sentence. I argue that accessibility is a function that assigns one element to the set of elements that fit the description by which a new discourse item is introduced. The global accessibility structure of a discourse consists in the conjunction of all these local accessibility structures. The global accessibility structure can be changed or updated by both definite and indefinite NPs.

In section 2, I present different aspects of accessibility such as the accessibility-property of the activated entity, the accessibility-relation between antecedent and anaphoric term, and the accessibility-structure of a discourse. I concentrate on the latter notion and compare the approach of Discourse Representation Theory with that of Centering Theory. Finally, I modify the purely structural approach to accessibility with respect to the descriptive material of the expression involved. In section 3, I develop a dynamic semantics that is characterized by the following three features: First, it represents definite and indefinite NPs not as quantifier phrases, but as terms. Their referential behavior is formally captured by a choice function, which assigns to a set one of its elements. Second, accessibility is analyzed as that aspect of discourse information that determines the reference of a definite expression. Therefore, discourse-dependent choice functions reconstruct the concept of accessibility developed here. Finally, changes in accessibility structure are reconstructed as updates of choice functions. In section 4, I extend the analysis of the change of accessibility given so far to definite NPs. It is shown that definite NPs do not only depend in their interpretation on accessibility, but they also change it. The formalism is modified to capture this behavior. Definite and indefinite NPs induce the same accessibility change potential reflecting the similarity of their semantic function.

2. Accessibility and Discourse

Accessibility is an often-used term in discourse analysis expressing different concepts. It may denote a property that is assigned to the referent of a referring expression, it may refer to a relation between a referring expression and its referent, or to a structural property of a discourse domain or segment. The first view is taken by Sgall et al. (1986) or Hajičová et al. (1995), who give an explicit algorithm to assign different grades of activation to referents in the shared knowledge. These assignments change with the progress of the

discourse. The second view is implicit in the hierarchies presented by Ariel (1990) and Gundel et al. (1993), which both go back to the work of Givón (1983). Ariel (1990: 73) proposes the Accessibility Marking Scale according to which the speaker selects an expression to refer to an accessible entity. If the entity is highly accessible, a pro-form or a pronoun is used, whereas definite NPs are employed for less accessible items. Accessibility is influenced by factors such as *distance*, *competition*, and *syntactic and discourse structure*. Gundel, Hedland & Zacharski (1993) present the Givenness Hierarchy, which orders referring expressions in a ranking with six statuses: *in focus*, *activated*, *familiar*, *uniquely identifiable*, *referential*, and *type referential*. The third view on accessibility as a structural property of discourse segments or domains is assumed by Discourse Representation Theory (DRT) and Centering Theory. In the remainder of this section, I compare DRT and Centering Theory and present a complementary proposal. The two approaches differ in whether accessibility is a gradable or non-gradable notion and whether it is applied to discourse domains or discourse segments. A discourse domain contains all expressions that have an equal relation to discourse domain creating operators like negation, modals or verbs of attitudes. Discourse domains are nested and represented as DRSs or boxes in DRT. Discourse segments, on the other hand, are suprasentential units of two or more connected sentences. They determine a local domain in which certain rules for pronominal reference are defined.

2.1 Accessibility in DRT

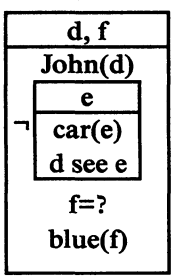
In DRT of Kamp & Reyle (1993), both indefinite and definite expressions introduce new discourse referents. The discourse referent of a definite or anaphoric expression must be identified with an already established discourse referent to meet the familiarity condition. Hence, the anaphoric relation is reconstructed as an identification of the new discourse referent with an accessible one. There are structural restrictions on the accessibility of discourse referents, which are encoded in the construction rules for DRSs. For instance, a discourse referent can only be linked to another one that is represented in the same discourse domain (or box) or in a superordinated one.

This is illustrated by the discourse representation structures (DRSs) (1a), (2a), and (3a) for the sentences (1), (2), and (3), respectively. The DRSs each represent the discourse structure of two sentences. Anaphoric pronouns introduce a new discourse referent, which must be identified with an already

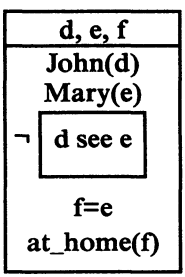
established one that is accessible (and that matches the gender of the pronoun). In (1a), the discourse referent *f*, which represents the pronoun *it*, cannot be identified with the discourse referent *e*, which represents the indefinite NP *a car*. The discourse referent *e* stands in the subordinated domain that is governed by the negation and, therefore, is not accessible for *f*. This discourse structure reconstructs the fact that the pronoun *it* cannot refer to the indefinite NP *a car* in (1). In contrast, the proper name *Mary* in (2) introduces a discourse referent *e* into the main domain of (2a), which is accessible for the pronoun *she*, explaining the possible link between the pronoun and the proper name in (2). In example (3), the discourse referent *f* for the first anaphoric pronoun *him* can access the discourse referent *d* for *a man* since it occurs inside the domain (or box) in which the discourse referent *d* for *a man* was introduced. However, the discourse referent *g* for the second anaphoric pronoun cannot access *d* because it occurs in the main domain, whereas *d* was introduced in the subordinated domain governed by the first negation.

(1) John does not see a car. *It is blue.
(2) John does not see Mary. She is at home.
(3) A man does not see a woman that does not see him. *She is proud.

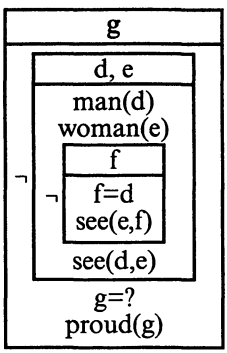
(1a)



(2a)



(3a)



The discourse referents form a set of accessible antecedents with respect to a discourse domain. We will confine the discussion on accessible referents to those in the main discourse domain (or the main box).[1] Accessibility in DRT is a non-gradable notion and a structural property of a discourse domain.

[1] Subordinated domains are always embedded in superordinated domains. The accessible discourse referents of a subordinated domains consists of the set of discourse referents introduced in this domain and all discourse referents introduced in the superordinated domains.

The problem is that there is no additional "fine-tuning" between different accessible discourse referents in the same domain, a fact already noted by Bosch (1988: 207):

> Although a limitation of the search to discourse domains is certainly a step in the right direction, and although the assumption of discourse domains seems useful also for a number of other purposes, they are still too large to serve as search spaces for reference resolution. It is highly implausible, for instance, that a personal pronoun like *she* should be interpretable unambiguously only in a discourse where precisely one woman has occurred.
>
> A more promising alternative is the notion of temporary salience of particular discourse referents and a corresponding dynamic salience structure or focus structure, which may or may not be superimposed on discourse domains.

2.2 *Accessibility in Centering Theory*

In Centering Theory, a complementary family of approaches to the representation of discourses (cf. Grosz et al. 1983; Grosz et al. 1995; Walker 1998), the discourse structure has three components: the linguistic structure, the intentional structure and the attentional state. The attentional state represents the availability of discourse referents at any given point in the discourse in form of an ordered set. According to Centering Theory, each utterance U_i in a coherent local sequence of utterances (a discourse segment) $U_1 \ldots U_m$ affects the structure of the discourse model in two ways. First, each utterance activates a set of discourse entities called Forward-looking centers, or $\{Cf\}$. The elements of this set are ordered according to factors such as grammatical roles in the sentence. Second, the set contains a marked element called the Backward-looking center, or *Cb*. The *Cb* connects the current utterance with the previous discourse. Centering Theory formulates constraints on the relation between the *Cf* and *Cb* expressing the local coherence between adjacent sentences. For instance, a lower-ranked element of *Cf* cannot be pronominalized unless the higher-ranked one is. This constraint is illustrated by the following example, where (4c) is a coherent continuations of (4a) and (4b), whereas (4d) is not a coherent one (Gordon et al. 1993: 313):

(4a) Susan gave Betsy a pet hamster.
$Cf = \{\text{Susan} > \text{Betsy} > \text{hamster}_1\}$

(4b) She reminded her such hamsters were quite shy.
$Cb = \text{Susan}$; $Cf = \{\text{Susan} > \text{Betsy} > \text{hamster}_1\}$

(4c) She asked Betsy whether she liked the gift.
Cb = Susan; Cf = {Susan > Betsy > gift = hamster$_1$}

(4d) Susan asked her whether she liked the gift.
Cb = Susan; Cf = {Susan > Betsy > gift = hamster$_1$}

The sentence (4a) creates the Forward-looking center *Cf*, i.e. the ordered set of accessible discourse items, {Susan > Betsy > hamster$_1$} according to the grammatical roles they occupy. In (4b) and (4c) the actual antecedent of the pronoun *she* is linked to the first element of the ordered set. In (4d) the most prominent item is realized by the proper name *Susan*, whereas the second prominent item is realized by the pronoun *she*. This violates the mentioned constraint that lower ranked elements can only be represented as pronouns if the higher one is a pronoun. This constraint accounts for the awkwardness of the sentence (4d).

Centering Theory assumes a fine-tuning among accessible discourse items, which is mirrored in the lexical choice of the anaphoric expression. The more accessible the referent is the less marked is the anaphoric expression.[2] This approach on the local coherence of discourse segments provides strategies for finding antecedents for anaphoric pronouns. However, it does not account for the antecedent of a definite NP, which depends on a global accessibility. Centering Theory distinguishes between local and global accessibility or focusing, but describe only the local interaction with pronouns, as pointed out by Gordon et al. (1993: 312):

> Two kinds of focusing were distinguished: global focusing and immediate focusing. It was claimed that global focusing affected the production and interpretation of definite descriptions, whereas immediate focusing affected the production and interpretation of pronouns.

Summarizing, DRT perceives accessibility as a function of the structure of a discourse domain (box) that yields a set of discourse referents. The structure is defined by the construction rules of DRSs. Expressions like negation or modals create subordinated domains and NPs like proper names and indefinites differ in whether they introduce their discourse referents in the current domain or in the main domain, reflecting the traditional concept of scope interaction. The set of accessible discourse referents constantly

[2] At this point, the structural view on accessibility of Centering Theory connects with the concept of accessibility of Sgall et al. (1986), and the relational view of Givón (1983), Ariel (1990) and Gundel et al. (1993). See Gundel (1998) for the distinction between Centering Theory and her Givenness Hierarchy.

increases in a progressive discourse forming sets of discourse referents with respect to discourse domains. However, there is no "competition" or ranking between different discourse referents in the same domain. Thus, accessibility is a non-gradable notion, i.e. a notion which either applies or not.

Centering theory, on the other hand, assumes that accessibility is a function of a discourse segment that yields an ordered set of discourse items, i.e. accessibility is a gradable notion: An element can be more or less accessible than another. Linguistic expressions introduce discourse items into the set and rank them. Subsequent expressions not only introduce new elements but also change the ranking. However, there are only constraints on pronominalization in local domains, and no rules for accessibility of anaphoric expression in general. Both approaches assume one set of accessible items for each discourse as a whole, which they describe in structural terms: DRT on scope interaction and Centering Theory on grammatical roles. However, they neglect the role of the descriptive content of the expressions by which the discourse items are introduced.

2.3 *Accessibility with respect to the descriptive content of NPs*

In the remainder of the paper I concentrate on the analysis of anaphoric NPs with descriptive material, i.e. definite anaphoric NPs, and argue that accessibility is not a function of a discourse as a whole that yields a unique set of accessible elements; accessibility is rather a function of the discourse with respect to a set of elements that fit a certain descriptive content. In this view, each set that corresponds to the descriptive material of a NP used so far, is assigned one item, which is the most accessible one. In order to distinguish this notion of accessibility from the gradable and non-gradable one, I call the accessible referent of a kind the "most-accessible" or the "uniquely accessible". The phenomena which are captured by this notion are illustrated by the discourse in (5) which has the schematic structure (5a) and the representation (5b). Two discourse referents d_n and d_k are introduced by two occurrences of the indefinite NP *a student*. The two discourse referents for the two occurrences of the anaphoric NP *the student* are unambiguously related to one of the two already introduced referents. However, in DRT there is no formal tool to decide why to identify the discourse referent d_l for the second definite NP *the student* with the discourse referent d_k standing for the second indefinite NP and not with d_m representing the first indefinite NP. In Centering Theory, there is no

principle to relate different occurrences of one definite NP to their indefinite counterparts.[3]

(5) The dean is very busy these days: This morning, a student complained about his exam. The dean had to talk to the student for more than two hours. Then a student came to talk about his neighbors, who play the trumpet every night. The dean moved the student to a different place.

(5a) P_1 (a student)...P_2 (the student)...P_3 (a student)...P_4 (the student)

(5b) $\{\ldots, d_n, \ldots, d_m, \ldots d_k, \ldots, d_l \ldots | \ldots P_1(d_n) \ldots P_2(d_m)\ \&\ d_n = d_m \ldots, P_3(d_k) \ldots P_4(d_l)\ \&\ d_k = d_l \ldots .\}$

In the view defended here, the first indefinite NP a *student* changes the accessibility structure of the discourse. In particular, it modifies the accessibility structure for the set of students in such a way that the referent of the indefinite becomes the "most-accessible" element of that set. The following definite NP *the student* is interpreted as referring to the most accessible element of the set of students, i.e. it refers to the same object as the preceding indefinite. The second indefinite a *student* varies the accessibility again. The referent of the second indefinite becomes the "most-accessible" element of the set of students. The second definite NP *the student* is interpreted according to this newly modified accessibility and refers to the object that was introduced by the second indefinite.

The excerpt (5c) of Hemingway's story *A Clean, Well-Lighted Place* also illustrates the point. Two waiters are introduced (the occurrences of referential expressions that refer to them are in bold). The two occurrences of the definite NP *the waiter* (here in italics) refer to different waiters, namely the one which was mentioned last.

(5c) **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**

[3] The original paper of Grosz et al. (1983) and more recent papers (e.g. Passoneau 1998) discuss the way anaphoric (definite) NPs are related to their antecedents. However, they do not discuss cases like (5) and (5c) in which two occurrences of one and the same definite NP are related to different antecedents.

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.

3. Dynamic semantics and accessibility

Dynamic semantics, such as the File Change Semantics (Heim 1982), Discourse Representation Theory (Kamp 1981; Kamp & Reyle 1993), or Dynamic Predicate Logic (Groenendijk & Stokhof 1990), assumes that a sentence provides information which changes the information states of the participants. This is generally called the context-change potential of a sentence and it is reconstructed as changing the assignment functions that assign objects to discourse items (file cards, discourse referents, or variables).

The Salience Change Semantics developed in von Heusinger (1996; 1997) and Peregrin & von Heusinger (to appear) stands in the tradition of dynamic semantics, but differ from other theories in at least the following three aspects: First, definite and indefinite NPs are represented as possibly complex terms, which can change the context. Second, definiteness is not reduced to uniqueness or to familiarity, but it based on the more general principle of salience. Definite NPs refer to the most salient or most accessible object of the set that is described by their descriptive content.[4] Third, the context-change potential affects the accessibility structure, rather than the assignment functions as in other theories.

3.1 Definiteness and choice

I assume that the "unambiguousness of the reference" of definite expressions is not caused by a Russellian uniqueness condition but by a context-dependent "choice" of the referent. The referent of a definite expression is selected from a set of similar objects. This notion can be reconstructed by

[4] The difference between the notion of "accessibility" and the concept of "salience" is vague. However, there are some implicit differences: first, salience is only used to describe a property of a referent, whereas accessibility is also applied to the relation between anaphoric term and antecedent. Second, accessibility is applied with respect to anaphoric reference, whereas salience covers the concepts definiteness and anaphora in the same way. See Lewis (1970) for the idea and Egli & von Heusinger 1995 and von Heusinger 1997 for an explicit approach of salience.

choice functions (Egli & von Heusinger 1995, von Heusinger 1996, Peregrin & von Heusinger (to appear)). Choice functions are functions that take a set and yield one of its elements:[5]

(6) $\Phi : \wp(D) \rightarrow D$ such that $\Phi(s) \in s \Leftrightarrow s \neq \emptyset$ for $s \subseteq D$

Thus, choice functions model the concept of referentiality: they ascribe one element to a set described by the descriptive material of a definite NP. The interpretation of a definite NP depends on a choice function that is given by the context or discourse. Such a context-dependent choice function reflects the accessibility structure of a discourse. Thus, we add the new parameter Φ to the model-theoretic interpretation, and interpret an expression α according to the model $\mathfrak{M}$ and the choice function Φ: $[\![\alpha]\!]^{\mathfrak{M},\Phi}$. The definite NP *the student* is interpreted as the operation of applying the choice function Φ to the set that is described by the property of being a student. The choice function picks out one element of the set although the set might have more than one element. It selects the one relevant or salient, i.e. the most-accessible, student.

(7) $[\![\text{ the student }]\!]^{\mathfrak{M},\Phi} = \Phi([\![\text{ student }]\!]^{\mathfrak{M}})$

The notion of accessibility defended in section 2.3 can be formally represented, since context-dependent choice functions reconstruct exactly the idea that accessibility can only be described with respect to a set of elements with a certain description.

3.2 Salience Change Potential

The accessibility, represented by discourse-dependent choice functions, is changed in the process of a discourse by different factors such as lexical information, syntactic construction or situational knowledge. In the following, we concentrate on the change induced by linguistic expressions, in particular by indefinites. I have termed this aspect of meaning the "salience-change potential" (von Heusinger 1997). In DRT, indefinites introduce a new discourse referent in the appropriate domain. In the current approach they rather pick an arbitrary element out of the set their descriptive material

[5] This definition is purely extensional. It has often been pointed out that an extensional approach to choice functions is linguistically not adequate. This criticism is correct. However, I keep to the extensional version for reasons of simplicity.

describes and raise it to the most-accessible item of that set (cf. von Heusinger 2000). A very similar approach was developed by Reinhart (1997), Winter (1997), Kratzer (1998) among others. However, they do not extend their analysis of indefinites as choice functions across the sentence border, i.e. they do not account for intersentential binding.

We merge both aspects, i.e. the choice of the referent and its context-change potential, into a new function ρ that takes a choice function Φ and a set s as arguments and yields an updated choice function Ψ that differs from the original choice Φ in the assignment of the choice function to the set of s. For the definition of this function we first define the set of all choice functions $\mathbb{A}$. The update function is a function that takes a choice function and a set and yields a choice function. The modification of the updated choice function is indicated by a set s and an element d, i.e. the modified choice function is equal to the original one except the value for the set s which is d.

(8) $\mathbb{A} = \{\Phi : \Phi \in \wp(D) \rightarrow D\}$

$\rho : \mathbb{A} \times \wp(D) \rightarrow \mathbb{A}$ such that $\rho(\Phi, s) = \Psi \Rightarrow \exists d \in D : \Psi = \Phi^s_d$

$$\Phi^s_d(s) = d$$
$$\Phi^s_d(s') = \Phi(s') \quad \text{for all } s' \neq s$$

The denotation of the indefinite is best described by applying the updated choice function to the set s yielding the element d, adjusting the semantics of indefinites to that of definites. For example, the denotational meaning of *a student* is derived by first updating the current choice function Φ to $\Phi^{||\text{student}||}_a$ (Φ modified by a for the set of students) and then applying the updated choice function to the set of students:[6]

(9) $[\![\text{a student}]\!]^{\mathfrak{M},\Phi,\rho} = \rho(\Phi, [\![\text{student}]\!]^{\mathfrak{M},\Phi,\rho})([\![\text{student}]\!]^{\mathfrak{M},\Phi,\rho})$

$= \Phi^{||\text{student}||}_a([\![\text{student}]\!]^{\mathfrak{M},\Phi,\rho}) = a$

[6] The function ρ replaces the assignment function g that assigns a value to the variables introduced by indefinite NPs. Since in the semantics given here, indefinites do not introduce variables but assign one element to the set their descriptive material denote, we need a more complex function that combines the denotational value and the salience-change potential of an expression. Furthermore, this semantics treats both definite and indefinite NPs as terms, which are interpreted by using choice functions. For a detailed account of the advantages of such a treatment see von Heusinger (1997).

3.3 *Salience Change Semantics*

We represent linguistic expressions in a predicate logic that is enriched by two term operators: the eta and the epsilon operator representing the indefinite and the definite article, respectively. The operators were introduced into metamathematics by Hilbert and Bernays (1939), and the eta operator was first used by Reichenbach (1947) for the indefinite article. Both take an open sentence as argument and return a term. In order to keep the fragment as simple as possible we confine the rules to terms, atomic sentences and conjunctions.[7]

Syntax

S1 If x is a variable and ϕ a formula, then $\varepsilon x\ \phi$ is a term.

S2 If x is a variable and ϕ a formula, then $\eta x\ \phi$ is a term.

S3 If R is an n-place predicate and $t_1, \ldots, t_n$ are terms, then $R(t_1, \ldots, t_n)$ is a formula.

S4 If ϕ and ψ are formulas then $\phi\ \&\ \psi$ is a formula.

For the interpretation of an expression we use a model $\mathfrak{M} = \langle D, I \rangle$ with the non-empty individual domain D and the interpretation function I for all constants. We interpret an expression α according to the model $\mathfrak{M}$, a starting-choice function Φ and the salience-change function ρ: $[\![\alpha]\!]^{\mathfrak{M},\Phi,\rho}$. We define the salience-change potential *SC* recursively and in parallel to the definition of the denotational meaning *DM*. Every linguistic expression α has a salience-change potential $\ll\alpha\gg$, i.e., a function from choice functions into choice functions.[8]

Definite NPs are represented by epsilon terms that are interpreted as the operation of applying the actual choice function to the set described by the expression. For the time being, we assume that definites do not change the accessibility structure of the discourse since they already refer to the most-accessible element of the set they describe:

DM1 $[\![\varepsilon x\ Fx]\!]^{\mathfrak{M},\Phi,\rho} = \Phi([\![F]\!]^{\mathfrak{M},\Phi,\rho})$

SC1 $\Phi \ll \varepsilon x\ Fx \gg = \Phi$

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7 For an expanded fragment see Peregrin & von Heusinger (to appear) and von Heusinger (1997).

8 The function $\ll\alpha\gg$ can be defined in terms of a generalized function ρ^* that takes a choice function Φ and a denotation of an expression α and yields an updated choice function $\Phi \ll\alpha\gg$:

$$\rho^*(\Phi, [\![\alpha]\!]^{\mathfrak{M},\Phi,\rho}) := \Phi \ll\alpha\gg$$

Indefinite NPs are represented by eta terms, which are interpreted as an arbitrarily chosen object out of the set of *Fs*. The change of the referent is licensed by the salience-change function ρ, that takes the current choice function Φ and the set of all F and yields the updated choice function $\Phi_d^{\|F\|}$. ρ guarantees that there is a referent d such that it is assigned to the set of *Fs*. We abbreviate $\rho(\Phi,[\![F]\!]^{\mathfrak{M},\Phi,\rho})$ by $\Phi_d^{\|F\|}$. If we apply $\Phi_d^{\|F\|}$ to the set of *Fs* we yield the denotation d of the indefinite *a F*. The salience-change potential of indefinites is the mentioned modified choice function.

DM2 $[\![\eta x\, Fx]\!]^{\mathfrak{M},\Phi,\rho} = \rho(\Phi,[\![F]\!]^{\mathfrak{M},\Phi,\rho})([\![F]\!]^{\mathfrak{M},\Phi,\rho})$
$= \Phi_d^{\|F\|}([\![F]\!]^{M,\Phi,\rho}) = d$

SC2 $\Phi \ll \eta x\, Fx \gg = \rho(\Phi,[\![F]\!]^{M,\Phi,\rho}) = \Phi_d^{\|F\|}$

Atomic formulas are internally and externally dynamic. They not only pass on a modified choice function to the next formula but they also change the choice function from one term to the other. In this way, examples like (10) can be computed, which are problematic for other theories that allow only for a context-change potential of an atomic formula, but not for a context-change potential of a term. In (10), the indefinite NP *a donkey* in the first argument of the sentence modifies the choice function which is passed on to the second argument. Therefore, the definite NP *the donkey* must be interpreted as referring to the same object as the indefinite NP *a donkey*.

(10) A man who has a donkey and a cow beats the donkey.

The interpretation of atomic formulas consists of two parts. The first part guarantees that the modified choice function is passed from one term to the other, and the second part states the truth conditions as usual. More formally, an atomic formula with n terms becomes true if there is sequence of n choice functions that are licensed by ρ such that each term is interpreted according to the corresponding choice function that was possibly modified by the interpretations of previous terms, and if the denotation of the terms under the appropriate choice functions are inside the denotation of the predicate. The salience-change potential of an atomic formula is composed out of the salience-change potentials of the terms in the formula.

DM3 $[\![R(t_1,\ldots t_n)]\!]^{\mathfrak{M},\Phi,\rho} = 1$ iff there are $\Phi_1 \ldots \Phi_n$ such that $\Phi \ll t_1 \gg = \Phi_1$ and $\Phi_1 \ll t_2 \gg = \Phi_2 \ldots$ and $\Phi_{n-1} \ll t_n \gg = \Phi_n$ and $\langle [\![t_1]\!]^{\mathfrak{M},\Phi,\rho}, [\![t_2]\!]^{\mathfrak{M},\Phi_1,\rho} \ldots [\![t_n]\!]^{\mathfrak{M},\Phi_{n-1},\rho} \rangle \in [\![R]\!]^{\mathfrak{M},\Phi_n,\rho}$

SC3 $\Phi \ll R(t_1,\ldots t_n) \gg = ((\Phi \ll t_1 \gg) \ll t_2 \gg) \ldots \ll t_n \gg$

The interpretation of a conjunction is dynamic, i.e. the second conjunct is interpreted with respect to the choice function that is potentially updated by the first conjunct. The salience-change semantics consists of the salience-change potentials of the two conjuncts:

DM4 $[\![\phi \ \& \ \psi]\!]^{\mathfrak{M},\Phi,\rho} = 1$ iff there is Φ_1 such that $\Phi \ll\!\phi\!\gg = \Phi_1$ and $[\![\phi]\!]^{\mathfrak{M},\Phi,\rho} = 1$ and $[\![\psi]\!]^{\mathfrak{M},\Phi_1,\rho} = 1$

SC4 $\Phi \ll\!\phi \ \& \ \psi\!\gg = (\Phi \ll\!\phi\!\gg) \ll\!\psi\!\gg$

With the rules given so far, we can analyze two sentences from example (5), repeated as (11), with the representation (or logical form) (11a) and the interpretation (11b–d). The interpretation is recursively decomposed: first the conjunction is resolved by inserting the output choice function Φ' of the first conjunct. It acts as input choice function for the second conjunct. In (11c), both conjuncts are decomposed according to the atomic sentence rule, and in (11d), the interpretation of the terms are applied.

(11) A student complained. The dean talked to the student.

(11a) $C(\eta x\ Sx)\ \&\ T(\varepsilon y\ Dy,\ \varepsilon z\ Sz)$

(11b) $[\![C(\eta x\ Sx)\ \&\ T(\varepsilon y\ Dy,\ \varepsilon z\ Sz)]\!]^{\mathfrak{M},\Phi,\rho} = 1$ iff there is Φ' such that $\Phi \ll\! C(\eta x\ Sx)\!\gg = \Phi'$ and $[\![C(\eta x\ Sx)]\!]^{\mathfrak{M},\Phi,\rho} = 1$ and $[\![T(\varepsilon y\ Dy,\ \varepsilon z\ Sz)]\!]^{\mathfrak{M},\Phi',\rho} = 1$

(11c) iff there is Φ' such that $\Phi \ll C\eta x\ Sx)\!\gg = \Phi'$ and $[\![\eta x\ Sx]\!]^{\mathfrak{M},\Phi,\rho} \in [\![C]\!]^{\mathfrak{M},\Phi,\rho}$ and $\langle [\![\varepsilon y\ Dy]\!]^{\mathfrak{M},\Phi',\rho},\ [\![\varepsilon z\ Sz]\!]^{\mathfrak{M},\Phi',\rho}\rangle \in [\![T]\!]^{\mathfrak{M},\Phi',\rho}$

(11d) iff there is a $\Phi' = \Phi_a^{||\text{student}||}$ and $\Phi'([\![S]\!]^{\mathfrak{M},\Phi,\rho}) \in [\![C]\!]^{\mathfrak{M},\Phi,\rho}$ and $\langle \Phi'([\![D]\!]^{\mathfrak{M},\Phi',\rho}),\ \Phi'([\![D]\!]^{\mathfrak{M},\Phi',\rho})\rangle \in [\![T]\!]^{\mathfrak{M},\Phi',\rho}$

In this example, only the indefinite changes the accessibility structure. Both definites, *the student* and *the dean*, are interpreted according to this updated choice function. However, the update does not play a role in the interpretation of *the dean* since the indefinite changes only the value for the set of students. The interpretation of sentence (12) in the context of (11) proceeds in the same way. We start with the output choice function $\Phi_a^{||\text{student}||}$ of (11d), which is updated by another occurrence of the indefinite NP *a student* to $\Phi_{a\ b}^{||\text{student}||\ ||\text{student}||}$ in (12b). This choice function assigns to the set of students the element b, to which the second indefinite refers. Therefore, the last occurrence of the definite NP *the student* refers to this element establishing the anaphoric relation unambiguously.

(12) A student went to the dean. The dean moved the student.

(12a) $W(\eta x\ Sx,\ \varepsilon y\ Dy)\ \&\ M\ (\varepsilon y\ Dy,\ \varepsilon z\ Sz)$

(12b) $[\![W(\eta x\ Sx,\ \varepsilon y\ Dy)\ \&\ M(\varepsilon y\ Dy,\ \varepsilon z\ Sz)]\!]^{\mathfrak{M},\Phi',\rho} = 1$ iff there is Φ'' such that $\Phi' \ll W(\eta x\ Sx,\ \varepsilon y\ Dy) \gg = \Phi''$ and $[\![C(\eta x\ Sx)]\!]^{\mathfrak{M},\Phi',\rho} = 1$ and $[\![M(\varepsilon y\ Dy,\ \varepsilon z\ Sz)]\!]^{\mathfrak{M},\Phi'',\rho} = 1$

(12c) iff there is Φ'' such that $\Phi' \ll \eta x\ Sx) \gg = \Phi''$ and $\langle [\![\eta x\ Sx]\!]^{\mathfrak{M},\Phi',\rho}$, $[\![\varepsilon y\ Dy]\!]^{\mathfrak{M},\Phi',\rho} \rangle \in [\![W]\!]^{\mathfrak{M},\Phi',\rho}$ and $\langle [\![\varepsilon y\ Dy]\!]^{\mathfrak{M},\Phi'',\rho}$, $[\![\varepsilon z\ Sz]\!]^{\mathfrak{M},\Phi'',\rho} \rangle \in [\![M]\!]^{\mathfrak{M},\Phi'',\rho}$

(12d) iff there is a $\Phi'' = \Phi^{\underset{a}{\|\text{student}\|}\ \underset{b}{\|\text{student}\|}}$ and $\langle \Phi''([\![S]\!]^{\mathfrak{M},\Phi',\rho})$, $\Phi''([\![D]\!]^{\mathfrak{M},\Phi',\rho}) \rangle \in [\![W]\!]^{\mathfrak{M},\Phi',\rho}$ and $\langle \Phi''([\![S]\!]^{\mathfrak{M},\Phi'',\rho})$, $\Phi''([\![D]\!]^{\mathfrak{M},\Phi'',\rho}) \rangle \in [\![M]\!]^{\mathfrak{M},\Phi'',\rho}$

This basic version of Salience Change Semantics is able to analyze sentences with multiple referents of the same kind. An anaphoric definite NP refers back to the last indefinite NP with the same descriptive material. The relation between antecedent and the anaphoric term is derived from the salience- (or accessibility-) change potential of the antecedent and the discourse-dependent interpretation of the anaphoric term.

4. The context-change potential of definites

The formalism of Salience Change Semantics given in the last section must be modified in order to catch the salience-change potential of definite expressions, as well. In the last section, it was assumed that definite NPs do not exhibit a salience-change potential since they would raise to salience an object that was already salient. However, the example (5c) from Hemingway's *A Clean, Well-Lighted Place* clearly shows that definite expressions can change the actual accessibility of a discourse. The definite *the younger waiter* refers to one of the two mentioned waiters. The subsequent definite *the waiter* refers to the same one. We can explain this by assuming that an expression not only changes the most-accessible element of the set introduced, but also that of some relevant supersets of this set. The definite *the younger waiter* changes the most-accessible element of the set of younger waiters and that of the set of waiters to the same element. Therefore, we can refer back to this referent by the expression *the waiter*.

(5c) **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 a first attempt to describe this data, we extent the definition (6) of the salience-change function ρ in such a way that not only the value for the described set s, but also for some supersets, is changed.

(13) $\rho : \mathbb{A} \times \wp(D) \rightarrow \mathbb{A}$ such that $\rho(\Phi, s) = \Psi \Rightarrow d \in D: \Psi = \Phi^s_d$
$\Phi^s_d(s') = d$ for $s \subseteq s'$ and $\Phi^s_d(s') = \Phi(s')$ else

We can now modify the salience-change potential of indefinites and definites (their denotational meaning remains the same). They differ only in the value that is assigned to the introduced sets. Indefinites assign a new value d that is licensed by ρ, whereas definites assign the value of the definite expression: $[\![\varepsilon x\ Fx]\!]$. They "project" the most-accessible element of the introduced set to its supersets, e.g. G being a superset of F:

SC2 $\Phi \ll \eta x\ Fx \gg = \rho(\Phi, [\![F]\!]^{\mathfrak{M},\Phi,\rho}) = \Phi^{||F||\ ||G||}_{d}$ for some G: $F \subseteq G$

SC1 $\Phi \ll \varepsilon x\ Fx \gg = \rho(\Phi, [\![F]\!]^{\mathfrak{M},\Phi,\rho}) = \Phi^{||F||\ ||G||}_{||\varepsilon x\ Fx||}$ for some G: $F \subseteq G$

With this modification we can analyze the two sentences in (14) from the quoted fragment.[9] In (14b), the conjunction is decomposed, and the modified choice function Φ' is passed on to the second conjunct. In (14c), both sentences are broken up into predicate and argument according to the atomic formula rule DM3. In (14d), the modified choice function is applied to refer to the intended referent. Here, the updated choice function $\Phi^{||\lambda x[Wx\ \&\ Yx]||\ ||W||}_{||\varepsilon x\ [Wx\ \&\ Yx]||}$ assigns one and the same element to the set described by young waiters, and the set of waiters, yielding the coreference of both definite NPs.

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[9] We omit the sentences in between, and we do not discuss the rules for pronouns here. Pronouns generally replace definite NPs if the antecedent is in the local environment and if no ambiguity as in (10) can arise. It is obvious from the quoted fragment that we very often find a sequence consisting of a definite or indefinite NP introducing or identifying the referent, a pronoun in the local domain referring back, and a definite NP in the more distant environment picking up the referent by stating descriptive material already used: *the younger waiter – he – the waiter* and *the waiter who was in hurry – he – the waiter*.

(14) The younger waiter went over. [...] The waiter went away.

(14a) $W\_o(\varepsilon x[Wx \;\&\; Yx]) \;\&\; W\_a(\varepsilon y\ Wy)$

(14b) $[\![W\_o(\varepsilon x[Wx \;\&\; Yx]) \;\&\; W\_a(\varepsilon y\ Wy)]\!]^{\mathfrak{M},\Phi,\rho} = 1$ iff there is Φ' such that $\Phi \ll W\_o(\varepsilon x[Wx \;\&\; Yx]) \gg = \Phi'$ and $[\![W\_o(\varepsilon x[Wx \;\&\; Yx])]\!]^{\mathfrak{M},\Phi,\rho} = 1$ and $[\![W\_a(\varepsilon y\ Wy)]\!]^{\mathfrak{M},\Phi',\rho} = 1$

(14c) iff there is a Φ' such that $\Phi \ll \varepsilon x[Wx \;\&\; Yx] \gg = \Phi'$ and $[\![\varepsilon x[Wx \;\&\; Yx]]\!]^{\mathfrak{M},\Phi,\rho} \in [\![W\_o]\!]^{\mathfrak{M},\Phi,\rho}$ and $[\![\varepsilon y\ Wy]\!]^{\mathfrak{M},\Phi',\rho} \in [\![W\_a]\!]^{\mathfrak{M},\Phi',\rho}$

(14d) iff there is a $\Phi' = \Phi^{\frac{\|\lambda x[Wx \;\&\; Yx]\| \, \|W\|}{\|\varepsilon x[Wx \;\&\; Yx]\|}}$ and $\Phi([\![\lambda x[Wx \;\&\; Yx]]\!]^{\mathfrak{M},\Phi',\rho}) \in [\![W\_o]\!]^{\mathfrak{M},\Phi,\rho}$ and $\Phi'([\![W]\!]^{\mathfrak{M},\Phi',\rho}) \in [\![W\_a]\!]^{\mathfrak{M},\Phi',\rho}$

5. Summary

I have developed a refinement of the accessibility relation between antecedent and anaphoric term with particular reference to anaphoric definite NPs. Accessibility is analyzed as a structural property of a discourse structure with respect to a set of elements that fall under the same description. I have used context-dependent choice functions as the formal means to represent the accessibility structure of a discourse, and update functions of choice functions to model the salience-change potential of linguistic expressions. With this semantics, we are able to describe anaphoric relations in discourse and the selection of the correct referent out of a set of equal referents. This extended formalism yields not only a more adequate representation of discourse, but also solves the problem of how to establish anaphoric links to definite NPs, and supplies a uniform representation of definite and indefinite expressions with respect to their potential to change the accessibility structure of the discourse.

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