Chapter 2
Context as Assumptions

Erich Rast

2.1 Introduction

In this article some phenomena of linguistic context-dependence are investigated from the perspective of regarding context as being constituted by the assumptions of individual discourse participants. In Sect. 2.2, a general overview of linguistic context-dependence is given and a distinction between indexicals and contextuals is introduced. After this exposition some adequacy criteria, or at least reasonable rules of thumb, for modeling the linguistic context-dependence of typical contextuals in a truth-conditional setting are laid out (Sect. 2.3). Finally, in Sect. 2.4 the modeling of contextuals will be addressed in some more detail. Simple type theory is used for giving examples. The central idea of that section is that interpretation is based on broadly-conceived abductive reasoning, an idea first investigated by Hobbs et al. (1993).

The distinction between indexicals and contextuals made in this paper has evolved from a recent philosophical debate about the nature of semantic content and the amount as to which pragmatic factors play a role in its computation. The main positions in this debate are currently semantic minimalism, see Cappelen and Lepore (2004, 2006) and Borg (2004, 2010, 2012b) and in a special form by Bach (2005, 2006, 2007a,c), moderate contextualism defended by indexicalists such as Stanley and Szabó (2000) and Stanley (2000, 2002), radical contextualism defended by Récanati (2004) and in another form by relevance theorists such as Sperber and Wilson (1986, 2006), occasionalism of Travis (2008), and assessment-relativism like in MacFarlane (2005b, 2007a,b, 2008, 2009) and Lasersohn (2005, 2008). However, it is not the purpose of this article to lay out all of these positions in

E. Rast (✉)
Faculdade de Ciências Sociais e Humanas, Instituto de Filosofia da Linguagem, Universidade Nova de Lisboa, Av. de Berna, 26-4° piso, 1069-061 Lisboa, Portugal
e-mail: erich@snafu.de

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detail.[1] Instead, we assume in what follows a moderate contextualist position as in Rast (2009). Many of the theses about context that will be defended below are neutral with respect to or compatible with other broadly-conceived contextualist positions, but they are more or less incompatible with occasionalism and Cappelen and Lepore's version of minimalism. These positions will be criticized indirectly, but presenting detailed arguments against them is beyond the scope of this paper and has been done elsewhere.[2]

2.2 Forms of Linguistic Context-Dependence

2.2.1 Context: A Brief Overview

Contexts are theory-dependent entities similar to propositions or electrons, and for this reason there is no such thing as *the* context. What a context is depends on the purpose and the intricacies of a specific theory of context. In the linguistic domain, broadly-conceived two traditions have evolved. First, based on work by Frege (1986), Reichenbach (1947), Russell (1966), and Bar-Hillel (1954) a view on linguistic contexts has become popular according to which contexts either represent these features of an utterance situation that are needed in order to determine the semantic value of indexical expressions or particular linguistic signs (tokens) of indexicals are represented explicitly. Originally having been motivated by the foundational question whether indexical context-dependence is in principle reducible or not, this tradition has shifted to a more descriptive perspective and in a sense culminated in the work of Kaplan (1988), whose type-based two-dimensional semantic approach has been very influential. In these accounts based on double-index modal logics the meaning of indexicals is represented by a function from context parameters to intensions ('semantic content') that are in turn functions from indices to extensions (see Fig. 2.1). The idea of parameterizing context-dependences is also exploited by relativists like MacFarlane and Lasersohn mentioned above, where in contrast to the classical contextualist position in their view certain contextual variations have to be located in the modal index instead of the context

Linguistic Meaning + Context ⇒ Content
Content + Index ⇒ Extension

Fig. 2.1 Two-dimensional semantics following Kaplan (1988)

[1] See Stojanovic (2008) and Borg (2007) for overviews.

[2] See for example Bach (2007a,b,c) for a critique of Cappelen and Lepore (2004) and Borg (2012a) for a critique on Travis.

parameter of a double-index modal logic, thereby allowing contextual variation of the same semantic content and the modeling of different evaluations or judgments thereof.

According to an alternative view that has been popularized by Perry in a vast number of publications, see for instance Perry (1977, 1979, 1997, 1998, 2005), the dependence of indexicals on features of the utterance situation is expressed by explicitly quantifying over reified utterances. Broadly-conceived token-based approaches like Perry's go back to Burks (1949) and Reichenbach (1947).[3]

A quite different view on linguistic context can already be found in work by linguists like Jespersen (1922), Bühler (1934), and Fillmore (1972), where context is investigated from a more general linguistic and cognitive perspective. Formal theories of cognitive contexts have been developed much later based on ideas by Stalnaker (1978) and their subsequent implementations in dynamic semantic frameworks such as Kamp and Reyle (1993), Heim (1983), and Stokhof and Groenendijk (1991) and, more generally, the influential Amsterdam tradition of dynamic epistemic modal logics such as van Benthem (2006) and van Benthem et al. (2006). Roughly speaking, context is in this tradition constituted by certain doxastic or epistemic states of discourse participants and these are updated when an agent obtains new information, accepts an utterance, or silently accommodates a presupposition. While Stalnaker (1978) was primarily interested in modeling the common ground between discourse participants, i.e., the communicative assumptions that they mutually share at a given time, in a more general approach assumptions, beliefs, or knowledge of individual discourse participants may be modeled explicitly in order to be able to faithfully represent cases of communication success *and* failure. In dynamic models context can also be considered in a more abstract fashion as a representation of content that is updated by context-change potential of linguistic expressions.

A third tradition of dealing with contexts has started in Computer Science with McCarthy (1993). In Artificial Intelligence research, contexts are often reified and made available within the object language, making it possible to reason explicitly about contexts within the object language and formulate so-called bridge rules for transitions between them. Work by Giunchiglia (1993), Serafini and Bouquet (2004), Buvač et al. (1995), Buvač (1995, 1996), and Thomason (2003) exemplifies this tradition. The way context is treated in these languages is similar to the way it is treated in descendants of Kaplan's Logic of Demonstratives insofar as contexts act as reference points, but since it is possible to explicitly formulate rules between contexts by using the full power of first- or even higher-order quantification the languages used in these accounts are generally more expressive than mere double-index modal logics.

[3]Token-reflexive analyses can also be found in earlier work by Peirce and Russell but not with the same amount of systematicity as that of Reichenbach (1947). Although Perry speaks about token-reflexive meaning, his account is strictly speaking utterance- and not token-based (see Perry 2003).

2.2.2 *Linguistic Distinctions*

It is fair to say that the toolbox available to the average philosopher or linguist has increased tremendously during the past few decades and in light of the sheer number of options for dealing with context formally in a truth-conditional setting some independent criteria are needed for determining which sorts of context-dependence are at play in a given linguistic example. First and foremost, linguistic context-dependence has to be detected. According to simple *context shifting arguments* (CSAs) a sentence ϕ is semantically context-dependent if an utterance of it is true and another utterance of it is false. Practically all sentences of any language are context-dependent in this way, because almost all languages have tenses.[4] A second question to ask is whether the expression in question semantically depends on the deictic center, i.e., the speaker, his location, body alignment, his pointing gesture (if there is one), and the time at which the utterance is made. These features comprise the narrow context Perry (1998) and an expression that semantically depends on these features is indexical. Whether or not an expression is indexical in this sense is implicitly known by a competent speaker and can be made explicit by the semanticist when he is informed by competent speakers. There are also a number of tests that can be used as a rule of thumb to detect indexicality in a sentence, although they do not work reliably in each and every case. For example, in order to report (1) *Alice: I am hungry* in indirect speech *I* needs to be replaced by *he*, whereas (2) *Bob: Alice says that I am hungry* obviously doesn't report (1). In contrast to this, (3) *Alice: John is tall* can be adequately reported as (4) *Alice has said that John is tall* in indirect speech without any need for additional transformations. This shows that *I* is indexical and *tall* is not, although both expressions are semantically context-dependent.[5]

To fix some terminology, let a context that represents features of the deictic center needed for the saturation of indexicals be an *utterance context* and one that represents doxastic or epistemic states of discourse participants be a *doxastic context*. Expressions that semantically depend on the utterance context will from now on be called indexicals. To these belong for example *I*, *you*, *here*, a special

[4]Cappelen and Lepore (2004) have terminologically introduced CSAs merely to criticize them, but we agree with Bach (2007a,c) that their arguments have remained inconclusive. Notice that according to Comrie (1985) there are some languages in which tenses are not grammatically realized (e.g., Burmese) or in which not all of them need to be grammatically realized (e.g., Mandarin Chinese). Nevertheless, suitable temporal relations between the reported event or situation and the time of utterance are still required from a semantical point of view.

[5]The test was devised by Cappelen and Lepore (2004) for checking whether an expression is context-dependent in general, but it obviously only separates expressions that semantically depend on the deictic center from others. Contrary to what Cappelen and Lepore (2005) have claimed, it is the semanticists job to determine whether or not *tall* is relational. Just like *and* cannot be regarded as a unary junctor—even in fully curried languages like $T\,\tilde{y}$ of the Appendix *and* must be considered as the composition of two other functions—no sensible non-relational account of tallness can be given.

and relatively rare use of *actually*, all absolute tenses, and also demonstratives such as *this* or *over there* uttered with an accompanying pointing gesture. Other cases of context-dependence cannot be explained by a dependence on features of the utterance situation and, as will be laid out further below, are subject to being interpreted on the basis of the doxastic context of an agent. These expressions will from now on be called *contextuals*. Most indexicals are also contextuals. For example, the boundaries of the time interval denoted by *now* are not determinable from the time of utterance or any other objective feature of the utterance situation and the same holds for the boundaries of spatial indexicals like *here*.[6]

Although many indexicals are also contextuals in the sense that a certain relevant feature of the deictic center is needed for but does not suffice for fixing their semantic value, indexicals, demonstratives, and anaphora form in many respects well-distinguishable and special classes of expressions that can be subcategorized according to further criteria like the respective dimension (temporal, spatial, grammatical person, modality) or the distinction between endophoric and exophoric context.[7] In contrast to this, contextuals do not form a homogeneous class and are merely defined ex negativo. Some of them such as *tall* require a semantic ingredient when they occur in a syntactically complete sentence, whereas others such as *to have breakfast* seem to only suggest certain default interpretations like *having breakfast on the day of utterance* while their use in a tensed sentence also expresses some literal meaning, for instance (5) *John had breakfast* expresses *there is a time before the time of utterance at which John had breakfast*. One may speak of primary context-dependence in the first case and secondary context-dependence in the latter.

2.3 Adequacy Requirements

In this section, a number of desiderata for the adequate modeling of linguistic context-dependence will be laid out. Not all cases of linguistic context-dependence will be considered, though, and for example anaphora will be excepted because their linguistic behavior has been studied in detail by semanticists in dynamic settings like DRT or DPL and their explicit dependence on the endophoric context makes them rather peculiar in contrast to other contextuals. Likewise special and not considered in what follows are uses of indexicals in narrative contexts, i.e., when a story is told, and text-deictic expressions like *former* and *latter*.[8]

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[6] See Bach (2004, 2005), Perry (2005), Mount (2008), and Rast (2009) on the underdetermination of indexicals.

[7] See Rast (2007, Chap. 5).

[8] In contrast to ordinary contextuals like *tall* or *enough*, anaphora and genuine text-deictics seem to depend to a large extent on the grammatical, rhetorical, and informational structure of the previous discourse in addition to how it has been interpreted so far.

2.3.1 *Utterance Contexts Cannot Be Reduced to Doxastic Contexts and Vice Versa*

Utterance contexts cannot be reduced to doxastic contexts and vice versa if semantic and pragmatic adequacy is desired. It is fairly trivial to show that the first direction of this thesis holds. Suppose, for example, that Alice believes it is 2 pm whereas it is in fact 1 pm, and utters (6) *Alice: It is now 2 o'clock*. With respect to the meaning of *now* the utterance content is underdetermined in the sense that it does not specify explicitly by linguistic means whether 2 am or 2 pm is meant and the boundaries of the time interval denoted by Alice's use of *now* are vague and not further specified by any linguistic meaning rule. There are also interpretations of *now* according to which the boundaries are fairly large, for example in (7) *Carla earns much more now than she used to 10 years ago*. However, a reasonable interpretation of (6) is constrained by general world-knowledge according to which the boundaries of the indexical in (6) are much smaller. Suppose that on the basis of their background knowledge all discourse participants agree that (6) is true in the given situation if the time of utterance was 14:00 h ± 2 min.[9] Then (6) is clearly false and Alice is mistaken about the denotation of her use of *now*. Neither her epistemic state nor her referential intentions determine that denotation. Features of the deictic center are given independently of the epistemic states of discourse participants.

The other direction of the thesis is more complicated, as there are seemingly many ways to 'objectify' aspects of doxastic context. First, one might attempt to simply store a relevant aspect in context parameters of a double-index modal logic. From a purely logical point of view, almost anything can be stored in a parameter according to which truth is relativized and for some technical purposes enriching parameters might make sense. However, the way in which relevant features of epistemic states are encoded formally should properly reflect the role they play in the resolution of context-dependence. Beliefs and assumptions of agents don't generally *determine* missing ingredients of contextuals, because the (deep) interpretation of contextuals is optional in case of secondary context-dependence, and, moreover, beliefs and assumptions are individual. For example, particularly when uttered with verum-focus, a speaker might intend (8) *John had breakfast* to be interpreted according to its literal meaning rather than its usual default interpretation (see Sect. 2.3.3). In this case nothing is missing that could be stored

[9]For the sake of the current argument, the potential 'higher-order' vagueness of the ± margins or cases when discourse participants assume different standards of precision can be ignored. It is assumed in the above example that all discourse participants agree on the margins and that they are much smaller than 1 h. From a more philosophical angle one could also claim that expressions like *now* or *2pm* denote instants in time rather than time intervals and the above interpretations are only adequate when Alice is considered as speaking loosely. As interesting as it may be from a philosophical perspective about time, this view is not helpful for doing natural language semantics. People do not have such rigid standards in ordinary conversations.

in a context parameter.[10] Even in the case of primary context-dependence an agent might refrain from deep interpretation and instead only existentially quantify over missing argument places.

It is also crucial to notice that referential intentions of speakers are not part of the context and generally are not adequate for determining the truth-conditional contribution of indexical contextuals.[11] If for example Bob points to the K2 while intending to refer to the Mount Everest (9) *Bob: This is the highest mountain on earth* is false, just like in example (6), since the pointing gesture picks out the K2 instead of the Mount Everest.

Although the above considerations speak against it, they do not constitute a principal 'knockdown' counter-argument against parameter-based contextualism according to which contextual variation of a contextual is expressed by using different, suitably enriched parameters of a double-index modal logic that may vary from agent to agent to reflect his or her interpretation. For example, relativists like Lasersohn (2005, 2008) have suggested to put a judge into the index parameter, thereby allowing for two people to disagree about the same semantic content of an utterance containing a predicate of personal taste without one of them being at fault.[12] The general usefulness of these kind of theories is questionable, though. Contextual variation is in these theories merely expressed formally without explaining how an agent arrives at a particular interpretation, and when the interpretation of contextuals is modeled by resorting to parameters, context or index parameters are multiplied respectively: one parameter is needed for the deictic center and other parameters for representing different interpretations and what the speaker has in mind. As a result, the connection between communicative assumptions and beliefs of discourse participants and their preferred interpretation of an utterance at a given time is left unexplained. As long as one is only interested in expressing or encoding contextual variabilities in a logical language this might be acceptable, but in the long run it is not satisfying. A good theory of contextuals needs to say something about how rational agents arrive at interpretations based on what they believe and assume.

2.3.2 Knowledge Is Not Indexical

Both contextualism and relativism about knowledge or knowledge ascriptions have been defended recently.[13] While a general critique of these positions is beyond the

[10] Cf. Bach (2004, 2005).

[11] See (ibid.), Bach (2009).

[12] Note that a relativism like that of MacFarlane (2008) is quite a different story; here, a metaphysical claim about the truth or falsity of utterance content at different evaluation times is made and whether this view is adequate hinges on metaphysical arguments.

[13] See for example Cohen (1990) and DeRose (1996, 2009) for contextualist and Richard (2004), and MacFarlane (2005a) for relativist positions.

scope of this article, there is a strong argument against a crude form of indexicalism of factive knowledge. Let there be a weak epistemic context c_w and a strong one c_s, let Kp stand for 'it is knowable that p', and $M, c \vDash \phi$ express the fact that ϕ is true with respect to context c in a model M. Now assume that p is itself not sensitive to epistemic contexts. Given all that, according to the indexicalist premise it can be the case that (i) $M, c_w \vDash Kp$ and (ii) $M, c_s \vDash \neg Kp$. But from (i) it follows by factivity of knowledge that $M, c_w \vDash p$. Since p is by assumption not sensitive to epistemic contexts, it is also the case that $M, c_s \vDash p$. Given all that, the last and crucial step of the argument is as follows: The fact that p holds in the strong context and the fact that this fact in turn can be derived on the basis of uncontroversial logical principles, the factivity of knowledge, and the indexicalist premise taken together should suffice as a justification for the claim that it is also knowable in c_s that p, i.e., for establishing $M, c_s \vDash Kp$, in any particular case. This contradicts the contextualist assumption (ii).

Some epistemologists don't seem to like this argument. They tend to attack it either by resorting to an alternative notion of contexts or by attacking the last inference step. Regarding the first counter-argument, notice that the original argument is independent of the actual formal modeling of the contexts in question and so it does, for instance, not help to consider contexts as sets of possible worlds instead of simple reference points.[14] The argument does not rest upon any assumptions about the structure of contexts at all; it applies to any sort of *determinative* context, i.e., to any sort of context that partly determines the truth or falsity of a knowledge attribution such that (i) and (ii) may hold at the same time and within the same model. Second, it is hard to see how the very fact that some claim can be derived by logical principles from acceptable assumptions cannot be a valid justification. Conversely, the justificational value of such a fact should be stronger than any empirical claim. It is easy for an agent to ascertain in any particular case that the embedded proposition is true in the strong context when it is already known in a weak context. Hence, the agent certainly has good reasons to believe that it holds in the strong context and, since the embedded proposition is true and the justification is correct, according to the justified true belief view the agent also knows that the proposition holds. The only thing that would keep an agent from knowing the embedded proposition would be a lack of awareness about the logical principles that govern strong knowledge or a lack of inferential skills in general. After all, a heavily resource-bound agent might not even be able to recognize simple instances of modus ponens as correct inferences. However, it is not easy to see how switching to resource-bound agents could salvage epistemic contextualism, since the resulting kind of contextualism would be fairly trivial. In this view, the agent would simply fail to recognize that it follows from the fact that he knew the embedded proposition in the weak context that the embedded proposition is also true in the strong one, yet it would still be knowable in the strong context that the embedded proposition holds. We should be able to convince such an agent of the fact that the embedded

[14] Many thanks to Manuel Rebuschi for fruitful discussion of this issue.

proposition is true as easily (or hard) as it might be to convince someone of the fact that modus ponens is a valid inference scheme.

What lesson should be drawn from this argument? One might be tempted to consider the verb *to know* a contextual as laid out above. If *to know* indeed worked exactly in parallel to expressions like *tall*, then stronger or weaker readings of it would be obtained by interpreting the respective knowledge ascription, and a statement of the form *A knows that p* would be semantically underdetermined in a sense that will be laid out in more detail in the next sections. No such readings seem to be available, though, and so invariantism is a better response. Strong knowledge might have its place in epistemology only as a limit to which justified beliefs converge ideally.

2.3.3 *Deep Interpretation Is Sometimes Optional and Sometimes Mandatory*

Bach (2004, 2005) has argued that the recipient does not always need to find a missing ingredient of a contextual. As mentioned earlier, in (5) *John had breakfast* a default interpretation is indicated according to which John had breakfast on the day of utterance, but the literal meaning of the sentence can be prevalent in a given conversational situation. For example, when previously someone has mentioned that John has never had breakfast in his life, Alice may reply with (5) and add that she has seen John having breakfast last week, although it was a quite hasty one. Another example is (10) *Alice bought a car*. From the point of view of lexical semantics buying something involves a legally binding transfer of a property between a buyer and a seller at a certain price, since otherwise the act of buying cannot be distinguished from similar acts like borrowing or stealing. But many times when (10) is uttered, the recipient does not need to determine a *specific* seller or price in order to understand what (10) says or what the sender intended to say by uttering (10). Finding a specific contextual ingredient is optional in such a case, but by virtue of semantic competence a recipient must still know implicitly that buying something involves a purchased object, a buyer, a seller, and a price. When a specific ingredient is determined by the recipient, this is called *deep interpretation*. In contrast to this, the existential completion that for the above example may be paraphrased as *There is a seller and there is a price at which Alice bought a car at some time in the past* is the result of *partial interpretation*. If Bach (2007b) is right, partial interpretation by existentially quantifying over open argument places is optional as well, because sometimes other than existential quantifiers might yield the desired interpretation. It is, however, presently unclear under what circumstances contextual sentences can be interpreted using another than the existential quantifier. For example, it seems that (11) *John ate* cannot be interpreted as (12) *John ate most of the cookies* and (11) cannot be uttered felicitously to convey this interpretation.

Sometimes deep interpretation seems to be mandatory. For example, assuming some place of arrival for (13) *Alice arrived last week* seems to be required by the conventional meaning of *to arrive*.[15] In other words, there is a sense in which someone who interprets (13) as (14) *Alice has arrived at some place during the week before the utterance of (13)* has not fully understood (13) in the given conversational situation, although he has grasped its linguistic meaning, whereas the same cannot be said about the existential completion of (10). The fact that *to arrive* has an indexical and a nonindexical reading similar to *left* and *right* might account for this difference. While certain contextuals are not indexical in the narrow sense of semantically depending on the deictic center, they still semantically depend on features of another center in the same way as indexicals.

2.3.4 Doxastic Contexts Are Constituted by Assumptions

Doxastic contexts are in a sense given by the belief states of discourse participants, but as plenty of research on presuppositions has shown: not directly. Stalnaker (1978, 2002) and many others have argued that in order to account for the silent accommodation of presuppositions doxastic contexts are comprised of mutual assumptions of discourse participants, i.e., their common ground. Consider the following example due to von Fintel: (15) *I am sorry that I am late. I had to take my daughter to the doctor.* Among the presuppositions of these sentences is the existential presupposition that the speaker of (15) has a daughter. It is fairly obvious and a common phenomenon that a hearer doesn't need to know that the speaker has a daughter in order to fully understand (15), because he can simply add this presupposition to his belief base on the fly, thereby maintaining the common ground.

However, mutual assumptions alone do in a trivial sense not suffice for modeling discourse in general, if the model is supposed to reflect not only what happens during successful, but also what happens during unsuccessful communication. What happens if the hearer doesn't accommodate the presupposition? Clearly, the assumptions of discourse participants have to be modeled on an individual basis as well, and from these epistemic states the common ground can be computed at any time. Moreover, although mutuality plays a crucial role in explaining certain cases of Gricean interdependent reasoning processes by means of which an agent arrives at an interpretation, its role for everyday communication has been exaggerated in the past. Often a hearer just maintains a model of what the speaker appears to believe and on the basis of that model interprets his utterances and accommodates presuppositions accordingly. It should also be remarked that assumptions, as opposed to beliefs, play a less important role for the interpretation of contextuals than for dealing with presuppositions. In case of primary context-dependence the fact that a contextual misses an argument can be inferred from the

[15] Many thanks to Richmond Thomason for having brought this to my attention.

lexicon, but usually the speaker does not presuppose or implicate any particular instance of the missing ingredient. For example, when someone interprets (3) *John is tall* he cannot accommodate the missing comparison class, because it is not indicated by the utterance at all—it is neither expressed explicitly nor does it have to be implicated or presupposed. In this case, the agent might arrive at a comparison class by taking into account the *question under discussion* (QUD) and might not need to resort to Gricean reasoning at all. Is the utterance about playing basketball and John plays basketball? Then the members of his team might be a preferred comparison class.

In a simplified view of assumptions without iterated mutuality (what I assume that you assume that I assume...), a doxastic basis for interpreting utterance can be generated from what the recipient believes about what the message sender believes. Ideally, these beliefs should be compartmentalized in dependence of the QUD. How agents compartmentalize beliefs on the basis of what has been said so far and how this dependence may be modeled in a logical setting under ideal rationality assumptions is currently still an open question, though.

2.4 Some Remarks on the Modeling of Contextuals

In the remainder of this article the question of how to represent contextuals in a formal, truth-conditional setting shall be addressed. Most of what follows is merely meant as a suggestion to explicate some of the points made previously in a more rigorous fashion. To provide a link to general semantics in the Montague tradition mechanisms from epistemic modal logic are directly encoded in higher-order logic. The reader is asked not to pay too much attention to the particular implementation, which serves no more than as a proof of concept, and to consider the general ideas underlying it.

2.4.1 Using Free Variables

We take a closer look at the semantic content of some contextuals in a simple type theory called $T\tilde{y}$ (see Appendix), whose only difference to standard type theory is that a special notation is used to give functions a second extension. In case of a function A from entities of some type to truth-values $\{1, 0\}$, $\sim A$ is interpreted as inner negation. This means, for example, that for an ordinary, non-intensional predicate $P_{(et)}$, $\neg P(a) \wedge \neg \sim P(a)$ may be true in a model, thereby representing the fact that P is not applicable to a. Consequently, semantic objects of type s can be regarded as situations as opposed to worlds, because from the fact that $\neg P_{(st)}(s_0)$ it does not follow that $\sim P_{(st)}(s_0)$, whereas the opposite direction holds, and the inner negation must be considered the 'genuine' negation. In general, this makes the logic

very similar to a partial logic that corresponds to a 3-valued Kleene system, but without giving up bivalence or having to introduce additional junctors.[16]

Two-dimensional semantics can be implemented in this framework by combining terms of type $(s(sT))$ for various types T. The type $(s(st))$ for sentences is abbreviated τ and the type $(s(se))$ for intensional objects is abbreviated ϵ. In what follows, the variable u is used for the utterance situation and s for what may be called the topic situation, i.e., it stands for the situation that is implicitly described by the utterance. To give an example, let (16) $\lambda u \lambda s.speaker(u)$ be an expression of type ϵ for the English first-person pronoun, (17) $\lambda P_\tau \lambda u \lambda s.PRES(u, s) \wedge P(u)(s)$ for the present tense, where $PRES(s_1, s_2)$ is true if s_2 overlaps s_1 from the right and does not end significantly later than s_1, and (18) $\lambda x_\epsilon \lambda u.\lambda s.wait(s, x(u, s))$ is a lexicon entry for the verb *to wait*. The sentence *I wait* is then analyzed as (19) $\lambda P_\tau \lambda u \lambda s.PRES(u, s) \wedge P(u, s)[\lambda u \lambda s.speaker(u) \lambda x_\epsilon \lambda u.\lambda s.wait(s, x(u, s))]$, which reduces to (20) $\lambda u \lambda s.\ PRES(u, s) \wedge wait(s, speaker(u))$.[17]

If what has been said so far is correct, the context-dependence of *tall* in (3) *John is tall* cannot be adequately expressed in the same manner in terms of a function of the utterance situation like in (21) $\lambda u \lambda s.PRES(u, s) \wedge Tall(s, j, f(u))$, where f is a function from a situation-type variable to a comparison class (viz. corresponding predicate). This representation would not be adequate because the missing comparison class of *tall* is not actually provided by a shared context. For this reason it is better to represent the missing comparison class as a free variable, like in (22) $\lambda u \lambda s.PRES(u, s) \wedge Tall(s, j, C)$.[18]

For the present purpose of investigating interpretations of utterances, a free variable must at some point be bound by an existential quantifier in contrast to the usual practise in mathematical logic of assuming implicit universal quantification. Formula (24) $\lambda u \lambda s.\exists C[PRES(u, s) \wedge Tall(s, j, C)]$ represents the *existential completion* of (22). Existential completion plays a crucial role in keeping interpretation conventional from a logical perspective, because it allows one to avoid explicit

[16]This view goes back to non-traditional predication theory of Sinowjew (1970), Sinowjew and Wessel (1975), and Wessel (1989). Some philosophers and logicians don't like it, because it cannot be readily extended to deal with quantified statements and moreover one or both of $\neg$ and $\sim$ might no longer satisfy ones favorite criteria for negation. Non-traditional predication theory is nevertheless useful for expressing some form of situations without making the underlying logic partial. See Muskens (1995) for a genuine partial type theory.

[17]Details of the tense logic and underlying interval relations cannot be addressed here; the reader is referred to Allen (1983), Ladkin (1987), and van Benthem (1991). Notice that 'not significantly later' is a condition for the English present tense as opposed to, say, the German present tense which may extend significantly into the future. For simplicity the fact that the tenses like most other indexicals are also contextuals is ignored and we focus on nonindexical contextuals in what follows.

[18]In contrast to this, the present tense predicate *PRES* is indexical and therefore does depend on u. A crude definition for *tall* could be given as (23) $Tall := \lambda u \lambda s \lambda x \lambda C.\ most\ y(C(s, y))(height(s, y) < height(s, x))$, where the quantifier and function names are self-explanatory. These details don't matter in what follows.

representations of incomplete content such as structured propositions with all of the problems that come along with such approaches.[19]

Admittedly, not all missing ingredients of contextuals *have* to be represented as a free variable. First, it would, of course, also be possible to bind the variable by a λ-operator and delay the evaluation until the end of semantic composition. This would significantly complicate syntactic and semantic construction, though. Secondly, dependences on the utterance situation can be modeled to some extent by introducing an accessibility relation for a new modality and quantifying over situations reachable by this relation in a suitable way just like it is done in case of the modal index. When quantifiers are properly relativized to these situations, for example by a domain predicate of type $(e(st))$, even quantifier domain restriction, nominal restrictions, and other implicit domain dependences like that of spatiotemporal indexicals can be dealt with. However, generally open variables are preferable over implicit dependences on the underlying semantic objects because they allow for a more controlled modeling of deep interpretation.

2.4.2 Belief and Assumptions

Instead of a normal modal logic account of belief, such as assuming the familiar modal logic KD45, strong belief will be modeled as the minimum of a total preorder relation over states.[20] The reasons for this choice will become apparent further below. For generality the preorder may be implemented as a relation that additionally depends on an agent and a base state. Let R of type $esssst$ represent this relation and $C_{x,u}(s,t)$ be a shortcut for $C(x,u,s,t)$; the subscripts are left out if they are arbitrary. The following constraints are needed:

$$C(s,s) \tag{REF}$$

$$[C(s,t) \wedge C(t,u)] \rightarrow C(s,u) \tag{TR}$$

$$\forall P.\exists v P(v) \rightarrow \exists s(P(s) \wedge \neg\exists t[P(t) \wedge C(t,s)]). \tag{WO}$$

The well-ordering principle WO is only needed for infinite domains, because in such a domain there could be an infinite descending chain $s_{i-n} \leq \cdots \leq s_{i-2} \leq s_{i-1} \leq s_i$.

[19] Kent Bach is one of the primary advocates of 'propositional skeletons', see Bach (2005). However, this position leads to a number of logical problems. Specifying the logical consequences of incomplete content and attitudes towards such content in particular is far from trivial. Apart from that, structured propositions also tend to lure philosophers of language into metaphysically dangerous parlance, as if there was an ethereal 'third realm' of meanings.

[20] For belief such a preference relation is also used by Baltag and Smets (2006, 2011) and Lang and van der Torre (2007). The following implementation is based on Rast (2010, 2011) with changes made to account for the use of non-traditional predication theory.

The condition prohibits the existence of such chains for any non-empty intension P of type st. We stipulate that these conditions also hold for $\sim C$.

To obtain strong belief first the minimum has to be obtained by making use of

$$\lambda xuCP\lambda s.P(s) \wedge \neg\exists t[P(t) \wedge C(x,u,t,s) \wedge \neg C(x,u,s,t)], \qquad \text{(MIN)}$$

where C is of type $essst$ and P, Q are of type st. An agent x's unconditional belief set at u can be expressed as (25) $MIN(x,u,R,\top)$, where $\top$ is a Verum-intension of type st like, for example, $\lambda s.p \vee \neg p$ for arbitrary p of type t. We write $\mathcal{B}^{C}_{x,u}(P)$ for $\forall s.MIN(x,u,C,\top)(s) \rightarrow P(s)$ and leave out x,u,C when they can be inferred from the context.

In an account with truth-functional negation only, beliefs can be updated in light of new evidence that P by making all P-worlds minimal for the respective agent at a given time. This method is known as lexicographic update and can be used with only slight alterations in the present setting, too.[21] Additional care needs to be taken that the update methods deals adequately with the respective anti-extensions $\sim P$ of a given P.

Let *if* p_t *then* q_t *else* r_t abbreviate $(p \rightarrow q) \wedge (\neg p \rightarrow r)$. The lexicographic update of an ordering C of type $essst$ to C' of the same type by P of type st with respect to an agent x's belief in a base situation u_o is computed by the following function[22]:

$$\begin{aligned}&\lambda xu_0CP\lambda C'.\forall u_1,y,s,t[\mathit{if}\ x = y \wedge u_1 = u_0 \wedge P(s) \qquad \text{(LUP)}\\ &\wedge \neg P(t) \wedge C(y,u_1,t,s)\ \mathit{then}\ C'(y,u_1,s,t)\\ &\mathit{else}\ C'(y,u_1,s,t) \equiv C(y,u_1,s,t)].\end{aligned}$$

This is ordinary belief update. We also need a way to generate assumptions from a hearer's beliefs about what the speaker believes, where only definite beliefs of the hearer about what the speaker believes are taken into account when generating the assumptions. Let $\mathcal{B}_{(a*b)}P$ stand for the belief obtained from updating a's beliefs entirely by those of b. (Iterated belief is represented as a separate belief in this setting.) Let $\overline{A}$ be $\sim P$ if A is of the form P and P if A is of the form $\sim P$. Then the desired belief update must satisfy the condition that (26) for any non-empty P of type st, be it in positive or negative form, if $\mathcal{B}_b P$ then $\mathcal{B}_{(a*b)}P$; otherwise $\mathcal{B}_{(a*b)}P$ iff. $\mathcal{B}_a P$.

[21] See Baltag and Smets (2011) for a detailed investigation of lexicographic update and similar update method for qualitative graded belief based on prior work by van Benthem and Liu (2005) and Liu (2008).

[22] Cf. Rast (2010, p. 394).

Spelled out as a conditionalization dependent on two agents x_0, y_0 and a base situation u_0 this revision operation is very similar to the above simple revision:

$$\begin{aligned}&\lambda x_0 y_0 u_0 C \lambda C' \forall P.\exists s P(s) \rightarrow \forall s, t, u_1 \forall x_1, y_1 [\mathit{if}\ u_1 = u_0 \qquad \text{(REV)}\\ &\wedge x_1 = x_0 \wedge y_1 = y_0 \wedge P(s) \wedge C(y_1, u_1, s, t)\ \mathit{then}\ C'(x_1, u_1, s, t)\\ &\mathit{else}\ C'(x_1, u_1, s, t) \equiv C(x_1, u_1, s, t)].\end{aligned}$$

We write $\leq_{a*b,u}$ for $REV(a, b, u, \leq)$ and leave out arguments when they are not relevant for the discussion. This revision is clearly based on lexicographic update, but notice that if $\mathcal{B}_{x,u} P$ then $\neg \mathcal{B}_{x,u} \overline{P}$. The same holds for revised belief, which follows from the definition of $B_{x,u} P$ as $\forall s.MIN(x, u, \leq_{x,u}, \top)(s) \rightarrow P(s)$ and the inner negation constraint from the Appendix. Second, the revision has the property that if $\mathcal{B}_b ?P$ and $\mathcal{B}_a P$ then $\mathcal{B}_{a*b} P$, where $?P$ abbreviates $\lambda s.\neg P \wedge \neg \sim P$. The antecedent condition of (REV) cannot shift any P- or $\sim P$-situation into the new minimum; by the *else* clause all situations in the new minimum will thus be P-situations. Finally, it is also the case that if $\neg \mathcal{B}_b P$ and $\neg \mathcal{B}_b \sim P$ but $\mathcal{B}_a P$, then $\mathcal{B}_{a*b} P$. The first two assumptions say that there are one or more situations s in the minimum of b such that $\neg P(s)$ (viz., $\neg \sim P(s)$). But for any such situations the *else* clause will apply and so by the third assumption a P-situation will be preferred over these. On the other hand, if $\mathcal{B}_b P$ then $\mathcal{B}_{a*b} P$ by the *then* clause of (REV), and likewise for the $\sim P$ case. So the update operation really just takes over the definite beliefs from the second beliefs which in the present case represent the hearers iterated beliefs about the speaker's beliefs.

To give a rationale for this kind of updating consider an utterance of the sentence (27) *John is ready*. Suppose that in a given interpretation situation the hearer believes that the speaker believes that the conversation so far has been about John's pending advancement (P). The hearer needs to take this belief into account when interpreting the utterance even if he disagrees with it. Suppose further that the hearer believes that the speaker does not believe that P or that he is undecided in the sense that he believes that $?P$.[23] In this case the hearer will have to resort to his own non-iterated beliefs when interpreting the utterance. In other words, when interpreting an utterance involving contextuals the hearer *may* take into account a model of what the speaker believes but the model might only be partial; what is not specified clearly by the model is completed by the hearer on the basis of his ordinary beliefs.

[23] We have chosen one particular way to interpret $?P$ that is not the only one. In another context it could also be argued that an agent decidedly believes that $?P$ if $\mathcal{B}?P$ is true. Under this interpretation the above update operation would need to be adjusted to also revise by $?P$.

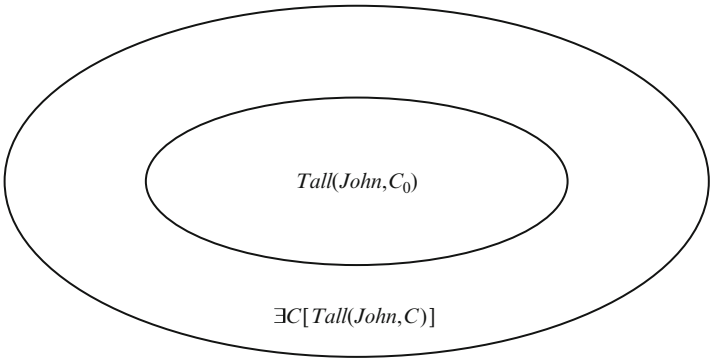

Fig. 2.2 Relation between an interpretation and an existential completion, where C_0 is a constant

2.4.3 Towards Interpretation

In the previous section it was suggested to represent the meaning of contextuals by open variables of an appropriate type. Subsequently, these have to be bound by existential quantifiers. The semantic content representing this existential completion is then narrowed down—or, from a syntactic point of view, enriched—to some more specific content that implies the existential completion. This step is essentially an abductive inference; it involves finding the interpretation of the literal meaning that the hearer finds most plausible at a given time. Subsequently the hearer might check this interpretation against his own beliefs to see whether he finds some perhaps even more restricted interpretation compatible with what he believes in the given situation. This last step, involving a checking, is a form of non-prioritized belief revision, which is problematic from a philosophical point of view. On the one hand, if the checking step never succeeds the hearer will never learn anything new from another person. On the other hand, if the checking always succeeds like in ordinary belief revision or the above lexicographic update the hearer will come to believe anything he is told. Obviously, some middle ground seems to be desirable. The checking issue is left open in what follows.[24]

Figure 2.2 illustrates the relation between an interpretation and its existential completion. The process of arriving at an interpretation is an instance of free enrichment, see Récanati (2004, 2010), and seems to be the usual, albeit not

[24]The checking problem might be the main reason for switching to quantitative accounts, where for example belief update by Jeffrey Conditioning is available and well-understood. For it is quite obvious that a checking step only makes sense if the hearer is able to learn something from the speaker not with apodictic certainty but only to some degree. In any case, these issues are fairly complicated both from a philosophical and a technical perspective and there is no room in this article to further delve into them.

mandatory way of interpreting contextuals. Although we do not assume this here, interpretation by narrowing down semantic content could be taken as a criterion for separating contextuals from other phenomenas of linguistic context-dependence such as semantic transfer in cases of metaphor, metonymy, and deferred ostension.

The idea of regarding deep interpretation as a form of abductive inference has first been explored in a formal setting by Hobbs et al. (1993).[25] However, Hobbs et al. use a purely syntactical, cost-based account. They assign numerical preference values to formulas of a first-order language and their parts, whose 'cost' is then minimized, but they do not provide a way to update these valuations in light of new evidence. In the present setting where qualitative graded belief (viz., assumptions) is available, a semantic account is more natural and also mandatory for the simple fact that higher-order logic with standard models is not compact and therefore does not fare well with syntactic symbol manipulation.

Before laying out a fairly simple 'proof of concept' some general words of caution are advisable. As is argued in more detail in Rast (2011), *merely* assuming abduction will not do. A reasonable account of interpretation as abduction based on preferences needs to be accompanied by a theory of how these preferences are updated in the light of new evidence since otherwise the formal model will amount to no more than an unnecessarily complicated way of expressing the trivial fact that discourse participants consider some interpretations more plausible than others. The question is not whether they do that but *how*, and a fruitful answer to this question in a logical setting must presume additional ideal rationality criteria. The limits of the representation of graded belief and its update method—in this case belief as a set of situations and a variant of lexicographic update—also determine the limits of the respective account of abductive interpretation.

With that caveat in mind, we now briefly take a look at interpretation. Two-dimensional semantic representations slightly complicate the matter because the context variable is not always treated on a par with the one representing the modal index. At one occasion the hearer might take into account his beliefs about the utterance context directly whereas on another occasion he might have reasons to take into account his beliefs about what the speaker believes about the utterance situation.[26] This issue is ignored for simplicity and only the interpretation of intensions of type st obtained from intensions of type sst $(=\tau)$ by applying the actual context u_0 is considered in what follows. (In reality hearers also interpret indexicals, of course.)

According to what has been said so far, first the hearer's iterated beliefs about what in his opinion the speaker believes are updated by the literal meaning of the utterance provided that the hearer also believes that the speaker is honest and sincere. It is assumed that a stands for the hearer and b is an index for a's beliefs about what the speaker believes. Given some existential completion P, in an interpretation situation u the first step is then represented by $LUP(b, u, \leq, P)$.

[25] Cf. also Stone and Thomason (2002).

[26] See Rast (2010) for more on this topic.

Subsequently, the revision of a's beliefs by b is computed. The final step is then to 'abduce' the most plausible states that imply P on the basis of this revised ordering relation. For generality, we assume that there is an abduction relation R of type sst between situations that is similar to an accessibility relation in modal logic. The following function then characterizes a hearer a's interpretation of an existential completion P uttered by b in a given situation u:
(28) $MIN(a, u, REV(a, b, u, LUP(b, u, \leq, P)), \lambda s.\forall t[R(s,t) \rightarrow P(s)])$. Relation $R(s,t)$ could for example be interpreted as *s causes t*, *s is a reason for t*, or just as the identity relation. Different readings of the abduction relation give rise to different sorts of abductive inference. In the present case, all of them are limited to being based on a point-wise comparison of states. Both for the ordering and for the abduction relation it might be fruitful to explore the possibilities of relaxing this requirement and consider set-wise comparisons.

Primitive as it may be, this form of abduction should convey the general idea. The hearer infers from the assumption what he considers the most plausible interpretation in the given situation. As mentioned before, a way to revise the plausibility ordering in light of new evidence is crucial in any such model, since otherwise the modeling would be vacuous and ad hoc.

From the discussion in the previous section it is, however, clear that many cases of secondary context-dependence require additional machinery to obtain a convincing picture of how a rational agent arrives at an interpretation. In particular, some adequate representation of common sense knowledge that includes default rules or inferences based on typicality seems to be needed for even seemingly simple examples. Consider for instance the case of *having breakfast* + tense again. One typically has breakfast in the morning after having woken up. Moreover, when someone talks about a past event in the afternoon that describes a daily activity that typically takes place in the morning, it is likely that this past event took place in the morning of the day of utterance unless there is additional information that suggests another past reference time frame. (Such additional information may for example be introduced explicitly as the origin of a sequence of narrated events.) In the meantime, exceptional inferences like the one from (5) *John had breakfast* to (29) *John didn't have breakfast in the morning of the day of the time of utterance of (5)* must not be prohibited. So in this example, defeasible reasoning and a rich background common sense belief basis is needed to make the underlying inference chain explicit. Likewise, in order to arrive at preferred interpretations of (6) and (7) one has to resort to the QUD and a lot of common sense assumptions about the typical precision of talking about the time of the day, the periods during which salaries remain constant, how average salaries are typically measured, and so on. For these reasons the modeling of genuine contextuals can become a rather complex task. At least in the foreseeable future such models will only be able to approximate certain aspects of human interpretation for the very simple reason that humans regularly (though not always) make use of their intelligence when they interpret utterances—and only certain aspects of this intelligent behavior can be captured by formal tools under strong rationality postulates.

2.5 Summary and Conclusions

It has been argued that indexicality needs to be carefully distinguished from other forms of linguistic context-dependence. Contextuals such as *ready* and *tall* are semantically incomplete or—as in the case of expressions like *having breakfast*, tenses and the boundaries of spatiotemporal indexicals—their apparent semantic completeness is an artifact of the underlying possible world, event, or situation ontology and they commonly require additional interpretation. They may be indexical or not. Some adequacy criteria for dealing with contextuals in a truth-conditional setting have been laid out and it has been argued that modeling the context-dependence of contextuals like indexicality is generally inadequate. It has been suggested to compute existential completions first and consider how an agent arrives at an interpretation on the basis of that content by free enrichment instead. An example has been given how to achieve this in a qualitative setting by ordering the intensional base states by a preference relation and 'abduce' the most plausible subset of states satisfying a certain intension.

A crucial problem for modeling deep interpretation in this way is, however, how to obtain and explain the preference relation in the first place which yields an agent's preferred interpretation. In an ideally rational approach this relation has to be connected to ways in which an agent deals with evidence obtained from sources of varying reliability. The account needs to be linked up with existing results in Formal Epistemology such as theories of graded belief based on probabilities, Dempster-Shafer belief, and possibility theory. It is likely that in the context of modeling natural language interpretation more mechanisms than graded belief and some form of abductive inference are needed. In particular, the role played by the QUD has to be investigated in more detail and richer ontologies with default reasoning are needed.

Appendix: Language $T\tilde{y}$

Types. Base types are e for entities in D_e, s for situations in D_s, and t for truth-values. If α, β are types, then $(\alpha\beta)$ is a type. Nothing else is a type. $D_t = \{1, 0\}$. For better readability, parentheses around types are sometimes left out; for example, sst may abbreviate $(s(st))$.

Terms. We assume a fixed vocabulary of expressions, using x, y, z for variables of type D_e and s, u and indexed variants for variables of type s. An expression of base type α is a term of type α. If A is of type $(\beta\alpha)$ and B is of type β, then (AB) and (BA) are of type α. If x is a variable of type β and A is an expression of type α, then $(\lambda x.A)$ is a term of type $(\beta\alpha)$. For each pair of terms A, B of type α, $(A = B)$ is a term of type t. Familiar infix notation may be used for the standard logical connectives $\vee, \wedge, \equiv, \rightarrow$. The binder notation will be used

for standard quantifiers, i.e., $\forall xA$ is written instead of $(\forall(\lambda x.A))$, and a dot may be used to indicate a left parenthesis whose implicit closing right parenthesis has maximal scope. Traditional operator syntax will also be used in many places, types and parentheses are sometimes omitted, and implicit β-conversions are allowed for better readability. This means that for instance $Hungry(s, Alice)$ may be written instead of $(((\lambda s_s(\lambda x_e.Hungry_{(s(et))}))\, s_s)\, Alice_e)$. A term of the form $\sim A$ is the inner negation form of A and there is no inner negation form of an inner negation form.

Semantics. A standard $T\tilde{y}$ frame consists of a set containing sets D_α for each base type α and domains $D_{(\alpha\beta)} = D_\beta^{D_\alpha}$ for all compound types $(\alpha\beta)$. We write g for an assignment and $g[x/a]$ for the assignment that is the same as g except that $g(x) = a$. A standard model $\mathcal{M}$ for $T\tilde{y}$ is a tuple $\langle \mathcal{F}, [\![.]\!] \rangle$ consisting of a standard frame $\mathcal{F}$ and an interpretation function $[\![.]\!]$ that in dependence of a variable assignment g maps terms to their denotation according to their type as follows:

1. $[\![x_\alpha]\!]^{\mathcal{M},g} = g(x)$ if x is a variable, where $g(x) \in D_\alpha$.
2. $\left[\!\left[(A_t \wedge_{(t(tt))} B_t)\right]\!\right]^{\mathcal{M},g} = 1$ if $[\![A]\!]^{\mathcal{M},g} = 1$ and $[\![B]\!]^{\mathcal{M},g} = 1$; 0 otherwise.
3. $[\![\neg A]\!]^{\mathcal{M},g} = 1$ if $[\![A]\!]^{\mathcal{M},g} = 0$; 0 otherwise.
4. $\left[\!\left[(A_{(\beta\alpha)} B_\beta)\right]\!\right]^{\mathcal{M},g} = [\![A]\!]^{\mathcal{M},g}([\![B]\!]^{\mathcal{M},g})$, where $[\![A]\!]^{\mathcal{M},g} \in D_{(\beta\alpha)}$; likewise for terms of the form $(B_\beta A_{(\beta\alpha)})$.
5. $\left[\!\left[(\lambda x_\beta.A_\alpha)\right]\!\right]^{\mathcal{M},g}$ is that function f in $D_{(\beta\alpha)}$ such that for any a in D_β, $f(a) = [\![A]\!]^{\mathcal{M},g[x/a]}$.
6. $[\![(\forall(\lambda x_\alpha.A))]\!]^{\mathcal{M},g} = 1$ if $[\![A]\!]^{M,g[x/a]} = 1$ for any $a \in D_\alpha$; 0 otherwise.

Inner Negation Constraint. $[\![A]\!]^{M,g} \cap [\![\sim A]\!]^{M,g} = \emptyset$ for any expression A, i.e., a positive term A and its inner negation form $\sim A$ have distinct extensions.

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