

# Indexicals and Compositionality: Inside-Out or Outside-In?

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## Abstract

Two different approaches to the compositional semantics of indexicals are compared. The outside-in approach uses  $\lambda$ -abstraction and is heavily lexicalised. The inside-out approach treats indexicals by presupposition resolution. The former is relatively simple to implement and deals in a natural way with multiple occurrences of indexicals. The latter is more complex, but has potential to deal with a wider range of indexical phenomena. However, it needs to be constrained in a practical implementation as it over-generates.

## 1 Introduction

Indexicals, linguistic expressions such as *I*, *you*, *today* that are highly sensitive to context, pose a challenge for compositional semantics, because their interpretation is highly context-sensitive. Sentences such as (1), demonstrating direct speech, and (2), showcasing reported speech, have similar meaning (the second entails the first, but not vice versa, as John might have uttered different words to indicate that he left). Hence, an algorithm developed for compositional semantics should predict this entailment.

- (1) **John said that he left.**
- (2) **John said, “I leave”.**

In semantic parsing it is considered to be advantageous to use a systematic, compositional approach, as it scales up to implementations that require robustness and wide coverage. There are various theoretical approaches to the interpretation of indexicals (Schlenker, 2004; Maier, 2009). In this paper I compare two different theories, in order to evaluate which of the two is more suitable for wide-coverage semantic parsing.

The first approach is what I dub an “outside-in” approach: once a proposition is contextualised, indexicals inside it are resolved with the information from outside (the context). I think this approach can be characterized as Kaplanian (Kaplan, 1989), although the implementation that I present here is new – as far as I know. The second approach is an “inside-out” approach: it deals with indexicals by treating them as anaphoric species of presuppositional nature, finding antecedents outside in the surrounding context. This approach finds its roots in the *presupposition as anaphora* theory (Van der Sandt, 1992), and has been worked out in detail for indexicals by Zeevat (1999), Maier (2009) and Hunter (2013).

## 2 Methodology

The comparison of the two approaches is carried out in the framework of Discourse Representation Theory (DRT). Unlike standard DRT (Kamp and Reyle, 1993), I assume a neo-Davidsonian approach with an inventory of thematic roles similar to that of VerbNet (Kipper et al., 2008). The basic assumption is that sentences such as (1) and (2) have the meanings that are represented by the Discourse Representation Structures (DRS) shown in (3) and (4), thereby predicting that the latter entails the former.

$$(3) \quad \llbracket (1) \rrbracket = \begin{array}{|l} \hline x \ s \ p \\ \hline \text{person}(x) \ \text{named}(x, \text{"John"}) \\ \text{say}(s) \ \text{agent}(s,x) \ \text{topic}(s,k) \\ \hline p: \begin{array}{|l} \hline e \\ \hline \text{leave}(e) \ \text{agent}(e,x) \\ \hline \end{array} \\ \hline \end{array}$$

$$(4) \quad \llbracket (2) \rrbracket = \begin{array}{|l} \hline x \ s \ p \\ \hline \text{person}(x) \ \text{named}(x, \text{"John"}) \\ \text{say}(s) \ \text{agent}(s,x) \ \text{topic}(s,p) \ p = \text{"I leave"} \\ \hline p: \begin{array}{|l} \hline e \\ \hline \text{leave}(e) \ \text{agent}(e,x) \\ \hline \end{array} \\ \hline \end{array}$$

In the remainder of this paper, the two approaches are compared by giving a compositional analysis of (2) using the basic machinery of the  $\lambda$ -calculus. I will use  $\llbracket \cdot \rrbracket_{oi}$  to denote meanings for natural language expressions from the outside-in approach, and  $\llbracket \cdot \rrbracket_{io}$  to denote meanings from the inside-out method. In cases where there is no distinction in meaning between the two approaches the subscript will be dropped. As we will see, the two approaches have completely different ways to deal with indexicals, but will eventually – for this simple example, at least – produce the same meaning representation.

### 3 Approach I: Contextualising Indexicals Outside-In

The basic idea of this approach is to use a distinct set of indexed variables that denote indexical meanings. This must be a finite set, and for the purposes of this paper we can take this to be a small set of free variables  $i_{speaker}$ ,  $i_{hearer}$  and  $i_{now}$ . These free variables are introduced in the lexical semantics of indexical expressions. For instance, the first-person pronoun *I* will get the following meaning representations ( $\oplus$  denotes merging of DRSs):

$$(5) \quad \llbracket \mathbf{I} \rrbracket_{oi} = \lambda p. \left( \begin{array}{|l} \hline x \\ \hline x = i_{speaker} \\ \hline \end{array} \oplus p(x) \right)$$

In (5) an explicit discourse referent is introduced for the first-person pronoun. It is unclear to me whether this is necessary from a theoretical point of view, as eventually, the free, indexical variables will be substituted by variables bound by discourse referents provided by the context in which the indexical expression is analysed. Therefore, I assume a simplified (but logically equivalent) lexical meaning for the first-person pronoun in (6).

$$(6) \quad \llbracket \mathbf{I} \rrbracket_{oi} = \lambda p. p(i_{speaker})$$

Suppose we combine the meaning in (6) with the meaning of an intransitive verb (7). This will yield the DRS (8). Note that the resulting DRS contains the free variable  $i_{speaker}$ . It is free because it is not contextualised yet. Quotation is a way to close the boundaries of a proposition and make it sensitive to the context. This is done in (9) by  $\lambda$ -abstracting over all indexed variables (for the sake of simplicity we just do it here for the free variable representing the *speaker*).

$$(7) \quad \llbracket \mathbf{leave} \rrbracket = \lambda x. \begin{array}{|l} \hline e \\ \hline \text{leave}(e) \ \text{agent}(e,x) \\ \hline \end{array}$$

$$(8) \quad \llbracket \mathbf{I leave} \rrbracket_{oi} = \llbracket \mathbf{I} \rrbracket_{oi}(\llbracket \mathbf{leave} \rrbracket) = \begin{array}{|l} \hline e \\ \hline \text{leave}(e) \ \text{agent}(e, i_{speaker}) \\ \hline \end{array}$$

$$(9) \quad \llbracket \text{"I leave"} \rrbracket_{oi} = \lambda i_{speaker}. \llbracket \mathbf{I leave} \rrbracket_{oi} = \lambda i_{speaker}. \begin{array}{|l} \hline e \\ \hline \text{leave}(e) \ \text{agent}(e, i_{speaker}) \\ \hline \end{array}$$

Now we are ready to provide the context, as the quotation of the reported speech in (2) is the direct object of the transitive verb (10). Here,  $\mathcal{P}$  is a function that returns the phonetic form that triggered the meaning representation. Function application then will yield (11), resolving the indexical; combining this with (12) will give the desired DRS (4).

$$(10) \quad \llbracket \text{said} \rrbracket_{oi} = \lambda k. \lambda x. \begin{array}{|l} \hline e \ p \\ \hline \text{say}(e) \\ \text{agent}(e,x) \\ \text{topic}(e,p) \\ p = \mathcal{P}(k) \\ p: k(x) \\ \hline \end{array}$$

$$(11) \quad \llbracket \text{said} \rrbracket_{oi}(\llbracket \text{"I leave"} \rrbracket_{oi}) = \lambda x. \begin{array}{|l} \hline e \ p \\ \hline \text{say}(e) \\ \text{agent}(e,x) \\ \text{topic}(e,p) \\ p = \text{"I leave"} \\ p: \lambda i_{\text{speaker}}. \begin{array}{|l} \hline e \\ \hline \text{leave}(e) \\ \text{agent}(e, i_{\text{speaker}}) \\ \hline \end{array} (x) \\ \hline \end{array} = \lambda x. \begin{array}{|l} \hline e \ p \\ \hline \text{say}(e) \\ \text{agent}(e,x) \\ \text{topic}(e,p) \\ p = \text{"I leave"} \\ p: \begin{array}{|l} \hline e \\ \hline \text{leave}(e) \\ \text{agent}(e,x) \\ \hline \end{array} \\ \hline \end{array}$$

In sum: this approach assumes a small finite set of variables distinct from the usual set of first-order variables. It further assumes that contextualisation is dealt with in the lexicon, by expressions that indicate reported speech. No special, new machinery is required: the  $\lambda$ -calculus can deal with it all.

## 4 Approach II: Contextualising Indexicals Inside-Out

In the second approach, resolution of indexicals is considered to be part and parcel of an existing presupposition projection algorithm. Hence, indexicals are viewed as presupposition triggers and are lexically represented as such. I assume a projection theory similar to that of Van der Sandt (1992) and Hunter (2013). Presuppositional material is separated from assertive information using the  $*$  operator, following Venhuizen et al. (2013). Consider now the lexical entries for the presupposition triggers in (12) and (13).

$$(12) \quad \llbracket \text{John} \rrbracket = \lambda p. \left( \begin{array}{|l} \hline x \\ \hline \text{person}(x) \text{ named}(x, \text{"John"}) \\ \hline \end{array} * p(x) \right)$$

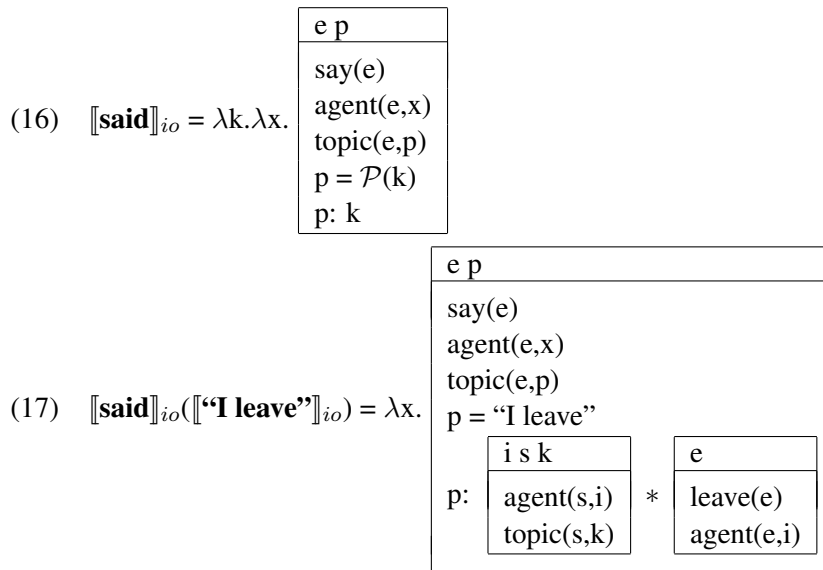
$$(13) \quad \llbracket \text{I} \rrbracket_{io} = \lambda p. \left( \begin{array}{|l} \hline i \ s \ k \\ \hline \text{agent}(s,i) \\ \text{topic}(s,k) \\ \hline \end{array} * p(i) \right)$$

The indexical presupposition of the first-person pronoun is here, closely following Hunter (2013), a complex proposition of a speech event, its agent, and its topic. Combining this with the intransitive verb (7) yields a meaning representation (14) with the presupposition that there is some speech act with the speaker co-referring with the agent of the “leaving” event. The question is what role quotation plays in the second approach. For now I assume the quotes don’t alter the meaning in the inside-out theory of indexicals (if it would, it would need to do so by adding some semantic information to the DRS), and hence we can state the equation in (15).

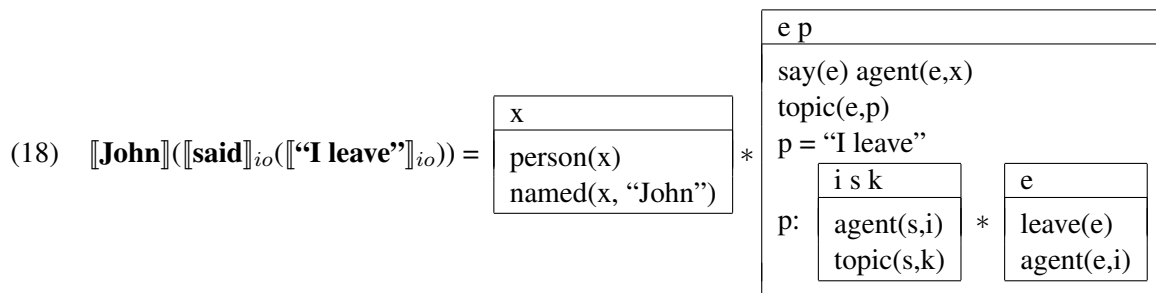
$$(14) \quad \llbracket \text{I leave} \rrbracket_{io} = \llbracket \text{I} \rrbracket_{io}(\llbracket \text{leave} \rrbracket) = \begin{array}{|l} \hline i \ s \ k \\ \hline \text{agent}(s,i) \\ \text{topic}(s,k) \\ \hline \end{array} * \begin{array}{|l} \hline e \\ \hline \text{leave}(e) \\ \text{agent}(e,i) \\ \hline \end{array}$$

$$(15) \quad \llbracket \text{"I leave"} \rrbracket_{io} = \llbracket \text{I leave} \rrbracket_{io}$$

Now consider the lexical meanings for the speech reporting verb in the inside-out approach (16). It differs from (10) because it does not have to alter its argument. Instead, it will combine with (15) to produce (17).



Combining (17) with (12) will yield (18), a *proto*-DRS, using the terminology of Van der Sandt (1992), with two presuppositions that need to be resolved. The first presupposition triggered by the proper name "John" cannot be resolved by linking it to an accessible antecedent, so it will be accommodated. The second, indexical presupposition can be resolved in the context as the "saying" event provides a suitable antecedent. This will yield, then, a DRS equivalent to (4).



In sum: this approach requires a rich lexical representation for indexicals. It further assumes that contextualisation is dealt with during the presupposition projection. No special, new machinery is required, as one needs to deal with presuppositions anyway in a formalism aiming at a wide coverage of linguistic expressions. However, to constrain the resolution of indexicals it is required that particular rules need to be added to the algorithm (there could be several potential antecedents for an indexical presupposition, but only one can be correct; local accommodation needs to be banned). This has also been recognized by advocates of the inside-out approach (Zeevat, 1999; Maier, 2009; Hunter, 2013), who propose various extensions to the presupposition resolution algorithm to include indexicals.

## 5 Comparing the Approaches

Both approaches lead to the same meaning representation, but the way in which the composition process evolves is radically different (Table 1). In the Kaplanian outside-in approach,  $\lambda$ -abstraction is used to contextualize indexicals. In the Van der Sandtian inside-out framework, indexicals are contextualised under the umbrella of presupposition resolution. Neither of the approaches uses new machinery:  $\lambda$ -abstraction and function application is used in the general process of semantic composition, and presupposition projection is required to deal with the large variety of presupposition triggers (such as names, definite descriptions, factuality, and so on).

Table 1: Comparing the two approaches to indexical interpretation.

	<b>Approach I: Outside-In</b>	<b>Approach II: Inside-Out</b>
Origin	Kaplan (1989)	Zeevat (1999); Maier (2009); Hunter (2013)
Representation	Simple	Complex
Machinery	$\lambda *$	$\lambda *$
Resolution	$\lambda$	*
Knowledge	Lexical	External
Quoted Speech	plays an important role	not considered
Extra	indexed variables	dedicated resolution strategies

Arguably, the meaning representations of the outside-in approach are way simpler. The inside-out approach does not require a distinct set of indexed variables, but needs to impose dedicated rules in the presupposition projection algorithm to deal with indexicals. It is also unclear how the latter incorporates direct speech in the meaning representation, for it seems to be important to steer the resolution of indexical presuppositions. Consider, for instance the following contrasting pair of examples:

- (19) John said that Mary said, “I am happy”.  
(20) John said, “Mary said I am happy”.

Clearly, (19) and (20) differ in meaning. The outside-in approach will deal with this in a straightforward way. The inside-out approach will face a difficulty here, as the proto-DRS for the two sentences will be identical since quotes are ignored in the DRS.

Another issue are sentences with multiple occurrences of indexicals, as “I love my dog.” Here the outside-in approach takes advantage of the fact that both the personal pronoun and the possessive introduce the same free indexical variable. The inside-out approach needs to guarantee that both presuppositions that are invoked, will be resolved to the same antecedent.

## 6 Conclusion

It is perhaps attractive to have one mechanism that covers all kind of contextual phenomena. But there are many kinds of contextual phenomena each showing quite different types of behaviour. Although Maier (2009); Hunter (2013) argue that viewing indexicals as a type of presupposition solves some of the puzzles to do with bound pronouns, it also requires a complex implementation of the presupposition projection algorithm. A simple Kaplanian approach, as presented in this paper, might well be a good alternative for the purpose of wide-coverage semantic parsing: it is easy from a representational point of view, and cheap to implement. This is also the choice of analysis in the Parallel Meaning Bank, a large semi-automatically annotated corpus of DRSs for four languages (Abzianidze et al., 2017).

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