Mechanisms of Linguistic Behavior
Theory of Mind in Hard-Science Linguistics

Douglas W. Coleman
University of Toledo

Abstract: Theory of mind has been defined in various ways. What it attempts to explain also enters into many cases of everyday communication. However, describing simple communicative acts typically presents a linguistically intractable problem of referential decoding—but not in hard-science linguistics. This paper examines several linkages in detail and shows how orthoconcepts eliminate cases of purported intractability and make possible an explicit formal approach to many questions relating to reference. It will be shown that this is because of the ability of HSL to interconnect descriptions at the social (linkage) and individual (participant / role part) levels of analysis.

Keywords: theory of mind, hard-science linguistics, human linguistics, orthoconcepts, reference

Languages: English

In a classic experiment, the researcher shows a child a candy box and asks the child to guess what is in the box. The child, of course, guesses candy. The researcher then shows the child that the box, in fact, contains pencils. Then a second child who has not yet seen what is in the box is brought into the room. The first child is asked to say what the second child will guess is in the box. Sometimes instead of a second child, a puppet is used (Miller 2007:254). Children who are described as not yet having developed a theory of mind answer pencils, not candy (Hogrefe et al. 1986). They cannot distinguish their own understanding of the state of affairs in the world from the (incorrect) understanding of another person. (Hence such experiments are often referred to as false-belief studies.)

“Theory of mind” has been defined in various ways, perhaps most generally as “how people go about making sense of other minds” (Astington & Gopnik 1991:7, paraphrased by Costall & Leudar 2004: 624). The term “theory of mind” is attributed to Premack (Premack & Woodruff 1978, cf. Leudar et al. 2004). There are those whose treatment of intentionality as captured by theory of mind “is profoundly Cartesian—epistemically and methodologically dualist” (Leudar et al. 2004:573). This is not an empty criticism:

People are more than their physical bodies. We are more than dynamic bags of skin that can be seen, heard, and weighed.... [P]ersons also have beliefs, desires, and intentions that lie below the surface behavior. One cannot directly see, taste, smell,
or hear mental states, but it is an essential part of our ordinary adult understanding that other people have them.\(^1\) *Theory of mind* research investigates the development of this framework. (Meltzoff 1999:257)

Moreover, “I would not want to suggest that this theory is reducible to behavior, but more strongly I would also deny that it is based on behavior” (Gopnik 1993:10, cited by Costall & Leudar 2004:636).

For many theory of mind researchers, the developing child is regarded as a theorist much like the developmental psychologist:


Hence the “theory” in “theory of mind.” Children (and when they grow up, adults) are seen as theorists who must construct representations of others’ mental states. Leudar et al. (2004:574) argue that this way of thinking about the problem and the typical experimental tasks used in studies on theory of mind “both intellectualize intentionality and put abstract solipsistic reasoning about solipsistic mental states on centre stage.” The alternative Leudar et al. offer “is to take situated social actions as the object of psychology, whose intentionality is directly graspable, without the benefit of an inference or mediating theory” (ibid.). While we may certainly question what intentions are “directly graspable” as opposed to “inferred,” we can certainly avoid the most serious methodological problems simply by taking to heart the advice of Lieberman (2003:3): “We can only study the physical characteristics of living species” (emphasis added).

Indeed, it has been suggested by recent research on mirror neurons that they may function so as to allow an individual not only to perform basic motor procedures without thinking about them but also to comprehend those acts when they are observed, without any need for explicit reasoning about them. (Rizzolati et al. 2006:56, emphasis added)

This conclusion was based on various research studies showing that patterns of neural response correlate between performing an act and observing it performed by another.

In this paper, I have two primary goals. The first is to show how understanding of others of the kind theory of mind (henceforth, ToM) tries to capture can be formalized in a linguistic theory. The second is to show how this can be done without introducing dualism and thus without logical-physical domain confusions (Yngve, 1996:45–46, *passim*; Sypniewski 2007:*passim*).

\(^1\) Note the confusion here between that which cannot be *directly* observed and that which is not physically real. Gravity is not physically real, yet as a force it is part of a theory of the physical world, as are other entities not *directly* observable at the time they entered theories of physics, chemistry or biology (e.g., atoms, radio waves, genes).
1. Orthoconcepts in Hard-Science Linguistics. Orthoconcepts are properties of a person communicating in the real world, couched in physical domain terms. As Yngve (2006:268) says, they “form in the observing role part of an observer” and “are not free-standing abstractions. Orthoconcepts are properties in a theory of a real observer that model a physical reality and require an observer in which to form.” Thus, in addition to modelling a person as a participant in a particular linkage, we can model him as a participant in an observing linkage, one in which he is an observer of the linkage in which he is taking part. With orthoconcepts we can thus model a person’s understanding of objects and other people in the linkage he is observing. To demonstrate this, I will take the case of the classic false-belief experiment of the unexpected contents task type involving the candy box which contains pencils (Hogrefe et al. 1986).

2. The Classic False-Belief Experiment Described in Terms of People and Orthoconcepts. A linguistic analysis might typically focus on the discourse between the researcher and child, as in (1). The real-world objects (the box, the pencils, the Sesame Street puppet Ernie) and most of the events (the researcher opening the box to show the child what is in it, reclosing the box, and bringing out the Ernie puppet) are treated as an afterthought—not as the core of what is to be described. But in a Hard-Science Linguistics (henceforth HSL) analysis, we focus on all of the relevant real-world objects and events, modelling the people in terms of participants and their role parts, the objects in terms of props and their prop parts, and the energy flow (the light waves and sound waves moving among the people and objects) in terms of channels and their channel parts.2

(1)  
\[ \text{a. Researcher: What do you think is in this box?} \]
\[ \text{b. Child: Candy.} \]
\[ \text{c. Researcher: Ann hasn’t seen inside this box. What will Ann think is in the box before I open it?} \]
\[ \text{d. i. Candy.} \]
\[ \text{ii. Pencils.} \]

(2)  
\[ \text{a. [unexpectedContents] = [researcher] + [child] + [child] + [candyBox]} \]
\[ \text{b. [candyBox]<contents/pencils>} \]

We can model the interaction between the researcher and the child as a linkage [unexpectedContents], with the people modelled as participants—the subsystems [researcher], [child], and [child] and the candy box containing pencils modelled as a prop—the

2 In HSL we distinguish between our view of an object or event in terms of its structure as a physical system (e.g., participant) vs. its functional cause-effect role (e.g., role part) in a larger system of which it is only one component; we label the larger system in this case a linkage.

3 One reviewer noted my inclusion of you think in this narrative and questioned the validity of the unexpected contents task as we may not be sure “how a child decodes a sentence with you think in it.” However, this is only my version. The unexpected contents task has been applied many times without a fixed script, e.g., with What is in this box? and What will Ann say is in this box? etc.
subsystem \([\text{candyBox}]; [\text{child}_1]\) represents Ann; see (2)a. The candy box has the property of containing pencils, we indicate this as \(<\text{contents/pencils}>>\), as in (2)b.

(3)  
   a. \([\text{Obs}_1] = [\text{researcher}] + [\text{unexpectedContents}]\)  
   b. \([\text{researcher}] < [\text{candyBox}] < \text{contents/pencils}>>\)

The researcher is also an observer of the linkage in which he takes part. We model this as the observing linkage \([\text{Obs}_1]\) in (3)a, which consists of \([\text{researcher}]\) as the observing participant and the linkage \([\text{unexpectedContents}]\), of which \([\text{researcher}]\) is a member, but in a different role part. As an observer of the \([\text{unexpectedContents}]\) linkage, \([\text{researcher}]\) possesses the property \(<[\text{candyBox}]<\text{contents/pencils}>>\); this property models the researcher’s understanding of what is in the candy box during the experiment (3)a.

(4)  
   a. \([\text{Obs}_2] = [\text{child}_1] + [\text{unexpectedContents}]\)  
   b. \([\text{child}_1] < [\text{candyBox}] < \text{contents/candy}>>\)  
   c. \([\text{child}_1] < [\text{candyBox}] < \text{contents/pencils}>>\)

Likewise, the first child \([\text{child}_1]\) is also an observer of the linkage in which he takes part. We model this as the observing linkage \([\text{Obs}_1]\) in (4), which consists of \([\text{child}_1]\) as the observing participant and the linkage \([\text{unexpectedContents}]\), of which \([\text{child}_1]\) is a member, but in a different role part. As an observer of the \([\text{unexpectedContents}]\) linkage, \([\text{child}_1]\) possesses a property representing his understanding of the candy box. This property changes in value, from \([\text{child}_1] < [\text{candyBox}] < \text{contents/candy}>>\) before he has seen what is in the box to \([\text{child}_1] < [\text{candyBox}] < \text{contents/pencils}>>\) afterwards; see (4)b–c.4

(5)  
   a. \([\text{ObsObs}_1] = [\text{researcher}] + [\text{Obs}_2]\)  
   b. \([\text{researcher}] < [\text{child}_1] < [\text{candyBox}] < \text{contents/candy}>>\)  
   c. \([\text{researcher}] < [\text{child}_1] < [\text{candyBox}] < \text{contents/pencils}>>\)

The researcher is also an observer of the first child’s observing linkage; this is modelled via the linkage \([\text{ObsObs}_1]\), in (5)a. We can model the change in the researcher’s understanding of what the child understands about the contents of the box by showing a change in value of a property of the researcher in \([\text{ObsObs}_1]\) from (5)b to (5)c.

When Ann \([\text{child}_2]\) is brought in, we also model her understanding of the linkage in which she is taking part in terms of an observing linkage \([\text{Obs}_3]\), in (6). We attribute the property to her \([\text{child}_2] < [\text{candyBox}] < \text{contents/candy}>>\) before she has been shown what is in the box.

4 We can describe the change in value in terms of a combination of external events and internal states of the child, thus as procedural properties (Yngve, 1996:164, 246–274) of \([\text{child}_1]\). To do so we would specify the relevant causes in selection procedures and the changes in state, including motor activity, in task procedures. But these details will be left aside for now.
(6)  
\[\text{a. } \text{[Obs}_3\text{]} = \text{[child}_2\text{]} + \text{[unexpectedContents]}\]

\[\text{b. } \text{[child}_2\text{]}<\text{[candyBox]}<\text{contents/candy}>\]

If the first child is able to possess properties that correspond to those we model in terms of being an observer of an observing linkage, then he will also be an observer in the linkage modelled in (7). In this case, he will be able to form an understanding of the second child which we model as the critical property shown in (7)b, which would change value to what is shown in (7)c only after he has seen her see what is inside the candy box.

(7)  
\[\text{a. } \text{[ObsObs}_2\text{]} = \text{[child}_1\text{]} + \text{[Obs}_3\text{]}\]

\[\text{b. } \text{[child}_1\text{]}<\text{[child}_2\text{]}<\text{[candyBox]}<\text{contents/candy}>>\]

\[\text{c. } \text{[child}_1\text{]}<\text{[child}_2\text{]}<\text{[candyBox]}<\text{contents/pencils}>>\]

On the other hand, if the first child is unable to possess such properties—that is, if his cognitive development is such that he is not yet able to form such understandings of others, then what we are modelling in (7) will not apply to him at all. Having seen what is in the box, he will have only the property (4)c to access when the researcher asks, “What will Ann think is in the box before I open it?” Thus, what has frequently been labeled ToM we can model in HSL as the ability to take part in a linkage as an observer of another’s observing linkage.

3. UNDERSTANDING ABOUT OTHERS’ CONCERNS MORE THAN THE CLASSIC FALSE-BELIEF SCENARIOS OF TYPICAL TOM EXPERIMENTS. Understanding of the states of others enters into many cases of everyday communication. HSL deals with such cases not in terms of discourses consisting of utterances which might be contextualized, but rather begins in terms of the people and relevant objects in their environment. To further illustrate the difference in approach, take the following example in (8).

(8)  
\[\text{a. } \text{Peter: Could you hand me that book?}\]

\[\text{b. } \text{Quentin: Sure.}\]

Here we have a discourse assumed to consist of two utterances, *Could you hand me that book?* and *Sure*. In HSL we would instead start by considering the entirety of the event, which might go as follows. Peter is in his dorm room, at his desk working on a history paper. He has his back to a table, at which his roommate, Quentin, is also working; but Quentin is doing homework for a math class. There are two books on the table, both easily within Quentin’s reach, but well out of reach of Peter. Without even turning to look, and barely pausing in writing his draft, Peter reaches over his shoulder and says, “Could you hand me that book?” One of the two books is Quentin’s math book. The other is one of Peter’s books on French history, the topic of his paper. Without hesitation or conscious analysis, Quentin takes the history book and hands it to Peter. Describing simple acts of this type typically presents a linguistically intractable problem of referential decoding (see,
e.g., Levinson 2006:100–3 on the logical problem of indexicality)—but not in HSL (Yngve 1996).\footnote{A reviewer suggests that “indexicality became a problem because of the limitation [of one’s view] to a single sentence in its written form.... Pragmatics was brought in because indexicality was otherwise intractable under this limitation.” However, when pragmatics is brought in, it does not usually offer a way to know what real-world knowledge (\textit{RWK}) is relevant. A perennial problem in studies in artificial intelligence and natural language processing has been limiting the search over \textit{RWK} to a scope that is not intractable. This reviewer has raised an interesting point. For more, see the next footnote.}

We model the situation as four interrelated linkages \{BookRequest\}—Peter asking Quentin for the book \((9)a\); \{RoommateWriting\}—Peter writing his paper \((10)a\); and \{ObsWriting\}—Quentin observing Peter writing the paper \((11)a\).

\begin{align*}
(9) & \quad \text{a. } \text{[BookRequest]} = \text{[Peter]} + \text{[Quentin]} + \text{[book}_1\text{]} + \text{[book}_2\text{]} \\
& \qquad \text{b. } \text{[book}_1\text{]}<\text{topic/French history}> \\
& \qquad \text{c. } \text{[book}_2\text{]}<\text{topic/math}>
\end{align*}

\begin{align*}
(10) & \quad \text{a. } \text{[PaperWriting]} = \text{[Peter]} + \text{[paper]} + \text{[book}_3\text{]} \\
& \qquad \text{b. } \text{[paper]}<\text{topic/French history}>
\end{align*}

\begin{align*}
(11) & \quad \text{a. } \text{[QObsWriting]} = \text{[Quentin]} + \text{[PaperWriting]} \\
& \qquad \text{b. } \text{[Quentin]}<\text{[paper]}<\text{topic/French history}>>
\end{align*}

In the role part associated with Quentin in the \{QObsWriting\} linkage, we can model Quentin’s understanding of Peter writing his paper via the orthoconcept \{Quentin\}<\{PaperWriting\}> , a subpart of which is the orthoconcept \{Quentin\}<\{paper\}> ; see \((11)\) (a)-(b) and \((10a)\). When Peter asks for “that book,” Quentin must select between the books which are present, \{book\}_1 and \{book\}_2. Quentin selects \{book\}_1 because a property of the book, modelled as \{book\}<\text{topic/French history}>> in the \{PaperWriting\} linkage, matches a subproperty of that of his understanding of the paper, which we model as \{Quentin\}<\{paper\}<\text{topic/French history}>> in the \{QObsWriting\} linkage.\footnote{The same reviewer quoted in the previous footnote describes a similar situation from personal experience: “When my [college] roommate asked me for the math book, there were two on the desk. I handed him the one that was not mine without looking to see whether it was his. It was the simplest solution. No intractable indexical\{ity\} problem.” He also says, “I wasn’t aware of the indexical complexity at the time.” Of course not. The infinite regress problem and the more general problem of how to limit a search over \textit{RWK} to a scope that is not intractable. This reviewer has raised an interesting point. For more, see the next footnote.}
Note that we do not even need to model Quentin’s understanding of Peter’s understanding (either of the book or paper, for example) in order to predict that Quentin will be able to hand Peter the right book.

However, let’s consider a more complex case. Suppose that a breeze is coming in from an open window and Peter repeatedly has to work to keep some of his papers from being blown around. Now suppose that the French history book is very lightweight, a very thin paperback, but that the math book is a larger and heavy hardcover edition. We know that it is very likely Quentin will respond to Peter saying “Will you hand me that book?” not by handing Peter the French history book in this case, but by handing him the heavier math book. Whether Quentin hands Peter the math book is tied to whether Quentin notices the trouble Peter is having with the wind blowing the papers.

We need to model Peter as an observer of the paper-writing linkage in which he is a participant; this is the observer linkage \([\text{PObsWriting}]\) in (12)a. We model his understanding of the papers blowing as an orthoconcept in (12)b.

\[
\begin{align*}
(12) & \quad \text{a. [PObsWriting] = [Peter] + [PaperWriting]} \\
& \quad \text{b. [Peter]<[papers]<blowing>>}^7 \\
& \quad \text{c. [Peter]<[book,]<~heavy enough>>} \\
& \quad \text{d. [Peter]<[book,]<heavy enough>>}
\end{align*}
\]

In order for him to respond to Peter’s request appropriately this time, Quentin must have an understanding of Peter’s understanding of the paper-writing linkage. This is modelled as the linkage \([\text{QObsPObsWriting}]\), in which Quentin is an observer of Peter’s observing linkage; see (13).

\[
\begin{align*}
(13) & \quad \text{a. [QObsPObsWriting] = [Quentin] + [PObsWriting]} \\
& \quad \text{b. [Quentin]<[Peter]<[papers]<blowing>>} \\
& \quad \text{c. [Quentin]<[Peter]<[book,]<weight/~heavy>>} \\
& \quad \text{d. [Quentin]<[Peter]<[book,]<weight/heavy>>}
\end{align*}
\]

The books, now considered in terms of their internal physical structure (as props) rather than in terms of their functional aspects (as prop parts), must also be modelled in the [BookRequest] linkage as possessing their relative weight properties \([\text{book,}<weight/~heavy}>\) and \([\text{book,}<weight/heavy}>\). We can model Quentin again as performing a matching

---

7 At this point is is necessary to distinguish the papers as a physical system modelled as the prop [papers], a subpart of the linkage [PaperWriting], from their functional aspect within that larger system, this functional aspect being modelled as the prop part [paper]. These are two models of the same real-world object, one in terms of internal physical structure (prop), the other in terms of functional (cause-effect) relations within its physical-domain context. The same goes for the books. Earlier, we were considering it in terms of their functional aspect (prop part) when we modelled them as having the property <topic>. Now we are considering the book in terms of its internal structural properties (as a prop) when we assign it the property <weight>. Both theoretical constructs (prop and prop part) model real-world (physical-domain) aspects of an object.
operation, this time between the properties of the books in the book-requesting linkage [BookRequest] and the property in the [QObsPObsWriting] linkage in (13). In this way we can explain how it is that Quentin will hand Peter a different book depending on real-world conditions in which the two are communicating, such as whether Quentin knows the topic of the paper Peter is writing, whether Quentin notices there is wind blowing Peter’s papers around, and so on.

4. UNDERSTANDING SELF VS. ATTRIBUTING MENTAL STATES TO OTHERS. Research has shown that young children typically acquire an understanding of self before they can attribute mental states to others. As Keenan puts it,

> Children who haven’t gained understanding of self do not have an understanding of other. At a very simple level, once the child gains a basic sense of self, she gains a basic ability to attribute mental states. These abilities include understanding pointing and eye gaze. The 2-year-old can understand pointing and appears to be able to infer the intention of the pointer. (2003:93–94)

This is exactly what the above descriptions predict should occur.

Recall that an observing linkage in which a child takes part was described in (4)a as [Obs₁] = [child₁] + [unexpectedContents]. This is the observing linkage in which the child has the role part of observer, observing himself in the unexpected contents task. When the child has an understanding of the contents of the box as pencils, for example, we describe this via the orthoconcept [child₁]<[box]<contents/pencils>>, which requires the observing linkage (4)a in which to form. Thus, any property in the person that we describe via an orthoconcept in an observing linkage is one which requires an understanding of self.

The attribution of states by one person to another is more complex, and must be described in terms of an orthoconcept of an orthoconcept. For example, take the case when Peter’s papers are blowing and Quentin has an understanding that Peter knows his papers are blowing. An observing linkage in which Peter is the observer allows the description of the relevant property in Peter. The observing linkage is (12)a, or [PObsWriting] = [Peter] + [PaperWriting]. The property in Peter of being aware of the papers blowing is described as (12)b, [Peter]<[papers]<blowing>>. Quentin’s understanding of this property of Peter is arises in Quentin’s observing linkage, in which he is observing Peter’s observing linkage; the observing linkage of Quentin is (13)a, or [QObsPObsWriting] = [Quentin] + [PObsWriting]. Quentin’s understanding of Peter’s understanding of the papers blowing is described in terms of (13)b, an orthoconcept of an orthoconcept, specifically, [Quentin]<[Peter]<[papers]<blowing>>>. This what is commonly described in the literature on “theory of mind” as an attribution of a mental state to Peter by Quentin.

The HSL description thus predicts that, developmentally, understanding of self will precede the ability to attribute understandings to others.
5. CONCLUDING REMARKS. This paper shows briefly how so-called ToM can be explained entirely in terms of real-world properties of people communicating, without recourse to mixed-domain ghost-in-the-machine explanations. It shows how orthoconcepts (Yngve 2006) eliminate cases of purported intractability and make possible an explicit formal approach to certain questions relating to understanding reference in real-world situations. It also shows—in formal terms—how one person’s understanding of another’s understanding of a shared environment is critical to how people communicate. This is possible because of the ability of HSL to interconnect descriptions at the social (linkage) and individual (participant / role part) levels of analysis.

REFERENCES


