Semiotics as Theoretical Underpinning for Language Acquisition in Developmental Robotics

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Abstract. This extended abstract has the intention of advancing the idea that semiotics should play a key role in language acquisition systems for developmental robotics. Prominent points of view for semantics in computer science such as truth-functional semantics will be contrasted against the richer pragmatic theory of semantics. The scope of truth-functional semantics will be shown as being too narrow when implementing systems that aim to acquire and ground words and expressions of natural human language. This is caused by the abstraction away from the role of the interpreter in this type of semantics as well as the dynamic nature of semantics in human language development. Against this background some semioticians offer a considerably richer view of the nature of semantics as well as emphasizing the active role of the interpreter in semiosis. This pragmatic theory of semantics is not in opposition to the traditional truth-functional semantics but rather shifts the focus onto the communicative function of a particular utterance. We therefore argue for a pragmatic shift in terms of how researchers in the field think about semantics. We will therefore first give a very short introduction into the fields of developmental robotics and semiotics respectively. Subsequently we will elaborate on and argue for this pragmatic shift. This argument will be substantiated by invoking a practical example of how humans develop different uses and concepts of negation in early language development. A truth-functional analysis of this domain yields impoverished results whereas a pragmatically defined notion of meaning corresponds with our intuition of what infants actually communicate when engaging in this form of linguistic activity.

1 Introduction

Developmental robotics is concerned with devising methods that enable embodied agents to acquire autonomy and to exhibit behaviour that humans might label as intelligent. It might be categorized as a subfield of Artificial Intelligence Robotics (AI robotics) but has as well a strong theoretical overlap with cognitive science and developmental sciences (see (Murphy, 2001) and (Lungarella, Metta, Pfeiffer, & Sandini, 2003)). In the last two decades some researchers in AI robotics have been devoting effort to finding methods that enable artificial agents to acquire language. This area of research is the motivation for this study. Definitions of semiotics differ amongst philosophers. Trivially one can say that

semiotics is the science of signs. The signs of relevance in the given context are linguistic ones like words, utterances, or holophrases. Signs in semiotics always have a meaning thus sub-lexical units like phonemes or syllables are not considered to be signs. One major distinction in semiotics exists between dyadic and triadic sign models. We adopt a triadic sign model (see figure 1).
A dyadic model would collapse *interpretant* and *signified* into one "state". Signs are only meaningfully employed as part of sign systems (Goguen, 1999). A given physical entity or phonetic-sequence (= signifier) may play the role of different signs in different sign systems. The semiotic process (semiosis) is always embodied and situational. The mapping between signs and referent is typically not fixed in triadic models. Important for our purposes and not visible in figure 1 is the fact that the interpreter/locutor is always an essential part of the process. (Note: *interpretant* must not be confused with *interpreter*). We refer to (Nöth, 1995) for a comprehensive overview of semiotics.

2 The Move towards Pragmatics

The crucial distinction between truth-functional semantics and semiotics that forces us to postulate the necessity for a move in perspective towards semiotics is the following: Semantics in the former sense abstracts from the interpreter and adopts what is called a "third-person God's eye view" in (Nehaniv, 2000). Carnap expresses this stance in (Carnap, 1968): "If we are analyzing a language, then we are concerned, of course, with expressions. But we need not necessarily also deal with speakers and designata. [...] If we abstract from the user of the language and their designata, we are in the field of semantics." As robotic researchers concerned with the genesis of spoken human language we do not necessarily adopt a purely analytical but an analytical and constructive stance. Even when adopting a purely analytical standpoint the abstraction away from the language user reduces the ability of the language researcher to understand the mechanism behind the language acquisition process. This is especially prevalent in infants as the utterances used by them are deeply pragmatic in nature (see (Clark, 2009)).
Adopting semiotics as a theoretical and terminological framework only constitutes a first step of the pragmatical move: it directs the focus of the researcher away from the eternal ideas of the platonic realm (or the Oxford English Dictionary for that matter) back down to earth and to the particular agent. A plethora of different meanings of meaning is compatible with the semiotic triad, but only few seem to be compatible with the meanings of infant utterances: Wittgenstein proposed in (Wittgenstein, 1958) what is sometimes termed *the pragmatic theory of meaning*: "For a large class of cases - though not for all - in which we employ the word 'meaning' it can be defined thus: the meaning of a word is its use in the language." Nehaniv, Dautenhahn, & Loomes, 1999 extend this notion of meaning as follows: "*Meaning* is understood here as (1) *information in interaction games between an agent and its environment or between agents mediated with respect to their own sensors and actuators* and as (2) useful *for satisfying*

homeostatic and other drives, needs, goals or intentions." The second part of this definition links *interpretant* and motivational states of the agent explicitly. We expect this to be crucial in future experiments on the acquisition of negation. Note that we use *motivation* in a technical sense to encompass emotion, affect, drives, goals and intentions. Also "use" above should be interpreted in the sense of "manipulating the physical and social world".

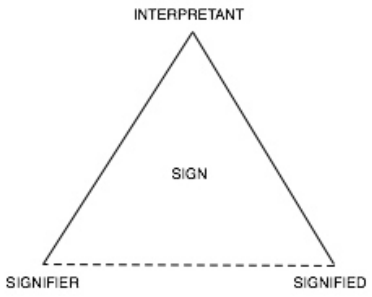

Fig. 1. The semiotic triangle (notation based on (Goguen, 1999))

Why Triads? The choice of a triadic sign model is motivated by the mutability of the link (interpretant) between signaling actions and their signified (which may e.g. be actions rather than propositions (Saunders, Lyon, Förster, Nehaniv, & Dautenhahn, 2009; Saunders, Nehaniv, & Lyon, 2010)). The *interpretant* links or mediates between *signifier* and *signified*. The relation between *signifier* and *interpretant* is a n:m mapping that is continuously updated during learning and and interaction and reflects the dynamic nature of how humans modify their concepts during language development.

3 A practical example: The meaning of 'No!'

In (Förster, Nehaniv, & Saunders, 2010) we analyzed the literature on early child language with regards to the developmental order and characteristics of different types of negation and drew design implications for our robotic architecture. The chosen taxonomy based on (Pea, 1980) distinguishes five different frequently occurring linguistic types of negation that emerge roughly in this order: *rejection*, *self-prohibition*, *disappearance*, *unfulfilled expectations*, and *truth-functional denial*. Typical one-word utterances of a infant engaging in these types of "negative speech-acts" in English are (the indicated two-word examples in brackets are exemplary utterances from two-word speech which children typically engage in from around 2 years on):

1. "no" (like in "no mash" for *rejection*) when the carer tries to feed the infant something that it does not like,
2. "no no" (for *self-prohibition*) when approaching a forbidden object or trying to perform a previously forbidden action like touching a hot stove,
3. "(all)gone" (like in "daddy gone" for *disappearance*) when the father just left the house
4. "(all)gone" (like in "dolly gone" for *unfulfilled expectations*) when the infant cannot find its favourite doll at its habitual location
5. and "no"(for *truth-functional denial*) as negative response to a question like "Did you break mummy's glasses?".

We can observe first a heavy overloading of communicative functions ("no" is used in three functions, "(all)gone" in two) and, second, a failure of (truth-functional) semantics for at least two cases: the *rejective* "no" and the *self-prohibiting* "no no". The question for a truth value can only be answered clearly in one case: *truth-functional denial*.
A prime example for the importance of motivation with regards to meaning is an infant's use of a rejective 'no'. Typically amongst the first words to be uttered by toddlers (Pea, 1980), its communicative function is not to comment on state of affairs. Children utter a rejective 'no' in order to prevent another person from doing something to them like for example feeding them or changing their diapers. The linguistic utterance is used to manipulate another agent. If the participant is abstracted away by taking a purely truth-functional stance to semantics, the utterance is rendered meaningless. In a semiotic framework with a pragmatic theory of meaning as formulated in the last section this problem disappears.

4 Summary

We promoted the idea that semiotics is a good and maybe even necessary way to think about language and its meaning - especially if one is concerned with developmental aspects of it. We explained briefly what we meant by "move towards pragmatics" and corroborated the claim for such a move with the example of the genesis of negation.

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