

# A Cognitive Model of the Acquisition and Use of Referring Expressions

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## Introduction

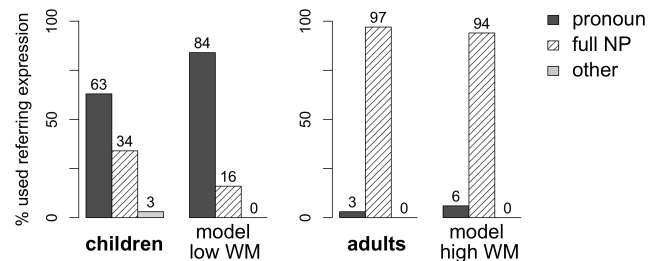
Referring expressions are used to describe a person, object or event. Different referring expressions can be used to describe the same person or object. For example, to describe a specific person, one could use a full noun phrase (NP) such as *the pirate*, or a pronoun, such as *he*. However, in certain discourse contexts using a pronoun would lead to an incorrect interpretation for the listener. Adult speakers use a full NP instead of a pronoun in these cases, suggesting that adult speakers take into account the listener's perspective. In contrast, children up to the age of 6 prefer to use a pronoun in these cases. In this study, we investigate how children acquire adult-like performance on their use of referring subjects by modeling experimental data using the cognitive architecture ACT-R (Anderson, 2007). The cognitive model allows us to investigate the complex interaction between formal linguistic constraints and cognitive factors. In addition, the model generates detailed and testable predictions with respect to linguistic performance.

## Experimental data

To test children's performance on the production and comprehension of pronouns in subject position, Wubs, Hendriks, Hoeks & Koster (2009) asked 31 4- to 7-year-old children and 23 adults controls to perform a production task, a comprehension task and a working memory task.

In their production task participants were asked to tell stories on the basis of series of six pictures (cf. Karmiloff-Smith, 1981). These stories were about two characters of the same gender. At the end of the story, the participants had to refer to the character that was introduced earlier in the story, but was not the current topic<sup>1</sup> of the story. Wubs et al. (2009) looked at the type of referring subject used to re-introduce this referent: a pronoun (*he*) or a full NP (*the pirate*). Selecting a pronoun would result in potential ambiguity for the listener, as pronouns are interpreted as reference to the current topic (a.o., Grosz, Weinstein, &

Joshi, 1995). Adults mainly used full NPs (97%). However, children showed a preference for using pronouns (63%) over full NPs (34%) (see Figure 1). That is, children often produced pronouns that are unrecoverable for a listener. These results support the hypothesis that adults take into account the listener's perspective. In contrast, children seem to only take into account their own perspective as a speaker. They preferably use the most economical form, a pronoun.



**Figure 1:** The type of referring subject used to re-introduce a character. The performance of the participants of Wubs et al. (2009)'s experiment is compared with the performance of our ACT-R model.

In the comprehension task of Wubs et al (2009), the same participants were asked to name the referent of an ambiguous subject pronoun at the end of pre-recorded stories with or without a topic shift. In contrast to adults, children showed no significant difference in their answers between the two types of stories. This suggests that they did not use discourse structure to resolve ambiguous pronouns. Notably, children's higher working memory scores were positively correlated with performance on the production and comprehension tasks.

## Cognitive model

We have implemented a cognitive model within the cognitive architecture ACT-R (Anderson, 2007) to explain children's difficulties with the production and comprehension of referring subjects. In this model,

children's non-adult performance is caused by (i) lack of processing efficiency and (ii) limitations in working memory capacity (WM). Although we will only explain the acquisition of adult-like *production* of referring expressions, the same model can also explain the acquisition of adult-like *comprehension* by using the same mechanisms.

### Processing efficiency

Adult speakers take into account the listener's perspective as a speaker to check whether the referring expression they intend to use can be interpreted correctly by the listener. As a result of this process, adult speakers will use a full NP to refer to a character that is *not* the current topic, because they know that a listener will interpret a pronoun as reference to the current topic. This process requires sufficient processing efficiency (as shown in a previous model of object pronouns, Van Rij, Van Rijn, & Hendriks, 2010). Initially, the model's processing is not efficient enough to carry out this process within a limited amount of time. Simulations show that the process gradually becomes more efficient as a result of frequent application of the same rules (i.e., production compilation mechanism of ACT-R, Taatgen & Anderson, 2002), ultimately resulting in adult-like performance.

### Working memory capacity

In addition, the model needs to determine the current discourse topic for using the grammar correctly, because the model will also produce pronouns that are unrecoverable for the listener when it incorrectly determines that the character to be referred to is the current topic. The model implements the hypothesis that children have difficulties to incorporate previous discourse structures in their interpretation and use of referring expressions. For adults the subject of the previous utterance is often the most salient discourse referent (a.o. Grosz et al., 1995). However, children do not seem to use information about grammatical roles in determining the current topic as a result of their limited WM capacity. For children the saliency of discourse referents is only determined by their frequency and recency of mentioning in the discourse. This follows from our implementation of differences in WM as differences in source activation, i.e., the activation used to maintain task-relevant information (cf. Daily, Lovett, & Reder, 2001). Only when WM increases, will children be able to use grammatical information of the previous utterance to determine the current discourse topic.

To summarize, not only sufficient processing efficiency is necessary for adult-like production and comprehension of referring expressions in subject position (cf. Van Rij et al., 2010), but also sufficient WM capacity.

### Future directions

Our cognitive model allows us to generate very precise and testable predictions with respect to linguistic performance, which can be tested with experiments. We are investigating two of the predictions of the model. The model predicts i)

that in a situation of increased WM load, adults will show difficulties in determining the current topic, because WM capacity affects the ability to incorporate discourse structure in determining the current topic, and ii) that manipulating the frequency and recency of mentioning of characters in the discourse will affect low WM children's performance on the comprehension task more than manipulating the grammatical roles.

In addition, we are planning to re-implement the sentence-processing component, because the sentence-processing component of the model is highly simplified. With the re-implemented model that not only processes structural information (cf. Lewis & Vasishth, 2005), but also semantic and discourse information, we can investigate how discourse information, syntactic and semantic information interact in resolving ambiguous pronouns during on-line sentence comprehension.

### Footnotes

<sup>1</sup> The discourse topic is the most salient referent in the current linguistic context, the discourse.

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