A UNIFIED EXPLANATION FOR PRODUCTION/COMPREHENSION ASYMMETRIES

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1. Introduction

In the past decades, research on language acquisition has identified several asymmetries between production and comprehension in various languages and in various areas of language. Many of these asymmetries came as a surprise to their investigators, because no asymmetries are expected under the traditional view of the grammar as a *direction-insensitive* system of rules. The aim of this paper is to show that viewing the grammar as a *direction-sensitive* system of constraints on form and meaning allows for a unified linguistic explanation of various types of production/comprehension asymmetries in language acquisition.

2. A puzzle: Incorrect comprehension, but correct production

When an average 6-year-old English-speaking child encounters the sentence "Ernie washed him" in a context in which Ernie and Bert are the only two individuals present, about half of the time the child will incorrectly understand the pronoun *him* as referring back to the subject Ernie (see, e.g., the landmark study of Chien and Wexler (1990)). However, children's production of pronouns is adult-like from an early age on (Bloom, Barss, Nichol, and Conway (1994); de Villiers, Cahillane, and Altreuter (2006)). Children will hardly ever use the pronoun *him* if Ernie washed himself, or the reflexive *himself* if Ernie washed Bert. So children's language production suggests that they possess the relevant grammatical knowledge. But if so, then why don't they use this knowledge when interpreting the same form? What is so difficult about the word *him* that its meaning is not yet mastered even at age 6? And is *him* somehow special, or do children at this late age experience difficulties understanding other linguistic forms as well?

To be able to maintain the traditional view on grammar, the delay in pronoun interpretation has been attributed to extra-grammatical factors such as problems with real-world knowledge (the "pragmatic account"; e.g. Thornton and Wexler (1999)) or lack of processing resources (the "processing account"; e.g. Reinhart (2006)). In contrast, this paper proposes an account for this delay within the

grammar (a "grammatical account"; cf. Hendriks and Spenader (2005/6)), that also explains other asymmetries in language acquisition. The central idea is that speakers and hearers place different demands on language. As a result, language production may favour certain pairings between form and meaning while language comprehension favours other pairings. Mature hearers can overcome these discrepancies by considering alternative forms a speaker could have used. If hearers are incapable of doing this (either because considering the speaker's alternatives is cognitively too demanding, or because they have no Theory of Mind which allows them to consider alternatives entertained by others), comprehension errors occur. If at the same time production of the correct form is adult-like, a production-comprehension asymmetry arises. A linguistic framework supporting such a view of the grammar is Optimality Theory (Prince and Smolensky (2004)). In Optimality Theory (OT), production and comprehension are modelled as different directions of use of the same grammar. Because the effects of certain constraints depend on their direction of use, as will be illustrated below, the grammar is direction-sensitive.

OT proceeds from the view that language users select the best output for a given input by optimizing over a set of constraints. The constraints that comprise the grammar are potentially conflicting and arranged in a hierarchy of strength. Conflicts among constraints are resolved by tolerating violations of weaker constraints, but only insofar as they contribute to the success of a stronger constraint. The optimal output is the output that satisfies the total set of constraints best. The input to the OT grammar can be either a form or a meaning. Taking a speaker's perspective, as in OT syntax, the input to optimization is a meaning. From this input meaning, a set of candidate output forms is generated. These candidates are evaluated against the ranked constraints. By selecting the optimal form, a mapping is established from the input meaning to this optimal output form. The same constraints can be used to establish a mapping from an input form to an output meaning, thereby taking a hearer's perspective, as in OT semantics.

Crucially, constraints in OT come in two types: faithfulness constraints and markedness constraints. These two types of constraints can be seen as embodying the competing forces shaping language: the force of communication, and the force of speaker and hearer economy, respectively. Faithfulness constraints establish a relation (a relation of identity in OT phonology, and a relation of association in OT syntax and semantics) between a particular input and a particular output. Because faithfulness constraints have a similar effect when used in the opposite direction, they promote a one-to-one mapping between forms and meanings. Markedness constraints, on the other hand, penalize certain forms or meanings irrespective of their input. Hence, they fail to have any effects when used in the opposite direction. Faithfulness constraints thus promote symmetry, whereas markedness constraints promote asymmetry. As a result, an OT grammar is inherently

direction-sensitive and can yield different form-meaning pairings depending on the direction of optimization.

3. Direction-sensitive grammar explains early production delays

The inherent direction-sensitivity of OT explains the well-known observation that children's ability to produce word forms such as *cat* generally lags behind their ability to comprehend the same forms. Young children may say *ta* when referring to a cat, while being perfectly capable of understanding the word *cat*. Smolensky (1996) argues that such early delays in production follow from a non-adult constraint ranking where one or more markedness constraints are ranked too high. Consider the following two simplified OT tableaux. In each tableau, the input to optimization is presented in the first column. Because the input is always given, it is kept constant across all possible outputs. A selection of relevant candidate outputs for this input is presented in the second column. If a particular candidate violates a constraint, this is marked by an asterisk in the corresponding cell.

Input = underlying form	Output = surface form	Markedness constraints on surface form	Faithfulness constraints
/kæt/	[kæt]	*!	
→	[ta]		*

Tableau 1: Children's production (from underlying form to surface form)

Candidate output [kæt] violates markedness constraints encoding a dispreference for syllables ending with a consonant (the constraint NOCODA) and for pronouncing dorsal segments like [k] (the constraint *DORS). Candidate output [ta] is unfaithful to the input /kæt/ because segments are inserted ([a]) and omitted ([k] and [æ]). If the markedness constraints are ranked above faithfulness constraints such as FILL and PARSE in the child's grammar, it is better to violate the faithfulness constraints than the markedness constraints. Consequently, the child will produce the unfaithful surface form [ta] to express the underlying form /kæt/.

Input = surface form	Output = underlying form	Markedness constraints on surface form	Faithfulness constraints
[kæt]	/kæt/	*	
→	/ta/	*	*!

Tableau 2: Children's comprehension (from surface form to underlying form)

In children's comprehension, in contrast, the pronounced form [kæt] violates the markedness constraints regardless of the hypothesized underlying form. This is indicated by asterisks in each row in the third column in Tableau 2. As a result, the lower-ranked faithfulness constraints are decisive and hence [kæt] is interpreted by these children as the faithful underlying form /kæt/.

4. Asymmetries in early syntactic development

A similar explanation can be given for comprehension delays in the acquisition of the grammar, as is argued by Hendriks, de Hoop, and Lamers (2005). They base their analysis on data from Chapman and Miller (1975), who found that young children perform much better on the production of word order than on its comprehension (see also McClellan, Yewchuk, and Holdgrafer (1986)). In a production experiment with 15 children between the ages of 1;8 and 2;8, Chapman and Miller found that the children tended to preserve subject-object order with respect to the verb. For example, they would say "car hit boy", "hit boy", or "car hit" when having watched the experimenter perform the action of a toy car hitting a boy doll, but rarely "boy hit car" or "hit car". This strongly suggests that these children have knowledge of English word order. However, the same children, when tested on the same type of sentences in a comprehension experiment in which they had to act out the meaning of the sentence with toys, significantly less often used cues from word order to determine the event to be acted out. When hearing the sentence "The car is hitting the boy", the children frequently demonstrated the action with the boy doll hitting the car toy, instead of the other way around. With an inanimate subject and an animate object, the percentage of correct responses was found to be lowest, namely 50.1%. These data strongly suggest that the correct production of basic word order by young English children precedes their comprehension. An explanation for this remarkable but largely ignored pattern in language acquisition is lacking under a traditional view on the grammar: If English-speaking children possess knowledge of basic word order, as is evidenced in production, why don't they use this knowledge in comprehension? Since basic word order is generally assumed to be determined by the grammar, neither pragmatic factors nor processing factors can explain this asymmetry.

Chapman and Miller (1975) observed that young children take animacy as a determining factor for subject-object status in comprehension, but not in production. Importantly, such animacy effects are present in all languages. Even in German, where the effects of animacy are usually suppressed by the effects of overt case, animacy effects show up in adults' online processing (Schlesewsky and Bornkessel (2004)). This suggests that the animacy effects observed by Chapman and Miller are the result of the grammar rather than of some extra-grammatical

heuristic. Now suppose that these animacy effects are due to an animacy constraint saying that subjects should outrank objects in animacy, and word order is due to a word order constraint saying that subjects should precede objects. Suppose further that the children in Chapman and Miller's experiment incorrectly assume that the animacy constraint, which is a markedness constraint on meaning, is ranked higher than the word order constraint, which is a faithfulness constraint establishing an association between a particular form (word order) and a particular meaning (subject-object status of the noun phrases). We now obtain exactly the opposite pattern as in Tableaux 1 and 2: Correct production is predicted to precede correct comprehension.

Input = meaning	Output = form	Markedness constraints on meaning	Faithfulness constraints
HIT (car_{SUBJ}, boy_{OBJ}) →	The car is hitting the boy.	*	
	The boy is hitting the car.	*	*!

Tableau 3: Children's production (from meaning to form)

Production is predicted to be adult-like (see Tableau 3), because the animacy properties of the actors involved in the event are already given as part of the input meaning. Therefore, all possible forms violate the animacy constraint, and the weaker word order constraint becomes decisive. As a result, the subject will be put before the object.

Input = form	Output = meaning	Markedness constraints on meaning	Faithfulness constraints
The car is hitting the boy.	HIT (car_{SUBJ}, boy_{OBJ})	*!	
→	HIT (boy_{SUBJ}, car_{OBJ})		*

Tableau 4: Children's comprehension (from form to meaning)

In contrast, when hearing a sentence with an inanimate subject and an animate object, such as "The car is hitting the boy" (Tableau 4), children will take animacy to be the determining factor because the animacy constraint is stronger than the word order constraint. Hence, they incorrectly interpret the animate noun phrase *the boy* as the subject. This explains why the correct comprehension of subject-object order emerges later than the correct production of subject-object order.

5. Integrating speaker's perspective and hearer's perspective

So if markedness constraints on form or markedness constraints on meaning are ranked too high, a delay in production or a delay in comprehension, respectively, may arise. Does this mean that the adult constraint ranking always results in a symmetrical pattern? No, this need not be the case. In various domains of language, children much older than 2 or 3 display production/comprehension asymmetries. For example, 6-year-olds have been found to display ambiguities in comprehension which are not witnessed in the adult language and which are not paralleled by non-adult forms in production (e.g., with object pronouns, see section 2). We may expect these children to have mastered the grammar of their native language, including the adult constraint ranking. Apparently, the adult constraint ranking still gives rise to asymmetries between production and comprehension. But if this is true, then why don't adults display such asymmetries? This may be because mature hearers take into account the speaker's perspective, and vice versa. This process is modelled in OT by integrating the two directions of optimization (i.e., the speaker's direction from meaning to form, and the hearer's direction from form to meaning) into a simultaneous optimization procedure. The resulting formal model of grammar is known as bidirectional OT (Blutner (2000)). In bidirectional OT, a form only has a certain meaning if the pair consisting of this form and meaning is bidirectionally optimal. Bidirectionally optimal pairs are identified by evaluating potential form-meaning pairs against the constraints of the grammar:

(1) A form-meaning pair <f,m> is bidirectionally optimal if and only if there is no pair <f',m> such that <f',m> is more harmonic than <f,m>, and there is no pair <f,m'> such that <f,m'> is more harmonic than <f,m>.

According to this definition, a form-meaning pair is bidirectionally optimal if there is no other pair with the same meaning but a better form, or with the same form but a better meaning. Only optimal pairs are realized. All suboptimal pairs are blocked.

Many instances of ambiguity and optionality still arising from an adult constraint ranking disappear under bidirectional optimization, because one of the potential meanings or forms is blocked. The presence of blocking in the adult grammar, and its absence in the child's, may provide a straightforward explanation for the pronoun interpretation delay (see Hendriks and Spenader (2005/6)). Children merely try to find the best form (as a speaker) or the best meaning (as a hearer), without taking into account the opposite perspective. Consequently, a form that can give rise to multiple meanings will be ambiguous for children.

Consider again the utterance "Ernie washed ..." in a context where Ernie and Bert are the only two individuals present. In this context, object pronouns and reflexives are produced correctly from an early age on (Fig. 1).

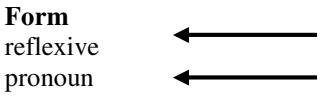

Fig. 1: Children's production (speaker's perspective)

The child will say "Ernie washed himself" if Ernie washed Ernie, and "Ernie washed him" if Ernie washed Bert. For children until at least the age of 6, object pronouns such as *him* seem to be ambiguous, and can be interpreted as conjoint to the subject Ernie, or disjoint to the subject, thus referring to Bert (Fig. 2).

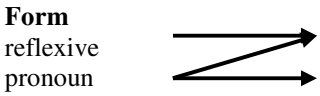

Fig. 2: Children's comprehension (hearer's perspective)

The asymmetry displayed in Fig. 1 versus Fig. 2 can be generated using only two constraints: a faithfulness constraint with the effect of Principle A of Binding Theory and a weaker markedness constraint preferring reflexives to pronouns (cf. Hendriks and Spenader (2005/6)).

In contrast to children, adults not only adopt the hearer's perspective when comprehending an utterance, but simultaneously consider the speaker's alternatives (cf. the definition in (1)). If the speaker would have wanted to express a conjoint meaning, the speaker would have used a reflexive, because this is the optimal form for this meaning (see Fig. 1). If the speaker uses a pronoun instead, an adult hearer will conclude that the speaker did not intend to express a conjoint meaning. As a result, the pronoun is interpreted as disjoint to the subject. So because there is a better way to express a conjoint meaning, the conjoint meaning is blocked for the pronoun. The blocked form-meaning association is indicated by the dashed arrow:

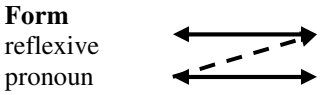

Fig. 3: Integrating speaker's perspective and hearer's perspective

So production and comprehension do not yield a symmetrical adult pattern when simply combined. To arrive at a symmetrical pattern, adults must discard communicatively suboptimal form-meaning associations that are not optimal in the opposite direction of optimization. Because children until at least the age of 6 are hypothesized to optimize in one direction only, their grammar is partly inconsistent and yields mismatches between production and comprehension, resulting in the observed delays in comprehension. The inconsistencies can only be repaired if the

child recognizes that speakers and hearers place different demands on language and is able to effectively use this knowledge in communication.

6. A two-stage optimization model of language acquisition

Under the proposed "grammatical account", children learning the grammar face two tasks. First, they have to learn the adult constraint ranking. Several learning algorithms have been proposed within OT to account for this task. If the adult ranking is not yet obtained, we may observe "early" delays in language acquisition. Second, children have to start to optimize bidirectionally, that is, to take into account alternative forms and meanings. If the child is not yet able to optimize bidirectionally, we may observe "late" delays in language acquisition. Bidirectional optimization may develop as a result of increased working memory capacity, sufficient speed of processing, or perhaps the development of the ability to apply (second-order) Theory of Mind reasoning in a communicative setting.

As a consequence of the proposed two-stage view on language acquisition, four types of asymmetries are predicted in language acquisition:

	Early delays	Late delays
Delays in production	Type 1	Type 3
Delays in comprehension	Type 2	Type 4

Fig. 4: Predicted types of production/comprehension asymmetries

Early delays in language acquisition result from a non-adult constraint ranking, where markedness constraints on form (Type 1) or on meaning (Type 2) are ranked too high. Late delays (i.e., delays lasting until at least the age of 5 or 6) result from a failure to use bidirectional optimization in those cases where the constraints of the grammar predict a mismatch between production and comprehension. This happens when the expressed meaning is not recoverable from the optimal form (Type 3), or when the encountered form is not the form that would be produced on the basis of the optimal meaning (Type 4).

7. Evidence for all four types of asymmetries

Is there any evidence for these four types of acquisition asymmetries? We already saw an example of an early production delay (Type 1) in section 3, namely children's errors with early word pronunciation. Section 4 discussed young children's limited comprehension of subject-object word order, an early comprehension delay (Type 2). A well-known example of a late comprehension

delay (Type 4) is the pronoun interpretation problem. Other comprehension delays have been observed in areas as diverse as sentence stress (Cutler and Swinney (1987)), noun phrase interpretation (de Hoop and Krämer (2005/6)), and tense and aspect (van Hout (2007)). Crucially, in most of these cases mismatches between production and comprehension have been found for the same type of sentences, in the same children, and in the same experimental sessions.

In addition to these three acquisition delays, the two-stage optimization model of language acquisition also predicts late delays in production (Type 3). Indeed, there is some suggestive evidence for such a delay with anaphoric subjects. Karmiloff-Smith (1985), in a production experiment with 240 English and French children, found that 4- and 5-year-olds used pronouns instead of full NPs much more often than older children, even in situations where the pronoun could be interpreted in a non-intended way. These children would typically produce strings of subject pronouns referring at times to the discourse topic and at other times to a non-topic, as *he* in the following fragment:

(2) The little boy's walking along. The man's giving him a balloon. He asks for some money so he gives him some money and then he gives him the balloon.

This pattern can be explained under the assumption that the older children and adults take into account the hearer's perspective in production, whereas the younger children are not yet able to do so. Because hearers tend to interpret subject pronouns as referring to the discourse topic, a bidirectionally optimizing speaker will only use a pronoun when intending to refer to the discourse topic. For non-topical referents, a full NP such as *the man* is used. Thus the adult pattern of anaphoric subject production emerges. Until the age of 6, children regularly produce non-recoverable pronouns (which from a speaker's perspective are more economical than full NPs) because they are unable to block this non-adult output.

To conclude, all four predicted acquisition delays seem to be witnessed in child language. The proposed constraint-based model is able to identify the exact grammatical conditions under which production/comprehension asymmetries arise. On the basis of the proposed model, we can now start looking for more asymmetries, and provide a formal linguistic explanation for observed but as yet unexplained asymmetries.

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