Simulating the temporal reference of Dutch and English Root Infinitives

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Abstract

Hoekstra & Hyams (1998) claim that the overwhelming majority of Dutch children's Root Infinitives (RIs) are used to refer to modal (not realised) events, whereas in English speaking children, the temporal reference of RIs is free. Hoekstra & Hyams attribute this difference to qualitative differences in how temporal reference is carried by the Dutch infinitive and the English bare form. Ingram & Thompson (1996) advocate an input-driven account of this difference and suggest that the modal reading of German (and Dutch) RIs is caused by the fact that infinitive forms are predominantly used in modal contexts. This paper investigates whether an input-driven account can explain the differential reading of RIs in Dutch and English. To this end, corpora of English and Dutch Child Directed Speech were fed through MOSAIC, a computational model that has already been used to simulate the basic Optional Infinitive phenomenon. Infinitive forms in the input were tagged for modal or non-modal reference based on the sentential context in which they appeared. The output of the model was compared to the results of corpus studies and recent experimental data which call into question the strict distinction between Dutch and English advocated by Hoekstra & Hyams.

Root Infinitives in Child Language

A striking feature of the speech of children who are acquiring their native language, is that, in many languages, children go through a stage where they produce *Root Infinitives* (non-finite verb forms in contexts that require a finite verb form). Thus, English-speaking children may produce utterances such as (1), and Dutch children may produce utterances such as (2).

(1) Daddy drink coffee
(2) Papa koffie drinken (Daddy coffee drink-inf)

This phenomenon has been subject to considerable linguistic theorizing, as the fact that it occurs in several languages (including English, Dutch, Swedish, German and French) suggests the operation of invariant principles. A particularly influential Nativist theory has been provided by Wexler (1994). According to Wexler's *Optional Infinitive (OI) Hypothesis*, by the time children begin to produce multi-word speech, they have already correctly set all the basic inflectional and clause structure parameters of their language. They thus have adult-like knowledge of the word order and inflectional properties of the language they are learning. However, there is a stage of development (the Optional Infinitive stage), during which the abstract features of Tense (TNS) and Agreement (AGR) can be absent from the underlying representation of the sentence. This results in children initially using both finite and non-finite verb forms in contexts in which a finite form would be obligatory in the adult language. The great strength of the Optional Infinitive Hypothesis is that it explains the data from a wide variety of languages, as well as the relative sparseness of other errors. However, the theory also has some important weaknesses.

Firstly, the theory assumes a large amount of innate knowledge and ignores the possibility that the Optional Infinitive phenomenon may be understood as the result of an input-driven learning process without the need to assume large amounts of innate knowledge. Simulations with the MOSAIC model have already shown that a simple learning mechanism which is sensitive to the distributional characteristics of the input can give a close quantitative fit to the prevalence of the Root Infinitives in English and Dutch over a range of MLUs (Freudenthal, Pine & Gobet (2002a, 2003, in preparation).

Secondly, while the Optional Infinitive phenomenon occurs in several languages, cross-linguistic differences exist in the finer detail of the phenomenon that are problematic for Wexler's theory. One obvious way of explaining these differences is in terms of differences in the distributional characteristics of the language being learned. In this paper we assess the viability of such an explanation by simulating cross-linguistic differences in the fine detail of the OI-phenomenon in Dutch and English using MOSAIC. The central aim of this paper is therefore to investigate whether the same mechanism that captures one of the key similarities in the speech of children learning different languages can also capture differences in the way

that this phenomenon patterns as a function of differences in the languages being learned, and hence can provide a unified account of patterns of cross-linguistic similarity and difference in children's early multi-word speech.

The Modal Reference of Root Infinitives

The majority of Root Infinitives that Dutch children produce carry a modal meaning: they tend to express desires and wishes, or relate to unrealized events. Hoekstra & Hyams (1998) have dubbed this the *Modal Reference Effect*. The type of verbs that occur as Root Infinitives also differs from inflected verbs. Dutch speaking children appear to use Root Infinitives when referring to actions rather than static situations. This has been called the *Eventivity Constraint*. Wijnen (1996), analysed the speech of four Dutch children, and found that 95% of the children's Root Infinitives contained eventive verbs, and 85% of the Root Infinitives had a modal reference, thus confirming the Modal Reference Effect and Eventivity Constraint. According to Hoekstra & Hyams, the Modal Reference Effect and Eventivity Constraint do not hold for English. They present data based on an (unpublished) paper by Ud Deen (1997), who found that only 13% of English Root Infinitives carry a modal meaning. Ud Deen also found that, while the majority of English Root Infinitives are eventive in nature, this effect is less pronounced than it is in Dutch, with 75% of English RIs containing eventive verbs. Hoekstra & Hyams explain this cross-linguistic difference by referring to differences between the English and Dutch infinitive form. The English infinitive, they claim, is not a true infinitive, but a 'bare form'. Dutch has a true infinitive as it has an infinitival morpheme. This infinitival morpheme is thought to carry an *irrealis* feature which is responsible for the modal reference. This, they argue, is evident from the analysis of the following utterances:

3. I see John cross the street*
4. I saw John cross the street
5. I see John crossing the street

Utterance (3) is ungrammatical in English, because the English bare form denotes 'not only the processual part of the event, but includes the completion of that event' (Hoekstra & Hyams 1998, p. 105). A correct description of an ongoing event in English would therefore require the use of the past tense as in (4), or the progressive as in (5). Sentence 6 makes it clear that this constraint does not operate in Dutch: an ongoing event may be described using a present tense construction. Apparently, the Dutch infinitive does not signal completion of the event.

6. Ik zie/zag Jan de straat oversteken
   I see/saw John the street cross-INF
   I see/saw John cross the street.

This difference between the English and Dutch infinitival form also explains the difference with respect to the eventivity of Root Infinitives, as, according to Hoekstra & Hyams it is the modal reading of Dutch Root Infinitives that forces the selection of an eventive verb. Since English Root Infinitives are not exclusively modal, they can occur with stative as well as eventive verbs.

Problems with Hoekstra & Hyams' Account

While the Hoekstra & Hyams' account explains the differential reading of Dutch and English Root Infinitives, it predicts that the proportion of modal readings of RIs in Dutch and English is radically different. Theoretically, all RIs in languages with an infinitival morpheme should be modal, while the reference of English RIs is free. The proportion of modal RIs in Dutch and German appears to be considerably lower than 1.00 however. Wijnen (1996) reports a proportion of .85 averaged over 4 children, and Ingram & Thompson (1996) report a proportion of .55 using a strict criterion and .79 using a lenient criterion.

Ingram & Thompson also suggest that the modal reading of RIs in German (and Dutch), is caused by the fact that infinitive forms in adult German and Dutch are typically used in conjunction with a modal, as in (7) and (8). Since Dutch-speaking children predominantly hear infinitive forms in modal contexts in the input, they come to associate these forms with the modal reading and use them predominantly to express desires.

7. Ik ga morgen werken (I go-FIN Tomorrow work-INF)
8. Wil je spelen? (Want-FIN you play-INF)

The proportion of modal Root Infinitives in English may also be considerably higher than the .13 that was found in a corpus study by Ud Deen. An inherent weakness of corpus studies is that the modal/nonmodal reading of an utterance is assigned on the basis of the context in which it is produced. However, since the corpora are transcripts of spontaneous speech, the information required to discriminate between modal and non-modal readings is often lacking. For this reason, Blom, Krikhaar & Wijnen (2001) conducted an experiment in which children produced descriptions of modal and non-modal events. In the experiment, the majority of Dutch children's Root Infinitives (68%) were used to describe modal events. For the English children this was 44%. While this difference was significant and in the expected direction, this finding is problematic for Hoekstra & Hyams, as it suggests that the difference between Dutch and English is not a qualitative difference, but a graded, quantitative one which may well be related to the distributional characteristics of the language rather than differences in infinitival morphology.

In this paper, MOSAIC will be used to investigate the source of the differential reading of Dutch and English Root Infinitives. MOSAIC has a number of characteristics that make it a suitable candidate for such an investigation.

Firstly, the model has already been shown to successfully simulate the developmental change in the prevalence of Root Infinitives in Dutch and English (Freudenthal, Pine & Gobet 2002a, 2003, in preparation), as well as phenomena related to Subject Omission in English (Freudenthal, Pine & Gobet 2002b). The model's success in simulating the finer detail of the OI phenomenon therefore provides a strong test

of an input-driven account of the OI phenomenon. Secondly, the model learns off Child Directed Speech. The use of Child Directed Speech ensures a realistic frequency distribution, so that differences in the surface characteristics of a language are reflected in the input in a quantitatively realistic way. This is of particular importance as the practice of using artificially created input sets (which is common in simulations of phenomena in child speech) may lead the researcher to misrepresent the distributional characteristics responsible for the phenomenon under investigation.

Thirdly, MOSAIC uses no built-in linguistic knowledge. Whatever representations it builds up during learning are a result of the interaction between its learning mechanism and the distribution of the input it sees. This last characteristic is important because Hoekstra & Hyams' explanation of the differential reading of RIs is dependent on the assumption that the child knows that the infinitival morpheme implies a modal interpretation (rather than learning the association through exposure to the input). MOSAIC will be described below, followed by the details of the simulation.

Simulating Language Acquisition in MOSAIC

Whilst the version used for the simulations discussed here has changed from the earlier simulations, the main theoretical underpinning of the model remains the same. The basic tenet of the model is that the learning of language is a performance-limited process which is heavily weighted towards the most recent elements in the speech stream (i.e., which has an utterance final bias). Several authors have argued that children are better at learning material that occurs towards the end of the utterance (Naigles & Hoff-Ginsberg, 1998; Shady & Gerken, 1999; Wijnen et al. 2001).

MOSAIC learns from orthographically coded input, with whole words being the unit of analysis. The model is a simple discrimination net (an n-ary tree) which is headed by a root node. At the start of learning the discrimination net consists of just the root node. More nodes (encoding words or phrases) are added as the model is shown more utterances. An important requirement for nodes to be added is that whatever follows the word to be encoded in the input, must already have been encoded in the model. That is, the model will only learn a new word, when it has already encoded the rest of the utterance. This results in the model building up its representation of the utterances it is shown by starting at the end of the utterance, and slowly working its way to the beginning.

If the model were to see the utterance *I go home* three times, it would on its first pass encode the fact it has seen the word *home* at the end of an utterance. On the second pass, it would encode the sequence *go home*. After a third pass, it would have encoded the whole utterance. Figure one gives a graphical representation of the model at this stage.

The fact that MOSAIC builds its representation of an utterance by starting at the end of the utterance is the major mechanism responsible for its simulation of the development of Root Infinitives in Dutch. Early in Dutch children's development, 80-90% percent of their utterances containing verbs are Root Infinitives. This drops to 10-20% later in development (Wijnen et al, 2001). Early in training, the model encodes many utterance final phrases. Since the infinitive takes sentence-final position (as can be seen in examples 7 and 8), the model produces many utterances with only non-finite verb forms. As the model encodes longer and longer phrases, these Root Infinitives are slowly replaced by auxiliary/modal plus infinitive constructions.

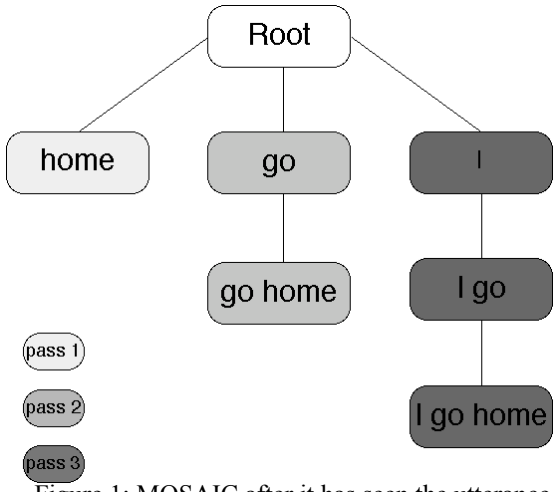

Figure 1: MOSAIC after it has seen the utterance *I go home* three times.

In the example illustrated in Figure 1, a (sentence final) word is encoded after one exposure. In fact, MOSAIC actually learns much more slowly than this, and the input corpus is fed through the model several times, so output of increasing average length can be generated after consecutive exposures to the input corpus. The probability of creating a node in MOSAIC is given by the following formula:

$$NCP = \left(\frac{1}{1 + e^{m - u/c}} \right)^{\sqrt{d}}$$

where: NCP = Node Creation Probability

m = a constant, set to 20 for these simulations.
c = corpus size.
u = total number of utterances seen.
d = distance to the end of the utterance.

The formula results in a basic sigmoid curve. The formula contains the size of the corpus and total number of utterances seen. The size of the corpus is included because the size of the available input corpora differs considerably (13,000 to 30,000 utterances for the corpora used in these simulations). The use of the term (m – u/c) ensures that after n presentations of the complete input corpus the Node Creation Probability is identical for corpora of different sizes. The 'distance to the end of the utterance' in the exponent causes material that occurs near the beginning of the utterance to have a lower likelihood of being encoded than material that occurs near the end. This effect decreases as the model sees more input.

Production of Novel Utterances

Utterance production in MOSAIC involves outputting all the utterances the model has encoded. However, the output that MOSAIC produces consists of more than the input it has seen. MOSAIC has a mechanism for linking words or phrases that have occurred in similar contexts. When the overlap between two words is sufficiently high (more than 10% of both the words that preceded and followed the target words are the same), the two words get linked. Two words that are linked can be substituted for each other when the model produces output. This mechanism allows MOSAIC to produce utterances that were not present in the input. Redington, Chater & Finch (1998), and Mintz (2003), have shown that similar mechanisms based on co-occurrence statistics can be quite effective in grouping words that are of the same syntactic category.

The model also includes a chunking mechanism, which results in frequent multi-word phrases being treated as one unit. Since the chunking mechanism does not play an important role in these simulations, it is not discussed any further in this paper.

The Simulations

In order to distinguish modal from non-modal Root Infinitives in the output of the model, infinitive verb forms in the input were tagged to reflect the context in which they occurred. In order to do this, all utterances in the input were (automatically) searched for words denoting a modal or not-realised context. These words constituted the standard modals, as well as some other words denoting a not-realised context, including *want* and *go*. The utterances containing a word denoting a modal context were then searched for words that matched an infinitive form. If such a word was found, it was tagged for having occurred in a modal context (by adding –MOD to the verb).

For both languages, two input corpora (available through the CHILDES data base (MacWhinney 2000)) were selected. For Dutch, these were the corpora of Matthijs (Simulation1) and Peter (Simulation2). For English the corpora of Anne (Simulation1) and Becky (Simulation2) were selected. The size of the corpora was approximately 13,000 utterances for Dutch, and 30,000 utterances for the English input. Since the input corpora consist of Child Directed Speech, the distributional characteristics are representative of the language that children hear. Each input corpus was fed through the model iteratively until the output reached a Mean Length of Utterance (MLU) of approximately 2.5. At this stage, all the utterances the model could produce were generated. The full output consisted of approximately 7,500 utterances for the Dutch corpora, and 15,000 for the English corpora. Next, all utterances in which all verbs matched the infinitive form were selected. The proportion of these utterances that had the infinitive form tagged for a modal context (i.e. had been learnt off a modal context) was then calculated. Table 1 gives the results for the English and Dutch simulations. For both Dutch simulations the proportion of modal infinitives is larger than it is for English. For all four possible comparisons of Dutch against English simulations, the difference was statistically significant ($\chi 2(1) > 12.00$ $p < .001$).

Table 1: Proportion of modal infinitives and total number of infinitives for Dutch and English simulations.

	Dutch	English
Simulation1	.70 (1447)	.47 (1577)
Simulation2	.54 (1474)	.48 (2581)

While these values are very close to those reported by Blom et al., this analysis ignores the complication that (especially in English) it is difficult to unambiguously identify the infinitive. In the English present tense, only the third singular differs from the infinitive. A true Root Infinitive can therefore only be identified in a third singular context (since many of the forms resembling the infinitive may actually be correctly inflected finites).

A second analysis was therefore performed on the subset of utterances that had a third singular subject (e.g. *He go/Hij gaan*). While the Dutch data could be restricted to all singulars rather than just third singular, it was considered preferable to use the same restriction for both languages. The results of these analyses are shown in Table 2.

Table 2: Proportion of modal infinitives and total number of infinitives for Dutch and English simulations, third singular context only.

	Dutch	English
Simulation1	.66 (104)	.43 (89)
Simulation2	.58 (102)	.42 (118)

Again, the proportion of modal RIs is larger in the Dutch simulations than it is in the English simulations (For all four possible comparisons, $\chi 2(1) > 4.30$, $p < .05$). Thus, MOSAIC clearly captures the difference between the two languages, suggesting that the differential reading of Root Infinitives in English and Dutch is related to the surface characteristics of the languages.

Having established that MOSAIC simulates the differential reading of RIs, we can now assess whether MOSAIC simulates the difference in verb types that occur in Root Infinitives. Hoekstra & Hyams cite a paper by Wijnen (1996) who found that 95% of Dutch Root Infinitives contained eventive verbs. In English, Ud Deen (1997), found that only 75% of Root Infinitives contained eventive verbs. While a direct comparison between these numbers is difficult as Wijnen and Ud Deen used a different set of verbs, stative verbs do appear to be used more often in English than in Dutch Root Infinitives. In order to perform a more controlled analysis, all Root Infinitives in Table 2 were coded for whether the main verb denoted an event or not. As can be seen in Table 3, MOSAIC does simulate the effect, though only three out of four differences are

statistically significant ($\chi2(1) > 6.20$, $p < .02$). The value of .92 for Dutch (simulation2) was not significantly different from .87 (English, simulation2). Inspection of the non-eventive verbs in simulation2 for Dutch revealed that 5 out of the 8 instances consisted of the verb *zien* (see), which was linked to the verb *kijken* (look), and was thus substituted in production. It thus appears that the generativity mechanism may have inflated the proportion of non-eventive Root Infinitives for this simulation.

Table 3: Proportion of Root Infinitives (third singular context only) that have an eventive main verb.

	Dutch	English
Simulation1	.98	.80
Simulation2	.92	.87

What causes the Modal Reference Effect?

The fact that MOSAIC simulates the difference between Dutch and English for both the modal reading of Root Infinitives and the eventivity of the main verb, suggests that these effects are related to differences in the surface characteristics of the two languages. In order to understand what these relevant surface characteristics might be, it is useful to examine more closely in what contexts third singular subjects are followed by a form resembling the infinitive. In both Dutch and English, the majority of the contexts are likely to be questions. English and Dutch differ however, in the way questions are formed. Whereas Dutch uses inversion to transform a declarative into a question, in English, the auxiliary *do* is inserted, resulting in phrases such as *Does he go*. While the auxiliary *do* patterns like a modal, it does not carry a modal or not-realised meaning. In English, a third singular subject followed by an infinitive form can therefore occur in both a non-modal (*Does he go*), and a modal context (*Can he go*). In Dutch, a third singular followed by an infinitive form can occur in double verb constructions such as *Kan hij fietsen* (Can he cycle-inf), or *Ik zie Jan lopen* (I see John walk-inf). The first of these is modal, but the second is not. Root Infinitives in the input are a further source of third singular plus infinitive contexts. In some situations (for example elliptical answers to questions) Root Infinitives are allowed in Dutch. In the two languages, the third singular is thus followed by the infinitive in different contexts. If a child learns Root Infinitives off the input, it is likely to produce them in the context in which they are most frequently encountered. One way of directly testing such an input-driven account of Root Infinitives is to search the input for occasions where a third singular is followed by an infinitive form, and noting whether the context is modal or not. Table 4 presents the results of such an analysis (using the most frequent third singular subjects that were present in the Root Infinitives of the model's output). Table 4 shows that in Dutch third singular plus infinitive constructions occur in a modal context more often than they do in English (again all four differences are statistically significant $\chi2(1) > 6.2$, $p < .02$).

Table 4: Proportion of modal contexts for third singulars followed by infinitive in English and Dutch input corpora.

	Dutch	English
Input1	.77 (113)	.37 (212)
Input2	.56 (140)	.41 (153)

Also of interest now is the question of what the non-modal contexts are in which these constructions occur. In English a large majority (90%) of these non-modal contexts do turn out to be 'do-questions'. Thus, while third-singular plus infinitive constructions can occur in modal as well as non-modal contexts, the dummy modal *do* alone makes up close to 40% of these contexts. In the Dutch input, non-modal contexts are limited in number, and largely confined to Root Infinitives (though a few double verb constructions do occur). The majority of non-modal Root Infinitives therefore appear to be learned off double-verb constructions in English and off Root Infinitives in Dutch.

Turning to the eventive-stative distinction it now also becomes apparent why Root Infinitives are more likely to contain statives in English. In English, stative verbs such as *want* or *need* frequently occur in utterances like *Does he want it*. In Dutch such an utterance does not carry the inflection on the dummy modal, but on the inverted main verb (*Wil hij dat; Wants he that*). As a result, statives in Dutch only occur as infinitives in very infrequent double verb constructions such as *Dat zou hij willen (That would he want*) The higher proportion of statives in English Root Infinitives can therefore also be explained in terms of the use of the dummy modal *do* in the input.

Conclusions

While Wexler's Optional Infinitive Hypothesis can explain the cross-linguistic occurrence of Root Infinitives, additional assumptions are required the explain the cross-linguistic differences in the fine detail of the phenomenon. Hoekstra & Hyams (1998), explain some of this fine detail (the differential temporal reference of Dutch and English children's Root Infinitives) by referring to qualitative differences between the languages. Specifically, they argue that the English infinitive is a bare form rather than a true infinitive. They argue that the English bare form does not carry the *irrealis* feature, which signals the modal reading of the infinitive. They therefore postulate qualitative differences in the fine detail of infinitival morphology between the two languages. Since children are thought to know the full grammar, English-speaking children will use Root Infinitives both in modal and non-modal contexts, and Dutch children should use Root Infinitives overwhelmingly in modal contexts. Experimental work by Blom et al. has shown however, that the difference is not as large as predicted by Hoekstra & Hyams, suggesting that it is a graded quantitative, rather than a qualitative difference.

In this paper MOSAIC was used to investigate whether the difference between Dutch and English could be related

to the surface characteristics of the two languages. The fact that MOSAIC has already been used to simulate the developmental patterning in the prevalence of Root Infinitives (relative to simple and compound finites) in English and Dutch lends credence to the basic mechanism for producing Root Infinitives that MOSAIC employs. While MOSAIC is clearly insufficient as a full model of the language acquisition process, it is a valuable tool for exploring how an utterance final learning bias can interact with the distributional properties of the input to produce the phenomena apparent in children.

MOSAIC clearly simulates the difference between English and Dutch in terms of the modal reading as well as the eventive/stative nature of the verbs in Root Infinitives. The fact that both phenomena can be explained by the use of the dummy modal 'do' (which patterns like a modal without ascribing modal meaning) shows that subtle differences in the distributional characteristics of languages can have quite profound effects on the patterning of child data. As these effects can be quite difficult to predict a priori, computational modelling can be an invaluable tool for investigating the complex relations between input characteristics and child speech.

The analyses reported here also underscore the importance of using realistic input when simulating child speech, as some effects are only likely to be simulated when realistic input is used. While dummy *do* is only one of many modals in English, it accounts for 40% of the third singular + infinitive contexts. However, *do* is also responsible for the occurrence of eventive RIs. Since these occur at a maximum rate of 20% in these simulations, an underestimation of the incidence of *do* in artificial input would likely result in failure of the model to simulate the effect. This is even more apparent when one realises that third singular plus infinitive contexts are largely restricted to questions; it seems unlikely that without prior knowledge of the importance of questions a researcher constructing artificial input would include 'do-questions' at a sufficient rate to simulate these effects.

The fact that the interaction between the learning mechanism and the distributional characteristics of the input can produce the different levels of modal Root Infinitives in the two languages strongly suggests that the observed phenomenon is related to surface characteristics (the contexts in which infinitives occur), rather than to differences in the infinitival morphology between the languages. Since MOSAIC does not have any knowledge of infinitival morphology (in fact does not employ any built in linguistic knowledge), these results clearly show that the Modal Reference Effect can be explained without assuming that children know the full grammar of their language, or the fine detail of infinitival morphology.

Acknowledgements

This research was funded by the ESRC under grant number RES000230211

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