The development of bimodal bilingualism

Implications for linguistic theory

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A wide range of linguistic phenomena contribute to our understanding of the architecture of the human linguistic system. In this paper we present a proposal dubbed *Language Synthesis* to capture bilingual phenomena including code-switching and 'transfer' as automatic consequences of the addition of a second language, using basic concepts of Minimalism and Distributed Morphology. Bimodal bilinguals, who use a sign language and a spoken language, provide a new type of evidence regarding possible bilingual phenomena, namely code-blending, the simultaneous production of (aspects of) a message in both speech and sign. We argue that code-blending also follows naturally once a second articulatory interface is added to the model. Several different types of code-blending are discussed in connection to the predictions of the Synthesis model. Our primary data come from children developing as bimodal bilinguals, but our proposal is intended to capture a wide range of bilingual effects across any language pair.

Keywords: bimodal bilinguals, language architecture, language acquisition, cross-linguistic influence, code-blending, sign languages

1. Introduction

What is the mental architecture of human language? In order to address this question, it is necessary to consider a wide range of linguistic phenomena. Modern linguistic theory has proposed answers based on consideration of detailed syntactic phenomena across languages. Researchers studying bilingualism have added to the data that such models must account for, arguing for the necessity of one version or another. In this paper, we add to the discussion data from *bimodal*

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bilingualism, that is, bilingualism involving both a sign language and a spoken language. Bimodal bilingualism introduces new types of bilingual phenomena, expanding our conception of what the human mental language faculty can generate. Yet, following in the footsteps of other bilingualism researchers, we argue that the variety of bilingual phenomena observed do not call for a radical restructuring of our conception of the mental linguistic computational mechanism. Rather, as we discuss here, these phenomena all fall out from a model that has independently been proposed only on the basis of monolingual speakers, with appropriate additions necessitated by the presence of two languages, and two modalities.

We begin this discussion with some background on bimodal bilingualism: who bimodal bilinguals are, and what data are available regarding bimodal bilingual phenomena. Given our own research program, we focus on child bimodal bilinguals, and assess how data from children relate to adult data. We then address the question of architecture, starting with linguistic models based on monolingual data, expanding to proposals to account for multilingualism, and then presenting our version of the model that includes a bimodal component. Following, we summarize a range of observations regarding the output of bimodal bilinguals, showing how they are generated by the model. We conclude by mentioning the great deal of research that remains to be done to fully understand bimodal bilingualism and its development.

2. Bimodal bilingualism

2.1 Who are bimodal bilinguals?

Bilingualism is widely understood as a capacity for two (or more) languages. Some researchers apply the term narrowly to those who were first exposed to their languages in infancy (de Houwer, 1995). However, for the purposes of this overview we will at times adopt the more general view that includes later learners who may well exhibit varying degrees of fluency with each language, in many cases preferring one or the other for particular contexts of use (Bhatia & Ritchie, 1999).

The term bimodal bilingualism is generally used to describe bilinguals whose languages exist in different articulatory modalities: a sign language and a spoken language, for example, American Sign Language (ASL) and English, or Brazilian Sign Language (Libras) and Brazilian Portuguese (BP).[1] This description would

1. Throughout this article the term 'sign language' is used to refer to one of the naturally-developed visual-spatial languages used in Deaf communities, not artificial sign systems for representing a spoken language.

include in the first place children with typical hearing who grow up in households that use sign language because one or both parents are Deaf members of a signing community.[2] Like other bilinguals, these children develop varying degrees of fluency in their two languages, and while some as adults may reserve the use of their sign language for family-related activities, others use their sign language as interpreters or in other professional capacities (Preston, 1995). Given the predominance of the spoken language in the larger community, hearing children of Deaf parents usually become more proficient in their spoken language. However, they often have a special affinity for their home sign language and their experiences as a hearing child in a Deaf family. Because of these sentiments, an organization was formed to bring together adults having had such experiences growing up (initially based in the U.S., this organization is now international; see www.coda-international.org). This organization was called CODA for Child of Deaf Adults (implying that the 'child', now adult, is hearing; see Bishop, 2006 for discussion of this history). In this article, we will use the term Coda to refer to adults with this background, and Koda for 'kids' (reserving the all-caps version CODA for the established organization).

Since Kodas typically grow up in households in which a sign language is the primary language but with a spoken language as the language of the broader community, some researchers have recently applied the term 'heritage signer' to parallel the special acquisition environment of heritage speakers (a household whose primary language is not the language of the broader community; Ashton et al., 2014; Compton & Compton, 2014; Reynolds & Palmer, 2014). As observed with heritage speakers, Koda/Coda heritage signers display highly variable proficiency in their heritage language. There are balanced heritage signers, as well as those for whom the spoken language is their primary language. Whether heritage signers display the same range of developmental characteristics as heritage speakers is a topic under current investigation (Chen Pichler et al., in press). To remain neutral on the issue, in this paper we will not focus on this characterization, but it is an important issue in our ongoing research (e.g., Quadros, Lillo-Martin, Polinsky, & Emmorey, 2016b).

Very recently, another population of children who have very early exposure to both a sign language and a spoken language has arisen: Deaf children who sign, and speak with the aid of a cochlear implant (CI). CIs are medical devices that are surgically implanted inside the ear. They permit the user to perceive sounds in the range used for speech, although it is a different percept compared to typical hearing and children need to be taught how to interpret and produce spoken

2. Deaf is written with a capital 'D' to indicate membership in a particular cultural group rather than audiological status per se (Woodward, 1972).

language (unlike children with typical hearing). CIs are increasingly used by Deaf children all over the world; the U.S. FDA (Food and Drug Administration) has approved implantation for children as young as 12 months of age. Most children who receive CIs are not exposed to a sign language, as medical and educational professionals frequently advise an oral-only approach (see Mellon et al., 2015 for views on both sides).[3]

In a few cases, the parents of children receiving an implant are Deaf signers, so the child has accessible input in a sign language from birth, with spoken language input after implantation around one year of age or later. One small group of such children was studied by Davidson, Lillo-Martin and Chen Pichler (2014), who focused on their performance on a range of standardized spoken English tests. The researchers found that the children all performed within the age-equivalent ranges on these tests, no different from the comparison group of Kodas they also tested. Overlapping sets of native signers using CIs were studied by Goodwin (2016) and by Palmer (2015). Both authors found that the children with CIs performed very similarly to Koda children, in spoken English morphology and ASL word order, respectively, although some differences were also observed (e.g., the children with CIs performed worse than the Koda children on English plurals). Further study will uncover to what extent native signers with early cochlear implantation are linguistically similar to Kodas regarding bilingual development.

If the term bimodal bilingual is employed broadly regardless of the age at which the second language is learned, it should apply also for the case of hearing users of a spoken language who subsequently learn a sign language, perhaps through formal education. These second language (L2) learners may have much in common with learners of a second spoken language, but there might also be interesting differences having to do with learning a second language in a new modality. Learners of a second spoken language have to learn to produce new sounds, but hearing learners of a sign language have to learn to use new linguistic articulators. For this reason, some researchers use the designation M2L2 to highlight that these L2 learners are learning in their second modality (M2) (Chen Pichler, 2012). While some M2L2 signers become quite fluent and use the sign language on a regular basis (for example, as sign language interpreters), very few research studies address either their course of sign language development or ultimate attainment (see Chen Pichler & Koulidobrova, 2016, for further discussion). Almost all

3. Some children are exposed to some amount of signing through 'Total Communication' educational programs, but the nature of the signing used in such programs is quite variable; others are exposed to a natural sign language through bilingual programs at some point. Overall, the amount and quality of sign language input may vary considerably across these cases, and very little is known about their development as bilinguals.

studies of adult bimodal bilingualism focus exclusively on participants who grew up using a sign language.

Finally, the term 'bimodal' bilingual is sometimes used to describe Deaf signers who are bilingual by virtue of their knowledge of a sign language and a spoken language, including cases where the spoken language is learned and used in its written form (sometimes the Deaf bilinguals also access spoken language through speechreading). In this sense, such bilinguals are not using their two languages in two different modalities, but in the same (visual) modality. Some researchers use the term 'bi-channel bilinguals' to refer to those who access both a sign language and the written form of a spoken language through the visual modality (Thompson, 2015), but others use the term bimodal or cross-modal in this context. There are many bilingual effects concerning interactions between spoken and sign languages that appear in the signing (Kuntze, 2000; Lucas & Valli, 1989) or writing (Lillo-Martin, 1998; Menéndez, 2010) of Deaf signers. It remains to be seen to what extent these effects are equivalent to the bilingual effects observed in those who access a sign language visually and a spoken language through the oral/aural modality, but there are clear psycholinguistic similarities (Emmorey, Giezen, & Gollan, 2016).

2.2 Binational Bimodal Bilingual (Bibibi) language development project

Data from our collaborative project studying the development of bimodal bilingual children will be frequently referred to in this paper. To provide a general introduction to the project, we summarize it here (see Quadros et al., 2015 and Chen Pichler, Hochgesang, Lillo-Martin, Quadros, & Reynolds, 2016, for overviews, and http://www.bibibi.uconn.edu for more publications).

The Binational Bimodal Bilingual (Bibibi) language development project includes studies of bimodal bilingual children in both the U.S. (acquiring ASL and English) and Brazil (acquiring Brazilian Sign Language, called Libras, and BP). The primary participant group is composed of Koda children, although we have also collected comparable data from a smaller group of Deaf children who sign and use a cochlear implant. Naturalistic data collection begins from as young as 0;10 (years; months) up to 8;06, with different age ranges analyzed in each of the studies summarized below.

The youngest children are filmed in naturalistic interactions in order to capture their spontaneous productions (SP) for primary data. During the naturalistic SP sessions, children interact with an adult and/or a trained research assistant; in sign-target sessions the interlocutor is generally a Deaf signer, often a parent, while in speech-target sessions the interlocutor is a hearing person (see Chen Pichler et al., 2016, regarding our filming procedures). While the target languages

are separated in this way, almost all the interlocutors are bilingual and the environment is highly bilingual, so language mixing often occurs spontaneously, and is not discouraged. Collecting data in both sign- and speech-target sessions allows for the investigation of children's language choice and developing grammatical skills.

After filming, child and adult productions are transcribed using ELAN (http://www.lat-mpi.eu/tools/elan), a multimedia program developed at the Max Planck Institute for Psycholinguistics, The Language Archive, Nijmegen, The Netherlands (Crasborn & Sloetjes, 2008). ELAN permits researchers to provide time-aligned annotations with digitized video (see Chen Pichler, Hochgesang, Lillo-Martin, & Quadros, 2010, regarding our annotation procedures).

Experimental data from older children are collected at language 'fairs' designed to provide families with fun opportunities while we engage them in multiple studies of comprehension and production (see Quadros et al., 2015 regarding these procedures).

3. Models of the architecture of the mental human language capacity

3.1 Minimalist models of bilingualism

For the most part, researchers proposing models of the architecture of the mental human language capacity only consider monolingual data. This has also been true in the development of the 'Minimalist' approach to grammar, which attempts to reduce posited computational mechanisms to the minimal amount necessary to account for the relationships between meaning and articulation, the 'external interfaces' of the computational system (Chomsky, 1995). In such approaches, attention is paid to accommodating differences across languages (e.g., parameters, feature strength), but the assumption is made, implicitly or explicitly, that each 'ideal' speaker-hearer is working with one grammar. It is of interest to see whether the output of the grammatical model aligns with what the linguist takes to be appropriate data for the language (or dialect) being investigated.

When researchers started to investigate the implications of bilingualism for linguistic theory, one important phenomenon that supplied valuable data for discussion was code-switching, the (possibly intra-sentential) change from one language to the next produced by bilinguals. For example, Belazi, Rubin and Toribio (1994) observed the contrast in (1). Spanish-English bilinguals accepted the code-switch in (1a), but rejected the one in (1b).

(1) a. The students *habían visto la película italiana*. (English-*Spanish*)
"The students had seen the Italian movie."
b. *The student had *visto la película italiana*.

As researchers discovered such patterns of acceptability for code-switching, this became a source of data for linguistic theory to explain. Some scholars proposed special rules or constraints that applied specifically for bilinguals; monolinguals would not have such constraints in their mental grammars. For example, Poplack (1980) proposed The Equivalence Constraint and The Free Morpheme Constraint to account for certain patterns she observed in code-switching. These constraints were intended as means to capture generalizations about where speakers would and would not switch languages. Similarly, Belazi and colleagues (1994) proposed The Functional Head Constraint, which employed concepts (such as government and agreement) used with monolingual data, but also required a feature indicating the language a functional element is associated with to be used and checked in the syntactic derivation.

In contrast, MacSwan (2000; 2005; 2014) argued that the previously proposed constraints are ad hoc and specific to bilingual code-switching. As detailed in his (2014) chapter, MacSwan followed the recommendations of previous scholars, and advocated an approach in which there are no grammatical constraints specific to code-switching; rather, all surface constraints should follow from independently-motivated grammatical requirements. Unlike authors such as Belazi

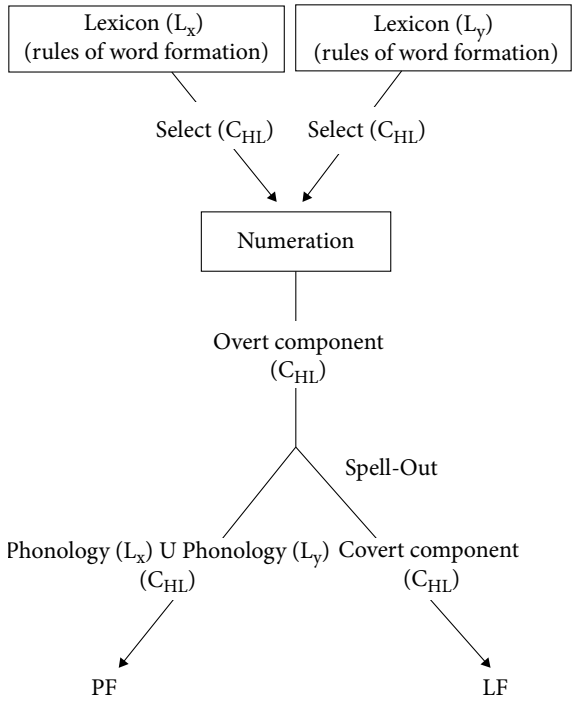


Figure 1. A Minimalist view of the bilingual language faculty (MacSwan, 2000, p. 52)

et al. (1994), he argued that there is no 'language' feature that can be appealed to in code-switching. Instead, he argued, "nothing constrains code switching apart from the requirements of the mixed grammars" (MacSwan, 2000). His model is given in Figure 1.

This model takes as its basis a lexicalist version of Minimalist theory (Chomsky, 1995). For monolinguals, there would be only one Lexicon and Phonology, while there are two illustrated in the model for bilinguals; otherwise the models are identical. The operation Select, by which elements from (either) Lexicon are entered in the Numeration, can choose from both Lexica for bilinguals. Then, provided all features are appropriately checked, a derivation may succeed in which some words come from Language_x and others from Language_y, accounting for code-switching. The model places constraints on code-switching only by requiring ordinary feature-checking; if an element from Language_y is not able to check the requirements from Language_x, such a derivation will fail.

One example MacSwan (2000, p. 49) gives for how this feature-checking requirement differentiates code-switching cases involves switching from Spanish pronominal subjects to Nahuatl predicates, as illustrated in (2).[4]

(2) a. *Tú *tikoas* *tlakemetl* (Spanish-*Nahuatl*)
tú ti-k-koa-s tlake-me-tl
you/SING 2s-3Os-buy-FUT garment-pl-NSF
"You will buy clothes"

b. Él *kikoas* *tlakemetl*
él 0-ki-koa-s tlak-eme-tl
he 3s-3Os-buy-FUT garment-pl-NSF
"He will buy clothes"

According to MacSwan, in 1st and 2nd person, Nahuatl verbs must move to T for agreement marking, but not in 3rd person, where the zero form is used. Then, the Nahuatl V, which does not mark gender, clashes in (2a) with the features on T, which must include gender for the sake of the Spanish pronouns; but no such clash is present in (2b), since the verb does not need to raise.

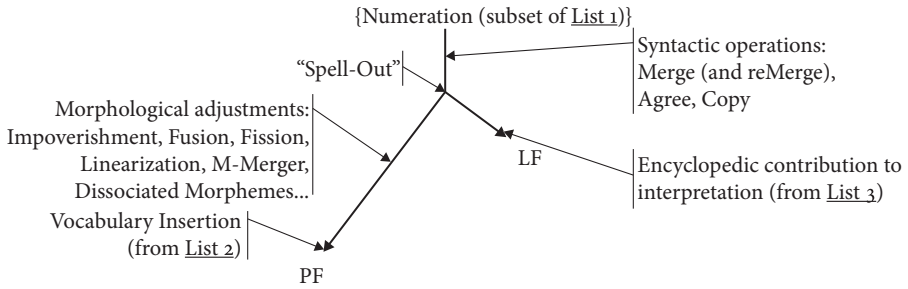
4. MacSwan (2000) provides the following information about abbreviations used in the glosses (only those relevant for examples in the present article are given here):

2s	second person subject agreement (unspecified for number)
3s	third person subject agreement (unspecified for number)
3Os	third person singular object agreement
FUT	future tense
NSF	noun suffix (sometimes called absolutive)
pl	plural marking (on nouns or verbs)

MacSwan and others have followed this 'constraint-free' approach to code-switching, leading to numerous important implications for linguistic theory (see MacSwan, 2014, and additional discussion below). However, other researchers have argued for a modification of this approach, to which we now turn.

3.2 Minimalism with Distributed Morphology

Some researchers, including Bandi-Rao and den Dikken (2014), Liceras, Spradlin and Fernandez Fuertes (2005), Liceras, Fernández Fuertes, Perales, Pérez-Tattam and Spradlin (2008), Liceras, Fuertes and la Fuente (2012), and Pierantozzi (2012), have argued for one important adjustment in the MacSwan-style approach to code-switching, which is to adopt the central tenets of the theory of Distributed Morphology (DM) (Halle & Marantz, 1993; for overviews of DM, see Bobaljik, 2015; Harley & Noyer, 1999; Siddiqi, 2010). The basic DM architecture is illustrated in Figure 2.



List 1: *Feature bundles*: Syntactic primitives, both interpretable and uninterpretable, functional and contentful.
List 2: *Vocabulary Items*: Instructions for pronouncing terminal nodes in context
List 3: *Encyclopedia*: Instructions for interpreting terminal nodes in context

Figure 2. Distributed Morphology Architecture (Harley, 2014)

There are three Lists referred to in the model and briefly described in Figure 2. Bilinguals would have two sets of each list, one corresponding to each language (although some of the features that contribute to List 1 feature bundles may be universal and thus possibly not duplicated).

One crucial concept of DM is that the elements that are selected and take part in the overt derivation are themselves abstract, and accordingly not specified for phonological information. These elements fall into two categories: lexical morphemes, or roots, and formal, or functional morphemes. Only during the component of the grammar between spell-out and PF does insertion of specific forms take place, through an operation known as Vocabulary Insertion (VI). At this point, it is possible to insert elements from Language$_x$ and/or from Language$_y$,

as long as the feature specifications do not clash. Thus, as in the MacSwan approach, code-switching will be possible and constrained only in the same ways that monolingual grammar is constrained. The difference between this approach and MacSwan's has to do with whether or not the input to the syntactic derivation includes fully specified lexical items. Some consequences of this difference concern whether or not word-internal switching is possible (this issue will not be discussed in the present article; see Bandi-Rao & den Dikken, 2014, for details).

One set of data from bilingual language production provides clear evidence for the notion that abstract items enter the derivation and may in principle be spelled out using vocabulary items from either language. This is the phenomenon of 'mixed agreement' in code-switched noun phrases, such as Spanish-English *el pen* or *la house* (Liceras et al., 2008; Pierantozzi, 2012). There are quite a number of studies investigating this phenomenon with varied results, but one consistent finding concerns the possibility of switching between a determiner and a noun in language pairs where the language of the determiner marks gender but the language of the noun does not (such as Spanish and English, respectively). Given that the noun has no gender, which form of the determiner is chosen? In some cases, the determiner chosen can be classified as a default. However, some studies reveal a strong preference for the 'analogical' gender – that is, the determiner is marked with the gender of the noun's translation equivalent in the other language, as illustrated in (3).

(3) Veo las$_{\text{f.pl}}$ *houses*$_{\text{pl}}$ (Spanish-*English*)
'I see the houses.' (Muysken, 2000, p. 23, as cited by Pierantozzi, 2012, p. 139)

In the DM version of code-switching, such cases are easily handled, as in the following analysis from Pierantozzi (2012). If the root has the feminine feature, it will properly agree with a feminine determiner. The feminine determiner will be pronounced *las*, but the noun can be inserted from either language. The English noun, which has no gender feature, is compatible with the root that is specified for gender due to the Subset Principle.

Similarly, it will be possible for the English determiner, without a gender feature, to be generated with the Spanish noun, as in (4). In this case, neither the determiner nor the noun root has a gender feature. Insertion of the Spanish [+feminine] noun is allowed on the assumption that roots do not compete (Harley & Noyer, 1999).

(4) I see the *casas*. (English-*Spanish*)
'I see the houses.'

Thus, an approach to code-switching like that of MacSwan (2000), but modified to adopt late insertion from Distributed Morphology, accounts for a range of data,

still without appealing to constraints that are specific to bilinguals. The approach discussed here can be considered a null hypothesis, in that it requires minimal differences between monolingual and bilingual grammars (namely, the presence of two sets of lists). The next question is whether it can also account for bilingualism effects observed in (apparently) monolingual utterances, such as cross-linguistic influence (including acceleration and delay; cf. Paradis & Genesee, 1996), or transfer effects commonly observed in language learners. In the next section, we discuss a proposal to do just that, the Language Synthesis model. This model also addresses bilingual phenomena unique to bimodal bilinguals, the most prominent of which is code-blending. In code-blending, aspects of an utterance are produced using both speech and sign simultaneously. The nature and derivation of code-blending will be explicated in some detail below.

3.3 The Language Synthesis model

In a series of works, we have proposed a model to pursue the consequences of having two sets of lists under a DM/minimalist approach to bilingualism. Because these phenomena involve combining parts of the grammar in new ways, we use the term *Language Synthesis* for this way of viewing them (Koulidobrova, 2012; Koulidobrova, 2016; Lillo-Martin, Koulidobrova, Quadros, & Chen Pichler, 2012; Quadros, Lillo-Martin, & Chen Pichler, 2016). The Language Synthesis model is intended to account for not only code-switching, but also code-blending and what we call syntactic synthesis.

To focus attention on the bimodal bilingual aspects that the Synthesis model adds to the typical DM model, we represent it in Figure 3. The only substantive difference between Figures 2 and 3 is the explicit mention in the latter that elements from each list may have two sources, and the explicit illustration of the possibility of two phonological levels, one for speech and one for sign. We explain each component of the model in turn.

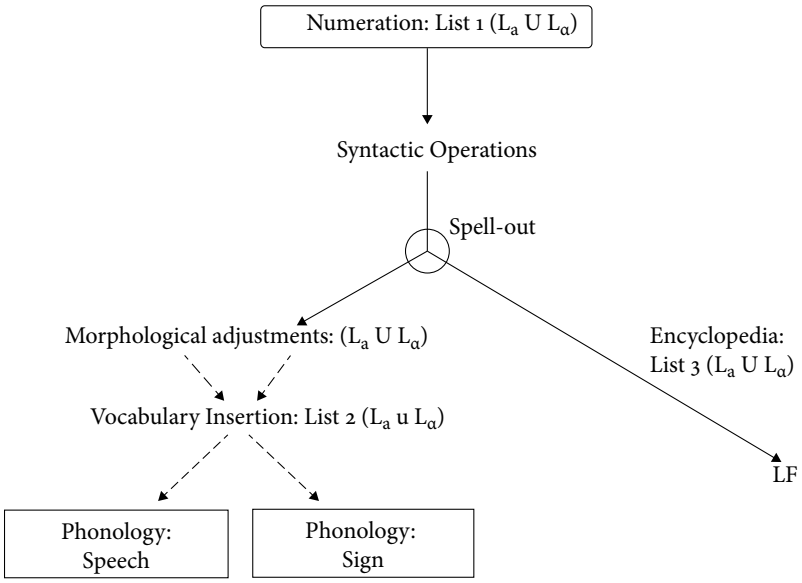


Figure 3. Language Synthesis model[5]

What code-switching looks like under the Synthesis model is insertion of vocabulary items (etc.) from the two language sets in sequence, just as for the approaches discussed in section 3.2. As long as features are appropriately checked (as in the examples in 2b, 3, and 4), there is nothing special that needs to be included in the model. Thus the Synthesis model accounts for code-switching in any language pair in the same way as other models incorporating Minimalism and Distributed Morphology.

Now, let us consider another possibility. Suppose that the abstract syntactic features that are selected come from both languages, but the vocabulary items only come from one language. A possible outcome is the production of utterances that exhibit what is known as *cross-linguistic influence, transfer*, or *calquing* (Romaine, 1995). These three terms are primarily used to characterize different contexts (early language development, second language learning, and language contact situations, respectively), but they all involve situations where it seems that the grammar of one language is used with words from another. On the view proposed here, there is no reason to think of them as different phenomena, or as coming from different grammatical sources. They are all examples of *Syntactic Synthesis*, simply generated by an architecture that allows feature bundles entering into a derivation

5. This model is modified in presentation from earlier versions presented in Koulidobrova (2012); Koulidobrova (2016); Lillo-Martin, et al. (2012); Lillo-Martin, Quadros, Chen Pichler, and Fieldsteel (2014); Quadros, Lillo-Martin and Chen Pichler (2016a); and other works.

to come from a different 'language' than the one that the vocabulary items are drawn from. That is, the Synthesis model is intended to capture all these types of phenomena in the same way with respect to derivation, eliminating the need for different mechanisms to account for each. Since these types of structures are generally associated with particular circumstances (such as early stages of language acquisition), it is likely that speakers come to reduce their selection of feature bundles from one language with the use of vocabulary items from a different language, or limit such grammatical choices to certain discourse situations, but we consider this a sociolinguistic issue (similar to choosing appropriate contexts for code-switching), not necessarily a change in grammar. Justification for this and examples of this phenomenon will be discussed in section 4.

In the case of bimodal bilinguals, the architecture of the Language Synthesis model also allows for an additional possibility. So far, we have only discussed cases that involve one input to the phonology – after all, unimodal bilinguals may switch back and forth between different languages, but they cannot produce two phonological representations simultaneously. On the other hand, bimodal bilinguals can produce both speech and sign simultaneously, and it turns out that they do so quite often. This blending of speech and sign is known in the literature as code-blending (Emmorey, Borinstein, Thompson, & Gollan, 2008a), and it is a uniquely bimodal phenomenon. Yet, it is not difficult to see how an approach such as the Language Synthesis model can generate code-blending. All the assumptions we have made so far about the possible mix of elements from the two languages up until the point of spell-out still hold. At some point after spell-out, there can be two paths toward phonology, one for sign and one for speech. Since the goal of the Minimalist approach is to define the computations that connect meaning and articulation, adding a second set of physical articulators requires such a move. At the same time, this approach places restrictions on the output of such code-blending. In section 5, we will present some evidence from code-blending, and discuss how the Synthesis model generates the observed patterns, including why there are multiple possible routes to blending.

We turn now to an overview of bimodal bilingual developmental data, connecting previous observations to the Synthesis model. We begin in section 4 by looking at cases of syntactic synthesis, in which features from one language are used and affect the syntax of the output, even if that output apparently employs vocabulary items only from the other language (one modality). Then in section 5 we turn to code-switching and code-blending, phenomena in which vocabulary items from both languages are apparent.

4. Syntactic synthesis

In one of the first works to come from the Bibibi project described in section 2 (Lillo-Martin, Quadros, Koulidobrova, & Chen Pichler, 2010), we presented an initial picture of the development of bimodal bilingualism in children from two countries, the U.S. and Brazil. This work provided evidence that 2- to 3-year-old bimodal bilinguals display cross-linguistic influence from their sign language to their spoken language. The structures of interest are ones in which the word order of a spoken utterance mirrors an order grammatical for the sign language, but not used (by monolingual children) in the spoken language. In each of the cases illustrated in (5) below, a plausible analysis involves use of a common structure from the sign language, as indicated in the heading for each example.

In (5a), the object *cabeça* 'head' appears between the subject and the verb, an order not found in BP but grammatical in Libras. In (5b), the verb is produced twice, with the subject appearing in between the two repetitions. This structure is similar to the 'doubling' found in ASL (and other sign languages), discussed further in section 4.1 below. In (5c), the context makes it clear that the child's target utterance is "it's stuck", referring to a bit of Playdoh modeling clay stuck in an extruder. He repeats the non-target order twice, and then the experimenter asks, "Is it stuck?", to which he replies, "yeah." Sentence-final subject pronouns are a productive process in ASL. Finally, in (5d) we see an example of WH-in-situ; while this is grammatical in the appropriate contexts in adult English, the child's use is a clear direct question, produced at an age at which monolingual English-speaking children do not yet use WH-in-situ. Empirical comparison between WH-questions produced by bimodal bilingual children and monolingual children is presented in section 4.1 below.

(5) a. O-V order (Igor 2;10)
BP: Mãe, Laura cabeça bateu
Mom Laura head hit
Target BP: Mãe, a Laura bateu a cabeça.
Mom the Laura hit the head
'Mom, Laura hit her head.'

b. Doubling (Ben 2;01)
AE: sleeping mouse sleeping
Target AE: the mouse is sleeping

c. Subject Pronoun Copy (Ben 2;03)
AE: stuck it
Target AE: it's stuck

d. WH in situ (Tom 2;04)
AE: bug go where
Target AE: where did the bug go? (Lillo-Martin et al., 2010, p. 271)

Lillo-Martin et al. (2010) argue that such examples provide evidence that cross-linguistic influence reflects possible structural convergences afforded by the bilingual grammar, as in the Language Synthesis model. Of course, many researchers have investigated cross-linguistic influence and transfer (and calquing) in detail, so it remains to be seen whether the Synthesis approach will appropriately generate all (and only) the types observed.

In the next three subsections we review evidence for the Synthesis approach from three domains; the first two, WH-questions (4.1), and argument omission (4.2), come from the Bibibi research group; the last section (4.3) reports a selection of earlier studies with data amenable to this kind of analysis.

4.1 Synthesis and WH-questions

Further evidence for the approach proposed by Lillo-Martin et al. (2010) comes from our analyses of WH-questions produced by Koda children (Lillo-Martin et al., 2012; Quadros, Lillo-Martin, & Chen Pichler, 2013). We provide evidence that cross-linguistic influence occurs both from sign to speech and from speech to sign. This evidence is briefly summarized here; a more detailed presentation with additional data can be found in Lillo-Martin, Koulidobrova, Quadros, & Chen Pichler (in prep).

The two sign languages under investigation, ASL and Libras, differ in their formation of WH-questions from the spoken languages English and Brazilian Portuguese (BP) in several ways. First, while English and BP permit WH-in-situ, in both cases these are restricted to particular pragmatic contexts analyzed as 'Common Ground' (Pires & Taylor, 2007). Otherwise, WH-phrases appear uniformly in sentence-initial position, analyzed as the specifier of CP (SpecCP). The sign languages are more permissive in their use of WH-in-situ structures (Quadros & Lillo-Martin, 2010). A detailed analysis of the pragmatics of different WH positions in these sign languages is not available, so it is assumed here that moved and in-situ questions are semantically equivalent. In addition, the sign languages permit their WH-elements to appear twice in one sentence, at sentence-initial and sentence-final position. These structures are known as doubling, and are analyzed as emphatic by some researchers (Nunes & Quadros, 2006; 2008). Illustrations of these WH-question types are given in (6) below. (Please see the Appendix for an explanation of the notation used for sign language examples. The examples are glossed using English; comparable orders are grammatical in both ASL and Libras.)

(6) a. WH-initial
wh
WHO YOU LIKE
'Who do you like?'
b. WH-in-situ
wh
JOHN SEE WHO TODAY
'Who did John see today?'
c. WH-double
wh
WHAT JOHN BUY WHAT
'WHAT did John buy?'

Let us assume that each of the structures illustrated in (6) is generated due to a functional element that comes from the sign language List 1: for the in-situ cases, this would be the version of the [+WH] C head that permits in-situ questions; and for the doubling, a particular [+emphatic] F head, following the analysis by Nunes and Quadros (2006, 2008). Then, if a bimodal bilingual uses the C from the sign language list in the numeration, but at VI uses only spoken language items, the output would be a spoken WH-in-situ utterance, where speech follows the sign order. This analysis fundamentally follows that by Tieu (2010), proposed to account for WH-in-situ productions in English by Cantonese-English bilingual children. Similarly, if the head F from the sign list is included in the numeration, but only spoken vocabulary items are inserted, the output will be a doubling structure in speech that follows the sign word order. As reported by Lillo-Martin et al. (2012) and Quadros et al. (2013), 2-year-old bimodal bilingual children produce such structures, as illustrated in (7). However, in our review of WH-questions produced by monolingual English or BP-speaking children at the same age, we found that such structures were never used, as WH-initial was followed virtually all the time.

(7) *in situ/final*
a. Mommy where? (Ben 2;00)
b. Bug go where? (Tom 2;04)
doubling
c. Where balloon where? (Ben 2;02)
doubling (BP)
d. Que eu quero que?
what I want what (Igor 2;01)
'What do I want?'

Evidence for speech structures used in sign is more subtle, since the spoken-language specific structure, WH-fronting, is also grammatical in the sign languages.

However, an elicited production study with 4- to 6-year-old Deaf ASL signing children (Lillo-Martin, 2000) can be used as a baseline for the expected relative proportion of each structure type (WH-initial, final/in-situ, double). As reported by Lillo-Martin et al. (2012), bimodal bilingual participants in the same age range overwhelmingly produced WH-initial structures, with far fewer instances of the other structures than the Deaf comparison group.

These studies show that bimodal bilingual children produce both speech and sign in ways unlike monolingual speakers or signers. This can be expected, given that "the bilingual is not two monolinguals in one person" (Grosjean, 1989), but rather one person who exhibits complex interaction between two grammars. We suggest that these structures result from Language Synthesis, as described in section 3.

4.2 Argument omission

Koulidobrova (2012, 2016) provided further evidence that cross-linguistic influence in bimodal bilingual children shows the effects of Language Synthesis. She studied argument omission in the spontaneous English production of two American Koda children ages 2;00–4;11. Her study follows a long line of literature reporting that bilingual children do not show cross-linguistic influence from a null-subject language (NSL) to a non-null-subject language (NNSL), but rather they tend to *over*-use overt subjects in their NSL (see summary in Serratrice, 2013; also Serratrice, Sorace, & Paoli, 2004; Sorace, Serratrice, Filiaci, & Baldo, 2009). This is so even if both of their languages permit null subjects, as in the study of Italian-Spanish bilinguals reported by Sorace et al. (2009). In contrast, Koulidobrova found that bimodal bilinguals do over-use null subjects in their NNSL, English, and she showed that these null subjects appear in structural configurations where they are not attested for monolingual English speakers. Furthermore, she found that bimodal bilinguals also use null objects in English, something that shows up with very low frequency in monolinguals.

Koulidobrova's report shows that the bimodal bilingual children she studied omitted English subjects and objects at rates similar to monolingual children early in development, in stages 1 and 2 (defined on the basis of MLUw up to 3.0), the age when subject omission is relatively frequent for English-acquiring children. Already this is surprising, given the widespread reports that bilingual children acquiring both a NSL and a NNSL surprisingly use fewer null subjects in both their NSL and their NNSL than monolinguals (Serratrice et al., 2004). Even more strikingly, the Koda participants in Koulidobrova's study continued to use null

subjects in stages 3 and 4 (MLUw 3.0–4.0 and >4.0, ages 3;05 and up),[6] at a rate that is significantly above that of monolingual or unimodal bilingual speakers; null objects were also used significantly more than the monolingual levels at these stages.[7] Furthermore, Koulidobrova demonstrated that null subjects are used in structural positions for which monolingual children typically never use nulls, such as following a modal, or as the subject of an embedded clause, as illustrated in (8).[8]

(8) a. Inv: It's a window. You are right.
Tom: This is gonna be a cool.
Inv: It is going to be cool. Yeah.
Tom: Can Ø give me this?

b. Lex: Thomas need to go.
Lex: Because he need to go chug fast
FAST
Inv: mmhm.
Lex: Because my train is fast.
Lex: Mister Conductor said# Ø won't crashed# he said

Koulidobrova's conclusions include the following. First, she argued that one highly influential approach to cross-linguistic influence, that and Hulk and Müller (2000), is empirically contradicted by these as well as other data. She shows that the previous proposals concerning transfer are too limited, and that the Synthesis model explains a wider range of data. Second, she proposed that the use of null arguments in the speech of bimodal bilinguals is a consequence of language synthesis, following from the use of the T and/or *v* functional heads from ASL in a structure that otherwise employed English. Finally, she speculated on the difference between unimodal bilinguals and bimodal bilinguals with respect to the use of null vs. overt arguments. Sorace et al. (2009) had proposed that unimodal bilinguals experience a processing load because of the continual effort to suppress one or the other language. On the assumption that overt subjects convey a processing advantage, the

6. Note that these stages are after the uncontroversial emergence of the C-domain in these children, as Koulidobrova shows using clear examples of structures requiring C.

7. Pirvulescu, Pérez-Leroux, Roberge, Strik and Thomas (2014) note a very high rate of object omission by 3- to 5-year old French-English bilinguals in their elicited production study. There are a number of differences between this study and Koulidobrova's, so the explanation for this difference awaits further research.

8. In these examples, Tom and Lex are pseudonyms for the child participants and Inv stands for Investigator. In example (8b), the notation FAST indicates that Lex produces the sign for FAST simultaneously with the spoken word (a code-blend). See section 5 for extended discussion of this phenomenon.

over-use of overt arguments in unimodal bilinguals can be expected. Following the proposal by Emmorey et al. (Emmorey et al., 2008a; Emmorey, Luk, Pyers, & Bialystok, 2008b) that bimodal bilinguals experience less need to inhibit one language, due to the possibility of code-blending, Koulidobrova concluded that bimodal bilinguals do not face the same overall processing load, and hence the use of null arguments would be seen. Note that in this context, it is proposed that bimodal bilinguals are using unseen aspects of ASL (such as null functional categories).

The Bibibi studies summarized above provide examples of syntactic synthesis based on recent and continuing analyses. However, there have also been some studies in the past that have observed cases of synthesis in bimodal bilinguals, although this term was not used. While linguistic recognition and analysis of sign languages is relatively recent, and was not well known in the 1970's, it is notable that as early as that period some researchers were already looking at the possibility that aspects of the syntax of ASL were present in the spoken language of young kodas.

4.3 ASL-influenced English: Previous studies

Todd (1971)[9] and Todd and Aitchison (1980) discussed the possibility of ASL influence in the spoken language development of a Koda child who had little exposure to spoken language until the age of 3 years. Todd (1971) considered three types of what he called 'structural interference across sensory modalities', drawing explicit parallels to cases of transfer in second spoken language development. He claimed that once the child began to speak English, "he spoke in sentences which are literal translations of structures found in his native sign language" (p. 103).

One example that Todd discussed is similar to the case of doubling brought up in the context of WH-questions above. Doubling applies to other constituents as well as WH-phrases, such as verbs, modals, quantifiers, and nouns, although there are some differences across types. Todd uses the term 'bracketing', but it is clear that he means the repetition of an element with other sentential material intervening between the two copies, the same general characterization used for doubling. Some examples of Victor's use of bracketing are given in (9).[10]

(9) a. Spider hear, spider (Victor, ~4 years)
'I hear spiders (…)'

(Todd, 1971, p. 110)

9. It appears that both articles are discussing the same child, although he is given the pseudonym Victor in Todd (1971) and the pseudonym Vincent in Todd and Aitchison (1980).

10. Todd says that Victor uses 'puter' to mean roughly make/do/perform.

b. What's-that puter, what's-that?
'What's this thing for?'

(Todd, 1971, p. 111)

Johnson, Watkins and Rice (1992) also explicitly considered the possibility of ASL influence in the spoken English development of one hearing child of Deaf, signing parents. Their subject, Becos, received input in ASL almost exclusively until the age of 2;03; they studied his language development from the age of 2;09 through 5;02, focusing on the analysis of over 3,000 utterances produced by him between 3;00 and 4;06. Unlike almost all previous studies of Kodas (with the exception of Mayberry, 1976), these researchers also examined their participant's development of ASL. Like Todd, they started with a set of differences between ASL and English and looked for effects in these areas.

Johnson et al. (1992) used reports from the literature to make comparisons between Becos and monolingual peers. In numerous domains for spoken English, including negation, omission of articles, use of correctly gendered pronouns, and tense, his performance was within the range observed for exposure peers, behind that for age peers, and curiously, behind what would be expected given his MLU (measured in morphemes). In the case of plurals, he was quite delayed. These are all candidates for influence from ASL, since ASL does not use articles, gender, tense, or plurals in the same way that English does. In the case of questions, and in several other areas, he used structures in his speech that seem to be clearly influenced by ASL. As with the subject studied by Todd (1971), Becos produced numerous types of repetition, especially repetition of the subject (see (10a)), and repetition of a synonym (as in (10b)). The researchers report that similar structures were also used (acceptably) in his ASL.

(10) a. He can push it, he (Becos, 3;05)
b. I wanna do that, read (Becos, 3;00)

(Johnson et al., 1992, p. 47)

The apparent influence of ASL in cases such as (10a)-(10b) is particularly compelling. As Johnson et al. state, "[t]he strongest case for influence of ASL on spoken English, then, would involve spoken word-order deviations from typical English patterns that mirror those seen in ASL and do not follow developmental patterns for English" (p. 35). They do not discuss whether there are any atypical structures that cannot be attributed to ASL influence.

The use of overt words from one language with a syntactic structure that seems to come from a second language has been observed for unimodal bilinguals in various contexts, as we have mentioned. We turn now to a type of bimodal effect that is found only with bimodal bilinguals: code-blending.

5. Code-switching and code-blending

On the Language Synthesis model, code-switching for any language pair, whether unimodal or bimodal, is accounted for in the same way, as discussed in sections 3.2 and 3.3. Bimodal code-switching consists of using one modality alone, then switching to use of the other modality alone. In the study by Emmorey et al. (2008a), adult Coda participants used such code-switching in only 6.26% of the utterances in the data analyzed. An example is given in (11). In this example, the vertical spacing of the notation for the sign indicates that speech stops after the word 'like' and resumes after the sign is produced.

(11) Eng: So they're like and he's like "ooh I gotta get that bird"
ASL: LOOK[reciprocal] Emmorey et al. (2008a, p. 47)

Bimodal code-switching has not been analyzed or presented in much detail, likely because of the much greater interest in code-blending. In code-blending, (aspects of) the signed utterance and the spoken utterance are produced simultaneously.

It is important right away to distinguish between code-blending and Simultaneous Communication, or SimCom. SimCom is a forced and artificial attempt to sign along with speech, often used in educational settings for the Deaf. In such contexts, the sign is usually some form of Sign Supported Speech, that is, an attempt to represent the spoken language on the hands (Maxwell, 1990). This type of SimCom is speech-driven, and while English grammar is not fully represented (Marmor & Petitto, 1979), typically the signing is far from natural ASL, and the signed content may be only 75% of the spoken content (Mallery-Ruganis & Fischer, 1991). Code-blending is very different from SimCom (Emmorey, Borinstein, & Thompson, 2005). Code-blending can be considered as the bimodal bilingual sociolinguistic analogue to code-switching among spoken language bilinguals. It serves similar sociolinguistic functions (Bishop, 2006) and is used very naturally by bimodal bilinguals interacting with other bimodal bilinguals. However, since it is formationally different from code-switching, which is also used by bimodal bilinguals, we maintain the term code-blending for it.

Code-blending is produced with varying amounts of overlap between signed components and spoken components. For the purposes of the current overview, we summarize four types of code-blending presented by van den Bogaerde and Baker (2005, 2008; Baker & van den Bogaerde, 2008) based on their study of three Kodas aged 1;06–6;00 acquiring Nederlandse Gebarentaal (NGT, the sign

language used in the Netherlands) and Dutch.[11] In van den Bogaerde & Baker's typology, utterances are classified according to the languages used for expressing content, without regard to the syntactic structures used.

First, code-blending can consist of utterances that are mostly spoken, with occasional concurrent production of signs that are close in meaning to the spoken words. This type of blend can be called speech-base (a generalization from the term Dutch-base used by van den Bogaerde & Baker). Code-blending can alternatively be sign-base, in which the utterance is primarily signed, with some accompanying speech. Van den Bogaerde & Baker use two additional categories: Full code-blended, in which the proposition is fully expressed in both modalities; and Mixed code-blended, in which aspects of the utterance are expressed in each modality and both are needed to determine the full meaning of the proposition. Examples given by van den Bogaerde and Baker of each of these four types of code-blends are given in (12).[12]

(12) a. Speech-base code-blending (Mother of Jonas, 3;00)

NGT		VALLEN	
Translation		fall	
Dutch	die gaat	vallen	
Translation	that goes	fall	
Translation of utterance	'That [doll] is going to fall.'		

b. Sign-base code-blending (Mother of Jonas, 3;00)

NGT	$INDEX_{hij}$	JAS	BLAUW
Translation	he	coat	blue
Dutch			blauw
Translation			blue
Translation of utterance	'He has a blue coat.'		

11. Van den Bogaerde and Baker include in their consideration of code-blending utterances that are signed along with words that are mouthed but have no vibration of the vocal cords (voicing) or even air turbulence (whispering). The status of mouthings with sign language is controversial, and the inclusion of mouthings in studies of code-blending varies: they are included by van den Bogaerde and Baker, but excluded by Emmorey et al. (2008), and by the Bibibi project (although whispering is included; see Petroj, Guerrera, & Davidson 2014). Perhaps the best approach is to separate blending as defined without mouthing from blending that includes mouthing, to determine empirically whether or not they behave similarly.

12. The notation provided by van den Bogaerde and Baker is used in quoting their examples, except that we have replaced their use of the terms 'signed' by NGT and 'spoken' by Dutch to clarify in the context of this article, where several signed and spoken languages are reported. As with other code-blending examples, vertical alignment between the notation for a sign and a spoken word should be taken as simultaneous expression. In (12b), the use of $INDEX_{hij}$ signifies a pointing sign directed to *hij* 'he'.

c. Full code-blending (Alex, 2;00)

NGT	MAMA LEZEN
Translation	Mummy read
Dutch	mama lezen
Translation	Mummy read
Translation of utterance	'Mummy [must] read.'

d. Mixed code-blending (Jonas, 3;00)

NGT	POLITIE	ANDER	MENSEN	SCHIETEN
Translation	police	other	people	shoot
Dutch	politie	andere	mensen	doodmaken
Translation	police	other	people	kill
Translation of utterance	'The police shot the other people.'			

(van den Bogaerde & Baker, 2008, p. 109–112)

It can be considered remarkable that the human language faculty could articulate two different languages simultaneously. Considering all that is involved in the derivation of an utterance in one language, how is it possible that two languages can be produced simultaneously? We put forward and consider three possibilities here, summarized in (13).

(13) a. Possibility 1
Code-blending illustrates the potential for two completely separate derivations expressing two different propositions

b. Possibility 2
Code-blending relies on two separate derivations, but expresses a single proposition

c. Possibility 3
Code-blending uses one derivation to express a single proposition

Possibility 1 can be quickly discounted on the basis of previous research. The four-way classification provided by van den Bogaerde and Baker is based on the observation that usually there is *congruence* between what is signed and what is spoken. Petitto et al. (2001) reported that in 89% of the simultaneous language mixes they observed in three bimodal bilinguals they studied who were acquiring Langue des Signes Québécoise (LSQ; the sign language used in parts of Quebec) and French (ages 0;10–4;03), the signs and words had the same meaning; similarly, Emmorey et al. (2008a) reported that 82% of the code-blends in the data they analyzed from 11 ASL/English bimodal bilingual adults constituted translation equivalents. Note that when the signs and the words are not translation equivalents, this does not mean that they are unrelated; Emmorey et al. stress that code-blending is not used to convey distinct information in the two languages. Rather, the non-equivalent forms may be cases where one language provides a more specific term than the

other, such as the sign BIRD produced along with the spoken word 'Tweety' (the name of a bird in a cartoon story being recounted) in Emmorey's data; and the word *doodmaken* 'kill' with the sign SCHIETEN 'shoot' in (12d). Such cases will be discussed further below.

In the Bibibi project's study of code-blending, a much smaller number of non-congruent blends are reported based on data from two children (ages 2;00–2;07) and adults interacting with these children (Quadros, Chen Pichler, & Lillo-Martin, 2014; Quadros, Lillo-Martin, & Chen Pichler, 2016a, to appear). This is because of several coding differences between our approach and those of previous studies. Starting with the hypothesis that code-blending is used to convey 'one proposition', we coded for congruence types that would comply or conflict with this hypothesis. Accordingly, more or less specific signs and words such as the BIRD/Tweety example are considered to be consistent with the hypothesis, and not scored as non-congruent (non-redundant in our terms). Only three examples out of 567 were non-redundant, and these were all considered to be lexical choice errors. As for code-blending types, the results from the Bibibi project are similar to those presented by van den Bogaerde and Baker (2005, 2008): most of the children's blends are either Full or Speech-base (with the adults producing fewer Full since their utterances are typically longer). One child in each study produced a notable number of Sign-base blends.

For these reasons, we reject Possibility 1, in accord with Emmorey et al. (2008a) and others. The difference between Possibility 2 and Possibility 3 is more subtle. What are the contexts in which two derivations might be needed? To consider this question, we need to turn to examination of code-blending types based on syntax.

As mentioned above, Petitto et al. (2001) studied the bimodal bilingual development of LSQ and French in three Koda children. They reported 6 instances of incongruent syntax (out of 320 mixes), where the speech and sign followed different word orders, each corresponding to the correct option for its grammar. Examples are given in (14).[13]

(14) a.

LSQ	CHIEN	MON	
Translation	dog	my	
French	mon	chien	
Translation	my	dog	

b.

LSQ	AMI	MON	LÁ
Translation	friend	my	there
French	mon	ami	Marcel
Translation	my	friend	Marcel

(Petitto et al., 2001, p. 489)

13. The identity and age of the child producing these utterances are not given, but the age is likely between 2;10 and 4;03.

Quadros et al. (2014, to appear) similarly reported a very small number of instances of blends with incongruent syntax: 1 utterance out of a restricted set of 59 cases having more than one sign and more than one word.

While such incongruities are not frequently reported in the code-blending literature, they form a core component of the work presented by Donati and Branchini (2013) on LIS (Italian Sign Language)/Italian bimodal bilinguals, aged 6–8 years. LIS and Italian may be a more conducive pair for such asymmetries, since the languages have opposing word order requirements in many cases. As Donati and Branchini report, LIS is uniformly head-final, while Italian is head-initial. Thus, for structures such as negation and WH-questions, a code-blend that contains opposite orders in the two languages might be expected. Examples are given in (15).[14]

(15) a. Italian: Non ho capito
Neg have.1SG understand.PTC
LIS: I UNDERSTAND NOT
'I haven't understood.'

b. Italian: Chi ha chiamato
Who have.3SG call.PTC
LIS: CALL WHO (Donati & Branchini, 2013, p. 109)
'Who has called?'

Donati and Branchini consider several possible models to account for the derivation of such structures, including one that follows what we labeled Possibility 2, using two separate derivations. In the end, in this paper they favor a model in which the syntactic derivation takes place on an abstract syntactic structure that represents hierarchy but not word order. Word order is derived by a very late process of linearization à la Chomsky (1995). A separate type of support for this view, they argue, comes from examples they characterize as 'no word order', in which the sign(s) and spoken word(s) produced simultaneously represent different parts of the syntactic hierarchy that have not been linearized at all, as in (16).

(16) Italian: Io
I
LIS: WIN (Donati & Branchini, 2013, p. 110)
'I win.'

The late linearization analysis is completely compatible with the Language Synthesis model, which hypothesizes only one derivation, as in Possibility 3. Recall

14. In these examples, Neg stands for negation, 1SG and 3SG stand for 1st and 3rd person singular (subject) agreement (respectively), and PTC stands for participle.

from Figure 3 that linearization applying after spell-out can lead to simultaneous production of two different word orders. Let us explore the possible outputs of the Synthesis model (incorporating Possibility 3) in more detail. In this part of the paper we will call on examples from children, the adults interacting with them, and our parallel studies with adult-adult code-blending (Quadros, Lillo-Martin, Polinsky, & Emmorey, 2016b).

In the Synthesis model, the abstract elements selected for the numeration may come from Lists associated with either language, but syntactic operations apply to one set of elements, not two operating in parallel. After spell-out, morphological operations apply, including linearization.[15] As we have indicated, at this point multiple structures can be invoked, corresponding to two sets of language-specific elements (to derive the two word order cases such as in (15)). This possibility for two separate sets of operations is illustrated in Figure 3 using dashed lines. However, in most of the cases we have observed, only one set of operations is needed. Finally, at Vocabulary Insertion, some elements can be inserted in both speech and sign (again indicated by two dashed lines), leading eventually to two sets of articulators, those for sign and those for speech.

One type of blended utterance that will result from this kind of derivation is what we call co-insertion: the simple insertion of both a signed element and a spoken element corresponding to some particular set of features. Examples are given in (17).

(17) a. ASL: HAT
Eng: really it's a hat (Hearing Adult to Ben, 2;00)

b. ASL: BLUE IX(card)
Eng: blue (Ben, 2;00)
'It's blue.'

On our conception, this includes the idea that roots have some degree of specification even at numeration. In the original version of the DM framework, roots would only contain the features needed in the syntax; otherwise they were considered generic (so, for example there would be no 'dog' root as opposed to a 'cat' root, since the difference between these was considered irrelevant for the syntax). However, other versions of the theory have proposed different types of specification, often symbolized using (square) root notation, such as √DOG (see Harley, 2014; Pfau, 2000, 2009; Siddiqi, 2010 for discussion of the nature of roots). On our view, insertion of 'hat' and HAT (rather than, say, 'hat' and DOG) will follow based on the presence of the root √HAT. Researchers within the DM framework have

15. We leave for future research whether there is evidence that other morphological operations, such as Impoverishment, Fusion, Fission, etc. apply separately.

debated whether or not roots should be considered specified at the numeration. Having specified roots makes it very straightforward to insert translation equivalents in examples like (17).

Another type of blended utterance involves insertion of an item matching a subset of the features in one language, while the other language may insert a fully matching item. Examples are given in (18).

(18) a. ASL: FINISH
Eng: are you finished (Hearing Adult to Ben, 2;00)

b. ASL: COW
Eng: the cows(Ben, 2;00)

c. ASL: FS(so) FS(he) IX(other-building LOOK EXCITE[+]
Eng: So he look excite excite excite
'So he looked in the other building and got very excited.'
(Coda Adult-Coda Adult)

Let's take first the case where the spoken component expresses more features than the signed one. If at the point of VI there is a root, say √FINISH, and features including [+past], this will (eventually) be produced in English as "finished". For ASL, there is no tense marking on verbs. Then, following the Subset Principle (Halle, 1997), insertion of the sign FINISH with no tense marking will not conflict with √FINISH[+past], and it will be allowed. Following this same line of thought, any instances in which the spoken version expresses a superset of the features expressed by the sign version can be generated, provided the signed version has a subset of the features available to it. This approach might also account for blends such as the "Tweety"/BIRD example cited earlier from Emmorey et al. (2008). If there is no (known) sign for the name "Tweety", the sign BIRD might be considered to express an appropriate subset of the relevant features.

It's also possible for the signed component to express a greater degree of detail than the spoken component, in a similar way, as in example (18c) above. In the example, the ASL sign EXCITE is produced with a morphological marker of intensity, involving repeated production. The simultaneous English verb 'excite' is repeated, but does not bear the appropriate English morphology. If the derivation includes the features necessary for the signed component, the accompanying speech would realize intensity by repetition but be stripped of the typical spoken morphology.

Co-insertion of signed and spoken items with matching or superset/subset features can occur multiple times in a single utterance, as illustrated in (19).

(19) a. ASL: WANT BREAD
Eng: I want some bread though (Adult to 2;06)

b. ASL: IX(self) THINK IX(self) SEE CAT
Eng: I thought I saw cat (Adult-Adult)
'I thought I saw a cat.'

As observed by Emmorey et al. (2008) and by Quadros et al. (2016b), a common type of code-blending involves signs that are known as classifiers or 'depicting' signs (Emmorey, 2003). The analysis of such structures in sign languages is under some debate; for the current purposes we will assume that they arise as multi-morphemic predicate structures involving morphemes that may code manner, path, instrument, and other concepts in expressions of motion/location (see Sandler & Lillo-Martin, 2006 for an overview of some of this debate). When classifiers are produced, the speech that is used in blending may reflect essentially the same information, as in an example provided by Emmorey et al. involving the spoken word "pipe" together with a classifier construction depicting a narrow cylindrical object (20a). In other cases, the two modalities express overlapping parts, but the sign may be more specified than the speech, as in the example in (20b).

(20) a. ASL: DS(narrow-cylindrical-object)
Eng: pipe (Coda Adult-Coda Adult)
'(a) pipe'
b. ASL: DS(handling-block-place-in-location)
Eng: Put it right there (Hearing Adult to 2;06)
'Put (the block) right here (in this spot)'

A complete analysis of such blends requires a more complete understanding of the analysis of so-called classifiers. For instance, Davidson (2015), argues that such constructions semantically involve demonstrations. She notes that blending with such demonstrations frequently involves production of a sound effect in the speech modality.

Finally, we have frequently observed 'complementary' blending that involves structures that clearly incorporate syntactic synthesis in the structure as well as blending in the output. For example, in (21a), ASL contributes a sentence-final subject pronoun copy, while English contributes the auxiliary verb, tense, preposition, and nominalization. In (21b), there is a combination of ASL-like topic preceding the spoken English clause-initial WH-phrase.

(21) a. ASL: IX(Inv) ALLERGIC CLEAN IX(Inv)
Eng: She's allergic to cleaning (Deaf Adult to 2;06)
b. ASL: RABBIT PU
Eng: Where go (Ben, 2;00)

6. Summary and conclusions

We have proposed that various bilingual grammatical phenomena can all be treated as different types of *Language Synthesis*. Language Synthesis starts with the basic idea that bilinguals, including bimodal bilinguals, differ from monolinguals only in having two sets of items (roots, functional morphemes, and/or vocabulary items) to enter into a single derivation. Our model also adds explicit recognition of a second modality of output, for sign languages, used alongside spoken language in bimodal bilinguals.

One advantage of the Synthesis model is that code-switching and phenomena traditionally called transfer, cross-linguistic influence, calquing, and the like, can all be similarly derived. Our intention is that this approach can be used to account for a wide variety of data with any language pairs, unlike other theoretical approaches.

In the case of bimodal bilinguals, with a second set of articulators, two outputs may occur simultaneously – the phenomenon of code-blending, unique to bimodal bilinguals. Yet, the only modification to the model needed is the additional set of articulators; otherwise, the same processes should apply to generate different surface types of blending. In ongoing work, we are investigating the types of code-blending in more detail (Quadros et al. , 2016b), including evidence that derivations take place by phase (see Gökgöz et al., in prep; cf. Berent, 2013).

Our view unifies what others have treated as disparate phenomena. This may be an advantage of the approach, provided it makes the correct empirical predictions about types of synthesis that are or are not derived. Such predictions depend on details of the morpho-syntactic analyses involved, since synthesized derivations will fail (that is, be ungrammatical) only if required feature-checking cannot take place. For example, in our work on WH-questions (Lillo-Martin et al., in prep), we propose that WH-movement structures are not found in the Cantonese of Cantonese-English bilinguals (unlike WH-in-situ in their English) because of a failure of feature-checking between the strong [+WH] C head (from English) and the WH-words of Cantonese. Since our model accounts for code-switching in the same way as other DM-based models, our predictions for spoken language bilinguals are not different from theirs. As for code-blending, we have found that establishing the predictions for types of blending that are (im)possible, as well as testing these predictions, require both more extensive DM-based analyses of sign languages than are currently available, and more detailed analyses of code-blends produced in adult-adult contexts. We are currently pursuing work in both these areas.

Our approach crucially relies on several concepts of Distributed Morphology, including late insertion and underspecification, and it makes the case for roots

with some amount of content specification. Further analyses are needed to discover whether other aspects of DM provide necessary components of this approach.

One topic that was not addressed was the extent to which children's use of synthesis structures might reflect their exposure to them in the input. Certainly, bimodal bilingual adults may use structures such as those observed in children's productions; would children spontaneously build such constructions in the absence of specific input? Further research comparing children's language 'mixing' structures with those in the input would be useful, particularly if there are families in which the use of mixing is quite infrequent.

There has been a good deal of recent research on the psycholinguistic and neurolinguistic aspects of bimodal bilingualism (for reviews see, Emmorey et al., 2015; Ormel & Giezen, 2014). This research has shown, among other findings, continued evidence for activation of both languages even in single-language contexts (both Deaf and hearing bilinguals); as well as decreased processing cost for activating sign with speech (hearing bimodal bilinguals) compared to the cost of inhibiting one spoken language (hearing unimodal bilinguals). Such evidence of similarities and differences between unimodal and bimodal bilinguals might bear on further refinement of linguistic accounts such as our proposal.

Finally, it should be clear that our proposal is not a production model, although we do have interest in how minimalist derivational models can be translated into psycholinguistically feasible production models (see Lewis & Phillips, 2015). Emmorey et al. (2008a) offer a production model of bimodal bilingualism that draws on proposals previously made concerning the production of speech plus gesture, with the major addition of a grammatical component for sign language (as opposed to gesture). Emmorey et al. observed that the spoken and signed outputs of blending are generally very closely timed prosodically, a finding with which our child data concurs, with some exceptions attributable to children's developing physical coordination (Quadros et al., 2016a, to appear). This production model calls for late lexical selection, offering optimism for the necessary reconciliation of the late insertion derivational models proposed here with performance-compatible requirements.

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Appendix – Notation

The sign language examples quoted from various works have adopted the source notation conventions, which may vary. Notation conventions used in this article are as follows:

SIGN	Signs are annotated using glosses; it should be borne in mind that the signed words might have a different range of meanings from the written word
#WORD, fs-WORD	The signed word is produced using fingerspelling
DS(desc)	A depicting sign (also known as classifier); a description of what the sign is depicting appears within parentheses
IX(ref)	A pointing (indexical) sign; the referent being pointed at is named in parentheses

_____	A line above a sequence of signs indicates the simultaneous production of a non-manual component (in ex. 6, wh indicates the production of non-manuals associated with WH-questions). Non-manuals are not indicated in most examples.
SIGN	Vertical alignment between the notation for a sign and a spoken word
Speech	indicates that the two are being produced simultaneously (code-blending)

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