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Chapter 3

LANGUAGE-COGNITION INTERACTIONS DURING BILINGUAL LANGUAGE DEVELOPMENT IN CHILDREN

Henrike K. Blumenfeld[1] *and Viorica Marian*[2]
1.San Diego State University
2.Northwestern University

ABSTRACT

A growing body of research suggests a close relationship between children's development of linguistic and cognitive skills, with language development and cognitive development mutually influencing each other. This chapter considers childhood bilingualism as a special case of language acquisition, with implications for the relationship between linguistic and cognitive processes. Specifically, during bilingual language development, language input is phonologically more complex and spans two languages instead of one. Given language input that includes phonetic inventories and vocabulary from two languages (consisting of two labels for most concepts), linguistic and cognitive implications for bilingual development are discussed. In addition, the chapter considers the consequences of simultaneous activation of two language systems and the juggling of two language codes in children. It is suggested that bilingual children may have a higher cognitive processing load during language use and learning, resulting in both linguistic and cognitive differences compared with monolingual peers. Recent research on linguistic and cognitive differences between monolingual and bilingual children is placed in the context of current theoretical models of language learning, development, and processing. In particular, we consider recent findings from monolingual and bilingual children in the context of learnability theory (with an emphasis on the influence of input complexity on linguistic / cognitive development), and in light of usage-based accounts of language acquisition (with an emphasis on the development of potentially different cognitive skills in monolinguals and bilinguals). We conclude that childhood bilingualism provides a unique context for examining the interaction between linguistic and cognitive mechanisms during development.

1 Corresponding Author: Henrike K. Blumenfeld, Ph.D., Assistant Professor, School of Speech, Language and Hearing Sciences, San Diego State University, 5500 Campanile Drive, San Diego, CA 92182-1518, E-mail: Henrike.Blumenfeld@sdsu.edu.

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INTRODUCTION

Cracking the language code presents infants with a problem of extraordinary computational complexity. Infants who learn their mother tongue have to identify patterns in the string of speech sounds that they hear, and map these sound patterns onto meanings that refer to objects, events, and other aspects of language. For children who grow up in bilingual environments, decoding and separating *two* language systems is likely to provide an even bigger challenge. What cognitive tools are available to babies to accomplish such impressive feats? A growing body of research suggests that specific types of cognitive processes may guide children's language acquisition, and that linguistic and cognitive development mutually influence each other.

In the present chapter, we consider childhood bilingualism as a special case of language acquisition, with implications for the relationship between linguistic and cognitive processes. Since simultaneous acquisition of two languages is likely to pose particular cognitive challenges, ways in which cognitive mechanisms are employed to acquire language may be especially salient in bilingual children. In general, examination of the relationship between linguistic and cognitive nonverbal processing is a central area of study in the cognitive sciences (e.g., Bates, Dale, and Thal, 1995; Fodor, 1983; Tomasello, 2007). Theoretical research in this area aims to delineate relationships between language and cognition and to develop models that specify the involvement of nonlinguistic cognitive mechanisms during language development and processing (e.g., Bates and MacWhinney, 1987, 1989; Dijkstra and Van Heuven, 2002; Green, 1998; Li and Farkas, 2002; Norman and Shallice, 1986; Tomasello, 2007). This line of research contributes to the decade-old debate between the *modular- / domain-specific view* of language as an encapsulated and specialized module (e.g., Fodor 1983, 1985; Chomsky, 1988; Pinker, 1984) and the *domain-general view* of language as a system that is tightly linked to nonverbal (and domain-general) cognitive abilities (e.g. Bates, Thal and Marchman, 1991; Bates, Thal and Janowsky, 1992; Bates and MacWhinney, 1987; Tomasello, 2007)[2]. The modular / domain-specific view claims that language is a separable "mental organ" (Chomsky, 1988), and that the neural correlates underlying this mental organ are subsumed *only* by language processing and no other (nonlinguistic) cognitive mechanisms.

[2] In the present chapter, the term "domain-specific" will be used to refer to processes that act within language and are likely to be unique to language. Conversely, the term "domain-general" will be used to refer to processes that are involved in both language-specific and *nonlinguistic* tasks, and can therefore be assumed to be located 'outside' and 'above' language in the cognitive hierarchy.

In contrast, the domain-general view claims that linguistic abilities are (at least to some extent) supported by nonlinguistic cognitive processes.

The modular and domain-general views of language embody two distinct theories of language acquisition. The modular view is that language abilities are cognitively encapsulated. As a consequence, the modular view suggests that the linguistic system develops without exterior cognitive influences, and that its features are largely innate.[3] As the infant becomes exposed to language input, only the specific features of the child's native language(s) are determined with exposure, thus "calibrating" a pre-existing system for a specific linguistic community. This theoretical orientation is supported by the *Poverty of the Stimulus* argument: Child language input is frequently incomplete and not always optimally grammatical; nevertheless, children consistently acquire full linguistic systems (e.g., Bickerton, 1981; Pinker, 1984).

In contrast to the modular view, the domain-general view is that language abilities are closely related to other cognitive abilities. As a consequence, language develops *through interaction with* other cognitive abilities. That is, language emerges with exposure to, and under the guidance of *general* cognitive learning mechanisms. This theoretical orientation is supported by evidence that language is learned by way of general learning mechanisms that systematically distill and make sense of the regularities within the language input. Research in this area suggests that child language input is in fact not as poor as was previously believed, and may be sufficient for the child to construct a language system, given a set of cognitive abilities and biases (e.g., Dietrich, Swingley, and Werker, 2007; Maye, Werker, and Gerken, 2002). In the present chapter, recent findings in bilingual language development will be considered through the prism of *usage-based models of language learnability*, which assume that the linguistic input that children receive contains more information than is apparent, and that children are in fact able to derive a language system based on patterns within this input and under the guidance of *general* cognitive mechanisms (e.g., Tomasello, 2007).

The study of language-cognition interactions in bilingual development holds great promise for the debate on how language is learned in general. Examination of the interface between language and cognition in bilingual children, compared to their monolingual peers, has the potential to contribute to debates in the cognitive sciences about the nature of language, and to models of language development. In addition, it is becoming increasingly important to understand mechanisms and pathways of bilingual language acquisition in childhood, as the bilingual population is growing. Currently, approximately 5.2 million bilingual children are enrolled in schools in the United States, which marks a 61% increase from 1994 (c.f., Goldstein and Fabiano, 2007). It is projected that, by 2030, 40% of school-age children in the United States will be native speakers of another language, and will be acquiring English as a second language (e.g., Goldstein, 2000; Roseberry-McKibbin and Brice, 2000). Therefore, the incidence of childhood bilingualism in the United States is predicted to grow, and the numbers of adult bilinguals who learned two languages at an early age will grow with it. In general, with the majority of adults throughout the world proficient in a second language (e.g., Romaine, 1995), and with bilingualism on the rise in the United States (e.g., US Census, 2000), the influence of bilingual experience on cognitive function becomes increasingly relevant.

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[3] But note that the language-specificity and innateness arguments are *separable*, since cognitive mechanisms that are domain-*general* may also be innate.

In the present chapter, we consider the nature of bilingual language input, the cognitive consequences of such input, and possible mechanisms of bilingual language acquisition. First, recent evidence is presented on how bilingual children separate two phonological and lexical codes from the input, and how these language acquisition paths may influence and shape cognitive processes, both in the linguistic and in the nonlinguistic domains. Second, we place recent findings on bilingual language development in the context of current models of language learnability- and usage-based accounts, and conclude that examination of linguistic and cognitive processes in bilingual children, compared to their monolingual peers, may yield evidence in support of theories that language development is guided by domain-general cognitive processes.

Language Input in Bilingual Children: Identifying Two Phonological Codes

Newborns are exposed to a constant flow of speech input, and spend the first years of their lives parsing this incoming information, first into systematic phonological patterns, and then into words and sentences. Children who grow up in bilingual environments must separate the incoming speech signal into two separate codes, each with its sound inventory, phonological patterns, words, and grammar. Behavioral and computational research suggests that, based on auditory input, children who grow up in bilingual environments construct two phonological systems that are, at least to some extent, independent of each other (e.g., Goldstein and Fabiano, 2007; Keshavarz and Ingram, 2002; Li and Farkas, 2002; Paradis, 2001; Werker and Byers-Heinlein, 2008). Babies' ability to tell apart languages based on sound is evident at birth: Newborns can distinguish between languages from different rhythmical classes (e.g., Christophe and Morton, 1998; Nazzi et al., 1998). Therefore, children are born with strong biases towards dissociating the language of their home-community from other languages, suggesting that language differentiation is a built-in early mechanism regardless of whether children grow up monolingual or bilingual.

In the first months of life, babies make quick progress in further distinguishing languages in their environment from each other. Bosch and Sebastián-Gallés (1997) showed that, at 4 months of age, bilingual infants can distinguish between their two languages, even if the two languages are within the *same* rhythm class. By 10-12 months of age, bilingual infants are able to make different *fine-grained* distinctions *within* each of their two languages. For example, Burns, Yoshida, Hill, and Werker (2007) showed that 10-12-month old French-English bilinguals were able to discriminate category boundaries of voiced and voiceless stops (i.e., voice onset time distinctions) accurately within both English *and* French, two languages for which these category boundaries differ.

During the first year of life, infants undergo substantial *perceptual reorganization,* where discrimination abilities for speech sounds that are part of the ambient language input are honed, while discrimination abilities for speech sounds that are *not* part of the language are reduced. While monolingual infants can successfully distinguish between a wide range of phonetic contrasts early on, their sensitivity to non-native vowels is lost by 6-8 months of age (e.g., Kuhl, 2000; Polka and Werker, 1994), their sensitivity to non-native prosody variations (such as tones in tone languages) is lost between 6-9 months of age (Mattock and Burnham, 2006), and their sensitivity to non-native consonants is lost between 10-12 months of age (Werker and Tees, 1984). As a result of this perceptual reorganization, bilingual infants are typically sensitive to a wider range of speech sounds than their monolingual peers by the end of their first year of life, although this sensitivity may develop gradually, with one language leading the other (for a review, see Sebastián-Gallés and Bosch, 2005).

Bilingual infants' ability to tell their languages apart from an early age, and to establish fine-grained phonetic categories for each language independently, begs the following questions: (1) Do bilingual children develop *two* phonological systems or an integrated system, and (2) how do bilingual infants distinguish between phonological codes of their two languages. Whether bilingual infants' phonological systems are initially shared or separated remains an active area of research (e.g., Bhatia and Ritchie, 1999; Kehoe, 2002; Ingram, 1982; Keshavarz and Ingram, 2002; Paradis, 2001; Vihman, 2002). Models have been posited to illustrate the view of an initially shared phonological system (the *Unitary System Model*, Bhatia and Ritchie, 1999), the view that phonological systems develop separately from the beginning (the *Dual Systems Model*, Keshavarz and Ingram, 2002), and the view that phonological codes of the two languages are highly interactive from early on (the *Interactional Dual Systems Model,* Paradis, 2001).

Evidence in support of an initial *Unitary System* includes findings that children may first use components of the adult sound inventories that overlap across both of their languages (e.g., Leopold, 1970) and that children may acquire phonological properties of their two languages sequentially rather than simultaneously (e.g., Kehoe, 2002; Sebastián-Gallés and Bosch, 2005). In turn, evidence in support of an initial *Dual System* includes findings that children can distinguish between input from their two languages at an early age, and that bilingual children's first words can show drastic differences across the two languages in terms of phonological templates (e.g., 2-syllable templates in Italian and 1-syllable templates in English, see Ingram, 1982). Evidence for an *Interactional Dual System* includes findings that simultaneous acquisition of two phonological codes may result in acceleration of certain aspects of learning (e.g., earlier Spanish coda acquisition in children acquiring Spanish and German, Kehoe, Trujill and Lleo, 2001), and that initial words in one language may reflect stress patterns of the other language (Keshavarz and Ingram, 2002). It has also been argued that children do not develop phonological *systems,* but rather develop distributed knowledge of a set of phonetic contrasts, and that phonological systems emerge in tandem with language-specific vocabularies (Vihman, 2002). In sum, while the nature of early phonological representations in bilingual children remains under debate, bilingual children can distinguish between their languages early on, and are able to learn language-specific phonological features, with occasional interaction between the two systems.

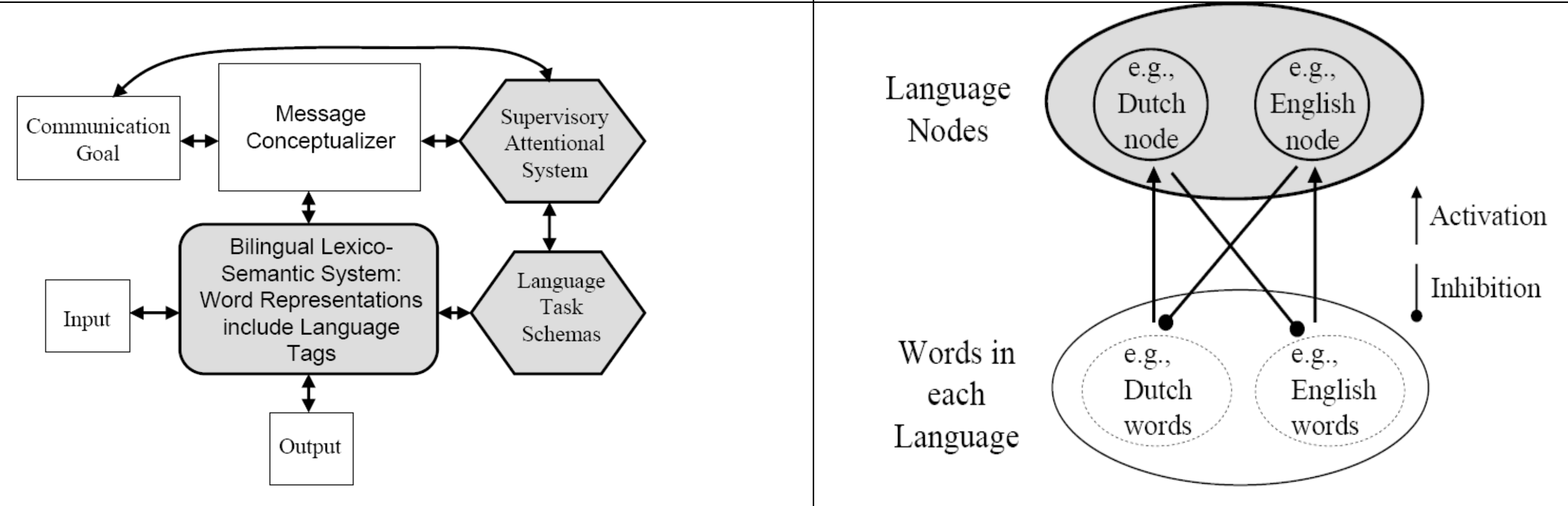
The nature of early phonological representations is likely to be tightly linked to how bilingual infants approach the task of distinguishing between two types of language input. In general, early evidence suggests that bilinguals' approach in distinguishing between languages may differ from monolinguals' approach from an early age. Specifically, Bosch and Sebastián-Gallés (1997) found differences in how monolingual and bilingual infants distinguish between native and unfamiliar languages at 4 months of age. To assess speech perception in pre-linguistic infants, the authors employed a *Head Turn Task* (also see Werker, Polka, and Pegg, 1997), where infants were taught to turn towards a speaker from where they heard a story told. Story sentences from one language were presented from a speaker to the right, and sentences from another language were presented from a speaker to the left. Infants' attention to a space between the two speakers was restored after each trial by presentation of colorful moving images. The authors measured how long it took infants to turn towards each speaker, and found that monolingual children were quicker to orient towards their native language than towards an unfamiliar language. In contrast, bilingual children were *slower* to orient towards a familiar language than towards an unfamiliar language. The authors suggested that bilingual infants' delay in orienting towards their familiar language (relative to an unfamiliar language) may be due to an initial attempt to discern *which* of their two languages is being spoken (also see Werker and Byers-Heinlein, 2008). Alternatively, it is possible that, since bilingual infants are exposed to more complex and varied auditory input (from two language systems instead of one), they may respond differently to unfamiliar input in general, and may maintain an interest in relatively unfamiliar phonological input for a longer period of time. In sum, findings suggest that bilingual infants approach language differently than their monolingual peers *early on* during the acquisition process, with differences likely to emerge as these future bilinguals start to separate two phonological codes.

Further research is needed to examine whether bilingual infants start to develop separate mechanisms for controlling their language systems at this early age. For example, children's ability to discern which of their two languages is being spoken at any point in time would imply early emergence of mechanisms to make such distinctions. Possible mechanisms for early language differentiation might be early precursors of *language tags* (e.g., Green, 1998) or *language nodes* (e.g., Dijkstra and Van Heuven, 1998, 2002) that emerge with phonological knowledge, as well as a growing awareness of phonological regularities within the input of each language. Language tags and language nodes have been posited to be part of adult bilingual systems, and serve to identify and distinguish between the two languages during processing. Language nodes and language tags are terms that refer to representations that signal the language-membership of a word (e.g., Dijkstra and Van Heuven, 1998, 2002). While a language tag has been posited to be part of each word's lexical representation, which is in turn linked to cognitive control mechanisms (Green, 1998, see Figure 1A), language nodes have been conceptualized as units that capture overall activation of a language across multiple lexical items and across time (Dijkstra and Van Heuven, 1998, see Figure 1B). These components of bilinguals' cognitive systems have been thought of as higher-level representations that are closely related to a goal-oriented cognitive system.

Bilingual infants can distinguish between the phonologies of their two languages at 4 months of age. While they may start to develop precursors to the adult language control system, it is also possible that bilingual infants rely solely on knowledge of distributional sound regularities to distinguish between their languages at this early stage (e.g., Maye, Werker, and Gerken, 2002; Li and Farkas, 2002), without formalizing attentional mechanisms.

Differences in phonetic sensitivity (spanning two language systems instead of one) may be reflected in bilingual infants' approach to language. That is, instead of starting to develop cognitive mechanisms specific to distinguishing between two native languages, differences between monolingual and bilingual infants in orienting towards an unfamiliar language may be the result of a general prolonged sensitivity to contrasts within unfamiliar input.

A. The Inhibitory Control Model Adapted from Green (1998)	B. The Bilingual Interactive Activation Model Adapted from Dijkstra and Van Heuven (1998)



Activation of the bilingual lexicon is controlled at various levels (at the level of specific language task schemas, and at the level of a general supervisory attentional system, SAS). Within the lexicon, language-membership of words is determined via *language tags* that are part of each words' lexical representation.	Activation of the bilingual lexicon is controlled at the language node level. For example, activation of English word representations, based on English input, results in activation of the English *language node*, which signals use of the English lexicon by inhibiting words in the Dutch lexicon.

Figure 1. Cognitive control mechanisms that differentiate between languages during adult bilingual processing, including language tags as posited by the Inhibitory Control Model, and language nodes as posited by the Bilingual Interactive Activation Model. Within each model, cognitive control components are highlighted in grey.

As bilingual children's phonological systems become more elaborate over the course of phonological and lexical acquisition, it remains an open question how the child's linguistic system evolves towards the bilingual adult's linguistic system. Bilingual adults activate their two languages *in parallel* when words in their two languages have phonological overlap with each other. For example, if a Russian-English adult hears the word *marker* in English, s/he may also look at a stamp (because the Russian word for *stamp* is *marka*) before identifying the marker (e.g., Marian and Spivey, 2003a,b; also see Blumenfeld and Marian, 2007; Ju and Luce, 2004; Weber and Cutler, 2004). Bilingual adults' ability to match auditory input to words in both of their languages within the first 200-400 milliseconds of comprehension, and to resolve this cross-linguistic competition in an efficient manner, reflects the flexibility of the bilingual system. It is likely that the capacity to consider words from both languages, and to resolve subsequent competition, is central to bilinguals' ability to switch between languages, and that it requires cognitive control (e.g., Blumenfeld and Marian, in preparation; Green, 1998).

Early evidence suggests that the ability to resolve phonological competition is acquired gradually. Early evidence from an eye-tracking study in 5- and 6-year old monolingual children suggests that children also activate similar-sounding words in parallel within their native language (similar to adults, Marslen-Wilson, 1987; McClelland and Elman, 1986), but that competition from these similar-sounding words lasts over 1 second longer than it does in monolingual adults (Sekerina and Brooks, 2007). This delay in competition implies that, at 5- and 6 years of age, children are less efficient than adults at resolving competition at the phonological level. It is likely that cross-linguistic activation of similar-sounding words follows a similar pattern, and that the cognitive resources necessary to more efficiently reduce phonological competition develop with age (e.g., Booth et al., 2003; Comalli, Wapner, and Werner, 1962; Posner, Rothbart, Farah, and Bruer, 2001).

To summarize, as is the case in adults, children consider multiple similar-sounding words *in parallel* during comprehension. However, children show delays in biasing the system towards *one* of these words, suggesting less efficient mechanisms than adults in "*zooming in*" on relevant linguistic information. It is likely that the efficiency of resolving *within-language* competition mirrors the efficiency of resolving *between-language* competition (e.g., Marian and Spivey, 2003a,b). Understanding the nature of between-language competition is linked to understanding *the need to formally distinguish between the two languages to avoid interference*. On the one hand, it is possible that this need arises early on during language development, while the two phonologies are being acquired and elaborated. Specifically, the ability to activate one language system more than the other may become crucial in order to fully learn language-specific information, such as acoustic boundaries of phonemic categories, and later phonotactic rules and phoneme-to-phoneme transition probabilities. For instance, children become sensitive to specific phoneme transitions that occur frequently in the input, and therefore have high transitional probabilities (Maye, Gerken, and Werker, 2002). As a consequence, bilingual children may focus their attention on *different* clusters of phonemes with high transitional probabilities *in each of their languages*, in order to parse out likely words from the speech stream (Fennell, Byers-Heinlein, and Werker, 2007; for a review, see Sebastián-Gallés and Bosch, 2005). On the other hand, it is possible that the need to formally distinguish between the two languages only arises once the bilingual child accumulates substantial word knowledge, and needs to efficiently retrieve words from *one* of the two languages, while discounting similar words in the other language.

LANGUAGE INPUT IN BILINGUAL CHILDREN: IDENTIFYING TWO LEXICAL CODES

In identifying the *meaning* of word units in their auditory input, children face the fundamental problem of mapping specific sound sequences onto specific referents in their environment. This fundamental challenge, known as the *Gavagai Problem*[1] (Quine, 1960), is indicative of the fact that children rely heavily on environmental cues to guide their attention towards specific objects while they hear language. Recent evidence suggests that attentional processes are closely related to children's learning of words (e.g., Smith, Jones, Landau, Gershkoff-Stowe, and Samuelson, 2002). At least two types of attentional processes may be isolated, and it is likely that bilingual children make extensive use of both types of attentional processes to build their lexicons.

First, children rely on mechanisms of *joint attention*, which allow them to assess what aspect of the environment others are paying attention to, and to guide their own attention in the same direction (e.g., Kaplan, Oudeyer, and Bergen, 2008). Mechanisms of joint attention allow children to make use of visual cues in order to map referents onto auditory input, and recent research suggests that bilingual infants may rely heavily on such visual cues (e.g., Weikum et al., 2007). In general, research suggests that external visual cues may provide particular support during bilingual acquisition, and that bilingual infants may pay closer attention to visual cues in their environments, compared to their monolingual peers. A recent study by Weikum et al. (2007) shows that 4- and 6-month old monolingual and bilingual infants can distinguish different languages based on lip-reading (*without* auditory input). However, at 8 months of age, monolingual infants lose this ability, while bilingual infants retain it, and maintain it into adulthood (Soto-Faraco et al., 2007). It is possible that bilinguals continue to rely on visual external cues from faces to aid them in separating their two language systems (Werker and Byers-Heinlein, 2008; also see Marian, 2009).

Second, in addition to paying attention to external cues to identify words from the speech stream, bilingual children may also pay closer attention to language-*intrinsic* cues to guide word acquisition. Children rely on their ability to pay attention to *specific aspects* of an object that have been meaningful during previous exposures. For example, Smith et al. (2002) showed that, as children learned words for objects with different shapes, they became increasingly better at paying attention to the shapes of new objects, and at assigning words they had learned to novel objects with the same shapes. Moreover, Booth, Waxman, and Huang (2005) showed that 18-month olds pay attention to *different aspects* of referents during word learning, depending on the *type* of referent: While children only paid attention to *shape* when learning words for artifacts, they also paid attention to *texture* when learning words for animates. These findings suggest that children can allocate attentional resources in a *targeted and goal-oriented fashion* from an early age, based on conceptual information about a referent. Moreover, this allocation of attention to specific aspects of an object is resistant to interference

[1] Quine illustrated the indeterminacy faced by the child in linking a specific sound sequence, such as *gavagai*, to a specific referent in the environment. In the *Gavagai* example, if the child saw a rabbit run by, and an adult speaker exclaimed *"gavagai!"*, would this word refer to the rabbit itself, to part of the rabbit, to the action of running, or to any other aspect of the visual scene?

from inconsistent visual cues. For example, Booth and Waxman (2002) found that children treated objects as artifacts during word learning if they had received conceptual information placing the objects in the artifact category, even if these objects had eyes. The finding that conceptual knowledge can drive attention suggests that attention to specific aspects of referents is allocated top-down, and is cued through an interface with the conceptual system. In sum, while joint attention provides *external* cues about objects and their names, paying attention to specific characteristics in the environment or the input can be seen as an *internal* process that is initiated by the child based on experience.

In addition to paying attention to specific aspects of objects, such as shape or texture, children may need to pay attention to fine-grained sound-differences between similar names that reference different objects. For example, Stager and Werker (1997) showed that children have initial difficulty in learning words that differ by only one phoneme, and are thus *minimal pairs* (e.g., /bih/ and /dih/). When Fennel and Werker (2003) examined *bilingual* infants' ability to learn object names that were minimal pairs, they found that bilinguals could not successfully learn such words until 20 months of age (while monolinguals had succeeded by 17 months, also see Fennel, Byers-Heinlein, and Werker, 2007). Since both monolingual and bilingual infants were able to perceive phonological contrasts at an earlier age, the authors concluded that limited cognitive resources might account for the findings, with a scarcity of available resources resulting in an inability to encode fine-grained phonological contrasts during word learning. It is possible that, because minimal pairs are perceptually the most challenging, they require the most attentional resources to process, leaving fewer resources for storage.

Specifically, bilingual children may initially have fewer cognitive resources available to pay attention to nuanced sound-differences during word learning. Within a *limited resources* framework, Bjorklund and Harnishfeger (1990) propose that, in development, a majority of cognitive resources are utilized for *processing*. At this young age, processing is thought to remain inefficient, necessitating allocation of these cognitive resources. As processing and the coordination of linguistic mechanisms become more efficient, more cognitive resources can be freed up for *storage*. Bilingual infants may recruit more cognitive resources overall to accommodate early phonological and lexical development across two language systems. Therefore, bilingual infants may have fewer resources available to pay attention to, and store, highly similar-sounding words, resulting in later onset of word learning that requires nuanced phonological distinctions. In sum, the finding of delays in minimal pair learning in bilingual infants is consistent with the idea that bilingual infants expend additional processing resources during word learning, since they have to make decisions about language membership, retain two sets of phonotactic rules, and map sound sequences onto words in *two* languages.

As bilingual children overcome initial barriers in learning words from two language systems, they soon encounter another hurdle that may prove more challenging for them than for their monolingual peers: objects frequently have *multiple labels*. Learning of translation equivalents for the same object may pose a special challenge to bilingual children because early word learning has been shown to be biased towards assignment of *one* label to each referent (e.g., Markman and Wachtel, 1988). This well-studied learning bias, known as the *Mutual Exclusivity Principle* is one in a set of word learning constraints that is believed to help children solve the *Gavagai* problem (Quine, 1960): If children hear a new word, but one of the objects in their environment has already been assigned a name, then the new word must refer to either a property or aspect of the already-named object, or to another object or action (e.g., Golinkoff, Mervis, and Hirsh-Pasek, 1994; Woodward, 2000). Research in the monolingual language acquisition literature suggests that, by 5 years of age, monolingual children loosen the constraints of the mutual exclusivity principle, and start assigning multiple names to single objects (e.g., *tricycle, trike, bicycle, bike*, Johnson, 1994). In an experiment measuring response latencies during word naming in high-constraint and low-constraint contexts (e.g., contexts where multiple labels for an object can be used vs. contexts where only one label for an object can be used), Johnson (1994) showed that, by the age of 9, children were sensitive to nonlinguistic context, using context-appropriate words when multiple labels were available. In addition, 9-year old children showed processing costs (delayed responses) when naming one of multiple object names during high-constraint situations. The authors took their findings to suggest that 9-year olds *inhibited* alternative names for the same object. The fact that Johnson (1994) found an inhibition effect for 9-year olds, but not for 7- or 5-year olds (also see Simpson and Lorsbach, 1983), is consistent with evidence that inhibitory control emerges relatively late in childhood (Bjorklund and Harnishfeger, 1990; Booth et al., 2003).

Since bilingual children face the challenge of learning multiple object labels, not only *within*-language but also *between*-language (i.e., translation equivalents), it can be predicted that they start disregarding the mutual exclusivity principle earlier than their monolingual peers. In fact, bilingual children have been shown to know both translation equivalents of early-learned words as early as within their first 50 words (Mikes, 1990). Mattock, Polka, and Rvachew (2006) recently showed that 17-month old bilingual infants were better than their monolingual peers at learning multiple labels for newly-trained pseudowords. Au and Glusman (1990) presented 3- and 6-year old bilingual children with novel stuffed animals, and provided labels in both English and Spanish (presented by two different speakers). They found that bilingual children accepted both labels for the object when they knew that the labels came from different languages. To examine whether suspension of the mutual exclusivity principle *between* languages would also result in its earlier suspension *within* language, Davidson and Tell (2005) conducted a word naming experiment with 3- and 6-year old monolingual and bilingual children. Children were shown familiar and unfamiliar objects, either by themselves, or with an attached spare part. They were then presented with novel names for these objects, and were asked whether the name referred to the whole object or to part of the object. The authors found that 6-year old bilingual children did indeed suspend the mutual exclusivity principle more frequently than their monolingual peers, and were more willing to accept a novel name to refer to an already-named object. It is likely that bilingual children's lower reliance on the mutual exclusivity principle is due to more frequent exposure to multiple names for one object, and that it paves the way for acquisition of two lexicons. It remains an open question whether bilingual children employ inhibitory control mechanisms to control activation of multiple object names across languages. In the adult bilingualism literature, evidence exists that selection of a word for production entails inhibition of its translation equivalent (e.g., Green 1998). Given the evidence from monolingual children for use of inhibitory control during naming of objects with multiple labels, it is likely that bilingual children also employ cognitive control mechanisms to functionally separate multiple object-names.

In sum, construction of a lexicon involves multiple stages, including detection of statistical regularities and recurrent patterns within the speech stream, identification of words, and separation of words that are similar to each other (either at the phonological level or at the semantic or contextual level). Throughout each step in this process, bilingual children encounter additional challenges, due to the complexity and breadth of input across their two language systems. Therefore, throughout their early years of language acquisition, from deriving phonological systems to constructing lexicons, bilingual children may address computational challenges by recruiting more cognitive and attentional resources for processing than their monolingual peers. In the next section, we focus more closely on the language-cognition interface in bilingual children, by examining cognitive consequences of early bilingual language exposure.

COGNITIVE CONSEQUENCES OF LEARNING AND USING TWO LANGUAGE SYSTEMS

Close relationships between the linguistic and cognitive systems have been found in monolingual children. For example, Nakamichi (2007) correlated children's performance on a variant of the Stroop task (the day / night task)[2] and a language-based counterfactual conditional reasoning task, and identified a strong positive relationship between performance scores on the two tasks. Using neuroimaging methodology, Blumenfeld, Booth, and Burman (2006) correlated children's ability to make semantic judgments with the extent to which they recruited the prefrontal cortex for this task, and found that low-performance children recruited the prefrontal cortex more than high-performance children. In addition to these patterns in monolingual children, findings in the linguistic and nonlinguistic domains suggest that bilingual children may have a higher cognitive processing load during language use and learning, resulting in both linguistic and cognitive differences from monolingual peers (for other reviews, see Bialystok, 2005; Cook, 1997; Nicoladis, 2008).

BILINGUAL / MONOLINGUAL PROCESSING DIFFERENCES IN THE LINGUISTIC DOMAIN

Bilingual children have been shown, on a number of tasks, to be more aware of the *function that language serves to accomplish certain communicative goals* and that linguistic symbols in themselves are arbitrary. This ability has been termed *Metalinguistic Awareness* (e.g., see Bialystok, 2001; Ricciardelli, 1992). Bilingual advantages in metalinguistic awareness have been examined at different levels of language processing. To probe metalinguistic awareness at the *phonological level* (also see Bialystok, Luk, and Kwan, 2005; Bialystok, Majumder, and Martin, 2003; Campbell and Sais, 1995; Rubin and Turner, 1989), Chen et al. (2004) compared the performance of first-, second-, and fourth-graders who were either Mandarin monolinguals or Cantonese-Mandarin bilinguals. Children performed *same-different tasks*, where they had to judge whether two words sounded the same or different in terms of tone, onset phoneme, or rime. In addition children performed *oddity tasks*, where they

[2] The day / night Stroop task, based on the classical color-ink Stroop task (Stroop, 1935), is a cognitive control task developed for use with children, and assesses children's ability to apply new linguistic labels and inhibit previously-learned linguistic labels. Children are taught to say "day" when they see a card with a *moon* on it, and to say "night" when they see a card with a *sun* on it. Young children have great difficulty with this task, with performance improving around 6 years of age.

had to choose the odd one out (in terms of tone, onset phoneme, or rime) upon hearing three words. Overall, bilingual children outperformed monolingual children in terms of tone awareness (Cantonese has a richer tone system than Mandarin), as well as for onset phoneme and rime conditions. The authors suggested that bilingual children's exposure to two sound systems lent them an advantage in terms of their analyses of sound units, especially at young ages. Specifically, bilinguals' advantage was strong in the second grade, but became weaker in the fourth grade.[3] Research across a number of different phonological awareness tasks and age groups suggests that bilingual children may not show phonological awareness advantages across all tasks at all ages (e.g., onset rime awareness, syllable awareness, phoneme awareness, etc), but rather that advantages are specific and shift as children get older, and with the onset of literacy (e.g., Bruck and Genessee, 1995; Chen et al., 2004).

To probe metalinguistic awareness at the *lexical level* (also see Yelland, Pollard, and Mercuri, 1993), Bialystok (1988) had 6- and 7-year old bilinguals and monolinguals perform two word tasks to evaluate their sense that word labels are arbitrary. On a *word substitution* task (for early versions of this task, see Piaget, 1929, and Ianco-Worral, 1972), children were asked "…suppose […] everybody decided to call the sun 'the moon' and the moon 'the sun'. What would you call the thing in the sky when you go to bed at night?" Bialystok predicted that the word substitution task would measure both (a) children's sense of the arbitrariness of words and (b) their cognitive control in maintaining word substitutions, and found that bilingual children outperformed monolingual children on this task. In a more abstract task, Bialystok then had children participate in a *word concept definition task*, where children were asked "What is a word? How can you tell if something is a word?" Bialystok found that bilingual children were better than monolingual children at describing the concept of what a word is, with partially bilingual children performing better than monolinguals, but worse than proficient bilinguals.

Finally, to probe metalinguistic awareness at the *grammatical level*, Ricciardelli (1992) had 5- and 6-year old bilinguals and monolinguals perform a word-order correction task, where they were asked to help a puppet character correct her sentences (also see Bialystok, 1988). Children were presented with sentences such as "Daddy the car washes". The authors found that bilingual children were more successful at correcting these sentences than monolingual children were. The authors suggest that, for bilingual children, increased exposure to multiple structures allows them to think about language more flexibly, allowing them to recognize the intended sentences, and produce appropriate corrections. Together, findings of metalinguistic awareness across different language processing levels suggest that bilingual children may develop a greater linguistic flexibility than their monolingual peers.

In addition to tasks that probe metalinguistic awareness at various processing levels, other findings comparing bilinguals' and monolinguals' linguistic processing also suggest bilingual advantages that may be linked to more detailed analysis of language in bilingual children. At the syntactic-semantic interface, Sheng, McGregor, and Marian (2007) recently found that 5- to 8-year old bilingual children may reach the *syntagmatic-paradigmatic shift* earlier than their monolingual peers. The syntagmatic-paradigmatic shift marks a gradual re-organization of the child's semantic system, where children shift from closely associating words that co-occur at

[3] The weaker bilingual advantage by the fourth grade is likely due to the fact that both monolingual and bilingual children receive more explicit instruction about their language systems as they progress in school and may, as a result, perform at ceiling in many phonological awareness tasks.

the sentence level (e.g., *cold* and *outside*) to closely associating words that occur in similar *contexts* (e.g., *cold* and *hot*). This shift is believed to require a re-analysis of language that progresses from analyses of surface structure towards analysis of internal structural patterns. It is possible that a quicker re-organization in bilingual children's semantic systems is brought about by a greater awareness that the surface level is in fact arbitrary and serves to communicate a consistent underlying system of meaning (e.g., see Bybee, 2001). In sum, influences of bilingual exposure on processing can be observed throughout the linguistic system, including the phonological, lexical, grammatical, and semantic levels. It is likely that monolingual / bilingual differences across these processing levels can be attributed to differences in processing demands as bilingual children construct their linguistic systems across these levels.

Bilingual / Monolingual Processing Differences in the Nonlinguistic Domain

A growing body of research suggests that bilingual children outperform monolingual children on tasks that require suppression of task-irrelevant information, tapping into processes of inhibitory control and selective attention. This pattern has been shown across a number of tasks where children were presented with conflicting information, resulting in two possible responses to a stimulus. Bialystok and Codd (1997) compared monolingual and bilingual 4- and 6 year olds on two tasks requiring assessment of quantity. One task required the children to ignore irrelevant and conflicting information (e.g., a tower with *fewer* blocks was *higher* than a tower with more blocks), while the other task contained no conflicting information. Bialystok and Codd found that bilingual children performed significantly better than monolingual children on the task containing irrelevant conflicting information, but performed the same as the monolingual children on the task containing no conflicting information. Similarly, Bialystok (1999) and Bialystok and Martin (2004) found that preschool children who were bilingual were younger (6 years old) when they became successful at tasks that required them to sort a deck of cards according to one rule (e.g., same shapes) and then switch to sorting the same deck of cards according to another (interfering) rule (e.g., same colors). Similar differences were found between bilingual and monolingual children on cognitive control tasks involving the ability to reverse visually ambiguous figures (Bialystok and Shapero, 2005), and on nonlinguistic inhibitory control tasks that involved competition between two possible responses (e.g., Martin-Rhee and Bialystok, 2008).

Martin-Rhee and Bialystok examined the performance of monolingual and bilingual 4- and 5 year olds on two different nonlinguistic inhibition tasks. On the first task (a classic Simon task, Simon, 1969), children were shown either a red or a blue square, and were asked to press a blue key (located on the right) when they saw a blue square, and to press a red key (located on the left) when they saw a red square. On the second task, children saw an arrow that pointed either right or left, and they were told to press a key on the right when the arrow pointed right, and to press a key on the left when the arrow pointed left. Both the colored squares and the arrows occurred sometimes to the right of a central fixation point and sometimes to the left of a central fixation point. Conflict between responses was created when the location of the stimulus was inconsistent with correct responses. For example, a blue square (*right* key) would appear on the *left* side of the display, or a *right*ward pointing arrow (*right* key) would appear on the *left* side of the display.

Bilinguals' superior performance on these two inhibitory control tasks has been shown to extend into adulthood (e.g., Bialystok, 2005). Others have replicated a bilingual advantage in young adults on the nonlinguistic arrow inhibition task (Blumenfeld and Marian, in preparation) and on Stroop-like flanker inhibition tasks (e.g., Costa, Hernandez, and Sebastián-Gallés, 2008; Colzato et al., 2008), that involve identification of an arrow's direction ("<" points *left*), given surrounding arrows that point the opposite way (e.g., ">>>> < >>>>"). In adult bilinguals who had learned both of their languages at an early age, Blumenfeld and Marian (in preparation) recently showed a close correlation between performance on the nonlinguistic arrow inhibition task and inhibition of similar-sounding words during language comprehension. Therefore, early evidence suggests that inhibitory control performance on a task that yields a bilingual advantage as early as at 4-6 years of age in bilingual children remains a task at which adult bilinguals outperform monolinguals, and is directly related to processing of ambiguous information during auditory word comprehension. As discussed in the first section of the present chapter, bilingual children face language input that spans two linguistic codes, resulting in more frequent ambiguity during language learning, both at the phonological and lexical levels. We can thus speculate that a link between nonlinguistic inhibitory control and auditory comprehension processing in bilingual adults is tied to language development[4], as children start to separate and elaborate two phonological codes and start to extend them into two language systems that have to be easily accessible, with minimal interference between the two systems.

DEVELOPMENTAL MECHANISMS OF BILINGUAL / MONOLINGUAL DIFFERENCES

Current research suggests that children's linguistic-cognitive developmental trajectories may vary depending on their linguistic experiences. A need continues to exist to isolate specific mechanisms by which linguistic input (i.e., monolingual or bilingual) may simultaneously influence linguistic and nonlinguistic cognitive processes. It is possible that the organization of linguistic input into separate codes requires increased use of general cognitive mechanisms, and that the use and honing of these mechanisms in turn influences linguistic and nonlinguistic cognitive processes. One general cognitive mechanism that may be involved in bilingual children's processing is *inhibitory control,* or the ability to suppress one response in favor of another response. At the phonological level, bilingual infants are confronted early on with the need to separate, and selectively pay attention to, two separate codes. At the lexical level, bilingual children, more than their monolingual peers, rely on an ability to learn two labels for one object, and to correctly choose one label over the other, based on language context. At the grammatical level, bilingual children rely on learning which structures are associated with which language, and on correctly applying them. In sum, bilingual children

[4] Whether second language development in later childhood or in adulthood can also be linked to changes in nonlinguistic inhibitory control mechanisms remains largely unstudied, but evidence is emerging that cognitive changes, perhaps of a somewhat different nature, are also linked to late bilingualism (e.g., Linck,, Kroll, & Sunderman, in press).

may have to evaluate multiple linguistic options against each other more frequently than their monolingual peers.

Inhibitory control mechanisms, which aid in correct identification of one response, while another response is suppressed, have traditionally been localized to prefrontal cortex during neuroimaging studies and have been shown to develop slowly throughout childhood (e.g., Booth, Burman, Meyer, Lei, Trommer, Davenport, et al., 2003).

It is likely that development of inhibitory processes has its origin in children's first confrontations with duality. For example, the "terrible twos" generally mark a stage when children begin to understand that their own wishes do not necessarily coincide with those of others, and the word "*no*" reaches peak frequencies of usage as children systematically explore this phenomenon (e.g., Gopnik, Meltzoff, and Kuhl, 1999). Despite evidence that inhibitory control processes may start to develop early in childhood, findings from neuroimaging suggest that prefrontal cortex and executive control functions are not fully developed until the late teens and early twenties (e.g., Luciana, Conklin, Hooper, and Yarger, 2005). Therefore, language acquisition proceeds in the absence of fully developed cognitive control mechanisms. This general delay in development of executive function, together with findings that childhood bilingualism results in cognitive advantages in inhibitory control within the nonlinguistic domain, suggests that bilingual experience may in some instances support the gradual development of children's inhibitory control processes. Therefore, findings comparing bilingual and monolingual children's performance on inhibitory control tasks suggest that linguistic development may influence cognitive development. Specifically, it is likely that the processing demands associated with language development train and hone cognitive function. An example of such a potential relationship may be the case of inhibitory control and selective attention, which provides a useful tool at various stages of phonological and lexical acquisition. Use of these mechanisms within the context of language may render them increasingly efficient as language acquisition proceeds and as language processing demands grow. Conversely, more developed cognitive mechanisms are likely to constrain and guide language development. For example, the cognitive constraint instantiated with the mutual exclusivity principle aids children in directing their attention towards objects or features that have not previously been labeled and might therefore map onto novel phonological input. Similarly, instinctive use of cues in the visual environment creates an important framework for mapping phonological sequences onto the visual world.

In sum, although a large aspect of monolingual language acquisition research is dedicated to how children make use of cognitive mechanisms during language acquisition, and how language acquisition may trigger the development of cognitive mechanisms, a need remains for research and theoretical frameworks that explicitly link aspects of language development to aspects of cognitive control. Establishing direct links between linguistic and cognitive domains will have practical applications for education and speech-language services. In addition, establishing links between linguistic and cognitive processes has theoretical implications. Specifically, the finding that early bilingual exposure influences nonlinguistic cognitive control functions provides strong support for a domain-general view of language where general cognitive mechanisms are intimately involved with language processing. Clarification of how cognitive and linguistic processes interact will further constrain the debate on modularity vs. domain-generality, identifying which aspects of language can be tied to general cognitive mechanisms, and which aspects may be domain-specific.

Towards a Theoretical Account of Language-Cognition Interaction in Development

In the present section, we place current knowledge about language-cognition interactions in bilingual children within the context of theoretical models of language learning, development, and processing. In particular, we consider recent findings from monolingual and bilingual children in the context of learnability theory (with an emphasis on the influence of input complexity on linguistic / cognitive development), and in light of usage-based accounts of language acquisition (with an emphasis on the development of potentially different cognitive skills in monolinguals and bilinguals).

Contributions from Learnability Theory

As previously illustrated, monolingual and bilingual children receive drastically different language input in the early years of their lives. How does this input influence their ability to learn language? It is generally assumed that children's linguistic systems contain features that constitute a *subset* of adults' linguistic systems and that, in order to extend their linguistic repertoire towards the adult system, children have to be presented with complex input, at least part of which is *outside* their current body of knowledge (for a review, see Gierut, 2007, and Pinker, 1984). In this sense, complexity is in fact seen as a *trigger for learning* (Gierut, 2007). For example, Gierut and Dale (2007) found that children's progress in phonological development is typically more apparent in *low frequency* words, which are generally acquired later in childhood and are frequently more complex. In other words, children are in need of *positive evidence* of correct and extensive language features in order to correct previous mistakes, and to expand their linguistic knowledge (Marcus, 1993).

Contextualizing bilingual development within learnability theory yields two potential pathways (and outcomes) of bilingual language acquisition. On the one hand, it can be argued that bilingual children consistently receive more complex input than monolingual children. For example, bilingual children's phonological input spans the phonetic inventories of two languages rather than one. Perhaps as a consequence of this complex input, bilingual children may learn to maintain more of these phonetic contrasts based on increased positive evidence of widespread phonetic contrasts. In the same vein, research has suggested that some bilingual children have better phonological awareness than monolingual children (e.g., Bialystok, Majumder, and Martin, 2003). This phenomenon may also be explained by the fact that increased phonological complexity at the input level, in tandem with increased cognitive complexity as children construct their phonological representations, may result in improved phonological sensitivity, as well as in a tacit knowledge that phonological variation may be meaningful.

On the other hand, given input that is distributed across two linguistic systems instead of one, it is quite possible that bilingual children receive less *positive evidence* for specific linguistic structures. For example, Bialystok, Majumder, and Martin (2003) compared performance of two bilingual groups, relative to monolingual peers, on a phoneme segmentation task. One bilingual group, Chinese-English bilinguals, was acquiring two languages that had highly dissimilar phonetic inventories. The other bilingual group, Spanish-English bilinguals, was acquiring two languages that had more similar phonetic inventories. With Chinese-English bilingual children, Bialystok, Majumder, and Martin (2003) found a *dis*advantage over monolinguals on phoneme segmentation. In contrast, with Spanish-English bilingual children, the authors found an advantage over monolinguals on phoneme segmentation. Given the differences between Chinese and English phonetic inventories, and the relative similarities of Spanish and English phonetic inventories, it is possible that, while Chinese-English children did not receive enough positive evidence for phonetic distinctions in their languages, Spanish-English children did receive enough positive evidence and were able to derive benefit from complex input.

In addition to the linguistic system, complexity and frequency of input may also influence the *cognitive* system in bilingual children. Specifically, Wexler (1982) suggested that more complex input requires more *processing resources*. It is possible, then, that children who routinely receive language input that is more complex than the input of monolingual peers may consistently recruit more cognitive resources for processing. Such increased recruitment and repeated use of resources may eventually result in a more efficient processing system, as evidenced by findings of bilingual processing advantages in the nonlinguistic domain (e.g., Martin-Rhee and Bialystok, 2008). Bjorklund and Harnishfeger's (1990) proposed a model of limited resources, where increased recruitment of resources towards processing was posited to incur costs at the *storage* (i.e., representational) level. Bialystok (1999) proposed a similar *analysis-control* model to account for frequently observed cognitive advantages in bilingual children, as well as for possible early representational limitations, evidenced in slower bilingual vocabulary growth relative to monolingual peers (e.g., Verhoeven, 1994). While learnability theory is typically concerned with linguistic behavior, given certain kinds of input, the interaction between language and cognition in development can also be thought of within a class of models known as *usage-based accounts.*

CONTRIBUTIONS FROM USAGE-BASED ACCOUNTS

Usage-based accounts of language development (e.g., Bybee, 2001; Tomasello, 2007) differ from other accounts of language development (e.g., generative or connectionist views) in that they are *functionalist* accounts, "based explicitly in the expression and comprehension of communicative intentions (intention reading)" (c.f. Tomasello, 2007, pp 325). Thus, usage-based accounts are first and foremost *cognitive* accounts of language learning. It is assumed that children are born with an innate instinct to communicate, and that they have mechanisms at their disposal to interact and orient themselves within their environment from the day they are born (also see Gopnik, Meltzoff, and Kuhl, 1999). A center-piece of usage-based accounts is children's ability to direct their attention towards relevant sources of information. For example, at birth, children orient towards their native language and towards their mother's voice, because they are exposed to both in utero. Children develop other attentional processes within the first year of life, such as the capacity for *joint attention,* which will be their close ally in learning the names of objects in their environments. Finally, children understand, even *pre-linguistically*, that the purpose of language is communication, as they babble and coo interactively with their caregivers. In sum, while usage-based accounts are similar to connectionist accounts in that they posit statistical analysis and organization of language input, they differ from most current connectionist models in their *functional* approach. In short, the intent to communicate and the ability to direct attention provide strong top-down biases on perceptually based (i.e., bottom-up) language learning.

The linguistic challenges faced by bilingual children support a functionalist account of language acquisition that incorporates an attentional component. Many cognitive differences between monolingual and bilingual children emerge in the area of selective attention and inhibitory control. For example, infants who acquire two languages have to orient towards one language vs. the other, and separate two phonological and (later) lexical and grammatical systems. Moreover, once bilingual children acquire language, they are likely to make more decisions (such as what language to speak in) than their monolingual peers, necessitating a cognitive/pragmatic decision component that is in close contact with the language system. In this way, the manner in which bilingual children meet linguistic challenges may be more clearly explained within a language learning account that incorporates an explicit attentional component.

Although a strong case can be made for the presence of higher-level attentional components in a functional framework of bilingual language acquisition, the consensus within usage-based accounts remains that linguistic and cognitive learning is driven by *input.* At the beginning of life, children listen to their environment and orient towards sources of salient input. At this stage of development, the influence of goal-oriented cognitive biases is likely to be minimal, with a focus on perceiving linguistic input, and identifying initial patterns in making sense of this information stream through the use of general cognitive mechanisms. A current developmental connectionist model of bilingual processing is the *Self-Organizing Model of Bilingual Processing* (*SOMBIP,* Li and Farkas, 2002). The *SOMBIP* posits that the bilingual system is dynamically organized with language acquisition, based on the principle of lateral inhibition between representations. As such, inhibitory relationships *emerge* as the bilingual system develops. Inhibitory control mechanisms within the *Self-Organizing Model of Bilingual Processing* are *language-specific,* and are tightly linked to language representations (despite the fact that lateral inhibition is a general and system-wide mechanism).

As bilingual representations are organized in the process of bilingual acquisition, native-language and second-language representations form clusters, with lateral inhibition mechanisms reinforcing this trend (Li and Farkas, 2002). As a consequence, it is likely that stronger lateral inhibitory connections are present *between* language clusters (since activation of one language typically implies de-activation of the other) than *within* language clusters (since activation of within-language words co-occurs). Therefore, while the same inhibitory control mechanism is present both *within-language* and *between-language*, it may act more strongly *across* languages. An account of the present literature on bilingual development in the context of the *Self-Organizing Model of Bilingual Processing* is particularly appropriate, because the model is a dynamic developmental model, and may therefore be most suitable for the description of emergence of linguistic and cognitive changes with bilingual experience.

Developmental models such as SOMBIP are heavily based on *frequency of exposure* to language exemplars, and are based on the assumption that children derive linguistic knowledge and structure from their linguistic environment. Empirical research suggests that this assumption is a reasonable one. At the linguistic level, evidence exists that input frequency influences learning. For example, research with infants suggests an especially strong reliance on word frequency during word recognition at early stages of word learning, with gradual maturation of the phonological system leading to better abilities to segment both high-frequency words and nonwords from the speech stream (Singh, Nestor, and Bortfeld, 2008). Nicoladis, Palmer, and Marendette (2007) showed that the accuracy with which French-English bilingual 4- and 6-year olds produce regular and irregular verbs in their two languages depends on the frequencies of these verbs within their input language (English and French have different frequency distributions for regular and irregular verbs). Nicoladis (2005) found similar frequency effects in a longitudinal case study of a child between the ages of 2 years 8 months and 5 years.

In general, words with high frequencies of occurrence in the language are more likely to be words that children acquire early. A study with 8- and 13-year old monolingual and bilingual children suggests that children perform better at recognizing high-frequency words than at recognizing low frequency words (Windsor and Kohnert, 2004, but see findings by Goldstein, Fabiano, and Washington, 2005, concerning overall frequency of language exposure). Finally, recent evidence suggests that frequency-of-exposure effects may reach beyond the word-level, with 17-month olds showing successful sound-to-meaning mappings only for words that they had previously been exposed to during fluent speech, with opportunities for segmentation (Graf Estes, Evans, Alibali, and Saffran, 2007), and with 2-year olds showing better repetition of 4-word chunks that frequently occur in language input (e.g., "sit in your chair") than of chunks that are less frequent (Bannard and Matthews, 2008).

At the cognitive level, evidence of exposure-based influences is more sparse. Ricciardelli (1992) compared monolingual and bilingual 5- and 6-year olds at different language proficiencies on a number of cognitive tasks. Bilingual children only showed cognitive performance advantages over their monolingual peers when they were highly proficient in both of their languages. Based on these data, Ricciardelli proposed a *Threshold Model of Bilingual Cognitive Development* (also see Cummins, 1979), with development of bilingual cognitive advantages relying on the child reaching a certain level of competence in both languages. In an earlier version of this model, Cummins (1979) had proposed a two-tiered threshold model, where children's failure to reach the first (and lower) threshold of bilingual language proficiency would result in cognitive performance lower than that of monolingual peers, children's reaching the first (and lower) threshold of bilingual language proficiency would ensure cognitive performance similar to that of monolingual peers, and children's reaching the second (and higher) threshold of bilingual proficiency would ensure certain cognitive advantages. This model is consistent with the idea that cognitive changes develop gradually and dynamically as children acquire their two languages (e.g., for behavioral evidence of gradually emergent cognitive changes see Bialystok, 1988; Kaushanskaya and Marian, 2008; Yelland, Polard, and Mercuri, 1993), and it accounts for frequent variability in the literature in terms of finding bilingual advantages.

For example, Kaushanskaya and Marian (2008) found that adult bilinguals who learned their second language early in life (i.e., at an average of 3 years of age) were more successful than monolinguals at learning novel words in adulthood and showed changes from monolinguals in how they recruited working memory mechanisms to recall novel words. In contrast, a group of bilinguals who learned their second language later in life (i.e., at an average age of 12 years of age) showed trends towards the performance pattern of early bilinguals, both in terms of learning novel words and in terms of recruitment of working memory mechanisms (also see Van Hell and Mahn, 1997). Consistent with the threshold model, it is likely that reaching of bilingual competence early in life conferred a set of cognitive benefits on early bilingual participants that were reflected in different relationships between linguistic and cognitive processing, and in a lasting improvement in the ability to learn new verbal material. In sum, bilingual children who show cognitive advantages are typically raised in environments where both languages are frequently used from an early age, and adult studies that have found bilingual advantages have also featured highly proficient bilingual participants.

TOWARDS A DEVELOPMENTAL ACCOUNT OF LANGUAGE-COGNITION INTERACTIONS

An emerging literature on bilingual language development suggests that, from its earliest stages, bilingual acquisition differs from monolingual acquisition, not only in the fact that two language systems are created instead of one, but also in terms of how cognitive resources are employed to accomplish this end. While current studies are mostly concentrated in the linguistic and nonlinguistic domains, research is needed that directly examines *links* between linguistic and cognitive processes during bilingual development, in order to more fully specify a developmental account of language-cognition interactions in bilinguals. Given current findings in the linguistic and nonlinguistic domains, a picture of bilingual development is emerging where increased complexity within the perceived input recruits and shapes cognitive processes of selective attention and inhibitory control at early stages of language learning. Table 1 provides a brief summary of this picture, where language acquisition challenges that children face as they become bilingual are related to nonlinguistic, metalinguistic, and linguistic aspects of processing that may be related to these learning hurdles.

While no current model of bilingual development can fully account for the confluence of factors that interact during bilingual language development, we believe that a number of developmental models make important contributions, and may in the future be combined into a wider framework of linguistic / cognitive development. Specifically, connectionist frameworks can effectively simulate children's statistical learning of regularities and patterns within the phonological input, and the *Self-Organizing Map of Bilingual Processing* by Li and Farkas (2002) realistically simulates bilingual infants' separation of auditory input into two distinct phonological systems, based on the cognitive mechanism of lateral inhibition. Nevertheless, the connectionist framework is currently lacking the *functional* cognitive dimension that is likely to be an important contributor and guide to bilingual acquisition.

While adult models of bilingual language processing posit levels of intentionality and language control (Dijkstra and Van Heuven, 2002; Green, 1998), the origin of such levels in development has not currently been addressed. In the spirit of usage-based accounts, it may be possible to derive cognitive mechanisms that support bilingual language development and processing from domain-general cognitive resources, with increased efficiency and specificity of cognitive mechanisms visible as the system matures and as language development progresses.

Table 1. Examples of differences between bilingual and monolingual children in language acquisition, linguistic processing, metalinguistic processing, and nonlinguistic processing

Language Acquisition Differences in Bilingual Children	The speech signal contains two phonological codes instead of one. Phonological codes have to be separated and individually refined. The speech signal has to be parsed for words according to two sets of phonotactic rules, transitional probabilities, and linguistic contexts. Two labels have to be learned for each object. Exposure to two language systems instead of one may mean less exposure to each language.
Linguistic Processing Differences in Bilingual Children	Bilingual infants are sensitive to a wider range of phonetic contrasts than their monolingual peers. Bilingual children generate paradigmatic word associations more frequently than monolingual peers. Lower resting activation of representations and more effortful retrieval / lower vocabulary.
Metalinguistic Processing Differences in Bilingual Children	Bilingual infants orient quicker to unfamiliar language input than native-language(s) input; monolingual infants do the reverse. Bilingual children show better phonological awareness on some tasks. Bilingual children perform better on lexical awareness tasks and suspend the mutual exclusivity principle more frequently than monolingual peers.
Nonlinguistic Processing Differences in Bilingual Children	Bilingual children rely more strongly on visual cues, such as lip reading. Bilingual children outperform monolingual children on nonlinguistic inhibitory control tasks.

In general, the current state of science on bilingual development suggests that a broader approach must be taken towards modeling language development, with a tight link to cognitive development, and a cognitive system that encounters duality and conflict, and is trained to appropriately resolve such situations. Importantly, the mutual influence of linguistic and cognitive development on each other must be represented, such that linguistic exposure can effectively trigger changes in cognitive control mechanisms. Finally, current functionalist approaches can account for the demands of bilingual language acquisition, with language development driven by an intention to communicate, and to achieve specific communicative goals.

CONCLUSION: LINGUISTIC AND COGNITIVE CONSEQUENCES OF BILINGUAL DEVELOPMENT

Childhood bilingualism provides a unique context for examining the interaction between linguistic and cognitive mechanisms in development. Specifically, evidence that bilingual children differ from their monolingual peers in the linguistic *and nonlinguistic* domains, supports the view that general cognitive tools may support language acquisition. In the words of Liz Bates, "*[n]ature is a miser. She clothes her children in hand-me-downs, builds new machinery in makeshift fashion from sundry old parts, and saves genetic expenditures whenever she can*" (Bates, 1979, p. 1). More recently, Gary Marcus wrote about language "*[w]here Shakespeare imagined infinite reason, I see something else, what engineers call a "kluge." A kluge is a clumsy or inelegant – yet surprisingly effective – solution to a problem. Nature is prone to making kluges because it doesn't "care" whether its products are perfect or elegant. […] Adequacy not beauty is the name of the game*" (Marcus, 2008, pp. 3-6).

Research in bilingual language development confirms the notion that children build a language using general cognitive guides and building blocks, by showing that linguistic experience in childhood seems to influence general cognitive processing mechanisms. Future research on childhood bilingualism may further elucidate specific influences of bilingual input on cognitive processing, while taking into consideration important factors in bilingualism research, such as age of acquisition, language dominance, language exposure, the specific language pairs that are being acquired, etc. (e.g., see Marian, 2008). Considering such factors is important for theoretical reasons, in order to isolate specific mechanisms and thresholds for language-cognition interaction, and for practical reasons, in order to define specific cognitive consequences of childhood bilingualism across a tremendously diverse population of bilingual children (e.g., see Goldstein, 2000).

Although bilingualism is pervasive (e.g., US Census, 2000), it is sometimes seen as a disadvantage rather than an advantage, especially in education settings where English non-native bilingual children may initially lag behind their monolingual peers in vocabulary development (e.g., Verhoeven, 1994). It is less well-known that bilingualism may yield significant cognitive benefits, both in childhood development and across the lifespan (e.g., Bialystok, Craik, Klein, and Viswanathan, 2004; Bialystok, Craik, and Freedman, 2007). Research on *how* linguistic input influences cognitive capacities is increasingly necessary to make the case for the teaching and maintenance of two languages in the education system. Findings that cognitive benefits can be tied to aspects of bilingual processing may encourage creation of language-learning environments where English non-native children can maintain their first language (such as dual-immersion programs), and may provide support for early foreign-language learning and immersion in standard curricula.

In sum, we propose that the study of language-cognition interactions in childhood bilingualism can inform dynamics of language development in general, as well as the *nature* of language. Specifically, current evidence that bilingual exposure during childhood results in cognitive changes in the nonlinguistic domain lends support to the view that language is not a strictly modular system, but is highly interactive with general cognitive mechanisms, and is therefore (at least in part) a *domain-general* system. As a corollary, this recent evidence lends support to *usage-based* accounts of language acquisition, with linguistic systems *emerging* given statistical analysis of spoken input and general cognitive mechanisms that guide and bias learning. The view of bilingual development that is proposed here is consistent with the view of a *dynamic* bilingual system, where continuous reorganization of representation goes hand in hand with language learning, and the system evolves with continued bilingual exposure (e.g., Kroll and Stewart, 1994; Li and Farkas, 1998). Recent evidence (e.g., Spivey, 2006) suggests that, not only do linguistic representations undergo continuous re-organization during language acquisition, but general nonlinguistic representations may also be honed and re-shaped with continued exposure to specific language environments. The present chapter makes first strides in extending this dynamic model to include higher-level cognitive function in bilinguals.

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