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Review

Bilingual beginnings to learning words

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At the macrostructure level of language milestones, language acquisition follows a nearly identical course whether children grow up with one or with two languages. However, at the microstructure level, experimental research is revealing that the same proclivities and learning mechanisms that support language acquisition unfold somewhat differently in bilingual versus monolingual environments. This paper synthesizes recent findings in the area of early bilingualism by focusing on the question of how bilingual infants come to apply their phonetic sensitivities to word learning, as they must to learn minimal pair words (e.g. ‘cat’ and ‘mat’). To this end, the paper reviews antecedent achievements by bilinguals throughout infancy and early childhood in the following areas: language discrimination and separation, speech perception, phonetic and phonotactic development, word recognition, word learning and aspects of conceptual development that underlie word learning. Special consideration is given to the role of language dominance, and to the unique challenges to language acquisition posed by a bilingual environment.

Keywords: bilingualism; language development; infancy; speech perception; word learning; effects of linguistic experience

1. INTRODUCTION

The ability to acquire language is one of the hallmarks of our species, deeply embedded in our biology. Given the enormous complexity of language, it is remarkable how children acquire their native language so quickly and seemingly without effort. Languages employ units and patterns at several levels from speech sounds to morphemes, words, clauses and sentences, to describe the world and our thoughts, beliefs, feelings and plans about it. To acquire their native language children need to learn not only the individual words of that language, but the regularities at every level, including the knowledge of what information is expressed and where. Bilingual language acquisition presents the problem of acquiring two such interlocking sets of regularities simultaneously. As seemingly difficult as this challenge is, many of the world’s children grow up learning two native languages at the same time, with the same apparent ease that monolinguals show in acquiring a single language (Werker & Byers-Heinlein 2008).

A reasonable question is whether the acquisition of two linguistic systems means that bilingual infants follow a different course of language acquisition from monolinguals. Until very recently, the bulk of the research addressing this question was either

observational or correlational in nature. On the basis of such studies, there was general agreement that bilingual and monolingual children pass critical milestones in language acquisition at approximately the same age (Pearson & Fernández 1994; De Houwer 1995; Oller *et al.* 1997; Petitto *et al.* 2001), and that same-aged bilingual and monolingual children have relatively equal sized vocabularies when the vocabularies of both languages is taken into account (Pearson & Fernández 1994; Pearson *et al.* 1995; Petitto *et al.* 2001; Paradis & Nicoladis 2008). Indeed, some reports of early comprehension have found that bilinguals have larger overall vocabularies than same-aged monolingual peers (De Houwer *et al.* 2008). At a descriptive level, then, it appears that the developmental sequence of bilingual language acquisition conforms to that of monolingual acquisition.

Yet, an investigation of developmental milestones cannot reveal the whole story of how monolingual and bilingual acquisition compare. Cross-linguistic studies of monolingual acquisition show that although all children acquire the phonology, morphology, syntax and semantics of their native language within the first few years of life, the structural properties of the particular language they are learning can influence both the age and the order in which different structures are mastered. Thus, it is reasonable to consider how exposure to two languages simultaneously could also influence the microstructure of language acquisition in bilingual children.

There is every reason to presuppose that identical proclivities and learning mechanisms underlie both

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monolingual and bilingual acquisition, but that the input differences activate these mechanisms in different ways, both in terms of timing and degree. The goal of our research, and of this review, is to understand how these operate. Specifically, by studying bilingual acquisition, we can shed light on which aspects of acquisition remain constant and which change—and in what ways—in response to input from two different languages. As we hope will be illuminated in the following pages, this approach ultimately furthers understanding of how strongly conserved biases and general learning mechanisms work together to enable language acquisition.

A full characterization of the microstructure of bilingual acquisition is beyond the scope of this paper, so here we focus on one topic that illustrates how bilingual infants begin to integrate multiple language systems: the application of phonetic sensitivities to word learning and word recognition. This is a particularly illustrative example because it requires an examination of both phonetic development and word learning, as well as their intersection. By investigating early-acquired perceptual processes (phonetic perception) and later-acquired conceptual processes (word learning), it will give us a clear window into bilingual language development throughout the infancy period while retaining focus on one central question. However, before describing how bilingual infants use sound detail in word forms, we must discuss the necessary antecedent for successful bilingual acquisition: the separation and discrimination of the two languages.

2. LANGUAGE DISCRIMINATION

A prerequisite for successful bilingual acquisition is an ability to discriminate the two languages that are being acquired. An infant growing up bilingual must somehow notice that the input is structured with respect to two languages rather than just one language, and must be able to segregate the input from each language. It was once believed that bilingual-learning infants confuse their two languages at the beginning of life, and only gradually come to pull them apart after beginning to establish a vocabulary in each (Volterra & Taeschner 1978). The first large-scale study to seriously challenge this view comes from the work of Barbara Pearson. She showed that even in the earliest stages of vocabulary acquisition, when infants are only able to say 12 words or fewer, bilingual infants can produce translation equivalents—words with the same meaning in each of their languages (Pearson *et al.* 1995). This finding showed that young bilinguals do not avoid learning two words for the same referent when those words are in different languages, implying that the two languages are pulled apart from the beginning (see also Vihman 1985, for similar evidence from a case study). Other research has shown that as soon as they begin speaking, young bilinguals use words appropriately depending on the language spoken by their interlocutor (Genesee *et al.* 1995, 1996). An ability to modulate the use of two languages further suggests an ability to distinguish them.

(a) *Auditory language discrimination*

There is evidence that even in the first months of life, bilingual infants have perceptual abilities that allow them to discriminate their two languages. The first test of this came from a study with bilingual 4-month-old Spanish–Catalan-learning infants (Bosch & Sebastián-Gallés 2001). Infants were first familiarized to sentences from one language or the other. Following familiarization, they were tested in a head turn preference procedure. In this task, a flashing light draws the infants' attention to one side of a testing booth. Sentences from one of the languages are played as long as the infant orients towards the light. If infants can discriminate between the two languages, they are expected to show a different reaction when the familiarized language is played than when the non-familiarized language is played. In this study, Spanish–Catalan bilinguals showed the expected 'novelty preference' of looking longer during trials when the non-familiarized language was played. Indeed, their ability to discriminate the two languages was similar to that shown by monolingual infants of the same age. The strength of this finding lies in the fact that Spanish and Catalan are rhythmically similar languages. Past research with monolingual newborns (Mehler *et al.* 1988; Nazzi *et al.* 1998), and 5-month-olds (Nazzi *et al.* 2000) has shown that discrimination of rhythmically similar languages is not evident at birth, but instead develops over the first few months of life in relation to language experience (Nazzi & Ramus 2003). Thus, the discrimination of Spanish and Catalan presents the most stringent test of bilingual infants' ability to distinguish their native languages early in development.

Although in the head turn preference procedure described above, monolinguals and bilinguals showed similar performance, an alternative procedure for testing language discrimination in bilingual infants has suggested some differences in the microstructure of how discrimination proceeds (Bosch & Sebastián-Gallés 1997). In a study that relied on language recognition, Bosch & Sebastián-Gallés assessed language discrimination via infants' latency to orient to the native language versus their latency to orient to an unfamiliar language. When presented with a flashing light to one or the other side, accompanied by either the native language or an unfamiliar language, monolingual infants aged 4 months orient more rapidly to the light when the native language is presented (Bosch & Sebastián-Gallés 1997; Dehaene-Lambertz & Houston 1998). However, bilingual 4-month-olds show a very different pattern: they orient more rapidly to an unfamiliar language than to a native language (Bosch & Sebastián-Gallés 1997). A possible explanation for this finding is that bilinguals first try to ascertain which of their two native languages is being spoken before orienting, thus delaying their orientation time. Such a strategy might be related to precocious inhibitory skills in infants growing up bilingual (Kovács & Mehler 2009). These results hint that although monolinguals and bilinguals may have similar capacities for language discrimination, the microstructure of how discrimination proceeds may be different between the two groups.

To investigate the roots of bilingual language discrimination, we turned to newborns. Previous research has suggested that experience with the native language during the last months of pregnancy can result in preference for that language (Moon *et al.* 1993). We compared preference of English versus Filipino in a unique group of newborn infants: those who had received prenatal exposure to both English and Filipino because their mothers had spoken both languages throughout pregnancy. We also tested newborns who had been prenatally exposed to only English on their language preference. To assess preference, newborns sucked on a pacifier attached to a computer that registered their sucking strength and frequency. Sentences, which were low-pass filtered to reduce surface segmental cues while preserving rhythmic information, were presented in alternating minutes in either English or Filipino. While monolinguals sucked more to hear English sentences than Filipino sentences, bilinguals showed no difference in their sucking to sentences in the two languages (Byers-Heinlein *et al.* submitted, in press). One interpretation of these data is that learning leads to a preference for familiarity, thus preparing the English-exposed neonates to listen selectively to English and the bilingual-exposed neonates to be similarly interested in both languages. However, an alternative interpretation is that the bilingual neonates show no preference because their listening experience has eliminated their ability to discriminate the two languages. To test discrimination, we habituated the infants to sentences from one language (either English or Filipino) until their sucking frequency declined. We then switched the sounds to new sentences from the same language (the control group) or new sentences from the other language (the experimental group). The control group showed no increase in sucking, hence no evidence of discrimination. As expected from previous work, English-only exposed newborns increased their sucking when they heard sentences from a new language, but importantly, neonates who had heard both languages *in utero* also increased their sucking. These results show that neonates who have heard two rhythmically distinct languages throughout gestation can discriminate their two languages from birth, an essential foundation for the separation and ultimate acquisition of their two languages.

Moreover, these results show that the same initial proclivities (discrimination) and learning mechanisms (preference) operate to prepare the monolingual infant to attend preferentially to, and ultimately acquire only a single language and the bilingual infant to attend to two native languages, while nonetheless not confusing them. This illustrates how comparing the microstructure of acquisition in bilingual to that in monolingual infants can illuminate our understanding of language acquisition in general.

(b) *Visual language discrimination*

Although auditory cues might seem the most obvious route for language discrimination, the multimodal nature of language means that babies growing up

bilingual might have other cues available to help them to tell their languages apart. Indeed, babies are remarkably adept at using whatever information is available in their world to learn its regularities. In another recent set of studies, we compared monolingual and bilingual infants on their ability to discriminate two languages visually—that is by watching silent talking speakers, wherein the only cues to language identity are in the movements of the face (Weikum *et al.* 2007). We habituated both English monolingual and French–English bilingual infants to video displays of three bilingual speakers reciting sentences in one language, with the sound turned off so that only visual information was available. Once infants showed a decline in interest in these videos, they were shown the same three speakers either reciting new sentences in the original language, or new sentences in the other language. Monolingual infants were tested at 4, 6 and 8 months-of-age and bilingual French–English infants were tested at 6 and 8 months. At the two younger ages, the monolingual infants were able to discriminate English and French just by watching silent talking faces, but at 8 months-of-age the monolingual infants no longer succeeded. In contrast, the bilingual infants successfully discriminated English from French at both 6 and 8 months-of-age, thereby continuing to discriminate the two languages at an age when monolinguals failed.

As in so many other aspects of perceptual development, infants seem to begin life with a broad sensitivity to any distinctive perceptual detail, with the effect of experience being one of maintaining sensitivity to those features that are important in the native cultural environment, and a concomitant decrease in sensitivity to those that are not (Werker & Tees 1999; Pascalis *et al.* 2002; Werker *et al.* 2009). In the case of visual language discrimination, each group of infants behaves optimally for their language-learning situation. Maintenance of a sensitivity to cues in talking faces that distinguish one language from another provides yet another source of information that could contribute to language separation for the bilingual child.

3. NATIVE PHONETIC CATEGORIES: LEARNING THE SOUNDS OF TWO NATIVE LANGUAGES

Sounds are the building blocks of words. To understand word learning in the bilingual context, it is pivotal to consider how infants develop the sound systems of their languages. The smallest unit that distinguishes meaning in a language is the phoneme. The set of phonemes used to distinguish meaning varies from language to language. For example English uses /r/ and /l/ to distinguish words such as ‘rake’ and ‘lake’, whereas many languages including Japanese do not. On the other hand, in Japanese the difference between a long and a short vowel can signal difference in meaning (e.g. ‘kado’ *corner*, ‘kaado’ *card*), whereas in English it cannot. In addition to these differences in phoneme inventories, the precise phonetic realization of any particular phoneme varies from one language to the next. A well-known example is that ‘p’ is different in English than in French. In English it is aspirated

with a puff of air at its release, whereas in French it is not (see Caramazza & Yeni-Komshian 1974 for a more in-depth discussion of these differences).

There are well-documented achievements in phonetic perception in the first year of life in infants growing up monolingual. Very young monolingual infants are able to discriminate many of the speech sound distinctions used across the world's languages, including distinctions that are not used in the native language. For example, at 6 to 8 months-of-age both English-learning and Hindi-learning infants discriminate two 'd' sounds that are used contrastively in Hindi but not in English, but by 10–12 months-of-age English infants no longer discriminate this distinction whereas Hindi-learning infants still do (Werker & Tees 1984). Cross-language studies with infants exposed to a single language show listening experience with the native language serves to maintain (Werker *et al.* 1981; Werker & Tees 1984; Baker *et al.* 2006; Mattock & Burnham 2006), improve (Kuhl *et al.* 2006; Narayan *et al.* in press) and realign (Burns *et al.* 2007) discrimination of the phonetic distinctions used in that language.

The pattern of phonetic learning in infants growing up bilingual shows interesting differences and similarities to monolingual phonetic development. Just like monolinguals, bilinguals refine their native phonetic categories in the first year of life, going from being universal listeners to narrowing-in on the native contrasts. However, bilingual infants may have an interval in development when they temporarily collapse some native-language categories before successfully pulling them apart again. While Spanish–Catalan bilingual infants of 4- and 12-months discriminate vowel distinctions that are used only in Catalan, at 8 months they perform like monolingual Spanish infants who do not hear these vowels and fail (Bosch & Sebastián-Gallés 2003; Sebastián-Gallés & Bosch in press). A similar pattern was reported by Bosch & Sebastián-Gallés for a consonant contrast between the fricative sounds, /s/ versus /z/, that is distinguished in Catalan but not in Spanish (Sebastián-Gallés *et al.* 2008). Here again there seemed to be a temporary broadening of the phonetic category in the bilingual infants to include two different Catalan sounds as instances of a single phonetic category. In this case, the decline in sensitivity to and re-emergence of the contrast occurred later in development than in the case of vowels, as is typically reported for consonant perception. Spanish–Catalan infants of 4- and 16-months discriminated the contrast, but failed at 12-months-of-age, the age at which monolingual infants have settled on their native consonant categories.

However, this temporary decline and re-emergence is not seen across all contrasts. There are two published reports in the literature which indicate that bilingual infants establish native consonant categories in each of their languages at the same age as do monolingual infants. One study compared monolingual-learning infants to bilingual French–English infants on their ability to discriminate differences in both the English and French /b/–/p/ distinction. This contrast is of particular interest because although English and

French each have a distinction involving these two phones, the boundary is quite different in the two languages.¹ By 12 months, monolingual infants discriminate only the boundary used in their native language (Burns *et al.* 2007). There are several ways that bilingual infants might show a different pattern of development. First, bilingual infants could have a preference for one boundary over the other. Second, they could experience a period of temporarily broadening the category as seen in the Catalan–Spanish bilingual studies, in which case they should fail to discriminate either the French or the English distinction. However, bilingual infants actually showed a third unique pattern. At 10–12 months-of-age, bilingual French–English infants discriminated both boundaries (Burns *et al.* 2007). Thus, for these consonants, bilingual infants were ultimately able to make the distinctions that were meaningful in each of their languages.

But what happens if the highly similar consonants are from two different languages that the bilingual child is learning, rather than from within a single language? The answer to this question comes from recent work by Sundara *et al.* (2008). They compared monolingual French-learning and monolingual English-learning infants to French–English bilingual infants on their ability to discriminate the phonetic difference between the [d] used in English (an alveolar /d/) from the [d] used in French (a dental /d/). To discriminate this distinction, infants had to compare a consonant in one language to its realization in the other language. By 10 months-of-age the French monolingual-learning infants, who have only one /d/ in their input, had stopped discriminating this distinction. However, the bilingual infants continued to discriminate it. Perhaps the best explanation for these findings is that bilingual infants not only track statistics separately for each language, they also set up acoustic–phonetic space in a language-specific fashion. Why would the bilingual Spanish–Catalan infants show a temporary inability to discriminate a distinction used in one of their languages while the French–English infants did not?

One explanation implicates the specific types of phonetic contrasts that were tested in each population. Studies to date have tested Spanish–Catalan bilinguals on vowels and fricatives, and French–English bilinguals on stop consonants. Future studies that test the same type of contrast in two different populations are needed to pull apart the thus-far confounded effects of the specific languages being learned, and the developmental pattern associated with the perception of a given contrast.

A different type of explanation now favoured by Sebastián-Gallés is that bilingual infants are able to discriminate native contrasts throughout the first year of life, but at certain ages some experimental paradigms might be inappropriate for evidencing their discrimination abilities (Sebastián-Gallés 2008). Most paradigms for testing discrimination in infants rely on habituation-switch designs, where infants are expected to pay increased attention to a change in stimulus. However, bilingual infants may be more flexible in how they interpret phonetic differences.

Although they may detect a change, it may not be 'surprising' or 'unexpected', as bilinguals typically experience a more varied phonetic environment than monolinguals. This would be particularly true if they are hearing accented input in one of their languages. This position has received support from a recently published study that used anticipatory looking methods, which showed successful discrimination of a phonetic contrast by bilingual Spanish–Catalan infants at an age where habituation methods have shown failure (Albareda-Castellot *et al.* submitted). Such a possibility implies that researchers should take extra caution in interpreting the results of studies that show differences between monolinguals and bilinguals, as such differences could be artefacts of an inappropriate methodology for the population in question rather than true differences in competencies.

The available evidence reviewed above indicates that around the *end* of the first year of life bilingual infants discriminate many phonetic distinctions in each of their native languages, and do so as well as do monolingual infants. However, studies of phonetic perception with bilingual adults suggest that the final developmental picture of these abilities may be somewhat more complex. Some studies indicate that bilingual adults have robust representations of their phonetic categories, and show discrimination of the phonetic boundaries in each of their languages particularly if both languages were acquired simultaneously from birth (Pallier *et al.* 1997, 2001; Sundara & Polka 2008). However, if the languages are not equally dominant, bilingual adults may show different patterns of discrimination in their dominant when compared with their non-dominant language (Sebastián-Gallés *et al.* 2005; Sundara & Polka 2008). Some studies even suggest that bilingual adults might have phonetic category characteristics that are either intermediate to those of their two languages, or that exaggerate the differences between the two (Flege *et al.* 2003; Fowler *et al.* 2008). It should be noted that most of the studies with adult bilinguals differ from those with infants in that the adults are typically sequential bilinguals, that is, they learned a single native language, and then learned a second language later in life. Problems with phonetic discrimination seem to apply most often to the second language (Bosch *et al.* 2000). Nevertheless, the possibility exists that although bilingual infants have phonetic systems that are quite separate in perception at the end of the first year of life, phonetic categories may shift once a lexicon begins to be established.

4. PHONOTACTIC DEVELOPMENT

In addition to differing in their phonemic inventories, languages differ in how sounds may combine to form a word. Phonotactics refers to the allowable phoneme sequences in a language. In English, consonant clusters are allowed, but there are strict limitations on which consonants can come before others (e.g. 'spl' can occur, whereas 'slp' cannot), and in which position in a word. For example, 'tr' is allowed at the beginning of words but not at the end, whereas 'rt' is allowed only in word-final position. As such,

phonotactic rules provide infants with strong cues to word candidates and word boundaries, and thus serve as an intermediate step between phonetic development and word recognition. Languages differ in their phonotactics, with some languages, such as Japanese, favouring words that alternate between single consonants and single vowels, and others such as Czech allowing long sequences of consonants. Considerable research indicates that by 9 months-of-age, monolingual infants are sensitive to the native-language phonotactics, and show a preference for listening to lists of words that contain high-frequency legal sequences over lists of words that contain low frequency, or illegal phoneme sequences (Friederici & Wessels 1993; Jusczyk *et al.* 1993). Learning the phonotactics of two languages simultaneously requires not just noting differences, but also calculating probabilities of co-occurrence in each language.

To examine whether infants growing up bilingual can learn the phonotactic regularities of their native languages as early as do monolingual infants, Sebastián-Gallés & Bosch (2002) tested 10-month-old Spanish monolingual, Catalan monolingual and Spanish–Catalan bilingual infants on their preference for legal versus illegal Catalan sequences. The bilingual infants were further divided into two groups: those who were dominant in Spanish and those who were dominant in Catalan, as measured by maternal language and the amount that each language was spoken in the home. At 10-months-of-age, the monolingual Catalan infants showed a robust preference for legal over illegal Catalan words, whereas the monolingual Spanish infants showed no preference for either type of Catalan words. The results from the bilingual infants were more complex. The Catalan-dominant bilinguals performed like the Catalan monolinguals, and showed an equally robust preference for legal over illegal Catalan words. The Spanish-dominant bilinguals did not show a significant preference for legal Catalan words, but their performance fell between that of Spanish monolinguals and the Catalan groups (monolinguals and Catalan-dominant bilinguals), suggesting some sensitivity to Catalan phonotactics. Thus both timing of exposure and amount of exposure seem to contribute to the learning of phonotactics.

5. WORD RECOGNITION

The refinement of phonetic categories and establishment of phonotactic sensitivities help infants recognize familiar words in continuous speech. From as young as 7 months, monolingual English-learning infants show a preference, by listening longer to passages that contain familiarized words over passages that do not contain them (Jusczyk & Aslin 1995; Jusczyk 1997). Moreover, they are not foiled by similar-sounding mispronunciations (e.g. 'tup' instead of 'cup'), suggesting that they have not only encoded the words' consonant onsets with full phonetic detail, but that they are able to use that detail to distinguish one recently familiarized word form from another (Jusczyk & Aslin 1995). When tested on their recognition of words they have likely heard in everyday

speech, rather than being specifically taught the words in the laboratory, French-learning monolingual infants succeed again, but at a later age (11 months). When given a choice to listen to lists of frequent (e.g. 'bonjour', 'voiture', 'lapin'), and hence likely familiar words, versus lists of phonotactically similar infrequent words, these infants listened longer to frequent words. At this age, however, infants will also choose to listen longer to a list of words that are minimal pair deviants (e.g. 'vonjour', 'boiture', 'napin') over a list of infrequent words (Halle & Boysson-Bardies 1996); see also Vihman *et al.* 2004 for a similar study that explored interactions with prosody). These results suggest that although infants may be able to encode phonetic detail when listening to words, a period of development is required before the phonetic detail assumes privileged status in recognition.

Only a few studies have been published to date on word form recognition in bilingual infants. Previous research has shown that by around 13-months-of-age, the event-related potentials (ERPs) recorded from scalp electrodes are different in familiar when compared with unfamiliar words in both latency and topography (Mills *et al.* 1993, 1997). To explore whether words are equally strongly represented in the bilingual brain, Vihman and colleagues (2007) compared ERPs of English monolingual and Welsh monolingual infants to English–Welsh bilingual infants. The monolingual English infants showed the anticipated effect: a difference in brain response to familiar versus rare words. The monolingual Welsh infants did not show the effect, which may reflect the fact that Welsh has phonological mutation (i.e. the onset consonants of some words change depending on the words that precede them), which could make it harder to track words. The difference could also reflect a property of Welsh that makes the second syllable of words most salient, while in English the first syllable is typically most salient. Interestingly, the bilinguals showed a pattern that would not have been predicted based on the monolingual results: bilinguals' brain responses to English word lists mimicked those of English monolinguals, and their responses to Welsh lists showed a similar, although temporally later difference in response to familiar versus rare words. Thus, the bilinguals appear to have transferred their ability to encode and recognize English word forms to Welsh. Although there are many factors (e.g. sociolinguistic) that could have contributed to this pattern of results, these studies suggest that the bilingual brain recognizes familiar words at the same early age as does the monolingual brain. This study also demonstrates the importance of considering language-specific factors when studying bilingual populations, even in infancy. Characteristics of the two languages themselves, rather than bilingualism *per se*, may explain certain developmental patterns. We will return to this point in the discussion of minimal pair word-learning.

6. WORD LEARNING

Truly knowing a word runs much deeper than simply recognizing its form. The everyday notion of 'word'

invokes a linguistic symbol that stands for something else, for example an object, an idea or a relation in the world. Yet, there are many antecedent developmental achievements before children can fully understand and use words. In this paper we review the steps required in word comprehension, with a focus on the learning of count nouns—words that stand for objects (see Hall & Waxman 2004; Waxman & Lidz 2006). We begin with simple word–object association, consider next the role of language-specific phonetic categories in guiding word learning, and end with a brief exploration of conceptual foundations that might underlie word learning.

(a) *Associating word and object*

A prerequisite for referential word knowledge is the ability to associate a word with a concept. Among the earliest words acquired by young infants are words for common objects. Although infants begin to recognize frequent word forms (Jusczyk & Hohne 1997) and even to learn the associative meaning of some highly common words by 6 to 8 months-of-age (Tincoff & Jusczyk 1999), the process of learning words is fairly slow until around the middle of the second year of life (Oviatt 1980; Nazzi & Bertoncini 2003). Before this time, infants are most likely to be successful in learning to comprehend new words when there is rich contextual support for the mapping (Hollich *et al.* 2000), including when there is pointing and/or shared eye gaze towards the target (Baldwin 1993), when the target object has high perceptual salience (Pruden *et al.* 2006), and when there is synchrony between touching or moving the object and the production of the word (Gogate & Bahrick 1998; Gogate *et al.* 2000). By 13–15 months, infants become more adept at linking the sound of a word with its referent even without broad contextual support (Woodward *et al.* 1994; Schafer & Plunkett 1998).

In our work, we examined the age at which infants can learn to associate two different words with two different objects in a laboratory task. In a procedure called the 'Switch' task (from Younger & Cohen 1986), we presented infants with a moving object (Object A) on a screen paired with a single word (Word A) on some trials, and a different moving object (Object B) paired with a different word (Word B) on other trials (figure 1a). Following habituation to such word–object pairings, we presented infants with both a Switch trial (e.g. Object A paired with Word B) and a Same trial (e.g. Object A with Word A) (figure 1b). If infants learned about both words, both objects and the associative link between them, they should be surprised to see a violation of the associative link as in the Switch trial. We tested infants of 8, 10, 12 and 14 months-of-age. We found that at 14 months, but not before, infants could learn the associative word–object pairing, as evidenced by longer looking to the Switch than to the Same trial (Werker *et al.* 1998).

In a recent follow-up study, we asked whether the ability to learn associative word pairings is evident at the same age in bilingual as in monolingual-learning infants. The fact that bilingual and monolingual

infants have a similar-sized overall vocabulary might suggest that this skill would emerge at the same age in both groups. On the other hand, there is some work suggesting that in certain situations, bilinguals may have an advantage over monolingual infants in learning associative rules. One study trained 7-month-old infants to orient to one side (e.g. to the right) in response to an auditory stimulus in order to see a visual reward. After a number of trials, the procedure switched so that a visual reward appeared on the other side (e.g. to the left). Although monolinguals and bilinguals were equally able to learn the first contingency, bilingual infants were better able to switch sides when the contingency changed, successfully inhibiting the previously taught rule (Kovács & Mehler 2009*a*; see also Kovács & Mehler 2009*b*).

To test whether bilingual infants are able to learn associative word–object pairings at the same age, or earlier than monolingual infants, we compared monolingual and bilingual infants of 12 and 14 months on their ability to learn the dissimilar words, ‘lif’ and ‘neem’ in the Switch word-learning task (Byers-Heinlein *et al.* submitted; figure 1). The results were clear: there was neither an advantage nor a disadvantage for the bilingual infants. Replicating the original Werker *et al.* (1998) studies, infants from both language groups failed at 12 months and succeeded at 14 months by looking longer at the Switch than at the Same word–object pairing. These results confirm that one of the fundamental components of word learning, the ability to learn the associative link between a word and object, emerges synchronously in both monolingual and bilingual infants.

(b) Learning similar-sounding words

To begin to unpack how the different components of word learning interact, and more specifically, to empirically test whether the phonetic categories established in the first year of life can be used to direct word learning, we extended our associative word learning work to test monolingual infants on their ability to learn minimally different words. We began with the /b/–/d/ distinction that is used not only in English, but in virtually every language of the world. Infants of 14 months were tested in the same Switch task as in our earlier work on dissimilar-sounding words (figure 1). To our surprise, when tested on their ability to learn the similar-sounding words ‘bih’ and ‘dih’, which differ only in a single phonetic feature, infants were not able to succeed at the Switch task at 14 months (Stager & Werker 1997), although they were at 17- and 20-months-of-age (Werker *et al.* 2002; figure 2). This is in stark contrast to their ability to learn dissimilar-sounding words in the same procedure at 14 months.

In an attempt to understand why monolingual infants fail to learn minimally different words at 14 months, we and others conducted a number of follow-up studies. Manipulations that give infants more information while performing the task can allow them to succeed at this age. Additional information that has been shown to improve performance includes testing infants on words they already know

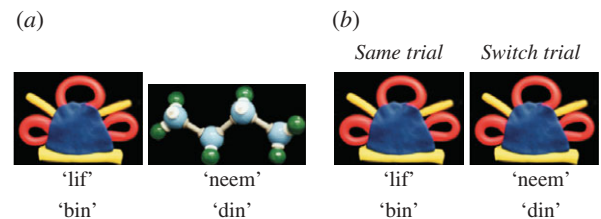


Figure 1. The standard Switch task with both the dissimilar word version (lif/neem) and similar word version (minimal pairs; bin/din) shown. (a) Habituation phase and (b) test phase.

(e.g. ball versus doll; Fennell & Werker 2004), placing the minimal difference in a consistent context (Thiessen 2007), and placing the to-be-learned words in a noun phrase (Fennell & Waxman *in press*). Moreover, infants of 14 months even succeed when the identical habituation phase was used as in the Switch task, but is then followed by a side-by-side, two-choice task in the test phase (rather than the sequential task used in the test phase of the classic Switch task) (Yoshida *et al.* 2009). This reveals that at 14 months, infants can pick up and encode critical phonetic detail in the learning phase, but are only able to reveal this learning in a test phase with reduced performance demands. Collectively, these studies suggest that monolingual infants are able to pick up and represent the phonetic detail that distinguishes words such as ‘bin’ and ‘din’, but are unable to apply this information under certain impoverished word-learning conditions (see Fennell & Werker 2004; Werker & Fennell 2008 for more details).

On the basis of these and other findings, we concluded that, although infants of 14 months can detect and represent the phonetic detail distinguishing one word from another, the computational requirements of learning two objects, two words and linking them to one another can prevent these novice word learners from being able to use the phonetic detail successfully. According to this ‘computational resource limitation’ (CRL) hypothesis, infants succeed by 17 months across word-learning situations, even context-poor situations like using isolated words, because by this age they have become more accomplished word learners (Werker *et al.* 2002; Fennell & Werker 2004; see also Naigles 2002; Nazzi & Bertoncini 2003; Newman 2008), making it easier for them to simultaneously hold on to the phonetic detail and to the word–object link. In our PRIMIR framework (Processing Rich Information from Multidimensional, Interactive Representations) (Werker & Curtin 2005; Curtin & Werker 2007), we argued more specifically that at 14 months-of-age, although infants now give phonetic detail more weight than indexical detail in word form recognition tasks (Halle & Boysson-Bardies 1996; Houston & Jusczyk 2000; Singh *et al.* 2004), the novice word learner does not yet weigh the contrastive phonetic difference any more heavily than other indexical details in a word learning task. Thus, both task-relevant and task-irrelevant information are kept in mind by the infant, contributing to the difficulty in word learning. We and others suggest that by 18 months-of-age infants have established a sizable enough receptive lexicon that they have learned that it is the speech sounds, not the indexical cues, that serve to distinguish one word from

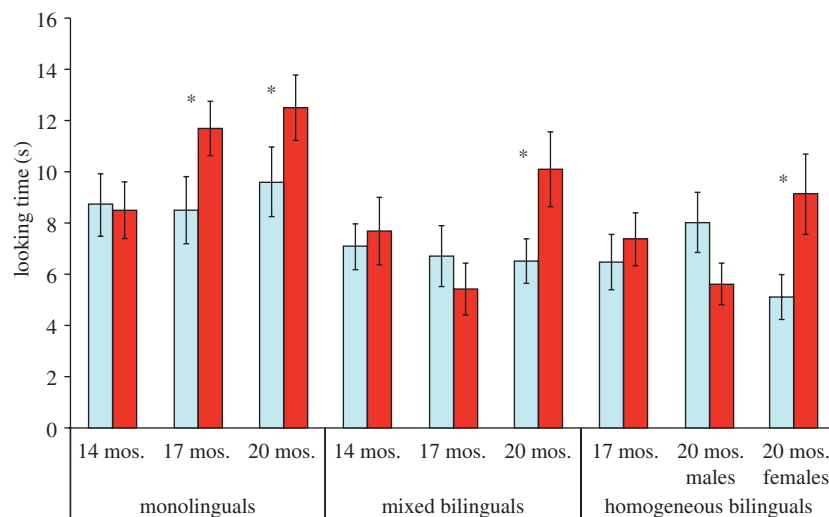


Figure 2. Minimal pair word-learning results across monolingual and bilingual groups. Error bars represent the s.e. of the mean. * $p < 0.05$. Open bars, Same trial; filled bars, Switch trial.

another (Beckman & Edwards 2000). This greater weighting of phonetic cues enables more abstract, phoneme-like units to emerge (Werker & Curtin 2005). We argue that these in turn serve to decrease the computational load by focusing infants' attention on the critical cues needed to successfully guide word learning, enabling success in the minimal pair Switch task.

Strong evidence is emerging that abstract phonological categories, rather than phonetic details, guide minimal pair word-learning by 18 months. In a recent study, English and Dutch toddlers were compared on their ability to learn the minimal pair words 'tam' and 'taam' that differ in only a vowel length distinction (Dietrich *et al.* 2007). This contrast is of interest because vowel length is phonemic (used to contrast meaning between two words) in Dutch but not in English. Nonetheless, because the difference between a long and a short vowel is both familiar and acoustically salient, English-learning infants are able to discriminate this contrast at 18 months (Mugitani *et al.* 2009). Using an identical procedure as in the other Switch tasks described above, Dietrich and colleagues found that at 18 months only Dutch-, but not English-learning toddlers could learn to associate the short vowel word 'tam' with one object and the long vowel word 'taam' with another (Dietrich *et al.* 2007). Thus, although both groups can hear the difference between a long and a short vowel, only Dutch infants, for whom the difference is phonemic, use this difference to guide word learning.

In monolinguals, the minimal-pair variant of the Switch task has proven to be extremely revealing as to how infants coordinate their growing phonological knowledge with their developing word learning abilities. Indeed, performance in the minimal pair Switch task at 17–18 months is correlated with both concurrent (Kemp *et al.* submitted) and later (Bernhardt *et al.* 2007) measures of vocabulary size and language development more generally. We now turn to studies of minimal pair word-learning in bilinguals to examine what this research has revealed about the microstructure of bilingual acquisition.

Do bilingual infants integrate their phonetic abilities, their nascent knowledge of phonology, and their early word learning in the same manner as monolingual infants, who succeed at learning minimal pair words in the Switch task at 17 months? Again, three predictions could be made. On the one hand, bilinguals face the task of coordinating two phonological systems with the task of word learning, increasing the computational load and suggesting a possible later age of success. In addition, even though the overall vocabulary is likely as large or larger in a bilingual than a monolingual child, the fact that the vocabulary is split between two languages suggests that there might be fewer well-solidified phonemes to guide information pick-up. Moreover, the precise phonetic characterization of even the /b/ and /d/ phonemes could be different between English and other languages, hence further complicating the word-learning challenge for bilinguals. But on the other hand, there is some evidence that bilingual preschoolers have a specific advantage in phonological awareness (Campbell & Sais 1995), leading to the prediction that bilinguals might be able to use phonetic detail to guide word learning at a younger age than monolingual infants are able to. Finally, it is possible that just as they pass simple associative word learning tasks at the same age as monolingual infants, bilingual infants might also match monolingual infants in the age at which they are able to use phonological differences to guide word learning.

To disentangle these hypotheses, we tested three groups of bilingual-learning infants (see Fennell *et al.* 2007 for more details). In the first study, heterogeneous bilingual infants (English plus some other language) were tested at 14-, 17- and 20-months-of-age. As before, the infants were tested on their ability to associate the minimally different words 'bih' and 'dih' with two different objects. Like the monolinguals, the bilinguals failed at 14-months-of-age to learn similar-sounding words, ruling out the possibility of a bilingual advantage. Unlike the monolingual infants, however, the bilingual infants also failed at 17-months-of-age. It was only the 20-month group

that succeeded in this minimal pair word-learning task. To control for the possibility that bilingual infants, for some reason, have difficulty discriminating similar-sounding consonants even outside of a word-learning task, we tested 14-month-old bilinguals in a simple phonetic discrimination task (Fennell 2005). The bilingual infants succeeded in discriminating 'bih' from 'dih', indicating that simple phonetic discrimination was not the problem. Thus, the results from the first group of bilingual infants indicated a later age of success at minimal pair word-learning.

In our next set of studies, we tested the possibility that the later success of the bilingual infants was not indicative of all bilingual infants, but might be driven by a subgroup of infants, for whom the phonological characteristics of the their two languages rendered the /b/-/d/ distinction particularly problematic in a word-learning task. Thus, we added two homogeneous groups of bilingual infants at 17- and 20-months: a Chinese (Mandarin or Cantonese)-English sample and a French (Quebecois or European)-English sample. These languages possess interesting similarities and differences when compared with English (the common language across the infants). Chinese languages have similar voicing and place of articulation to English for both of the relevant consonants (/b/-/d/). Thus, the Chinese-English bilinguals may find the task easier owing to the commonalities across their languages. French and English have different voicing for both /b/ and /d/ and a different place of articulation for /d/. These differences may make the target phonemes harder to consolidate for the French-English bilinguals, leading to behavioural differences in the task. Despite the varying level of cross-linguistic phonetic differences across the groups, the two homogeneous groups of bilinguals performed like one another, and more similarly to the heterogeneous bilinguals than to the monolinguals. Again the bilinguals were not successful at 17 months. Moreover, in these two homogeneous samples, only the females succeeded at 20 months. Perhaps, the reduction in the between-language variance owing to including homogeneous groups of bilinguals allowed for a subtler picture of bilingual success and failure. The task could be even more difficult than our original sample revealed, and only the girls, who are sometimes more advanced in language development and word learning, were able to succeed.

However, not all studies of minimal pair word-learning in bilingual infants have yielded findings identical to ours. Indeed, in one recent study, bilingual infants appear to have an advantage, at least under some testing conditions. In this work, Mattock *et al.* (in press) tested three groups of 17-month-old infants in a minimal pair word-learning study using the Switch task: French-English bilingual infants, monolingual French infants and monolingual English infants. Rather than using the /b/-/d/ distinction as used in Fennell *et al.* (2007), Mattock and colleagues tested the infants across multiple experiments on words beginning with /b/ versus /g/ ('bowce' versus 'gowce'). Both French and English have a contrast between /b/ and /g/, but each phoneme is realized slightly differently in each language. The researchers

recorded two sets of tokens from a single highly proficient bilingual speaker. Tokens were pronounced in either an English or in a French manner, which was accomplished by having the speaker embed the token in either an English or in a French carrier phrase.

In the first experiment, bilingual French-English, monolingual English and monolingual French infants were habituated to the word-object pairings with the words produced both in the English manner and in the French manner. In this study, only the bilingual infants succeeded, while both groups of monolingual infants failed. In the second experiment, monolingual French infants were taught the words produced only in the French manner and English infants were taught the words produced only in the English manner. With these more native-like productions, both groups of monolingual infants succeeded. In a final study, French monolingual infants were tested with the English-produced words, and in this case the French infants failed. Mattock and colleagues (in press) interpret these results as suggesting that it is not the case that bilingual infants are generally later relative to monolingual infants in their ability to use phonetic detail to guide word learning (as we argued in Fennell *et al.* 2007)—rather it is that all infants of this age perform best in a minimal pair word-learning task if the words are produced in a way that matches the input they have experienced in their everyday language learning world. Referring to the predictions from the CRL hypothesis, they suggest that in all cases, infants of 17–18 months have difficulty using phonological categories to guide word learning. Exposure to stimuli in the laboratory that match the characteristics of language experienced in the everyday world can lighten the processing load, and facilitate minimal pair word-learning, whereas exposure to stimuli that do not match increases the load, and interferes with successful performance.

One result that complicates this interpretation is that Fennell *et al.* (2007) found no relationship between 17-month-old bilinguals' exposure to English in their everyday environment (as measured by parental report) and their ability to use phonetic detail to guide word learning in the minimal pair switch task. As the stimuli in Fennell *et al.* (2007) were produced by an English speaker, then based on Mattock *et al.*'s interpretation, one would predict that bilingual infants with greater exposure to English and thus greater English dominance would be more likely to succeed on the task than those infants who were not English-dominant. However, no such relationship was found. Taken together these studies suggest that for bilingual infants, and perhaps even for monolingual infants, although an abstract phonological category might indeed be beginning to appear by 17–18 months, it does not yet work as efficiently to neutralize the phonetic variation that is irrelevant to a word-learning task as it does in adults.

(c) *Accessing phonological detail in recognizing meaningful words*

An ability to recognize already learned words is equally important to learning them in the first place. Just as in

word learning, infants need to apply fine-grained phonological sensitivities to the task of word recognition. To assess word recognition in infants, researchers often use a two-choice (Golinkoff *et al.* 1987) or 'looking while listening' (Fernald *et al.* 1998) procedure. In this procedure, infants are shown pictures of two side-by-side objects, and are then presented with a word that labels one of the objects. To investigate how infants apply phonetic sensitivities to word recognition, infants hear either a correct label or a mispronunciation of that label. For example, the display might contain both a doll and a car, and the infant hears either 'Baby. Can you find the baby?' or 'Vaby. Can you find the vaby?' In this task infants tend to look at the doll more than the car in response to both 'Baby' and 'Vaby', but the effect of mispronunciation is seen either by shorter looking time and/or by a longer latency to orient to the labelled object (Swingley & Aslin 2000, 2002; Swingley 2007). These studies provide convincing evidence that phonetic detail is available in the representation of known words.

In a recent study, Ramon-Casas *et al.* (2009) showed that word recognition is specific to phonetic contrasts that have phonemic status in the native language. When tested on mispronunciations that involve a vowel distinction that is used in Catalan but not in Spanish (/e/–/E/), Catalan 18-month-olds showed an advantage for the correctly pronounced words over the mispronunciations, while Spanish-learning infants responded identically to both correct and mispronounced versions. These results suggest Catalan-learners represent words in a way that distinguishes between the /e/ and /E/ vowels, while Spanish-learners' representations make no such distinction. To investigate whether bilingual children represent words with the same degree of specificity as monolingual Catalan-learners, and hence use the /e/ and /E/ phonetic categories in word recognition, the authors tested bilingual Spanish–Catalan infants at the same age as the monolinguals had been tested. At 18 months, bilingual Spanish–Catalan children performed like the Spanish monolinguals, as a group showing a similar response to the correctly pronounced and mispronounced words, although there was some suggestion that the Catalan-dominant infants were more sensitive to the mispronunciation than Spanish-dominant infants. A follow-up study tested a group of three-year-old bilinguals. Here, Catalan-dominant children showed a pronounced advantage for the properly pronounced word, whereas the Spanish-dominant bilingual children did not. These findings are similar to reports with adult Spanish–Catalan bilinguals wherein more time, or more information (in a gating task) is required for lexical use of a phonetic distinction that is phonemic in only one of the languages (Pallier *et al.* 2001).

These results are akin, in some respects, to those reported by Fennell *et al.* (2007). Both sets of studies converge on the suggestion that bilingual infants may require a longer period of learning in order to establish functional phonological representations in each of their languages. Perhaps, as suggested by the work of

Mattock and colleagues (in press), the reliance on stable, phonological representations emerges more slowly in the bilingual not because of bilingualism *per se*, but rather as an adaptive response to greater variability in the input speech heard. This interpretation is consistent with the evidence that even monolingual infants are easily thrown off in their use of phonological categories if an indexical cue (i.e. speaker identity) is changed between training and test (Hollich 2006).

(d) *Conceptual development underlying word learning in bilinguals*

Conceptually, infants need some assumptions and/or heuristics to facilitate the inductive word learning problem (Quine 1960). Candidates that have been identified include early understanding that count nouns refer to whole objects (Markman 1991), extend to members of a class (Golinkoff *et al.* 1995), and are likely to mean something different from any other count noun in their vocabulary (Markman & Wachtel 1988; Mervis & Bertrand 1994). Some studies have suggested that, because of the task of learning words in each of their languages, young bilinguals may differ in the development of word-learning heuristics (Davidson *et al.* 1997; Davidson & Tell 2005), although other studies have found few differences between monolinguals and bilinguals (Frank & Poulin-Dubois 2002). Recent research in our laboratory has established that the number of languages experienced in the input does, however, affect the emergence of initial word-learning biases. Specifically, we examined the emergence of the disambiguation bias (the tendency to link a novel noun to a novel object) and found that although this heuristic is robust in monolingual infants aged 18-months, it is less so in bilingual infants and not evident at all in infants growing up with three languages (Byers-Heinlein & Werker 2009). These findings suggest that either experience with single-noun single-object mappings is necessary for disambiguation to emerge, a condition specific to monolingual infants, or that this word-learning heuristic is in place prior to word learning, and that experience with translation equivalents (cross-language synonyms) interferes with its expression. In either case, these findings show an effect of exposure to multiple languages on the first steps in word learning.

7. CONCLUSION

The basic task of language acquisition in monolingual and bilingual infants is the same: to become a proficient communicator in the language or languages that surround them. To do so, learners must navigate a complex linguistic environment, particularly in the case of bilingual infants. In this paper we reviewed some of the first achievements in bilingual language acquisition, and how these early building blocks come together to facilitate ever more complex language tasks. For bilingual infants, a fundamental first step is the discrimination and separation of the two languages, so that representations of sounds and

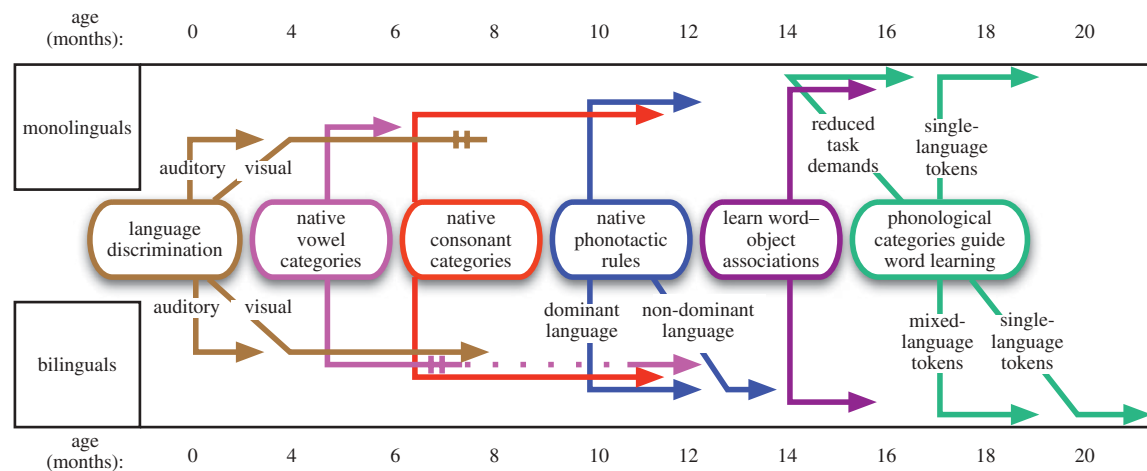


Figure 3. A summary diagram showing the age at which monolingual and bilingual infants show success in a variety of speech-processing and word-learning tasks.

words can be built for each. Just like monolingual infants, bilinguals must then learn the phonetic inventories of their native languages, and learn to attend to those distinctions that are meaningful, and ignore those that are not. For the bilinguals, some distinctions may be phonemic in one language and not in the other, and these types of distinctions might therefore be pulled apart later in development than they are in the monolinguals (e.g. the Catalan /e/–/E/ distinction which is not realized in Spanish; Bosch & Sebastián-Gallés 2003). In other cases, a distinction may be maintained as the difference between the realization of a particular phoneme in one language versus its realization in the other (e.g. the French and English /d/ sounds; Sundara *et al.* 2008). Monolinguals and bilinguals likely use the same mechanisms to refine their perceptual sensitivities, but as a result of the more complex learning environment, phonetic development may at times unfold slightly differently in the bilingual context as opposed to the monolingual context. Further, how phonetic development proceeds in bilinguals might depend on the similarities and differences in phonetic repertoire between the bilinguals' two languages.

When phonetic sensitivities are applied to word learning, we again see a slightly different unfolding of abilities between monolinguals and bilinguals. On basic word-learning tasks, monolinguals and bilinguals show identical abilities (Byers-Heinlein *et al.* submitted). Yet, in both word learning and word recognition tasks that probe bilinguals' ability to apply phonetic sensitivities, bilinguals succeed at a later age than monolinguals (Fennell *et al.* 2007; Ramon-Casas *et al.* 2009). At the same time, other studies using similar tasks have shown that bilinguals can outperform monolinguals (Mattock *et al.* in press). These seemingly contradictory findings may eventually be understood through the consideration of the demands required by bilingual acquisition. On the one hand, bilinguals may be later to form stable phonological representations, thus postponing their ability to succeed on some minimal-pair tasks. On the other hand, bilinguals likely experience a world with considerably more phonetic variability than

monolinguals. This might result in broader phonetic categories in the bilingual, hence greater caution in applying summary phonological representations might prove to be a valuable adaptation in the bilingual context. Further, bilinguals might experience a more complex language environment, leading to greater processing demands particularly as they try to discriminate and separate their languages. Open questions remain as to when and how bilinguals can apply their ability to discriminate their two languages to the task of minimal pair word-learning. Above we present figure 3 summarizing these results, showing the relative timing of success on various tasks in monolingual and bilingual infants.

Language dominance is another factor which must be carefully considered in the case of bilingual language acquisition. Dominance may influence how bilingual infants interpret different types of language information from an early age, including tasks that assess early phonotactic knowledge (Sebastián-Gallés & Bosch 2002) and word recognition (Ramon-Casas *et al.* 2009). Differences in infant brain responses to words from the dominant versus non-dominant language (Conboy & Mills 2006) hint at the neural differences which may underlie these dominance effects, supporting the idea that the dominant language may be fundamentally different and privileged. These results strongly suggest that the issue of language dominance should always be considered, even in the earliest stages of bilingual development. Further, caution should be taken when gauging the dominant language of a bilingual at any given point in time, as changing life circumstances (especially in younger bilinguals) can shift language dominance throughout development.

On the scale of language milestones, and in terms of the development of fundamental learning mechanisms, monolingual and bilingual acquisition differ little. Yet, in this paper we have illustrated how interesting differences can occur between monolinguals and bilinguals in the microstructure of acquisition. The study of bilingual acquisition at both macrostructure and microstructure levels can yield differing yet complementary perspectives on language acquisition.

At the macrostructure scale, similarities between monolinguals and bilinguals attest to the robustness of the infant's ability to acquire language, and to the flexibility of our biological endowments which support acquisition. At the microscale, differences between monolinguals and bilinguals can give insight into the detailed workings of mechanisms of acquisition, and reveal how the developing mind adapts to radically different types of early language environments and learning challenges.

ENDNOTE

¹In French, the distinction is between a prevoiced and a voiced unaspirated consonant, whereas in English it is between a voiced unaspirated versus a voiceless aspirated consonant.

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