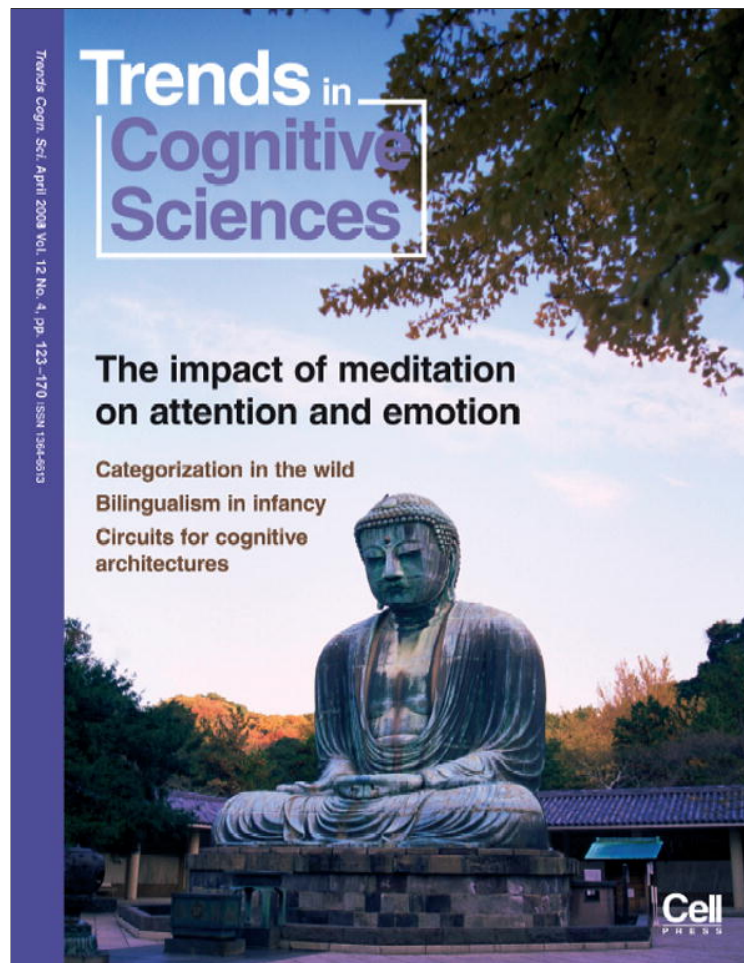


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# Bilingualism in infancy: first steps in perception and comprehension

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**Many children grow up in bilingual families and acquire two first languages. Emerging research is advancing the view that the capacity to acquire language can be applied equally to two languages as to one but that bilingual and monolingual acquisition nonetheless differ in some nontrivial ways. To probe the first steps toward acquisition, researchers recently have begun to use experimental methods to study preverbal bilingual infants. We review the literature in this growing field, focusing on how infants growing up bilingual use surface acoustic information to separate, categorize and begin to learn their two languages. These new data invite the expansion of standard linguistic theories to account for how a single architecture can support the acquisition of two languages simultaneously.**

In many communities, growing up bilingual is the norm rather than the exception. An extreme example is the Tukanan people of the northwest Amazon, where linguistic exogamy (marriage outside the linguistic community) is the rule, and as a consequence, all children grow up bilingual as a matter of course [1]. Indeed, all around the world there are children who successfully learn two languages simultaneously from birth. Here we take the stance that the human mind is as prepared to acquire two first languages as it is to acquire one. However, current theories of language acquisition are concerned primarily with explaining monolingual acquisition or acquisition of a second language after the first is established and fail to address simultaneous bilingualism. To understand the particulars of bilingual acquisition and to provide the information necessary for comprehensive, generalizable theories of language acquisition, research on bilingual acquisition is essential.

Below we review the newly emerging experimental research on the first steps of language acquisition in bilingual infants. By bilingual infants, we mean those children up to age 2 who have been raised in a bilingual environment from birth. Case studies on children's early productions have shown that children raised in a bilingual environment acquire their two languages simultaneously, and that in many (although not all) respects, their first words and sentences are similar to those of monolinguals [2,3]. Yet, it is now known that language acquisition begins in perception long before the production of the first word. Beginning with the pioneering work of Sebastián-Gallés and Bosch [4] on bilingual Spanish-Catalan infants in Barcelona, researchers

have increasingly turned to cognitive approaches and experimental methods to study bilingualism in preverbal infants and to probe competencies in older infants that cannot be studied from productions. These methods have already contributed to a better understanding of how language acquisition proceeds so rapidly in monolinguals despite imperfect and incomplete input. Indeed, there is increasing evidence that perception of the surface characteristics of language is instrumental in bootstrapping acquisition of the rule-governed aspects of language, including phonology, morphology, syntax and vocabulary. Below, we turn to the new area of experimental studies of acquisition in preverbal bilingual infants, to examine how these same core foundations play out in a bilingual context.

We review the literature on how bilingual infants discriminate and separate their languages, and the steps they go through in establishing the sounds, words, grammar and social usage of each of their languages. Much of the existing work on early bilingualism was designed to address theoretical issues specific to bilingual acquisition, such as language separation, while other work has attempted to address broader issues, including the contribution of age versus amount of experience to the process of acquisition. We are hopeful that our review will set the stage for even closer links between research and theory on bilingual acquisition.

## Language discrimination

Language discrimination is an essential task for the bilingual infant. Infants born into a monolingual home need to treat all the speech they hear or see as comprising a single language, whereas bilingual infants need to distinguish and separate speech input into two languages. Even in the one-person-one-language context, the infant needs to determine which differences between speakers are characteristics of the individual speaking and which are characteristics of the language they are using and then use this information in interactions with new speakers (Box 1). It was once widely believed that bilingual children begin acquisition with a default assumption that all language input is part of a single language and that they only separate their languages after establishing an initial lexicon and syntax [5]. Although there is ample evidence that a bilingual's two languages do influence each other [6], there is also increasing evidence, which will be reviewed below, that bilingual infants commence the process of language acquisition by separating the languages from the start [7–9].

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### Box 1. Language mixing in early bilingualism

Parents considering exposing their children to two languages early in life are sometimes concerned that their child will become confused and/or will experience a language delay. Part of this concern arises owing to the common phenomenon of code mixing, whereby children mix words in two languages across a single utterance or situation. As will be noted below, code mixing does not imply language confusion. Nonetheless, some parents of bilingual children adhere to a strict one-person-one-language policy in an attempt to minimize confusion.

There is little evidence to suggest that the one-person-one-language approach is advantageous, compared with other types of bilingual exposure. There also is little evidence to support the claim that early bilingualism leads to language confusion and/or delay in language acquisition. Indeed, all estimates suggest that the incidence of language disability is equivalent in bilingual and in monolingual children [53], and bilingual children pass language milestones at an age similar to monolinguals [54–56].

Rather than indicating confusion, research with young children has suggested that code mixing might reflect a child's attempt to communicate given limited linguistic resources. Children often seem to use words from a nontarget language when they do not know an appropriate word in the target language [57]. Moreover, code mixing in children is better characterized as rule governed rather than haphazard, and the rules that children's mixing follow are similar to those that characterize adult mixing [58].

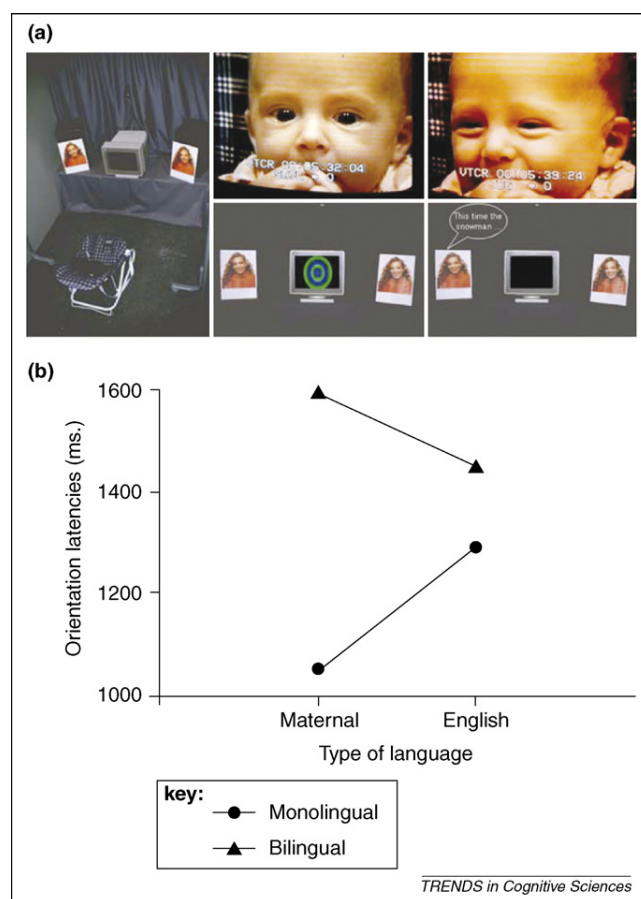
Other studies of young bilinguals have shown that even when they produce mixed utterances, bilingual children do show sensitivity to the language choice of their interlocutor. Two-year-old bilingual children reliably increase the proportion of words from a given language to match the language used by an interlocutor, either a stranger or a parent with whom that language is normally spoken [59,60]. Young bilingual children also are able to match their rates of code mixing to the rate modeled by an adult interlocutor [61].

The majority/minority status of the language also interacts with language dominance to influence the language choices of young children. A study of bilingual French-English 3- and 4-year-olds in a setting where French was the minority language revealed that English words were used in a French context more often than French words were used in an English context. Moreover, there was an interaction with language dominance. French-dominant children were more successful at using each of their languages appropriately when required, whereas English-dominant children showed more code mixing when speaking in a French context [62]. All of these findings suggest that instead of indicating confusion between the two languages, there are systematic factors that account for bilingual children's code mixing.

One source of information available to bilingual infants for distinguishing their two languages is the surface phonetic characteristics that differ among languages. A key characteristic that distinguishes languages is rhythm [10]. Roughly speaking, languages can be characterized as stress-timed (e.g. English, German), syllable-timed (e.g. French, Spanish) and mora-timed (e.g. Japanese). These rhythmical categories have quantifiable acoustic correlates [11]. Newborn infants can discriminate languages from different rhythmical classes but cannot discriminate languages from the same rhythmical class [12–14]. Sensitivity to differences within the same rhythmical class improves rapidly, such that by 4–5 months of age, monolingual infants can discriminate their native language from another language within the same rhythmical class but, importantly, cannot discriminate two unfamiliar languages from the same rhythmical class [9,15]. This has led to the suggestion that discrimination of two languages from within the same rhythmical class relies

on knowledge of one language and the resulting ability to notice another language as 'different' [15].

For bilingual infants both of the native languages are familiar. Thus, discrimination of two languages from within the same rhythmical class requires a different kind of processing than a simple decision of 'familiar' versus 'different'. Nonetheless, 4-month-old Spanish-Catalan bilingual infants discriminate Spanish from Catalan as well as monolingual Catalan- and monolingual Spanish-learning infants do [9], suggesting that the 'familiar' versus 'different' distinction is not essential for discrimination for bilingual infants. Moreover, it appears that bilingual infants use a different strategy than that used by monolingual infants to distinguish between a native and a nonnative language. When tested in an orientation latency procedure (Figure 1) on Spanish versus English, monolingual infants showed discrimination by orienting more rapidly to the native language, whereas bilingual Spanish-Catalan infants showed discrimination by orienting



**Figure 1.** The orientation latency procedure. (a) Infants are seated in a small room with hidden loudspeakers located to the left and to the right of the center, with each loudspeaker covered by a picture of a woman's face. Infants are familiarized to one type of stimulus (e.g. Spanish sentences), which is presented randomly to either the left or right loudspeaker. During the test, the infant hears some trials with new stimuli of the same type as during familiarization trials (new Spanish sentences) and other trials with new stimuli of a different type (English sentences) in a consistent left–right configuration. Reprinted, with permission, from [82]. (b) The time that it takes the infant to orient toward the sound during each type of test trial is measured and compared. Both monolingual (either Catalan or Spanish) and bilingual Catalan–Spanish infants show different orientation latencies to the maternal language and the unfamiliar language (English). However, monolinguals discriminate by orienting faster to the maternal language, whereas bilinguals orient faster to the unfamiliar language. Reprinted with permission from [4].

more rapidly to English, the unfamiliar language [4]. The authors speculate that in the case of a familiar language, bilingual infants first attempt to identify which of their two languages is being spoken before orienting, thus increasing the latency of their response.

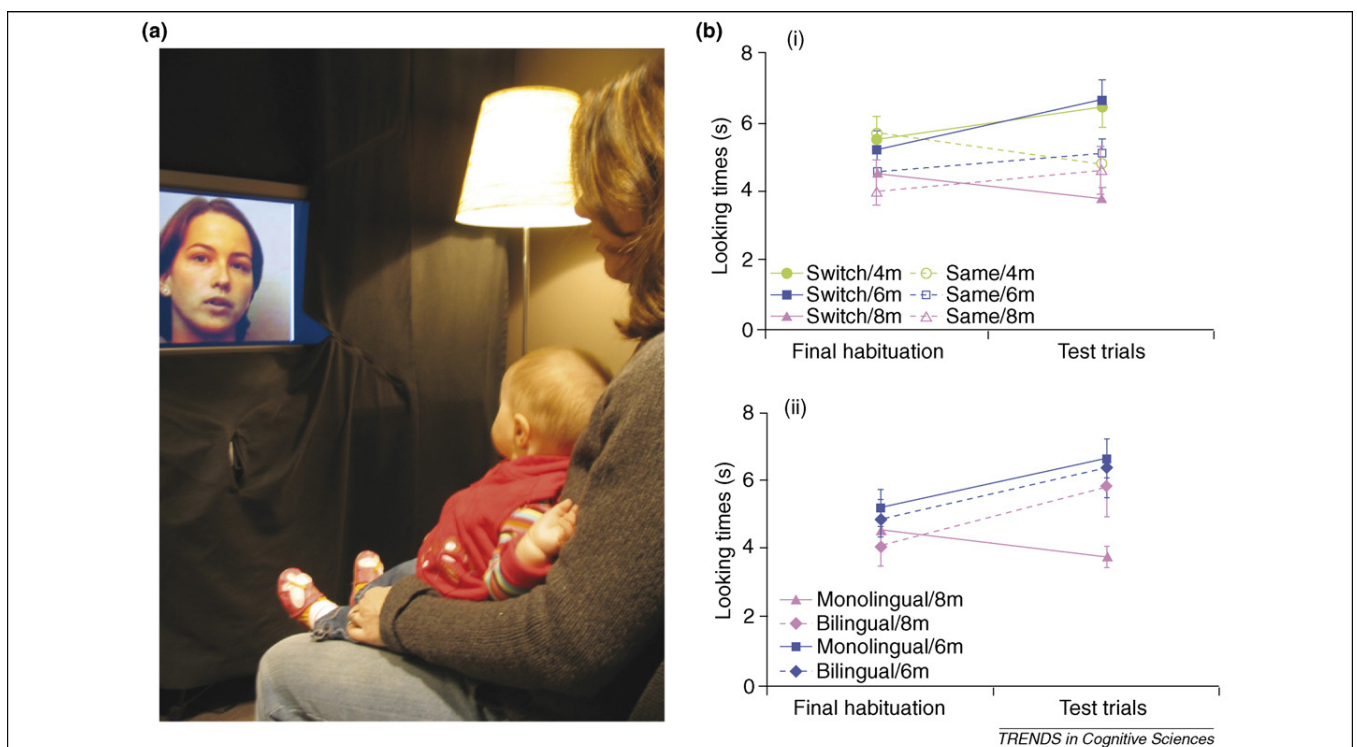
Discriminating languages by using rhythmical cues could undoubtedly help the bilingual infant keep her two languages apart. But rhythmical differences could play an even greater role in language acquisition. Analyses suggest a correlation across the world's languages between surface rhythmicity and underlying syntax. For example, languages that are stress-timed are more likely to have a subject-verb-object word order, whereas languages that are syllable- or mora-timed are more likely to have a subject-object-verb order [16,17]. Thus it has been hypothesized that surface rhythm could bootstrap acquisition of syntax [18]. This raises the possibility that an ability to separate languages on the basis of rhythmicity could assist the bilingual infant in acquiring two separate grammars.

Much of the information that distinguishes one language from another auditorily also is present in the visual cues on talking faces in the form of different mouth gestures, rhythm and overall facial movement [19,20]. Our laboratory, in collaboration with the Sebastián-Gallés group, recently showed that infants as young as 4 months can discriminate two languages from different rhythmical classes (French from English) just by watching silent

talking faces. Yet the course of development again differs between monolingual and bilingual infants. Although successful at 4 and 6 months of age, monolingual English infants fail to discriminate the languages at 8 months, whereas bilingual French-English infants continue to succeed at this age [21] (Figure 2). Early bilingual experience allows infants to maintain sensitivity to language differences in visual speech, a possible additional cue for language separation.

### Setting up sound systems

The smallest unit in language is the phonetic segment, the individual consonant and vowel sounds that comprise syllables and words. Very young infants are able to discriminate many consonant and vowel distinctions that are used in the world's languages, but sensitivity to nonnative distinctions declines over the first year of life [22] while discrimination of native distinctions sharpens [23]. Converging evidence from studies of maternal speech [24,25], artificial language learning studies with infants [26,27] and computer modeling studies [28,29], suggests that infants use distributional regularities in the input to learn their native phonetic categories. For example, unlike English, Japanese makes a distinction between short and long vowels. This is evident as a bimodal distribution of vowel lengths in Japanese, but not English, mothers' speech [24]. This type of distributional information could



**Figure 2.** Discriminating languages by watching silent talking faces. (a) Three bilingual women were filmed, while reciting sentences from a children's story either in French or in English. Infants were seated on a parent's lap and watched a television screen. In each trial, a (silent) film clip of one of the women reciting a different sentence was shown, with the order of presentation of the three women constant across each set of three trials. Infants were shown sentences from the same language (either French or English) until they habituated; their looking time dropped to 65% of what it had been for the first block of three trials. After habituation, infants were shown blocks of three trials comprising the same three women in the same order but in two conditions. In the control condition the women each recited a new sentence in the familiar language. In the experimental condition the women each recited a new sentence in the other language. (b) Evidence for discrimination between habituation and test was indicated by a recovery in looking time at the display. As shown above, infants did not recover significantly in the control conditions. In infants aged 4 and 6 months the monolingual English infants recovered to the change in language, but in infants aged 8 months, only the bilingual French-English infants showed a recovery. From Weikum, W.M. *et al.* (2007) Visual language discrimination in infancy. *Science* 316, 1159. Reprinted with permission from AAAS.

allow Japanese infants to infer two categories and English infants only one [26,27].

Bilingual infants simultaneously encounter phonetic segments from two languages, each with its own distribution. Fluent adult bilinguals who acquired both of their languages from birth can discriminate phonetic distinctions in each of their languages, although they often perform better in their dominant language. However, if they acquired one language after the other (sometimes called sequential bilinguals), there are phonetic distinctions for which they show poorer discrimination in the second language [30,31].

There are still only a handful of studies of the process by which bilingual infants establish the phonetic categories of each of their languages. One study of Spanish-Catalan bilingual infants suggested that bilingual infants might temporarily merge two vowel categories at 8 months while successfully discriminating the vowels at younger and older ages (4 and 12 months) [32]. An initial study of French-English bilinguals indicated that consonant perception might show a similar pattern, whereby consonant categories across the two languages were merged at age 10–12 months before separating again [33]. However, in a subsequent analysis with a larger sample, infants showed discrimination of the consonant boundaries in both of their languages throughout the first year of life [34]. Similarly, bilingual French-English infants maintain the ability to discriminate a French/d/from an English/d/[35]. These studies show that although sometimes showing a unique developmental pattern, bilingual infants are able to discriminate vowel and consonant distinctions in each of their languages by the end of the first year of life. The complexity of the pattern of results could reflect the variability among bilinguals as a function of different amounts of exposure to each language (Box 2).

Even as infants maintain discrimination of phonemes in the native language, they also must learn the rules for allowable sequences of these phonemes (the phonotactics). Monolingual infants can use both absolute frequency information [36] and distributional statistics to learn the phonotactic patterns of the native language [37,38]. Recent evidence indicates that bilingual infants show a different pattern of phonotactic learning from monolinguals. When tested at age 10 months, Spanish-Catalan bilinguals who were dominant in Catalan showed phonotactic preferences similar to same-aged Catalan monolinguals, whereas the performance of Spanish-dominant bilinguals was between that of Catalan and Spanish monolinguals [39]. These results suggest that even among bilinguals, differences in the amount of exposure to each language can have consequences for language learning.

### Word recognition and word learning

Word learning is a multifaceted task even for the monolingual infant. Among other things, it involves pulling a word out of the stream of speech, learning its phonetic form, linking the form to meaning, assigning it to a grammatical class and representing information about the word in the mental lexicon. The bilingual child has to apply these processes to two different languages and must ultimately establish two separable mental lexicons (see Box 3

### Box 2. Challenges in bilingualism research

A challenge facing bilingualism researchers is the heterogeneity that can exist among bilingual groups and bilingual individuals. Differences among bilinguals, which can be difficult to quantify, must be taken into account before claims about the nature of bilingualism or bilingual development can be made and before results from a single bilingual population can be generalized to other groups.

**Language pairs.** Each pair of languages poses a unique learning problem because languages can be similar or different on phonetic, phonological, syntactic and other levels. Language pairs can even differ in modality, for example, when a signed and a spoken language are learned simultaneously [63].

**Contexts of exposure.** Some children interact with a variety of bilingual adults, whereas other infants' exposure approximates a one-person-one-language structure. The influence of these different contexts of exposure on development has yet to be systematically investigated.

**Social status of the languages.** The two languages being learned by a bilingual can differ in social status. Children almost always acquire the majority language (that of the surrounding community), but the minority language is at risk to not be learned or to be later forgotten [64,65].

**Confound with socioeconomic status.** Within a given geographic area, bilingual individuals are sometimes of a systematically different socioeconomic status (SES) than monolinguals. This confound between bilingualism and SES could account for some differences seen between monolinguals and bilinguals, including both reported advantages and disadvantages for bilinguals [66,67].

**Language dominance.** Most bilingual adults have one language (the 'dominant' language) in which they perform best across a variety of language tasks [68,69]. Infants too can have a dominant language, but measuring dominance in infancy can be difficult, especially in the preverbal stages. An infant's dominant language often is defined as the one to which the infant has more exposure (frequently the maternal language) [4]. Once a child begins to speak, measures such as mean length of utterance (MLU) [70] and number of words understood or produced [71] can be used to quantify dominance.

**Age of acquisition.** Although this review focuses primarily on bilinguals who acquired their two languages from birth, many bilinguals acquire their two languages sequentially. Age of acquisition influences proficiency in the second language [72] such that individuals who learned two languages in childhood generally show better proficiency than those who learned their second language in adolescence or adulthood [73,74]. There also can be differences among highly proficient adult bilinguals who acquired both of their languages during childhood. Those adults who had simultaneous bilingual exposure from birth perform better in some tasks than do those sequential bilinguals whose exposure to a second language began after birth but before age 3 [75].

for a discussion of measuring vocabulary size in bilinguals). Further, the language experience of bilingual infants is split between their two languages, resulting in less exposure to the words and sounds of each language relative to monolingual infants. The experimental research to date indicates both similarities and differences between monolingual and bilingual infants in these first steps in word learning.

As reviewed above, infants have established native phonetic categories by the end of the first year of life. However, these categories are not necessarily immediately available to guide word learning. When tested in a habituation 'switch' procedure in which nonsense words are paired with novel objects (Figure 3), monolingual infants aged 14 months learned to associate two dissimilar words such as 'lif' and 'neem' to two different objects [40] but

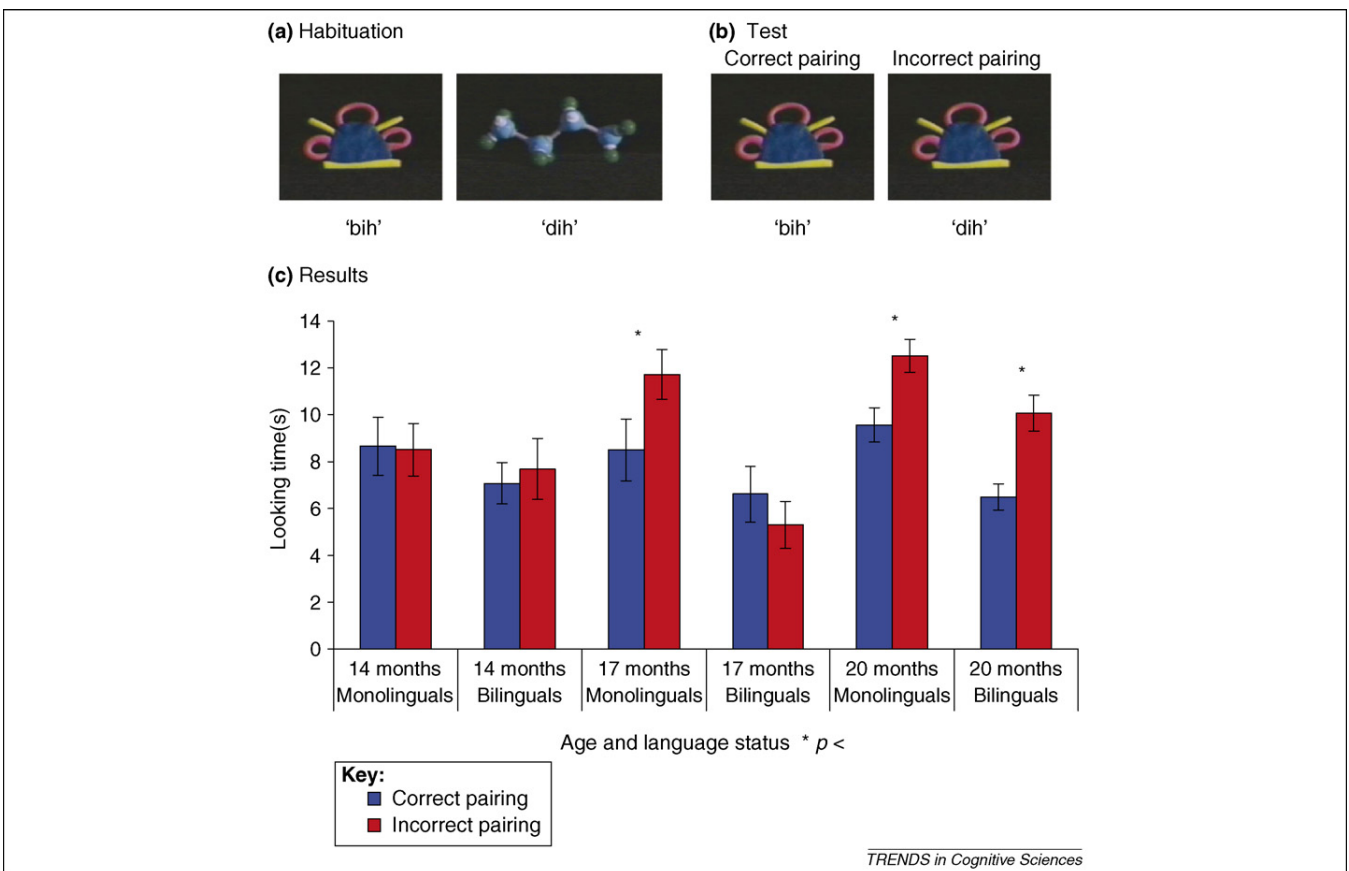
**Box 3. Measuring vocabulary in young bilinguals**

Researchers assessing vocabulary development in infants and toddlers often use the MacArthur-Bates Communicative Inventories (MCDI), which use parental checklist forms to measure both receptive and productive vocabulary [76]. This original form was developed in English, but adaptations are now available in a wide variety of languages. Although no versions of the form have been developed specifically for infants growing up bilingual, researchers studying bilinguals typically employ two forms concurrently (one for each language of exposure), which can either be filled out by the same individual or different individuals depending on who provides input to the infant in a particular language. This approach to measuring bilinguals' early vocabularies has been shown to have good validity in at least one sample of bilingual infants, as parental report was correlated with performance in laboratory language tasks and records of spontaneous speech [77]. The relative vocabulary development in each language seems to be closely related to the amount of input in each of the languages [78].

Using such parental checklists to determine the vocabulary size for a bilingual infant is not as straightforward as the analogous measure for a monolingual. For a monolingual infant, each nameable concept is usually linked to a single word. However, bilingual infants typically understand and produce translation equivalents (crosslanguage synonyms) from an early age [79,80]. As a result, bilinguals' total vocabulary size (total number of words) is different from their total conceptual vocabulary (the total number of nameable concepts) [56]. It remains unclear which of these measures is most comparable to simple vocabulary size measured in monolingual infants.

failed if the words differed in only their initial consonant, such as the words 'bih' and 'dih' [41,42]. Although simplifying the task can allow monolinguals to learn minimally different words at age 14 months [43], they do not succeed at the standard version until around 17 months. Infants growing up bilingual are faced with the task of learning two sets of phonological categories as well as two sets of linguistic labels. In a recent study testing three groups of bilingual infants (a heterogeneous bilingual group, a French-English bilingual group and a Chinese-English bilingual group), a different developmental pattern was found than had been reported for monolingual infants. As might be predicted given the greater challenge faced by the bilingual infants, they did not succeed in learning similar-sounding words until around 20 months of age [44] (Figure 3).

To our knowledge there are only two studies to date testing bilingual infants' recognition of familiar words. Before they necessarily know the meaning of the words, bilingual Welsh-English infants show implicit recognition of frequent over infrequent words in each of their languages within the same age range as monolingual infants. In both a behavioral task and ERP (event-related potential) recordings from the scalp, bilingual Welsh-English infants showed recognition of frequent words at 10 months of age, whereas the monolingual English



**Figure 3.** Testing word learning in infants. (a) Infants are habituated to repeated pairings of words and objects. (b) During the test infants are shown one trial with a correct pairing and one trial with an incorrect pairing. (c) Infants show that they have learned the two pairings by looking longer at the incorrect pairing than at the correct pairing. Monolinguals are able to notice the incorrect pairing as young as 17 months of age, whereas bilinguals notice the incorrect pairing from 20 months of age. Adapted with permission from [44].

## Review

comparison group showed recognition at 9 months and the monolingual Welsh group showed recognition at 11 months. The fact that the bilingual response fell within the age range bracketed by the two monolingual groups suggests that any small differences in age of recognition that exist must be driven by something other than bilingualism *per se* [45].

By 18–20 months of age infants recognize not only the form but also the meaning of words. Studies with monolingual infants at this age reveal that the ERP to known words is lateralized and seen most from electrode sites over the language areas of the brain in the left hemisphere [46,47]. A recent study with Spanish-English bilingual infants aged 19–22 months revealed characteristic ERPs to known words in both languages, but the ERPs to known words from the dominant language were different in form and latency from the ERPs to known words from the nondominant language and were strongly lateralized only in response to known words from the dominant language [48]. The finding of different ERPs to known words in the dominant versus nondominant language within the same infant is taken as evidence that monolingual and bilingual infants differ in brain organization. This is the first study with bilingual infants to address the challenging question of how the same neural systems can be used to process two languages while simultaneously marking them as different (see [49–51] for work with adult bilinguals).

Only recently have bilingualism researchers begun to use experimental tasks of word production to assess different theories of lexical organization in bilingual infants. One illustrative study used a nonsense-word repetition task to probe the organization of the bilingual lexicon. At 30 months of age, bilingual French-English toddlers performed similarly to monolingual French infants when repeating words in a French context but similarly to monolingual English infants when repeating words in an English context. The two distinct pronunciation patterns seen within the same children are most parsimoniously understood as revealing two separate phonological systems, one for each language [52].

### Conclusion

Infants growing up bilingual face the remarkable challenge of acquiring two communicative systems simultaneously. In this paper we have reviewed almost all of the published research to date that has employed experimental methods to assess the first steps taken by infant bilinguals as they begin the process of acquiring two languages. From the initial studies that have been conducted, the field has advanced considerably. Early perceptual sensitivities have been shown to assist infants growing up bilingual in discriminating and separating their two languages even before they speak their first word, and numerous studies have suggested that bilingual infants are beginning to build representations for each of their languages within the first year of life. With the growing interest in the topic and the number of experimental studies already underway in different laboratories, rapid progress is anticipated (Box 4).

Researchers studying bilingual acquisition do face continuing methodological challenges such as identifying rela-

### Box 4. Questions for Future Research

- What is the nature of the representation of two languages in the bilingual infant? Studies with adults indicate that the bilingual lexicon, although separable, is highly interactive [81]. What does it mean to have a separable or an interactive representation of each of the languages in the bilingual infant? Can languages be equally well separated if represented in common but ‘tagged’ for language identity?
- How do bilingual infants keep track of statistics (for example, in terms of phonetic distributions) in both of their languages? Can we use artificial language learning manipulations to mimic bilingual input to test specific theoretical predictions about language separation and representation?
- Are different brain areas activated in response to native language input in the bilingual infant in comparison to the monolingual infant? And are the same or different neural systems activated for the two languages in the bilingual?
- How can we incorporate knowledge of simultaneous bilingual acquisition into general theories of language acquisition? How can we design studies of bilingual acquisition to test more fully articulated hypotheses about how the mind learns, represents and applies the rules of two different languages?
- Can indexical cues such as gender and other individual voice characteristics provide support for language differentiation or are they unreliable relative to formal characteristics of the languages themselves? For example, what impact, if any, does exposure to a predominantly one-person-one-language environment have on bilingual development compared to exposure to other types of language environments?
- How can findings on bilingual acquisition be extended to trilingual and multilingual acquisition? Is there a limit to the number of languages that can be learned in infancy?

tively balanced bilingual infants, quantifying the degree of exposure to each language and designing experimental methods to probe language competence before production of the first word. Because the circumstances of bilingual acquisition vary so widely from one infant to the next, questions still remain as to whether and when it is possible to draw general conclusions about bilingual acquisition and when the conclusions must be restricted to the specific sample tested. The application of experimental research methods allows for more direct comparison of different groups of bilingual infants and hence increases the opportunity to reach generalizable conclusions.

The success of bilingual infants in negotiating their linguistic world attests to the power and flexibility of the developing mind, and suggests that we are as well equipped to learn two languages as we are one. Many of the studies reviewed here indicate that the pattern of acquisition in infants acquiring two languages is very comparable to that seen in monolingual infants. Still, the differences that have been identified in the microstructure and timing of language acquisition have the promise to be very informative about how an identical cognitive architecture adapts to very different language input situations.

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The WHO and six medical journal publishers have launched the Health InterNetwork Access to Research Initiative, which enables nearly 70 of the world's poorest countries to gain free access to biomedical literature through the internet.

The science publishers, Blackwell, Elsevier, Harcourt Worldwide STM group, Wolters Kluwer International Health and Science, Springer-Verlag and John Wiley, were approached by the WHO and the *British Medical Journal* in 2001. Initially, more than 1500 journals were made available for free or at significantly reduced prices to universities, medical schools, and research and public institutions in developing countries. In 2002, 22 additional publishers joined, and more than 2000 journals are now available. Currently more than 70 publishers are participating in the program.

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