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Perceptual foundations of bilingual acquisition in infancy

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Infants are prepared by biology to acquire language, but it is the native language(s) they must learn. Over the first weeks and months of life, infants learn about the sounds and sights of their native language, and use that perceptual knowledge to pull out words and bootstrap grammar. In this paper, I review research showing that infants growing up bilingual learn the properties of each of the their two languages simultaneously, while nonetheless keeping them apart. Thus, they use perceptual learning to break into the properties of each of the two native languages. While the fundamental process of language acquisition is the same whether one or two languages are being acquired, cognitive advantages accrue from the task of language separation, and processing costs accrue from the more minimal input received in each of the two languages. I conclude by suggesting that when there are sufficient cues to which language is being used, the cognitive advantages that accrue from language separation enable the bilingual infant to move forward in language acquisition even in the face of processing costs.

Keywords: language acquisition; bilingualism; infancy; perceptual foundations; review

Introduction

One of the most remarkable feats of human development is the acquisition of language. Children begin understanding individual words by 6 months of age, typically produce their first words before their first birthday, begin combining words into short sentences during the second year of life, and become highly proficient language users shortly thereafter. But these feats would not be possible without prior learning of the perceptual properties of the native language. There is strong evidence to show that by birth infants have perceptual biases that orient them to language[1] and that enable them to discriminate its particulate components, as well as the cognitive machinery to learn the rules and regularities of the language to which they are exposed.[2] Some learning of the properties of the native language is already in place by birth, presumably from prenatal or immediate postnatal exposure.[3,4] Over the next several weeks and months, infants become more and more adept at attending to and optimally processing the properties of the native language, and become less sensitive to variation that is not meaningful in the native language. The ways in which changing perceptual sensitivities and learning machinery operate in tandem to launch acquisition of the native language is an increasingly important area of research. Only with perceptual knowledge of the rhythmical properties of the native language, of the speech sound categories that distinguish one possible word from another, and of the sequences of sounds that are allowable within a word and/or the statistical learning of other cues to segmentation, is a child able to pull out individual words and grammatical structures and map these on to meaning. Research over the past four decades has increasingly taught us just how this achievement unfolds, and how it sets the stage for language acquisition.

But not all children grow up learning just a single language. Indeed, estimates suggest that more than half of the world's population is bilingual, with many of those individuals learning more than one language from birth.[5] The infant who is growing up in a bilingual environment must learn the perceptual properties and rules of two native languages, and ultimately do so without confusing them. Depending on the languages being learned, the child

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has to acquire, for example, the rhythmical properties of each of two languages, the phonetic categories of each language, the phonotactic rules, and the word order, in addition to having two lexical entries for each concept, and in some cases, different conceptualizations of the world.

In this review, I will focus on the perceptual foundations of bilingual language acquisition. As such, I will take the bilingual infant up to the initial stages of lexical acquisition, focusing almost exclusively on infants from birth through 2 years of age (for an excellent review of bilingual language acquisition in toddlers and preschool-aged children, see Genesee & Nicoladis;[6] for earlier reviews of bilingual infants, see Sebastián-Gallés[7] and Werker, Byers-Heinlein, and Fennell[8]).

Infants who acquire two native languages pass the milestones in acquisition at approximately the same ages as do children who are acquiring only a single language (see Box A).[9–12] This is the case whether the two languages are spoken languages, two signed languages, or include both a spoken and a signed language. Many researchers interpret these similarities in rate as indicative of a single, primarily maturationally determined driver toward language acquisition,[12] and argue that the fact that total vocabulary is equivalent, even if smaller in each language in the bilingual, as evidence for the robustness of a common language-acquisition mechanism, even when the input per language is smaller. Others, however, focus on the differences, as in a recent report showing a small but significantly later age of first two-word utterances in bilinguals.[13] They, in turn, argue that considerations of input are important.

Box A

There is a long-standing concern, and one felt by many bilingual families, that if exposed to two languages early in life, children will become confused and mix the languages up in one big language pot. However, although there is some language mixing, there is little evidence of language confusion. Indeed, from the time they begin to acquire their first words, bilingual infants show comprehension and production of translation equivalents (e.g., a Spanish child using "casa" and "house").[90,91] By as young as 2-1/2 years of age, children growing up bilingual are able to actively choose which language to use when speaking to others. They will use language A if appropriate, language B if appropriate, and even switch between the two in a rule-governed way that matches their interlocutors, that is, if in their home environment language switching among active bilinguals is the rule.[92] Moreover, bilingual children this young can repair communication breakdowns caused by nonmatching language.[93] What is interesting is that they only use this kind of language repair when a language mismatch has caused the communication breakdown. In other situations, they try other kinds of repairs.

Although the cognitive machinery for acquiring two languages is essentially the same as that used for acquiring a single language, within this universality, I suggest that differences do accrue from having two rather than only one language of input. Two types of differences will be highlighted. One stems from the fact that in bilingual homes, infants typically receive less exposure to each individual language than in a home where only a single language is spoken. As we will see in this review, this affects both the speed and efficiency of processing, even in infancy. The other difference is one that ensues from having to separate the languages for simultaneous acquisition of two languages, and from having to keep them separate and minimize interference even after both languages are established. The requirement for language separation arguably recruits extralinguistic cognitive resources along with those used in processing and learning the language(s).

It is well documented in the adult literature that bilinguals show both processing costs and cognitive advantages. One processing cost that has been extensively documented is word retrieval: bilinguals perform more slowly and make more mistakes,[14] particularly in speeded tasks, than do monolinguals.[15] Moreover, this processing cost is seen even in the dominant language.[16]

Adult[17–19] and child[20–22] bilinguals show a number of cognitive advantages over monolinguals, particularly in executive functioning[a] (see Ref. 24 for a

[a]In the adult literature, the processing disadvantages are discussed in terms of selection between the two languages (e.g., Marian & Spivey;[23] see Kroll, Dussisas, Bogulski & Kroff[24] for a review) rather than the amount of input.

review). Recent studies have shown that already by 7 months of age, bilingual learning infants also show enhanced cognitive control compared to monolinguals. Whereas both monolingual and bilingual infants can learn to turn toward one type of sound for a visual reward, bilingual infants are better able than monolingual infants to switch and learn to subsequently respond to a different sound.[25,26] By 24 months, bilingual toddlers show advantages in the Stroop task,[27] a standard test of executive function.

Below, I review in detail recent work with infants on the perceptual foundations of bilingual language acquisition. I begin with a consideration of the cues used for language separation, how such cues might bootstrap acquisition, how and when native speech sound categories are established and how this directs word learning, and end with a consideration of whether perception has influenced the cognitive biases that guide word learning. In every case, I first review what we know about monolingual acquisition, and use this as a lens to present work with bilinguals. Although both monolingual and bilingual acquisition are likely equally common and equally natural, comparing one with the other allows a consideration of the possible costs for the bilingual infant of a decreased amount of input in each language, along with the potential cognitive advantages of having to keep the two languages distinct.

Language discrimination and preference

The languages of the world differ on many different properties, with one of the most salient being rhythm. Languages such as English, German, and Czech are described as stress timed, a rhythmic pattern that entails having both strong and weak syllables (e.g., LANguage or SPEcies), relative isochrony from one strong syllable to the next in running speech, vowel reduction in nonstressed syllables, and fairly complex syllable structure, including consonant clusters.[28] Syllable-timed languages such as French, Spanish, and Italian have less syllable-level stress, less complex syllable forms, and relative isochrony from one syllable to the next in running speech (see Ramus, Nespor, and Mehler for one quantification[29]). These rhythmical properties are highly correlated with sentence-level word order,[30] and processing of them has been hypothesized to be the infants' first entry into the grammar of the native language structure. At birth, monolingual neonates can discriminate languages from different rhythmical classes,[31] even when the two languages are unfamiliar. Thus, the ability to discriminate languages based on rhythm seems to be present independent of prenatal listening experience. However, at birth monolingual infants nonetheless show a preference for listening to their native language, thus evidencing an effect of experience.[3]

The ability to keep the two native languages separate, even when they are from the same rhythmical class, emerges surprisingly early in development. Bosch and Sebastián-Gallés[32] were the first to find evidence of language discrimination in young bilingual infants by showing that Spanish-Catalan infants aged 4 months could detect a change, in a habituation task, from one of their syllable-timed native languages to the other. Moreover, although language separation was easy for these infants, they showed equal interest in listening to each of their native languages.

In some situations, the mother may speak only one language, whereas the father or other members of the family speak a different language. But in many cases, the mother has been speaking two languages throughout pregnancy. This again raises the question of how the experience of hearing two languages throughout gestation affects language discrimination and preference. Such experience could, on the one hand, enhance language separation. But on the other hand, it could also theoretically interfere with such separation, and establish a big category of all familiar languages.

To examine this question, we tested rhythmical language discrimination in neonates who had been exposed to two rhythmically distinct languages in utero. We presented both filtered English speech (stress timed) and filtered Tagalog (Filipino) speech (syllable timed) to both infants who had heard only English in utero and to bilingual English-Tagalog neonates whose mothers had spoken both languages approximately equally throughout their pregnancy. We habituated the neonates to one language in a contingent sucking procedure, and then presented them with the other languages. The results were unequivocal: both the English monolingual and the English-Tagalog bilingual neonates robustly discriminated the two languages. In a subsequent test of preference, we found that while the monolingual English-exposed neonates preferred listening to English, the bilingual infants listened to both languages

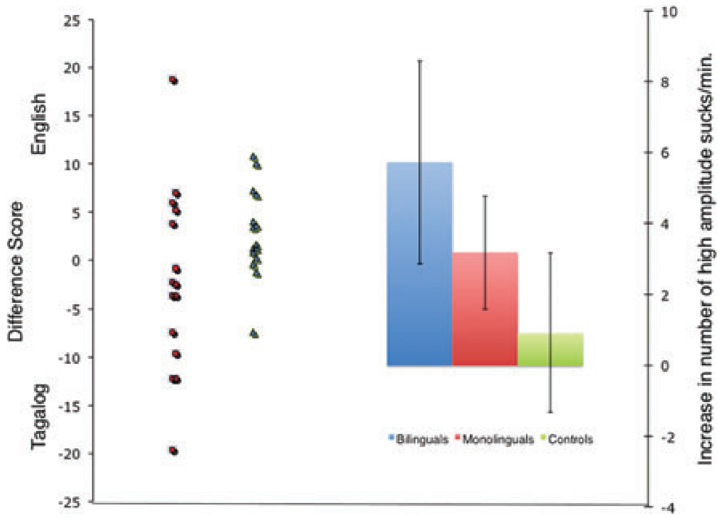

Figure 1. In the high-amplitude sucking (HAS) procedure, an infant's average sucking strength to a pacifier is measured in the first baseline minute. In subsequent minutes, every strong suck is followed by the presentation of a sound. In the preference task (left), in alternating minutes (5 of each), infants had the chance to listen to Tagalog or English. The number of HA sucks per minute was recorded. The English monolingual infants chose to listen more to English (green triangles), but the bilingual English-Tagalog infants listened equally to both (red circles). In the discrimination task (right), neonates were presented with filtered speech from one language (either English or Tagalog) for several minutes until they habituated (the number of HA sucks for 2 consecutive minutes dropped to 50% of the number during the highest 2 minutes). They were then presented with filtered speech from the other language (experimental group) or the same language (control group). Both the bilingual English-Tagalog and monolingual English infants discriminated the change in language as shown by the recovery in number of sucks in the 2 posthabituation minutes, whereas neonates in the control group did not. This figure has been modified from Figure 2 in Byers-Heinlein & Werker.[33]

equally. Hence, although listening experience can shape listening preferences, it cannot overwrite the sensitivity to the rhythmical cues that distinguish the languages. At a practical level, this allows the bilingual infant to pay close attention to both of her native languages while also keeping them apart. At a theoretical level, the continuing experience-independent sensitivity to rhythmical differences leaves the bilingual neonate with the tools required for later using rhythm to bootstrap acquisition of each of her native languages (Figs. 1 and 2).

Recently, we found that bilingual infants can use their sensitivity to the rhythm of language to help figure out its basic word order.[94] The languages of the world differ in their basic word order, with the two most canonical forms being subject–verb–object (SVO), as in languages such as French or English (e.g., "The boy threw my ball"), and subject–object–verb (SOV), as in languages such as Japanese or Turkish. Basic word order is highly correlated with the order of other constituents in the language. SVO languages, for example, tend to have articles (the, an) or pronouns (his, her) in front of nouns and tend to have prepositions (with, from) in noun phrases. SOV languages tend to have the article or pronoun occur after the noun and tend to have postpositions. This results in two kinds of statistics that are perceptually available to prelinguistic infants. First, in SVO languages, frequent words occur before infrequent words, whereas SOV languages have the opposite word order. By 7 months, infants can use frequency to parse an artificial language into phrases.[2,34] Second, prosody is correlated with word order. In VO languages, phrases tend to be trochaic (an unstressed syllable followed by a stressed syllable) and prosodic prominence is indicated by duration.[35] Thus, there is a short-long rhythm to noun phrases. In OV languages, prosodic prominence in a phrase is indicated by pitch, resulting in a high-low grouping in noun phrases. In a recent study, we found that at 7 months, bilingual infants[b] who are growing up in languages with two different word orders (so frequency is not a

[b]The infants were bilingual with English, an SVO language, and an SOV language (Japanese, Korean, Hind/Punjabi, Farsi, or Turkish).

Figure 2. The photo shows a newborn sucking on the pacifier that is connected to a pressure transducer for measurement and stimulus control in the HAS procedure.

predictable cue) are able to use prosody to segment noun phrases (J. Gervain & J.F. Werker, unpublished results). Hence, learning the rhythmic properties of each of their two languages seems to prepare bilingual infants to acquire the word order of each of their two languages. Moreover, they are sensitive to a cue—prosody—that monolingual infants seem not to use.

Language discrimination using visual information

Of interest, heard language is not the only cue bilingual babies use to keep their two languages apart. They also use the cues seen in talking faces. When we speak, the shape of our mouths and the related muscles involved reflect the sounds we are producing,[36] and babies are sensitive to the match between heard and seen speech sounds.[37,38] Moreover, the timing of the opening and closing of the jaw tracks the rhythmicity of the language.[36] We asked whether infants could use their interest in the movement of talking faces to discriminate one language from another. We recorded three bilingual women reciting sentences from a children's story. We then presented these to monolingual infants aged 4, 6, and 8 months in a discrimination paradigm with the sound turned *off*. In each trial, the infant saw one face producing one sentence. Each of the three faces was presented in turn, always producing a new sentence, in subsequent trials until the infant habituated. We then showed the control group of infants the same faces reciting new sentences (as before) in the same language, and showed the experimental group the same faces reciting new sentences, but in the opposite language.

The results were startling. At 4 and 6 months, the monolingual English infants were able to discriminate the change, whereas the infants in the experimental but not control groups showed an increase in looking following habituation. However, at 8 months the monolingual infants failed, no longer paying attention to this cue. We then tested French–English bilingual-learning infants at 6 and 8 months and found that the ability to discriminate their two native languages by watching silent, talking faces was maintained. One can speculate that such sensitivity could be very useful to the bilingual child. Thus, an initial, universal perceptual bias to use visual cues to discriminate languages was attenuated in infants who experienced only a single language of input, and maintained in infants who experienced both, again shows the contribution of both universal beginnings and input-driven processes in preparing the bilingual infants for dual language acquisition.

Cognitive advantages

One question raised from the visual language discrimination work is whether the bilingual French–English infants maintained the ability to discriminate the two languages visually at 8 months because they were familiar with the properties in talking faces that correspond to French versus English, or whether it was because bilingual-learning infants simply pay attention to possible cues in their world that might help them distinguish one language from another. To address this question, we tested another group of bilingual infants at 8 months, Spanish-Catalan–learning infants, on their ability to discriminate visual English from visual French, and compared their performance with monolingual Catalan and/or Spanish infants. As expected, the monolingual infants were unable to discriminate the two unfamiliar languages at 8 months of age. However, the bilingual Spanish–Catalan infants succeeded—even though neither language was familiar.[39] These results suggest that bilingual experience may result in heightened perceptual vigilance, at least in the language domain. Perhaps this initial heightened perceptual attentiveness is an important factor contributing to the emergence of the broader cognitive advantages seen in bilingual infants and adults.

Language context as an anchor

To the extent that rhythmical cues are present, or there is information from talking faces or some other source, it might be increasingly easier for the bilingual-learning infant to separately track and learn about the properties of each of her two languages. Although there is little evidence that adult bilinguals use such cues to help separate each of their native languages,[40] recent work using artificial-language–learning manipulations has shown that in the presence of two voices,[41] or two difference faces,[42] adults can learn to segment nonsense syllables in two different ways. If distinct cues are effective in learning, bilingual learning infants might be able to rely on what they have already learned about each language (e.g., its rhythmical properties or its phonotactics) as a context for separately tracking and learning more properties of each of their native languages.[43] I will return to this theme periodically in this paper.

Establishing and using native phoneme categories

Monolingual infants

The fundamental units that distinguish one word from another, as in the words "bog" versus "dog" versus "fog," or "bog" versus "bag," are called *phonemes*. The languages of the world differ in the number and precise phoneme categories that they use. In English, for example, there are six stop consonants as exemplified in the syllables /ba/, /da/, /ga/, /pa/, /ta/, and /ka/, whereas in Hindi there are 16. Similarly, English makes a distinction between /ra/ and /la/, whereas Japanese has only a single phoneme, which is intermediate between the two. Infants begin life discriminating many of the sounds of the world's languages. Development during the first year of life includes sharpening those sound categories that are used in the native language,[44–46] and "narrowing" perception such that those distinctions not used in the native language cease to be readily discriminated.[47–49]

One focus of current research is to determine what the learning mechanisms are that enable infants to establish their native phoneme repertoire. In my lab, we have examined two broad classes of mechanisms. One involves relatively passive tuning to the most frequently experienced input, for example, by distributional learning.[50] A second that we call "acquired distinctiveness"[51,52] could be a closer route to meaning: the cooccurrence of two phones with two different objects could help pull them apart, whereas the cooccurrence of two phones with a single object could help collapse the distinction.[53]

The speech sound categories established in the first year of life ultimately guide word learning. Thus, by 18 months a child growing up in Dutch, for example, will treat the difference between a long /aa/ and a short /a/ (a distinction used in Dutch) as referring to two different words, whereas a child growing up in English has learned that this distinction is not useful and will treat both pronunciations as referring to the same object.[54]

Bilingual infants

Infants who grow up bilingual need to be able to discriminate the speech sound contrasts used in each of their languages, while also distinguishing a particular sound in one language from that in the other. Research shows that they do this remarkably well: by the end of the first year of life, they show robust discrimination of the speech-sound distinctions in each of their two native languages.[55–57] Moreover, by this age infants also discriminate the same phone me as used in each of their languages. For example, at 10–12 months, French–English bilingual infants can discriminate a /d/ pronounced with a French accent from one pronounced with an English accent.[58]

Impact on speed and efficiency of processing

Although bilingual infants do establish two sets of phonetic categories, the timing of a robust change from "universal" to "native listening" might be different. In the first experimental paper testing bilingual phonetic discrimination, Bosch and Sebastián-Gallés[57] compared Spanish and Catalan monolingual-learning infants to Spanish–Catalan bilingual infants on their ability to discriminate the /e/-/E/ (as in the English words "late" versus "let") distinction that is used in Catalan but not in Spanish.[57] As expected, at 4 months of age, infants in all three language groups discriminated the distinction, and by 8 months of age, while the Catalan monolingual infants maintained discrimination of their native distinction, the Spanish monolingual infants were no longer successful. Surprisingly, however, the Spanish–Catalan bilingual infants also failed at

8 months, even though they were hearing the distinction in one of their native languages. They succeeded again at 12 months, leading to the suggestion that there may be a temporary delay in bilinguals as they traverse the path of establishing two sets of native phonetic distinctions while also keeping them apart. Similar results of a period of potential confusion in bilingual infants have been reported for other phonetic contrasts,[59,60] and even with older bilingual infants.[61]

The first explanation for these results was based on the notion of distributional learning. There is an /e/-/E/ distinction in Catalan but only an /e/ vowel in Spanish (close to, but not exactly like the Catalan one, and overlapping somewhat with the Catalan /E/). Hence, a Spanish–Catalan bilingual might hear so many more /e/ than /E/ vowels, and with some of the /e/ vowels overlapping the /E/ category, the distinction between /e/ and /E/ could be temporarily swamped.[60] Alternatively, there are many cognates in the two languages (similar sounding words that mean the same thing, as in the Spanish "pera" and the Catalan "pEra," both of which mean "pear"—also a cognate in English). Thus, if acquired distinctiveness plays a role in learning native phonetic categories,[53] the presence of cognates referring to the same object in each language could provide conflicting information to the bilingual learner.[60,62] (For a more in-depth review and a slightly different argument, see Ref. 63.) Relatively, it has been shown that bilingual infants whose two languages are from different rhythmical classes are able to discriminate the /e/-/E/ distinction at 8 months, even when tested in a procedure similar to the one in which same-aged Spanish–Catalan bilingual infants failed. This is taken as evidence that bilingual infants rely on higher-level cues, in this case rhythm, to separately track the phonetic characteristics of each language.[64]

Context also plays a role in bilingual infants' use of native-language phonemic categories to guide-word-learning and word recognition. In a paper published in 2007, we reported a later age of success in bilingual than in monolingual infants. When tested in an associative-word-learning task in which they were shown one object repeatedly paired with the nonsense word "bih" and another object paired with the nonsense word "dih," and then shown two test trials—one with the "same" pairing (word A, object A), and one with the pairing "switched" (familiar word, familiar object, but now word A, object B), the monolinguals looked longer to the switch than in the same trial at 17 months, but the bilingual infants did not do so until 20 months.[65] However, a subsequent study[66] reported that if the pronunciation of the individual words is appropriate to signal a monolingual English, a monolingual French, or a bilingual English–French context, infants in each of those groups succeed at the same, 17-month age. It is only when the pronunciation does not match, e.g., English pronunciation tested with English–French bilinguals, that infants show difficulty. More recently, Fennell and Byers-Heinlein[67] showed that when first given sentences that specify the language being used, bilingual infants succeed at learning minimally different words even if the pronunciation of the individual words is slightly accented.

Although the above findings show that bilingual infants rely on context to let them know which set of phonological categories to use, it is still unclear whether bilinguals have as fully developed representations of the phonological categories of each language and simply wait for contextual cues as to which language to activate, or whether the representations are less robust at the same age, awaiting accrual of more input to become more firmly established. In electrophysiological recordings of the mismatched negativity (MMN), a negative event-related potential recorded around 250 ms after a change from a repeated standard to an oddball to test phonetic discrimination,[68] clear differences are seen between monolingual and bilingual infants. Whereas the MMN to a phonetic change shows increasing maturity between 3 and 36 months in monolingual infants—gradually changing from more positive to more negative and from posterior to frontal—the directionality and topography of the MMN response changes in less consistent ways during this time period in bilingual infants.[69] Similar findings were reported by Garcia-Sierra *et al.*[70] in a study comparing monolingual English infants to bilingual English–Spanish infants on their ability to discriminate the English and Spanish /da/-/ta/ distinctions. Overall, the MMN response matured more slowly in the bilingual than in the English infants. Indeed, while an ERP indicative of discrimination was seen in the monolingual infants at 6–9 months, nothing was evident in the bilingual infants until 10–12 months, suggesting a representational difference in the native phonetic categories in the two groups at the younger age (also see Petitto *et al.*[71] for complementary results using optical imaging).

In the Garcia-Sierra *et al.* study,[70] the amount of input in each language proved to be very important. The maturity of the MMN response was more mature for Spanish if the bilingual infants heard more Spanish than English, and visa versa. Moreover, vocabulary size in each individual language was correlated with MMN maturity. These results would suggest that while bilingual infants may be able to use context to help them disambiguate a difficult task, the amount of input in each language also independently influences the elaboration of the representation.

Results suggesting a difference in the robustness of the representation are also found in the word-recognition literature. Whereas there is a greater left than right hemispheric response over frontal and temporal cortex to known words in monolingual infants aged 19–22 months, it is less lateralized, and slower, in bilingual infants.[72] Moreover, the degree of difference is predicted by vocabulary size in the nondominant language. Behaviorally, monolingual English toddlers (30 months) are faster than bilingual Spanish–English infants at orienting away from the incorrect and toward the correct referent when presented with a single spoken label, and shown a picture of both a matching and a nonmatching object.[73] This difference is best predicted by the amount of input the infants receive in each language, and by their current vocabulary in each language as measured on the MacArthur-Bates Communicative Development Inventory (CDI) parental vocabulary checklist. Similarly, bilingual Spanish–Catalan toddlers aged 14–24 months are more likely than monolingual Catalan toddlers to treat a mispronunciation (from a Catalan /e/ to a Catalan /E/) of a known Catalan word as acceptable and still look at the "matching" object. This effect is also moderated by the amount of input in each language such that those bilingual infants who receive relatively more Catalan input are more likely to perform like their monolingual Catalan peers.[74]

The somewhat contradictory results reviewed previously make more sense when consideration is given to the possibility that two independent factors may be contributing. There are likely consequences in processing efficiency that result from less input from each individual language. At the same time, however, there may be cognitive advantages that allow the bilingual-learning infant to use contextualized perceptual cues to facilitate performance. As such, the bilingual infant is most likely to show processing costs when in an environment in which there are no contextual cues indicating which language should be used.

Word-learning biases

A well-studied issue in language acquisition is the problem of induction. When an infant hears a word like "cat," how does he or she know that it refers to the whole cat rather than a part of the cat, such as an ear, a property of the cat such as its color, or an action that the cat may be involved in? A number of word-learning constraints have been proposed to help explain why it is that in the initial stages of acquisition infants seem to treat words as nouns labeling whole objects, and more specifically as labels for categories, and only after such referents are established do they consider alternative meanings.[75]

One constraint that has been studied is commonly referred to as "mutual exclusivity." This is the assumption that each object category has only one label.[76] Hence, when first encountering a cat, the child will assume that the label "cat" refers to the entire category, but if they later encounter the same cat along with another animal, for example, a "dog," and hear the label "dog," they will reject that label as a second label for the cat, and treat it instead as a label for the other object. Mutual exclusivity has been shown to be evident by 17 months of age.[77] While there is agreement on the existence of this word-learning bias in monolingual infants, there is no agreement on what it means or where it comes from developmentally.[78] In this case, research with multilingual infants can help address a fundamental question in acquisition. While mutual exclusivity can be seen to be adaptive for monolingual-learning infants, bilingual infants regularly encounter—and need to learn—more than one label for the same object, as they receive labels in each of their languages. Moreover, bilingual children often hear language with a lot of "code switching," that is, words from the other language inserted in a rule-governed and regular way, but nonetheless resulting in mixed input. Research with bilingual children from the preschool to school-aged years indicate that by the time they reach school age, both monolingual and bilingual children understand that two objects can have the same label if the labels come from different languages,[79] but while still preschoolers, bilinguals can sometimes become confused and reject a second label even if it is in their second language.[80]

Two recent studies have tested mutual exclusivity in bilingual in comparison with monolingual infants.[81,82] In both of these studies, a disambiguation paradigm (as in Ref. 77) was used to test mutual exclusivity. In this paradigm, infants are tested in a two-choice preference task that includes two kinds of trials: known–known and known–unknown. In the first type, two known objects are presented side by side, and a label that corresponds to one is presented. Here, the child is expected to look longer to the matching object. In the second type, the child sees a known and an unknown object, and in disambiguation trials, hears a novel label. Mutual exclusivity is assumed if the child looks longer to the novel object in the presence of the novel label.

Mutual exclusivity was not as pronounced in bilingual as in monolingual infants in the Byers-Heinlein and Werker study,[81] and not evident at all in trilingual-learning infants. In the Houston-Price study,[82] mutual exclusivity was not seen in the bilinguals. In the Byers-Heinlein and Werker sample, no correlation with degree of mutual exclusivity was found between either the amount of input and/or the vocabulary size in each language. Hence, we claimed that the driving force in whether mutual exclusivity would be seen or not was the overall structure of the lexicon across the languages. If children had experienced more than one label for the objects in their world, they were more likely to entertain the possibility, even in an experimental task, that the same object category could be given more than a single label. In the Houston-Price *et al.* study, there was an effect of vocabulary size, but only in the monolingual sample. Those infants with a larger English vocabulary were more likely to show mutual exclusivity. Based on these findings, both groups of researchers have argued that rather than being a built-in constraint that guides word learning, mutual exclusivity may be a bias that emerges across development in monolingual infants as a function of establishing a lexicon made up of one-to-one word–concept mappings.

Summary

The perceptual systems provide the first entry point into acquisition of the native language. In this review, I have presented evidence showing that from birth, infants growing up with two languages can use perceptual cues to begin to separate the languages and to learn the sound properties of each. This in turn prepares them for word learning, and even for the first steps in bootstrapping grammar.

While the milestones achieved in bilingual acquisition are largely parallel to those achieved in monolingual acquisition, there is evidence of both processing challenges and cognitive advantages in bilingual acquisition. The challenges seem to stem, at least in part, from the fact that with two native languages, there is less input in each. This results in less well-established representations, processing inefficiencies, and in some cases, slight delays in acquisition. The cognitive advantages seem to come from having to separate, and keep separate, the two native languages while acquiring the properties of each. The cognitive advantages discussed included better attention to perceptual details that might distinguish a talking face, heard speech, or even individual sounds from one language versus another, as well as the ability to better use context to determine which language is being used. Thus, while the fundamental mechanisms supporting language acquisition are the same in the bilingual and in the monolingual infant, the input does play a role. This role can be seen in the brain systems involved in language processing and use, in speed of processing, in total vocabulary size in each language, in word learning and recognition, and perhaps more fundamentally in the biases children use to figure out the meaning of words.

Future directions

To date, the majority of studies with bilingual-learning infants have involved infants acquiring two spoken languages. There is, however, increasing work on bimodal bilinguals—who have one spoken and one signed language.[83] Initial steps in acquisition seem to be identical in bimodal/bilingual–learning infants to the steps in acquisition of a spoken language,[84] and involve the same language areas in the brain.[12] Although there is still significant interference between even spoken and signed languages in the adult brain, there may be less interference from the second language in signing-speaking adults,[85] in part because they are governed by different modalities.[86] Thus, the processing costs may be diminished. If the conclusions drawn in this review are correct, the pattern of results with adult bimodal/bilinguals would predict that the role of the input would play out differently in bimodal/bilingual infants. They may not have the processing challenges that the oral bilingual child has, and in turn they also may not have as pronounced cognitive advantages.

As evidenced in this review, there is increasing evidence that the amount of input in each language is important for fully understanding the first steps in bilingual acquisition. In addition to the several excellent parent-report questionnaires that are being used to estimate the amount of input in each language,[87] new tools are being developed. One is a language-mixing questionnaire developed by Byers-Heinlein[88] that provides a highly reliable estimate of the degree to which the bilingual input comes from two clearly distinct sources, or is more likely to come via mixing within individual speakers. Data from this questionnaire are already helping to advance theoretical understanding and empirical results.[13] A second is an exciting tool, LENA, which records all speech heard by an individual child over the period of time the recording device is worn. New research using this tool reveals much more nuanced information about how the qualitative properties of input speech, in addition to simple quantity, influence language development.[89] Recording tools such as LENA also have promise for better characterization of the language input in bilinguals. With betterinfluences characterization of the input, we will be better situated to address increasingly precise theoretical predictions.

Conflicts of interest

The author declares no conflicts of interest.

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