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THE LISTENING BILINGUAL

Speech Perception, Comprehension,
and Bilingualism

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Spoken Word Recognition

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Introduction

Children begin to speak around their first birthday, but their ability to recognize spoken words has its roots even earlier. As early as 6 months of age, monolingual infants can recognize some words for food and body parts (Bergelson and Swingley 2012). Parents of bilingual infants also report that they understand many words in both of their languages from early in development (De Houwer, Bornstein, and De Coster 2006). In child second language learners, comprehension also precedes production: learners often understand many more words than they can say (Gibson et al. 2012).

This chapter examines how bilingual children learn and recognize words. This is a multifaceted process that involves isolating words from fluent speech, linking the sounds of a word with its meaning, and eventually using this knowledge to recognize known words in real time. Known words must be stored and organized in the developing vocabulary. Mirroring these different tasks, this chapter begins by discussing how children locate words in the continuous speech stream. Next, we will consider how children link a word's sound with its meaning, and how this is related to their perceptual, cognitive, and social abilities. We will also consider whether bilingual children can effectively learn new words from media such as television, stories, and songs. We will then discuss how children recognize familiar words, as well as links between word learning and speech perception skills. The chapter will end by considering bilingual children's vocabularies: how many words they know, the relationship between receptive and productive vocabularies, and overlap in the meanings of known words across the two languages (translation equivalents).

Finding Words in the Speech Stream

In written language, individual words are easy to locate because spaces and punctuation mark their boundaries. However, in spoken language, it is much more difficult to find the boundaries between words. As any beginning learner of a language can attest, fluent speech does not necessarily have reliable pauses between words. Although some words

occur in isolation, many do not. The term speech segmentation is often used to describe the process of locating individual words within the speech stream. How do children isolate words in continuous speech, particularly when they are new to a language?

Research with monolingual infants has identified a variety of cues and strategies that learners use to locate words in running speech. One important source of information is the statistical properties of the speech stream. Eight month old infants automatically track which syllables reliably occur next to each other and which ones do not (Saffran, Aslin, and Newport 1996). This is a useful approach because co-occurring syllables are likely to be words, whereas syllables that seldom co-occur are likely to mark boundaries between words. Infants can also use the edges of utterances – the beginnings or ends of a sentence – as markers to identify potential word beginnings and ends (Seidl and Johnson 2006). Even infants' own names can help them, as the syllable that occurs immediately after their name is likely to be the beginning of a new word (Bortfeld et al. 2005). While these cues are language-general (i.e., useful no matter the language, for example, the baby's name), other cues are language-specific (i.e., only helpful for some languages). As an example of a language-specific cue, in English most words begin with a stressed syllable (e.g., BABY, BLANKet, MOMmy). Young English-learning infants use stressed syllables as a fairly reliable marker of the beginning of a word, even though sole reliance on this cue might be problematic for words with other stress patterns such as *gui*TAR (Johnson and Jusczyk 2001). As they grow, infants must learn which of these different types of cues to prioritize (Thiessen and Saffran 2003).

Bilingual learners sometimes need to use different speech segmentation strategies in each of their languages. As was just mentioned, stress is a language-specific cue, which is informative for speech segmentation in English, but stress does not provide a cue to word boundaries in French. As a consequence, a French–English bilingual can use stress to guess that a new English word is beginning, but the same strategy would not work in French. Even language-general approaches are challenging in a bilingual context. For example, bilingual learners need to track the statistical properties of each language separately, rather than collapsing them across the two languages. For example, though *ba-* and *-by* might often co-occur in English because together they form the word “baby”, in another language these two syllables might be more likely in other words.

How can we know whether bilingual infants successfully segment the speech stream in each of their languages? In everyday life, infants hear most words in running speech (i.e., embedded within a sentence) rather than in isolation. This means that if infants are able to recognize words that they hear frequently, this is likely because they have been able to extract them from longer sentences (although hearing isolated words could still play a role). In one study, Vihman et al. (2007) tested familiar word recognition in 11 month old Welsh–English bilinguals. The researchers created lists of presumably familiar words such as “bottle” and “apple”, in both English and Welsh, and also lists of unfamiliar but matched words such as “nettle” and “wacky”. Using the head-turn preference procedure (see Chapter 8 for a fuller description of this procedure), infants' attention was attracted by a flashing lightbulb, with one of the word lists played for as long as they listened. Infants looked longer to familiar words than unfamiliar words in both English and Welsh, showing that they recognized and thus had likely segmented words in both of their languages. This main finding was also supported in a second part of the study showing different brain responses to the familiar as compared to the unfamiliar words.

Other studies have more directly investigated bilingual infants' ability to segment speech presented in the lab. Researchers in Barcelona used the head-turn preference procedure to investigate whether 6 and 8 month old Spanish–Catalan bilingual infants could locate words in the dominant language speech (Bosch et al. 2013). During familiarization, infants heard several passages of fluent speech. Infants were signaled that a passage would begin by turning towards a flashing light. The passage played and the light continued to flash as long as they looked towards it, and so their looking was taken as an index of their interest in the passage. At test, they were played monosyllabic words that either did or did not appear in the passages, and infants' looking time was measured to these two types of words. Bilinguals at both ages appeared to segment the words, as they showed a difference in looking to the familiar as compared to the novel words. However, the infants at the two ages showed their ability in different ways: 6 month olds looked longer to the familiar words, while 8 month olds looked longer to the novel words. This might be due to processing differences, as research suggests that when infants are young or a task is challenging, they will have a greater tendency to attend to what is familiar over what is novel (Hunter and Ames 1988). Nonetheless, these results show that bilingual infants are able to segment speech from their dominant language by age 6 months.

Polka et al. (2017) were interested in whether infants could segment speech in both their dominant and non-dominant languages. They tested 8 month old bilinguals acquiring French and English. They used a similar paradigm as Bosch et al., but infants completed the sequence of the familiarization test twice, once in each language. In an initial study, they found that bilingual infants had some difficulty with the task. They successfully segmented French words when the French test was given first (looking longer to the familiar words), but otherwise did not show evidence of successful segmentation. There was no effect of language dominance. In a follow-up study, they demonstrated that the bilinguals could segment English when it was the only language presented in the study. These results suggest that, depending on the languages being learned and the test used, speech segmentation can sometimes be difficult for young bilingual infants. It is possible that bilingual infants would have successfully segmented both languages in an easier experimental task.

Singh and Foong (2012) studied whether changing pitch or tone would disrupt bilingual English–Mandarin-learning infants' ability to recognize segmented words. Recall from Chapter 8 that tonal languages like Mandarin Chinese use changes in pitch – called tones – to signal changes in meaning, while other languages like English do not. Using the head-turn preference procedure, the researchers tested infants in three age groups: 7.5, 9, and 11 months. A first experiment tested infants' responses to pitch variation in English, which they should ignore, as in English pitch changes do not signal a change in meaning; that is, in English, infants should recognize words as being familiar even if they change in pitch. Infants were first trained by hearing two target words (e.g., hat, bike). At test, infants heard passages containing one of the target words (“His bike had big black wheels. The girl rode her big bike...”), and other passages without the target words (“The tree was a hundred years old...”). In the current study, the test passages with the familiar words were played either at the same pitch as familiarization or at a different pitch. Note that this procedure is slightly different from the study conducted by Polka et al. (2017), where infants were trained on passages and then tested on words. At 7.5 months, infants only recognized the familiar English words when they were

played at the same pitch, which suggested that they had some difficulty in ignoring the irrelevant pitch change. However, at 9 and 11 months, infants recognized the words whether or not the pitch matched. This suggests that, by these ages, infants are flexible at recognizing English words even across pitch changes.

In a second experiment, Singh and Foong (2012) tested the same bilingual infants on a Mandarin tone change. Infants were familiarized to Mandarin words and at test they heard passages with words produced with a matching tone, a mismatching tone, or passages without the familiarized words. Here, the results should be different than when infants were tested in English, as tone is phonemic (meaningful) in Mandarin. Bilingual infants seemed to disregard the tone information at 9 months, listening more to both the tone matched and the tone mismatched passages than to the passages without the familiar words. However, at 7.5 and 11 months, infants only recognized the familiar word when its tone matched the one heard during familiarization. Although the authors interpreted infants' performance at 7.5 months to a language-general sensitivity to pitch changes (as seen in the English study), by 11 months bilingual infants appear to have matured their listening. They seemed to know that in Mandarin changes in pitch should not be ignored. Together, these results suggest that by age 11 months, bilinguals show language-specific listening as they locate words in the speech stream.

Learning New Words

At the same time as infants locate words in the speech stream, they must begin to link these words with meaning. When and how does word learning in simultaneous bilingual infants begin? The youngest age at which bilingual infants have been tested experimentally is 12 months. Byers-Heinlein, Fennell, and Werker (2013) used the Switch task, a looking-time procedure, to compare monolingual and bilingual infants' ability to associate a word and an object. Monolinguals were learning English and bilinguals were learning English as well as one of several other languages from birth. Sitting on their parents' laps, they were habituated to two word–object pairings. On each trial, infants saw one of two novel objects (a crown-shaped or a molecule-shaped object; see Figure 9.1) and heard novel words (“lif” and “neem”). The object moved back and forth on the screen, and the word was repeated in isolation for 20 seconds. The two word–object pairings

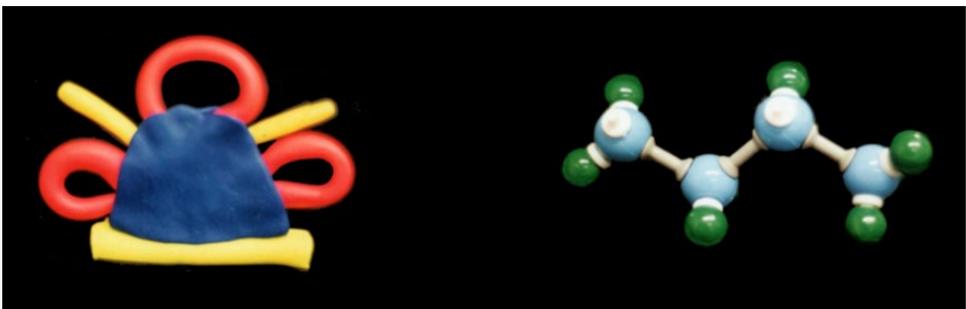


Figure 9.1 Unfamiliar crown-shaped (left) and molecule-shaped (right) visual stimuli used in word-learning studies.

were presented until infants' looking time to the screen declined, indicating that they were "bored" with the stimuli. Two trials were presented at test. Infants saw a "Same" trial that showed them a familiar word–object pairing (e.g., *lif*–crown or *neem*–molecule), as well as a "Switch" trial that showed them an object paired with the wrong word (e.g., *lif*–molecule or crown–*neem*). If infants have been able to make the word–object association, they should be surprised by an incorrect pairing, and should look longer at the Switch trial than at the Same trial. The results suggested that basic word learning in monolinguals and bilinguals develops similarly. Neither group noticed the change at age 12 months, but both groups noticed the change at age 14 months.

Most studies of basic word-learning abilities have focused on young simultaneous bilinguals. However, Kan and Kohnert (2008) investigated basic word learning abilities of 3 to 5 year old sequential bilingual children. All children were living in the United States and had learned Hmong as their L1 and English as their L2, beginning sometime between ages 2 and 5. Children were introduced to two novel objects, which were named with both a Hmong label and an English label. Participants showed similar memory for the words in their two languages, suggesting equal word learning skills in their L1 and L2.

Word-Learning Heuristics

The laboratory studies of word learning we have discussed so far often present children with a very simplified word-learning situation, usually a single object and a single word. However, word learning in the real world is not so straightforward. If a parent labels a toy in the playroom, the child has to decide which of several toys they are referring to. Do they mean a whole toy, a part of the toy, or some property such as its color? There is a potentially infinite number of possible meanings for any given word (Quine 1960).

Research with monolinguals has suggested that children use word-learning heuristics or biases to limit the possible meanings that they consider (Markman 1991). For example, children tend to expect words to refer to whole objects rather than their parts (the whole object bias) and to expect a new word to extend to other objects of the same kind (the taxonomic bias).

A third word learning heuristic – mutual exclusivity – is of particular interest in the case of bilingual children. Mutual exclusivity is the assumption that each object has a single label. There are several ways to demonstrate that children follow the mutual exclusivity assumption. If presented with a familiar object (e.g., a cup) and a novel object (e.g., a garlic press), monolingual children expect that a novel label refers to the novel object; that is, since they already know the familiar word "cup", children reject a second label for that object. If no novel object is present, children may sometimes interpret the novel word as labeling a property of the object (e.g., color, texture), a part of it (the cup's handle), or may simply fail to learn any meaning for the word.

Of course, for bilinguals, object labels are not mutually exclusive: objects have a name in each language. Thus, while mutual exclusivity might be a good strategy within a language (e.g., rejecting a second English label for an object), it is not a good strategy to apply across languages (e.g., rejecting a Spanish label for an object because the child already knows an English label). Research with 3 to 5 year old bilingual children suggests that, at this age, they are willing to accept two labels for an object if the labels are clearly from different languages (Au and Glusman 1990). However, evidence from

younger bilinguals suggests that the experience of hearing multiple labels for the same object might alter their early use of mutual exclusivity.

Byers-Heinlein and Werker (2009) compared mutual exclusivity in three groups of 18 month olds: monolinguals, bilinguals, and trilinguals. Infants had been learning their languages since birth, and all shared English as a common language. In the study, children sat in front of an eye-tracking monitor. On mutual exclusivity trials, they were shown a familiar and a novel object and were asked to look at the novel object (“Look at the nil!”). Looking to the target object as compared to a distractor object was measured and was compared to infants’ looking during silence. Infants’ responses depended on the number of languages they were learning. Monolinguals showed mutual exclusivity: they looked at the novel object upon hearing the novel label. However, bilinguals showed less of a tendency to do so and trilinguals were at chance (i.e., looked at both objects equally). This suggests that growing up bilingual influences children’s word-learning biases.

In another study, researchers compared monolingual and bilingual 18 month old infants’ willingness to learn a second label for an object, which would go against mutual exclusivity. Infants saw a picture of a familiar object (a dog). On some trials the dog was orange and it was labeled “dog”. On other trials the dog was green and was labeled “zabe”. This was meant to highlight the dog’s colour, so that children might use mutual exclusivity to infer that “zabe” means green. Next, infants were tested to see whether they expected “zabe” meant green or “zabe” meant dog. They were shown a green cat and a purple dog, and heard the label “zabe”. Monolinguals looked towards the green cat, suggesting that they rejected “zabe” as a second label for the dog and inferred that it referred to the dog’s color. However, bilinguals looked towards the dog, suggesting that they inferred that “zabe” was another label for the dog.

Similar results have been found in studies with older bilingual children. Kalashnikova, Mattock, and Monaghan (2014) tested 4 and 5 year old monolingual and simultaneous bilingual children. They presented children with two different situations in the context of a puppet show. In a mutual exclusivity situation, children saw a familiar and a novel object, and heard a novel label (e.g., “Can I have the kiv?”). Monolinguals and bilinguals in both the younger and older group tended to give the puppet the novel object. However, in the older group (5 year olds), monolinguals were more likely to give the puppet the novel object than bilinguals, suggesting that they had stronger use of mutual exclusivity. In a second situation, children were taught two different labels for the same object by two puppets. When tested on their recall of the labels, children in both age groups and from all language backgrounds performed above chance. However, in the older age group, bilinguals were more likely to recall both labels than monolinguals. This again suggests that they were less likely to use mutual exclusivity, which in this case boosted their ability to learn new words.

Together, these studies show that, even given the same information in the same word-learning situation, monolinguals and bilinguals use different word learning strategies. This is likely to help them each navigate their own unique language environments.

Social and Pragmatic Information in Word Learning

So far, we have discussed cognitive and perceptual influences on word learning, such as children’s ability to form word–object associations and the use of word-learning heuristics. Yet social and pragmatic cues can also be a rich source of information. For example,

eye-gaze or pointing can indicate what a speaker might be referring to. How do bilingual children use this type of information as they learn new words?

Some research suggests that bilinguals are more sensitive to social cues than monolinguals. One study compared how monolingual and bilingual 2 year olds extend the meaning of a new word (Brojde, Ahmed, and Colunga 2012). Researchers taught children a novel word (“That’s a zuly”) and at test showed them eight different objects that matched the original in shape, color, and/or texture. Recall the taxonomic heuristic, which leads children to extend the meaning of a word to other objects of the same shape. When an experimenter asked children to find the “zuly”, both monolinguals and bilinguals tended to give the experimenter all of the objects that matched in shape. However, on some trials, the experimenter gave a conflicting pragmatic cue, looking at the objects that did not match the original in shape. While monolinguals continued to respond that “zuly” referred to all of the objects of the same shape as the original, bilinguals were more likely to select the objects that the experimenter was looking at. Compared to monolinguals, bilinguals weigh pragmatic cues more heavily than shape cues.

In another study, 3 year old monolingual and bilingual children saw a pair of novel objects, one of which was hidden from the experimenter (Yow and Markman 2015). On some trials, the experimenter requested a visible object “*There’s* the spoodle! Can I have the spoodle?” and on other trials requested the hidden object “*Where’s* the spoodle? Can I have the spoodle?” Bilinguals were more likely than monolinguals to understand when the experimenter was referring to the hidden object. This shows an ability to consider both what an interlocutor can see and what she says, in inferring the meaning of a new word.

Other Parts of Speech

Although many studies have investigated bilingual children’s noun learning, many fewer studies have investigated other parts of speech. However, one interesting study explored how 3 year old bilinguals and monolinguals learn new adjectives. This is interesting because adjective learning is known to be more difficult for children than noun learning. Yoshida et al. (2011) showed children a familiar object with an interesting property (like a duck with a Velcro texture) and described it with a novel adjective (“This is a blickish duck”). Children were then shown two more ducks, one with the same property and one with a different property and were asked, “Can you get me the duck that is blickish?” The researchers measured how often children pointed to the duck with the matching property. Bilingual children were fairly good at the task – they pointed to the correct object almost 80% of the time. However, monolinguals found it very difficult – they were at chance, pointing to the correct object only 50% of the time.

What gave the bilingual children such an advantage? An aspect of the study provided a clue. A substantial body of research has suggested that bilingualism confers advantages in executive function abilities, particularly inhibition. One difficulty in learning a novel adjective is inhibiting the tendency to treat a novel word as a noun. Indeed, when the researchers tested the children’s inhibition abilities directly, bilinguals showed stronger inhibition. Further, within the bilingual group, those with better inhibition skills showed even better adjective learning. Together, these results demonstrate that bilingual children have an advantage in learning new adjectives, which seems to be

driven by their enhanced executive function skills. This contrasts with other studies of bilingual preschoolers' noun learning, which have found no link with executive function (Bialystok et al. 2010a).

Learning Words from Media and Multimedia

While many studies of infant word learning have presented children with to-be-learned words on a screen, this is very different from children's typical exposure to multimedia. Rather than seeing a single object on the screen and hearing its label, real-world multimedia is considerably richer and more complex. What role does multimedia play in word learning in bilingual children?

Television is a common way for children to be exposed to a new language; however, its benefits to L2 language learning are controversial. In one study of simultaneous bilingual toddlers, researchers found that the quantity of television viewing was not related to their vocabulary size (Hudon, Fennell, and Hoftyzer 2013). However, toddlers who watched low-quality television (e.g., background television, television unintended for children) had smaller vocabulary sizes. This suggests that some types of television viewing could prevent word learning in young bilinguals.

Other studies have investigated the type of television that can benefit older L2 learners. Neuman and Koskinen (1992) studied a group of 7th and 8th graders (aged 12–14 years) who were learning English as a second language in the United States. The researchers tested children's vocabulary learning from a science program. There were three different conditions: (a) the video alone, (b) the video accompanied by subtitles, (c) a control condition where children simply read the subtitles out of a textbook. The results showed that children in both video conditions recognized more of the words than those in the control condition. Further, there was some evidence that the subtitles boosted vocabulary learning beyond simply watching the video. Student's proficiency in English at the beginning of the study also mattered for their learning. Those students who started with better English skills were able to learn the most words. These results demonstrate that television, particularly if it is subtitled, can support L2 word learning in older children who already have some proficiency in the language.

Indeed, other studies confirm that video alone is not very effective for word learning in novice L2 learners. In a study of 7 year old Chinese students with little exposure to English, children had great difficulty learning new words from English video clips (Sun and Dong 2004). Children only seemed to be able to learn from the videos if they were pre-exposed to the target words before the clips, and when the clips were translated from English to Chinese sentence-by-sentence.

Another common way for children to encounter new L2 words is through stories and songs. Leńniewska and Pichette (2014) studied a group of native French-speaking preschoolers, aged 3–5 years. In weekly sessions, children were read stories and heard songs in English, a language that they did not previously have much experience with. After several weeks, researchers tested the children on their learning of words from the activities. Contrary to the authors' predictions, children recalled more of the words presented in the stories than in the songs, and presenting words in both mediums (both song and story) did not provide any additional word-learning benefit. This could be because, even though songs are engaging to children at this age, they may distract children from attending to the meaning of words. There were also differences amongst the

types of words that children learned best. Children were much more likely to learn words for animate concepts (e.g., cat, ghost) than inanimate concepts (e.g., bed, ear). Further, the more often children heard the word, the more likely they were to learn it.

Together, these research studies suggest that although television and song might be enjoyable for young bilingual language learners, neither of these media are particularly effective for word learning. Instead, many researchers have emphasized high-quality, high-quantity interactions with adult speakers of a target language will best promote early word learning (Byers-Heinlein and Lew-Williams 2013).

Recognizing Familiar Words

The previous section focused on how children link a word's sound with its meaning. Yet once this link is made, children must efficiently access this knowledge to recognize words in real-time from the speech around them. Many studies on this topic use the looking-while-listening method (also called preferential looking), which measures whether children look at a picture on the screen that matches an auditory stimulus. This is a simpler version of the visual world paradigm discussed in Chapter 4, in that typically there are only two different pictures (the target and one distractor) to choose from.

Marchman, Fernald, and Hurtado (2010) studied word recognition in Spanish–English bilinguals aged 2.5 years. Children were tested in each of their languages in a looking-while-listening paradigm. They heard a sentence (“Where is the dog?”) while seeing two pictures on a screen (a dog and a book; see Figure 9.2). Researchers measured how long it took children to look at the target object after hearing the word, as an index of the speed of their word processing. They also measured children’s



Figure 9.2 A child participating in a looking-while-listening study. Children see a pair of objects on the screen and hear one of them labeled (“Look at the dog!”). The proportion of time that children look towards the labeled object is measured.

vocabulary size in both languages using a parental checklist. They found language-specific links in these two measures. Those children with the largest English vocabularies responded the fastest on the English trials. Similarly, those children with the largest Spanish vocabularies responded fastest on the Spanish trials. However, there was no link across languages – children who were fast in Spanish or knew lots of Spanish words were not necessarily fast in English. The authors emphasize the real-time nature of speech. For example, children who are fast to comprehend words at the beginning of a sentence are more likely to be able to process words that occur later in the sentence. At the same time, children who know more words might become more efficient and fast at processing them. Language processing and vocabulary within each language develop hand in hand.

Follow-up research examined children's relative speed of processing in their two languages. The same researchers studied Spanish–English bilingual children aged 30–36 months (Hurtado et al. 2014). Once again, they tested children in both languages using the looking-while-listening paradigm. Children with balanced exposure to their two languages showed similar reaction times in both languages. Those with more exposure to Spanish were faster in Spanish, and those with more exposure to English were faster in English. Further, children who showed larger vocabulary growth (both in terms of comprehension and production) were better processors of a particular language and they heard relatively more of that language. Once again, these results support important links between bilingual children's language exposure, language processing, and vocabulary.

One study to date has looked at how children recognize words in code-switched contexts (Byers-Heinlein, Morin-Lessard, and Lew-Williams 2017). Twenty month old French–English bilinguals saw pairs of pictures (e.g., a dog and a book) and heard one object labeled in either a single-language sentence (“Find the dog!”) or in a code-switched sentence (“Find the *chien*!”). Children were less accurate to look at the labeled object when they heard the code-switched sentence, particularly when the switch was from their dominant to their non-dominant language. Moreover, their pupils were dilated when they heard the switch, suggesting that comprehending a word that was code-switched required greater cognitive load. A follow-up study found that switching did not impact children's word recognition when the switch occurred across a sentence boundary (“I like that one! *Le chien*!”). Together, these studies yielded several important insights. First, while code-switching can affect children's comprehension, it is highly dependent on the location of the switch. Second, the finding that children can respond differently to the same word depending on the sentence context (same-language or switch) suggests that, by this age, they know that synonyms like “dog” and “*chien*” are from two different languages.

Another method for measuring children's recognition of familiar words is the Computerized Comprehension Task. In this task, children sit in front of a touchscreen monitor showing two images (e.g., a chair and a cup) and are asked to touch one (“Where is the chair?” “Touch chair!”). Children are reinforced when they touch the correct image, and their reaction time as well as the proportion of correct responses is recorded.

A series of studies compared French monolinguals' and French–English bilinguals' performance in this task. Children's processing of familiar words became faster from 16 to 22 months, and bilinguals with more exposure to a particular language responded faster in that language (Legacy et al. 2016). Monolinguals and bilinguals showed similar

average reaction times, although the monolinguals were more accurate overall than the bilinguals (Legacy et al. 2015). Finally, the researchers noted some differences between the words children got correct in the task and those that parents reported they understood (Legacy et al. 2015, 2016). This suggests that different ways of measuring children's word knowledge can lead to somewhat different findings.

Finally, several studies have begun to explore how knowledge from one language might affect word recognition in the other language. Von Holzen and Mani (2012) asked whether both languages were active during children's word recognition. They studied German–English bilingual toddlers aged 21–43 months. Children were learning German at home and were attending a bilingual preschool where they heard both English and German. The researchers used a priming paradigm, where children heard an English prime word and a German target word. Other studies have shown that hearing a target word activates multiple lexical candidates – words that are similar in how they sound (e.g. hearing “dog” activates “log”). If the target word has already been activated by the prime word due to their similar sounds, the target should be recognized more easily. This phenomenon is called phonological priming. This study tested two types of overlap between target and prime. In one case, the prime and the target overlapped phonologically across languages. For example, the prime was “slide” and the target was “kleid” (dress). In the second case, they overlapped through translation. For example, the prime was “leg” and the target was “stein” (stone). Although these two words do not overlap directly, the translation of “leg” is “bein”, which does overlap with “stein”. Finally, some trials presented word pairs without any overlap. Infants' word recognition was measured by how long they looked at a picture of the target object relative to an unrelated distractor object. The results suggested that word recognition was affected both by phonological priming and by phonological priming through translation, as infants were more accurate at recognizing words that were related in this way. The authors concluded that, even early in development, bilingual toddlers' word recognition can be language non-selective, such that both languages are active and accessed.

While this study examined how bilinguals activate words with overlapping sounds, other research has examined activation of words with overlapping meanings. Also using a priming paradigm, Singh (2014) examined whether words in one language would activate words with a related meaning in the other language. Participants were Mandarin–English simultaneous bilinguals, aged 2.5 years. In a preferential looking paradigm, infants heard a prime word in one language and then a target word (e.g., “Look the cat! Dog!”). They were then shown two pictures, including the target word and a distractor (e.g., a car and a dog). On some trials the prime and target were related in meaning (cat–dog) and on some trials they were unrelated in meaning (button–dog). Priming is seen if children look at the named picture more when the prime is related than when the prime is unrelated. The researchers manipulated whether the prime and the target words were in the same language or in different languages. The results showed an important role for language dominance. Children successfully recognized the word when the related prime was in the dominant language, whether or not it was in the same language as the target. However, they were at chance when the prime was in the non-dominant language. As in the previous study (van Holzen and Mani 2012), this result suggested that hearing a word in one language can activate words from the other language, but that the strength of activation can depend on language dominance.

The Role of Speech Perception in Learning and Recognizing Words

Some types of word learning and recognition necessitate paying special attention to detailed sound information in the word. For example, similar-sounding words such as “bin” and “din” are called minimal pairs. To learn a minimal pair, infants must deploy both their word-learning abilities and their speech-perception skills (Werker and Yeung 2005).

A number of studies have used the Switch task to test bilingual infants’ minimal pair word learning. As a reminder, infants are habituated to two word–object pairings, and then shown a “Same” and a “Switch” trial. In minimal pair versions of the Switch task, these two words are a minimal pair. Given that bilingual speech perception develops somewhat differently from monolingual speech perception (see Chapter 8), it is interesting to ask whether these differences extend to minimal pair word learning.

Overall monolinguals and bilinguals seem to have equal – but different – minimal pair word-learning abilities. In particular, infants appear very sensitive to the type of speaker producing the minimal pair. Fennell and Byers-Heinlein (2014) found that bilingual 17 month olds could only learn the minimal pair “bos” and “gos” when the words were produced by a speaker who was herself bilingual and not when she was monolingual. Conversely, monolinguals could only learn the words from a monolingual speaker. This finding is consistent with what had been found in two previous studies comparing bilinguals and monolinguals. Bilinguals showed more difficulty than monolinguals in learning the minimal pair “bin” and “din” from stimuli produced by a monolingual speaker (Fennell, Byers-Heinlein, and Werker 2007), but greater ease than monolinguals with stimuli produced by a bilingual speaker (Mattock et al. 2010). In all cases, the differences between the speakers were very subtle, and adults listening to the stimuli could not readily identify the speakers’ origins. Infants, however, appeared sensitive to the speakers’ background in ways that adults were not, and learned best from a speaker who matched their own background (recall that bilingual infants often have bilingual parents and monolingual infants often have monolingual parents). Infants’ initial word-learning abilities may be fragile and easily perturbed by speaker characteristics. On the other hand, these results also reveal that infants’ learning abilities are well-matched to their environments: bilinguals do well in bilingual environments.

Other research has investigated whether the particular language pair being learned influences infants’ learning of minimal pair words. Havy, Bouchon, and Nazzi (2016) tested 16 month old bilingual infants’ learning of minimal pair words “koet” and “goet”. All infants were learning French and another language. Crucially, for some of these other languages, the pronunciation of /k/ and /g/ was similar to French (e.g., another Romance language such as Italian or Spanish), and for some languages it was quite different (e.g., a Germanic language such as English or German). Children interacted with a French-speaking experimenter who repeatedly labeled two objects with the words. At test, infants were asked to put one of the objects (either koet or goet) into a cup. The results showed that children learning one of the similar languages successfully learned the word, putting the correct object in the cup, while those learning a dissimilar language did not. Bilinguals’ minimal pair word-learning ability seems to depend on the particular language pair they are acquiring.

Other studies have tested children's speech perception during word recognition, rather than during word learning, by examining how they treat mispronunciations. A study of Spanish- and Catalan-learning toddlers (aged 1–2) investigated how they perceive mispronunciations of the /e/–/ɛ/ vowel contrast (Ramon-Casas et al. 2009). As discussed in Chapter 8, this is a subtle vowel contrast that occurs in Catalan but not in Spanish. In a preferential-looking task, infants saw a pair of familiar objects on a screen and heard one of the objects named. It was either named correctly or mispronounced with an /e/ vowel changed to /ɛ/, or vice versa. Children's eye movements were recorded and the amount of time that they looked towards the target in the two conditions was compared. As expected, Catalan monolinguals noticed the mispronunciation and looked less at the target when the word was mispronounced than when it was correctly pronounced. Spanish monolinguals did not notice the mispronunciation. Surprisingly, the Catalan–Spanish bilingual toddlers also did not notice the mispronunciation. However, a study that extended the research to older bilingual children around age 3 years showed that they could notice the mispronunciation, but only if they were dominant in Catalan. When it comes to subtle sound differences that are often mispronounced, bilingual children might accept a great deal of variation in how a familiar word is pronounced.

In a related study that tested word learning, Singh et al. (2014) were interested in how bilinguals treat vowel versus tone mispronunciations. They tested two groups of bilingual children at two ages: 18 and 24 months. One group was learning English and Mandarin and another group was learning English and a variety of other non-tone languages. Importantly, for all bilinguals, a change in a vowel changes a word's meaning (e.g., *cat* and *cut* are different words). However, tones change a word's meaning only for the English–Mandarin group, because Mandarin is a tone language. In a looking-while-listening study, children learned the names of two novel objects. At test, they saw the novel objects side-by-side and heard one of the novel words. On some trials the word was correctly pronounced. On other trials it was mispronounced, with either a change in the vowel or a change in the tone. They measured the amount of time looking at the correct object. If children notice the mispronunciation, their recognition of the word should be hindered and they should look less at the target.

Both groups of bilinguals showed poorer recognition of the word when the vowel was mispronounced, showing early and continuing sensitivity to the importance of vowels. The Mandarin–English bilinguals were sensitive to the tone mispronunciations at both ages. The bilinguals learning English and a non-tone language noticed the tone mispronunciation at 18 months, but correctly ignored it at 24 months. Together, this suggests that children's sensitivity to mispronunciations depends on both their age and the status of the sound change in their language. Younger bilinguals are sensitive to some mispronunciations that are not meaningful in their languages, while older bilinguals are sensitive specifically to meaningful mispronunciations. This indicates increasing sophistication in word processing.

How flexible are bilingual children at attending to different types of phonetic information? For example, can the same child pay attention to tone when hearing Mandarin, but ignore it when hearing English? Singh and Quam (2016) tested English–Mandarin bilingual children in younger (3–4 years) and older (4–5 years) age groups. Children were introduced to two novel objects labeled “biufa” and “fipu”, presented in a conversation between two puppets. The first syllable had a Mandarin tone (tone 2 or tone 4) and

the second syllable was neutral with respect to tone. At test, children saw the pair of objects on the screen and heard one of them labeled “Which one is the biufa?” On some trials the label was correctly pronounced and on others it was mispronounced by changing the tone from 2 to 4, or vice versa. Children saw two versions of the experiment, one in English and one in Mandarin.

Children in the younger group were above chance on all trial types: they recognized the correctly and mispronounced words equally well, whether in English or in Mandarin. However, the older group showed an effect of the mispronunciation, both in Mandarin (where tone is meaningful) and in English (where tone does not change meaning). Thus, this experiment did not find evidence that children could selectively attend to tone depending on the language. Rather, their performance was only affected by age and not by the language of the experiment.

A follow-up study changed the words in the English video to make them more English-sounding: “gripu” and “klafa”. The results for the younger children were similar to the previous experiment. However, for the older children, the mispronounced tone impaired performance in Mandarin, but not in English. This indicated mature, language-specific processing of tone. The different results in the two studies suggest that bilingual children need to hear language-specific phonology (e.g., words that sound especially English) to ignore tone.

Theoretical Explanations

By now, an astute reader might have noticed some apparent contradictions between speech perception skills in younger children (many of which were discussed in Chapter 8) and children’s ability to apply their speech perception skills in word learning and word recognition. For example, Catalan–Spanish children can robustly perceive the difference between /e/ and /ɛ/ by 12 months, but ignore the difference when a word is mispronounced (Ramon-Casas et al. 2009). Mandarin–English children are sensitive to changes in lexical tone in a speech segmentation task at age 11 months (Singh and Foong 2012), but 3 to 4 year olds fail to notice a mispronounced tone in a word-recognition task (Singh and Quam 2016). These apparent contradictions are not restricted to bilingual children. Monolinguals also sometimes show an ability to perceive a speech sound difference, but seem to ignore the same difference when learning new words (Stager and Werker 1997).

It is important for theories of monolingual and bilingual acquisition to recognize and explain these apparent contradictions. The PRIMIR (Processing Rich Information in Multimodal Interactive Representations) framework aims to integrate findings from infants’ speech perception and word learning. This framework was originally developed for monolinguals (Werker and Curtin 2005), and was later extended to address both monolingual and bilingual development (Curtin, Byers-Heinlein, and Werker 2011).

PRIMIR recognizes that the speech stream is rich with information and that learners are sensitive to this information. Further, all children, regardless of language background, are proposed to use the same learning mechanisms to acquire their language(s). However, the type of information that children use in any particular situation depends on a number of different factors, called “dynamic filters” in the PRIMIR framework.

A first dynamic filter is children’s perceptual biases. All children are born with the same perceptual biases – we come into the world listening to and perceiving our language in the same way, emerging from the structure of our auditory and cognitive

systems. These perceptual biases will continue to affect how we perceive and process language. PRIMIR points out that initial perceptual biases are the same for monolingual and bilingual children.

A second dynamic filter is the task demands. For example, when a task is very difficult (such as learning minimal-pair words in the case of younger infants) or when a language pair contains many cognates (such as in Spanish and Catalan), children might ignore some information, such as the subtle difference between two vowels. Task demands can be external, in that some experimental tasks are easier than others. For instance, processing words appears to be easier when the speaker matches the child's own language background: monolinguals do better when they learn new words from a monolingual speaker and bilinguals do better when they learn new words from a bilingual speaker (Fennell and Byers-Heinlein 2014; Mattock et al. 2010). Task demands can also be internal. For example, bilingual children might constantly monitor their input to decide which of their languages is being spoken, while monolinguals can assume that their native language is being spoken.

A third dynamic filter is the developmental level of the child. Children at different ages have different experiences with language and different capacities. For bilingual children, each language might be at a different developmental level, depending on when acquisition began and how frequently the language is heard. Children at a higher developmental level will pay attention to different information than children at a lower developmental level.

With age and experience, children become more efficient at processing language. Children initially have a general perceptual ability to perceive speech sounds. However, as they learn words and link them to meaning, they are able to create abstract representations of speech sounds (phonemes), which guide their information pickup as they listen to words. In PRIMIR, learning words can itself affect speech perception. By age 17–20 months, infants will be able to process information in one of three representational spaces: the general perceptual space, the phoneme space, and the word form space. Which of these spaces children access depends on the dynamic filters, and this will influence how children perform in any particular experimental task.

Bilingual Children's Vocabulary

So far, this chapter has largely focused on children's learning and processing of individual words: finding them in the speech stream, linking the sounds of words to meaning, and comprehending words during real-time speech. Here we explore the entire set of words a child knows: their vocabulary. The words that children know are organized in the lexicon, a sort of mental dictionary that stores a word's sound, meaning, and other characteristics such as its grammatical class (noun, verb, etc.). Our focus here is on receptive vocabulary (the words a child can understand), which as we will discuss later, is distinct from productive vocabulary (the words a child can produce). In the next section, we will describe bilingual children's vocabulary: its size, growth, and composition.

Vocabulary Size

Bilingual children must learn words in each of their two languages. Monolinguals and simultaneous bilinguals learn words at a similar rate and have a similar total vocabulary size (Pearson, Fernández, and Oller 1993; Thordardottir 2011). However, because

bilingual children's words are divided across two languages, they often know fewer words than same-aged monolinguals in *any particular language* (Bialystok et al. 2010b). Bilingual children's vocabulary size in a particular language depends on when they started learning the language (Scheffner Hammer, Lawrence, and Miccio 2008) and how much input they receive in that language (Pearson et al. 1997). Bilingual children's relative knowledge of their two languages can vary considerably over time as their situation changes (De Houwer and Bornstein 2016). Another important finding is that children from low socioeconomic backgrounds tend to have smaller vocabularies than those from high socioeconomic backgrounds (Hurtado, Marchman, and Fernald 2007). This is important because bilinguals can sometimes be of systematically lower socioeconomic status than monolinguals, for example, due to immigration.

Our knowledge about bilingual children's vocabulary size largely comes from instruments that have been developed for use with monolingual children (see Chapter 11 for more on bilingual assessment). Here, we will briefly describe two of the most commonly used tools for measuring receptive vocabulary: the MacArthur-Bates Communicative Development Inventories (MCDI) and the Peabody Picture Vocabulary Test (PPVT).

The MCDI is used to measure the receptive vocabulary size in infants and toddlers aged 8–18 months (Fenson et al. 2007). It is a parental report checklist of nearly 400 words, which parents indicate whether their child understands/says. The CDI was originally developed in English, but now has been adapted to dozens of other languages. For bilingual children, the form can be administered in both of a child's languages.

The PPVT is used to measure vocabulary size in children as young as age 2.5 years, and can even be used with adults. Children are shown a set of four pictures and asked to point to one. Items get more difficult as the test progresses, and testing stops once children answer incorrectly several times in a row. There are two main approaches for using the PPVT to measure bilingual children's vocabulary across both of their languages. One approach is to administer it twice, once in each language. Another approach is to administer it in one language and allow children to respond to missed items in the other language (Gross, Buac, and Kaushanskaya 2014).

Neither the CDI nor the PPVT measure *all* of the words that children understand. Rather, they assess children on a sample of words, which allows researchers to compare one child with another or to look at an individual child's vocabulary growth over time. Further, children's understanding of a word does not need to be particularly deep for it to count on either the CDI or the PPVT. Knowing a word could range from a vague understanding ("I'm pretty sure that a giraffe is some kind of animal") to quite complete ("A giraffe is a mammal with four legs that has a long neck"; Vermeer 2001). However, the former will be sufficient to point to a giraffe on the PPTV if the other three pictures are of a fork, a chair, and a car.

Should we be concerned about whether we are measuring children's vocabulary in a shallow versus a deep way? In a study of Dutch monolingual and bilingual 4 and 7 year olds, Vermeer (2001) found that breadth and depth of vocabulary were related. That is, both monolingual and bilingual children who knew more words in a recognition task (choosing the correct picture for a word) also had a greater depth of understanding (describing the meaning of a word). For both groups, this was also related to the frequency of words in the input at school. Children's vocabularies simultaneously grow

broader and deeper from the input that they receive. The implications of vocabulary breadth versus depth for language assessment are discussed in Chapter 11.

Relationship Between Comprehension and Production

While our focus here is on children's receptive vocabulary – their language comprehension – it is relevant to ask how this compares to their productive vocabulary. In general, both children and adults understand more words than they can produce. However, it is important to note that receptive and productive vocabulary are still related: children who understand more words usually produce more words.

Nonetheless, there are some interesting differences in the relationship between comprehension and production for bilingual as compared to monolingual learners. For young L2 learners, researchers sometimes report what is called the expressive–receptive gap. All children are expected to understand more words than they can say, but bilingual children sometimes have an especially large difference in these two vocabulary sizes, relative to monolingual children. This gap can appear in either L1 or L2. For example, Gibson et al. (2012) evaluated receptive and expressive vocabularies in both English and Spanish in a group of bilingual 5 year olds. The receptive–expressive gap was large in children's L1 (Spanish) and small in their L2 (English). How could we explain the different sized gaps in the two languages? The researchers suggested that since many of the children had just begun learning their L2 (English), they might be suppressing or deactivating their L1 (Spanish) to better acquire this new language. As their L1 was somewhat deactivated, it might have made it especially difficult to produce L1 words, which is generally harder than simply understanding them. This could explain the pronounced expressive–receptive gap in L1.

Keller, Troesch, and Grob (2015) identified two different hypotheses to explain the expressive–receptive gap. The first hypothesis was that for children who are learning two related languages (e.g., French and Spanish), it may be easier for them to transfer their receptive understanding in one language to the other language. For example, the Spanish word for cherry is *cereza* and the French word is *cerise*. These word pairs that share the same meaning and a common origin (here, the Latin word *cerasum*) are called cognates. Even if a French–Spanish bilingual child understood only one of these words, this might be enough to guess the meaning of the other word. However, because cognates are pronounced somewhat differently, they would not provide as much help in production. The second hypothesis was related to children's experience with each language. As children get less practice hearing individual words than monolinguals (because their time is divided between the two languages), their knowledge of words might be sufficient for them to understand them, but not quite strong enough to produce them (again, production is harder than comprehension). This is also known as the weaker links hypothesis (Gollan et al. 2005). To test these two hypotheses, the researchers measured receptive and productive vocabulary in over 400 children aged 3–4 years learning German as an L2, who were from a variety of L1 backgrounds. They tested children's receptive and productive vocabularies in German and reported that over 90% of the bilingual children had an expressive–receptive gap. Children who heard the most German showed the smallest gap, but there was no impact of the particular language pair being learned. These results supported the weaker links hypothesis that the expressive–receptive gap originates in less exposure to particular words in each language relative to monolinguals.

Vocabulary Overlap

A unique aspect of bilingual vocabularies is the presence of cross-language synonyms, often called translation equivalents. While not every word in a particular language has a translation equivalent in the other language (for example, the German word *wanderlust* is sometimes borrowed in English as it has no translation equivalent), most words do. Bilingual children understand translation equivalents from early in development. For example, De Houwer et al. (2006) studied a group of 13 month old children learning French and Dutch. Based on parental checklist data, all infants understood at least some translation equivalents, although the number varied a lot from child to child.

Legacy et al. (2017) measured translation equivalent knowledge in 2.5 year old French–English bilingual children. They assessed children’s understanding of translation equivalents via the Computerized Comprehension Task (touching a labeled picture) and through a parental checklist similar to the MCDI. Forty different items were tested in both English and French, and researchers measured the proportion of words in children’s vocabularies for which they understood a translation equivalent. Results were somewhat different using the two methods. The touching task showed that children understood translation equivalents for 52% of the words, but this increased to 68% according to parental reports. The researchers suggested that parents might sometimes overestimate the number of translation equivalents their children understand. Another possibility is that the touching task was difficult for children and it underestimated their knowledge of translation equivalents.

What causes children to know a word in one language but not in the other? In some cases, it is probably just chance. Whether they are monolingual or bilingual, children build their vocabularies gradually. When bilingual children’s vocabularies are sparse and small, they might be expected to know relatively few translation equivalents. Pearson, Fernández, and Oller (1995) found that, in production, the number of translation equivalents bilingual children (aged 8 months to 2.5 years) knew was equivalent to the overlap in randomly selected monolingual children. This suggested that bilinguals neither selectively learned nor selectively avoided translation equivalents.

However, unlike simultaneous bilinguals, who typically encounter both languages at home, older children often encounter their two languages in separate contexts; that is, their languages may have different domains of use. For example, one language might be used at home and another at school. In this case, children may encounter different sets of words in the two languages and may not know translation equivalents for words only encountered in one setting (see Chapter 1 for a fuller discussion of the complementarity principle).

For example, Bialystok et al. (2010b) studied the receptive vocabularies of over 1700 monolingual and bilingual children aged 3–10 years. Monolingual children were learning English and bilingual children were learning English and a variety of other languages. They found that the monolingual children had higher receptive English vocabularies than the bilingual children. However, this difference was largely accounted for by home words (e.g., squash, camcorder). When they limited their analysis to words likely to be encountered at school (e.g., astronaut, rectangle), there was very little difference between the monolinguals’ and the bilinguals’ English vocabularies. Although this study did not test children’s vocabularies in their non-English language, this suggests that, unsurprisingly, children may lack translation equivalents for words that they encounter only in one domain. This study shows how the particular domains of use of a language are important for which vocabulary words a child knows in that language.

Summary

Word recognition in bilingual children depends on a myriad of skills. Children must find words in running speech, use different sources of information to determine the likely referent of a word, apply their speech perception skills to learn similar-sounding words, and recognize familiar words in real-time. Words across the two languages are intertwined in the developing bilingual lexicon, such that words with related sounds and meanings can sometimes activate each other. We have observed some interesting differences between monolingual and bilingual children's knowledge and abilities, which often reflect adaptation to their language-learning environments and influences of domains of use. Development of bilingual children's vocabularies proceeds largely independently within each language.

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