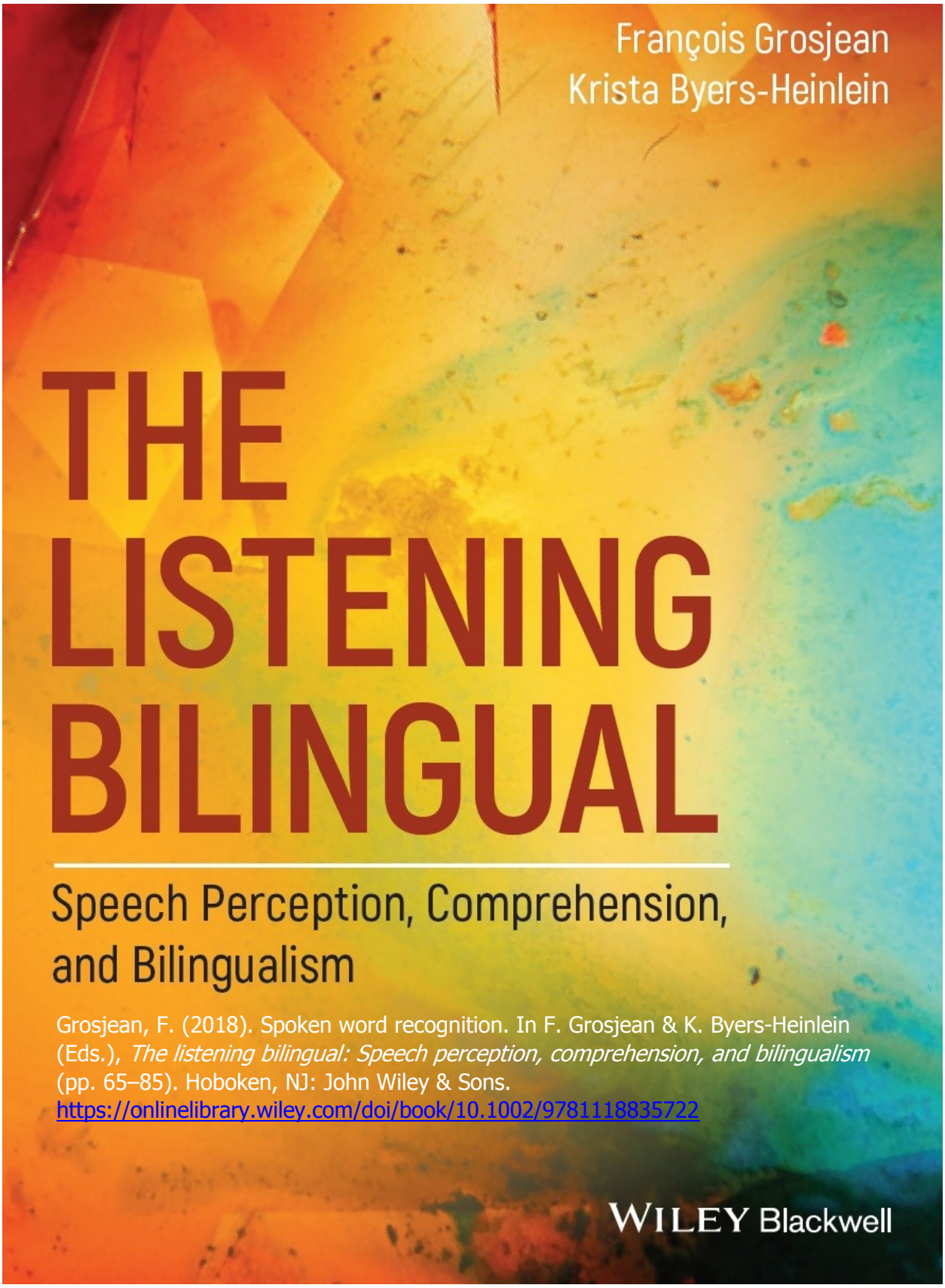
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4

Spoken Word Recognition

François Grosjean

Introduction

In our everyday interactions, we speak at a rate of about 175 words per minute, with quite a bit of variability depending on the topic, the listener, the context, and so on. This means that those listening to us have to recognize around three words a second, a remarkable feat when we examine the intricacies of word recognition.

Psycholinguists have been studying word recognition in monolinguals for more than half a century, both at the behavioral and the neurolinguistic levels, and considerable information has been amassed on how it is that we, as listeners, recognize the words that we hear. Most researchers agree that when a word is being recognized, a number of words in our internal lexicon – called "candidates" – are activated and one is finally chosen when sufficient information has arrived. Much less work has been conducted on bilinguals although the rate of research has picked up in the last fifteen years.

The first aim of this chapter is to present the intricacies of accessing words in our internal lexicon(s) and the underlying operations that take place so rapidly and so efficiently. A second aim is to account for the factors that play a role in how well bilinguals recognize words – from very efficiently to less so – in their two or more languages. We will show how a bilingual's language proficiency, language use, and language history play a major role, as does the perception of sounds that make up the word being processed. We will also review the differing processing mechanisms and strategies that bilinguals may use, or not, because of the fact that their languages are different from one another, or that they learned one later on in life. We will also discuss extensively the question of whether bilinguals activate words from their two or more languages when listening to only one language, leading sometimes to a greater number of candidates for a particular word and hence slowing down, momentarily, their word recognition.

Word recognition will only be addressed in a monolingual mode in this chapter, that is, when the speaker and the listener are only using one language. The recognition of words in a bilingual or mixed mode will be covered in Chapter 6.

The Listening Bilingual: Speech Perception, Comprehension, and Bilingualism, First Edition.
François Grosjean and Krista Byers-Heinlein.

How Does Word Recognition Take Place and How Do Bilinguals Fare?

Spoken Word Recognition

According to most models of spoken word recognition, lexical processing begins as soon as the first sounds of the speech wave are identified. Based on just a few milliseconds of a word being uttered, that word is activated in our internal lexicon (mental dictionary) along with other words that match the speech signal, at least in part. These candidates, also called "neighbors", compete with one another, and with the word actually being uttered. Little by little, as more information arrives, the recognition system narrows down the possibilities and finally selects the word in question (Cutler 2012; Goldinger, Luce, and Pisoni 1989; Marslen-Wilson 1989).

In addition to this activation process, cues in the speech stream, referred to as segmentation cues, help us identify such things as the beginning and end of words, and hence modulate the competition process. Thus, our knowledge of the lexicon helps us isolate candidates that are lexically plausible, as does what we know of the permissible combination of phonemes (phonotactic rules). We also use numerous acoustic-phonetic cues (allophonic variation, syllable duration, word stress, etc.) to help us narrow in on possible candidates (Mattys, White, and Melhorn 2005).

Many other factors will speed up or slow down the recognition of a word: how well it is articulated; the word's own frequency of use and/or familiarity; the number and frequency of competing neighbors during the recognition process; the point in time it becomes different from all the other candidates; the top-down information given by the syntax, semantics, and pragmatics of the discourse, as well as extra linguistic factors such as the situation, the person we are listening to, and our knowledge of the world.

Most often, a word is recognized before its end if it contains several syllables, sometimes after its end, that is, during the next word, if it is short. This final recognition allows us to gain access to the information about the word contained in our lexicon—its meaning or meanings, its grammatical category, its morphology, the syntactic and semantic structures that it can occur in, and so on. All of this, of course, usually takes place very efficiently and quickly as we have to keep up with the speaker articulating about three words a second, as we saw earlier.

How Do Bilinguals Fare?

Listeners who know and use two or more languages, that is, who are bilingual, go about recognizing words in much the same way as monolinguals and very often just as smoothly. Those who have been bilingual for a long time, as well as those who interact with them in everyday situations, rarely report that they have problems with word recognition when listening to someone talk. Several experimental studies have confirmed that bilinguals can indeed process speech, and in particular recognize words, efficiently and quickly. For example, Shi (2009) reported that simultaneous bilinguals who had acquired their second language before the age of 3, did as well as monolinguals when listening to English words in the quiet. Shi (2014) reported that, in the quiet again, there were no more errors in word recognition in "native bilinguals" – born and educated in a bilingual family – and in "intermediate bilinguals", who immigrated to the United

States in their early childhood and were educated in English, than in English-speaking monolinguals. Soares and Grosjean (1984) found that their Portuguese–English bilinguals recognized words just as rapidly as monolinguals; Blumenfeld and Marian (2011) found that bilinguals were as efficient as monolinguals at identifying target words in an experiment in the presence of competitors, and just recently Dijkgraaf, Hartsuiker, and Duyck (2016) reported that bilinguals listening to their second language can use the semantics of verbs to predict upcoming words just as well as monolinguals.

This said, there are other researchers who are far less optimistic about word recognition in bilinguals. Weber and Cutler (2004), reporting on their research results, paint a gloomy picture of word recognition in a second language and stress that non-native listening is "such hard work". Weber and Broersma (2012) write that listeners are often aware of the complexity of speech comprehension in a second language and that they are less efficient than native listeners in segmenting the speech stream into individual words. In addition, Cutler (2012) stresses that L2 listening is less efficient and that "this is true at very high levels of proficiency".

So where do we stand on the issue? A number of factors modulate how well bilinguals recognize words – from very well to less well – and we will examine them in what follows. We will show how a bilingual's language proficiency, language use, and language history play a major role, as does the perception of sounds that make up the word being processed. The differing processing mechanisms and strategies that bilinguals may use, or not, will also be reviewed. All this because of the fact that their languages are different from one another or that they learned one later on in life. We will then discuss extensively the question of whether bilinguals activate words from their two or more languages when listening to only one language, leading sometimes to a greater number of candidates for a particular word and hence slowing down, momentarily, their word recognition.

Language Proficiency, Use and History

In Chapter 1, we saw how crucial language proficiency, language use as well as language history are to our understanding of who bilinguals are and how similar or different they are from other bilinguals. These three factors, often broken down into subfactors, have played a major role in spoken word recognition research, both as independent variables and control variables. Thus, researchers often take into account some of these variables – rarely all of them – when choosing participants for their studies and/or explaining their results. We will illustrate this with two studies that have examined the recognition of words in the participants' second language (for a more extensive review, see Chapter 7). Examining word recognition in both the bilinguals' languages has not been as common, unfortunately, but we will mention two such studies afterwards.

Language History and Language Use

Meador, Flege, and Mackay (2000) were interested in examining the English spoken word recognition of Italian–English bilinguals who had all been born in Italy but who had moved to Canada at various points in their lives. They assigned participants, all in their forties, to different groups depending on their age of arrival in the country (AoA)

as well as their self-reported use of Italian at the time of testing. (It should be noted that the acronym, AoA, is normally used for the age of acquisition of a language but, in this case, age of arrival and age of acquisition are certainly highly correlated). An Early group had a mean AoA of 7 years and used Italian 32% of the time in their everyday life. Their mean length of residence (LOR) was quite substantial: 40 years. The Mid group had an AoA of 14 years and used Italian 20% of the time (LOR, 34 years). The Late group had an AoA of 19 years and used Italian 41% of the time (LOR, 28 years). In addition to these three groups, the authors examined the word recognition behavior of an Early-Low group that also had an AoA of 7 years and an LOR of 40 years but that used Italian much less than the Early group (8% of the time as compared to 32%). It should be noted that over all participants, AoA and LOR were inversely correlated – the earlier the AoA, the longer the LOR. This relationship was quite strong ($r = -0.62$), and so we will no longer mention LOR from here on.

A group of native speakers of English were also used for comparison. On this point, it should be noted that almost all word recognition studies of this type have a monolingual comparison group. The importance of having such a group can be questioned, however, if one defends the view that bilinguals are not two monolinguals in one person (Grosjean 1985, 1989) and hence should not always be studied in comparison with monolinguals. Studying them by themselves, or by comparing them to other types of bilinguals, often makes much more sense. We will report monolingual results in what follows because most studies do so, but we will try not to put the focus on the monolingual as the standard.

The participants in the Canadian study were presented with semantically unpredictable sentences, that is, sentences where the beginning does not predict what follows, such as, "The blond dentist ate the heavy bread" or "The nervous boy saw the hollow tree". To make the task a bit harder, each sentence was presented at four signal-to-noise (S/N) ratios, from more noise (–6 dB) to less noise (+12 dB), and after each presentation, the participants had to repeat as many words as possible. (For other studies of recognition of words in a sentential context and/or in noise, see Chapter 7 for an extensive review.)

The results obtained showed, not surprisingly, that the percentage of words repeated correctly increased systematically as the noise level decreased, with the best results obtained at the higher S/N. Averaged over the four S/N ratios, the Early group repeated more words (mean of 64%) than did the Mid (60%) and the Late groups (51%). As for the native English speakers, their result was 77%. At the highest S/N level (+12 dB), the Early group did as well as the native English group, showing that word recognition can be as good in bilinguals as in monolinguals in the quiet. The pattern found for the bilinguals, that is, the earlier the age of acquisition of a second language, the better the word recognition in that language, has been found repeatedly in studies over the years (see, for example, Shi 2009). However, it is unclear whether it is the actual age of acquisition of the second language that explains the results or how long a language has been known and been used. This remains an open question.

Concerning language use at the time of testing (and not the amount of language exposure over a period of time), the authors found that the Early-Low group obtained a mean overall score of 69%, that is slightly better than the Early group (64%). The former used Italian far less in their everyday lives – it was restricted to visiting relatives – than did the Early group, who reported using the language at home, at work, on the telephone, and at social gatherings. In sum, the more a second language is used, in this case English, the higher will be the recognition scores.

Several years later, Shi and Morozova (2012) also examined word recognition as a function of age of acquisition of a second language (English), length of residence in the country (the United States this time), and everyday exposure to, and use of, the language. Their participants were speakers of Russian as a first language and were broken down into two groups. The English-dominant bilinguals had a mean age of acquisition of English (AoA) of 6.93 years, a mean length of residence (LOR) of 15.32 years, and had 63.75% mean exposure/use of English. As for the other group, Russian-dominant, the means for the three variables were: 15.0 years (AoA), 10.90 years (LOR), and 46.00% (exposure/use), respectively. A group of monolingual English natives were also used. This time, all participants were asked to listen to single words presented in the quiet and they had to repeat and write them down.

The English-dominant group did very well (96.7%) and the Russian-dominant group less so (86.6%). The native speakers obtained a score of 98.6%. The error pattern obtained was the same for the English-dominant group and the English native speakers, but quite distinct for the Russian-dominant bilinguals, who showed problems with various vowel and consonant contrasts (we will come back to this issue below). Thus, once again, the earlier use of a second language, a longer period of exposure since the start of acquisition, and more use in everyday life, all play a role in word recognition. It should be noted again that the first two factors are difficult to separate since they are correlated in these studies.

The Importance of Language Proficiency

Language history and language use/exposure have been used in many other spoken word recognition studies. Fewer also take into account direct language proficiency measures such as fluency tests, self-rated proficiency, or even word familiarity indices. The two studies that will now be discussed did so and have the added advantage of having tested bilinguals in both their languages, something most studies do not do unfortunately. They usually concentrate on the bilinguals' second language and find, not surprisingly, that many bilinguals, especially those who acquired their second language in late childhood or early adulthood, do slightly less well than monolinguals!

Soares and Grosjean (1984) were interested in how Portuguese–English bilinguals perceived words in a monolingual and in a bilingual speech mode. They used fluent participants (mean age of 24.2 years) who had acquired English after age 12 when they moved to the United States. These bilinguals used both their languages on a regular basis and rated their overall fluency in both languages as being equal and high. They also read aloud passages in the same amount of time in the one and other language and named approximately the same number of objects in each language in a given amount of time. In the monolingual part of the study, they listened to sentences in English and, in a later session, in Portuguese. While doing so, they were asked to do a phoneme-triggered lexical decision task, that is, in a sentence listen for a word (or non-word) that begins with a prespecified phoneme. Once they had found it, they were to indicate as quickly as possible whether it was a real word or not. For example, in the sentence, "After lunch, the children asked for a piece of *cake* for dessert", they had to detect the word that began with the /k/ phoneme (written "c")—in this case "cake"—and to indicate its lexical status (word, non-word). A group of English monolinguals were also tested on the English sentences only.

Not only did the authors find no statistical difference between the monolinguals and bilinguals for the English part of the study (the bilinguals were in fact a few milliseconds faster than the monolinguals) but they found no difference for the bilinguals between the English and Portuguese parts. Clearly, fluent bilinguals can access words as rapidly in their two languages and do so as well as monolinguals, even when they acquired their second language during their adolescence. Such a result is important to underline when we are faced with the kinds of negative comments presented in the preceding part.

Of course, if bilinguals are dominant in one language, they will perform better in that language than in their other language(s). This is exactly what Shi and Sánchez (2011) showed in a study in which their Spanish–English bilingual participants had to repeat and write down the words they heard, presented one at a time, in quiet and at two noise levels. They tested two groups: English-dominant and Spanish-dominant bilinguals. The English-dominant listeners learned English earlier compared to the Spanish-dominant listeners (age of acquisition: 4.3 years versus 13.91 years, respectively), were exposed to English for a longer period of time (25.23 years versus 11.94 years), and used English more frequently (daily exposure: 61.15% versus 45.68%). In terms of language proficiency, the two groups differed mainly in their Spanish proficiency, with Spanish-dominant listeners showing significantly higher proficiency in all skills tested than English-dominant listeners. Skills in English only differed significantly for speaking-related areas whereas their listening proficiency was similar.

As might be expected, the English-dominant bilinguals performed better than the Spanish-dominant bilinguals on the English words (95% versus 90% in the quiet) and the Spanish-dominant bilinguals performed better than the English-dominant bilinguals on the Spanish stimuli (98% versus 76%, also in the quiet). One factor that Shi and Sánchez approached without testing it directly is functions of languages. As we saw in Chapter 1, bilinguals usually acquire and use their languages for different purposes, in different domains of life, with different people (we have named this the Complementarity Principle). The authors did not test word recognition as a function of domains of use but they did ask their participants to give familiarity ratings of the words they had heard, once for the Spanish words and then again for the English words. They used a seven-point scale that had three anchors: 1: don't know the word; 4: recognize the word but don't know its meaning; 7: know the word.

The authors found, as expected, that the English-dominant listeners were less familiar with the Spanish words than the English words, whereas the reverse was true for the Spanish-dominant listeners. More importantly, they found that the familiarity ratings were correlated with the word recognition results in the listeners' non-dominant language, and they concluded that misrecognition tends to occur with words unfamiliar to listeners. In general, familiar words are better recognized than unfamiliar words.

Were we to start examining spoken word recognition in terms of domains of language use, we would probably find that if bilinguals use a particular language for a particular domain, and have been doing so for many years, there is every chance that they will do so well, even if it is in their weaker language. As we saw in Chapter 1, Bialystok et al. (2010) found that bilingual children had the same amount of receptive vocabulary than monolinguals in a domain they shared, school activities. Although, to our knowledge, no study with adults exists involving spoken word recognition, Carroll and Luna (2011) have examined visual word recognition in terms of domains of use with Spanish–English bilinguals. When words were shown in Spanish and they belonged to the Spanish-language

domain (e.g., family and friends), they were recognized faster than the same words shown in English. When words were shown in English and they belonged to the English-language domain (work), they were recognized faster than the same words shown in Spanish.

To conclude this section, it is fair to say that word recognition in bilinguals will suffer if a person does not know a language well, does not use the language very often, and has not had a lot of exposure to the language over the years. This can often be made up in everyday communication by the fact that word recognition usually takes place in context – linguistic and extralinguistic – and that language is highly redundant. If, on the other hand, bilinguals are quite fluent in their languages, have used them extensively over the years, and the words tested belong to their habitual domains of use in each language, then there is every chance that word recognition will be very effective (although it may suffer in noise, as described in Chapter 7).

Lower Level Information

Since spoken word recognition depends heavily on the perception of lower level information, most notably the speech sounds that make up the word being uttered, it is important that speech perception takes place optimally. Sometimes, however, this is not the case. A situation that has been studied quite extensively is when the first language has only one sound category and the second language two, which are assimilated to just one category under the influence of the stronger first language. For example, the two English categories /æ/, as in "sat", and /ɛ/, as in "set", might not exist in the English of native speakers of Dutch since their language only has one category, /ɛ/. Hence, Dutch–English bilinguals, dominant in Dutch, may sometimes not be able to differentiate the two English sounds. Another example comes from Catalan, which has the contrast /e/-/ɛ/, which may be difficult to perceive by Spanish–Catalan bilinguals, dominant in Spanish, since the latter only has the /e/ category. Hence, they may have difficulties differentiating the minimal pair /netə/ (granddaughter) and /nɛtə/ (clean, feminine) (Pallier, Colomé, and Sebastián-Gallés 2001). This can lead to a number of word recognition problems such as increasing the number of candidates prior to word recognition and hence delaying it, activating phantom words momentarily, that is, words that are not actually present in the speech signal, or even causing an error in recognition. We will examine the first two consequences in what follows.

Weber and Cutler (2004) were interested in showing that phonetic discrimination difficulties in a second language can lead to the activation of spurious word candidates during the word recognition process. They tested English vowel and diphthong contrasts that are attested to be difficult for Dutch listeners, the lax vowel pair /æ/-/ɛ/ and the diphthong pair /aɪ/-/eɪ/. Dutch contains the vowel labeled /ɛ/ and a diphthong labeled /ɛɪ/, but no /æ/ or /aɪ/. They used an eye-tracking approach, also called a visual-world paradigm, in which listeners looked at a monitor displaying a 5 × 5 grid on which there were four geometric shapes (e.g., a circle, a triangle, etc.) and four line-drawings (e.g., a strawberry, a panda, etc.). The participants wore a head-mounted eye-tracker, which recorded the locations and latencies of their eye movements. They were asked to click on one of the pictures using a mouse (e.g., *Click on the panda*) and then to move the picture on top of one of the four geometric shapes (e.g., *Now put it on top of the circle*). The crucial aspect of this kind of experiment is that one picture is the target

(e.g., panda) and another picture is a competitor (e.g., pencil), their names differing in a specific way on the first syllable, in this case the vowel /æ/ in "panda" and /ɛ/ in "pencil". The interesting question is whether the Dutch dominant bilinguals will look at the picture of the pencil when listening to the word "panda" more so than when another, less confusable, pair is concerned. If so, their failure to discriminate the vowels /æ/ and /ɛ/ have led them to activate, momentarily, words that begin with /pɛn/.

The participants who took part in their study were native Dutch speakers who were highly proficient in English. They had learned the language in school beginning at age 11 and as students they used it in their studies, both orally (e.g., to follow lectures in English) and in its written form. A group of British native speakers were also used in the study. The results showed that the Dutch listeners fixated longer on distractor pictures with names containing confusable vowels (fixating on a pencil given the word "panda") than on pictures containing less confusable vowels (fixating on a beetle given the word "bottle"). It is only later in the word, after the initial syllable, that the target word became the primary candidate. Further experimentation showed that the confusability of the vowel contrast was asymmetric (hearing "pencil" did not cause more looks to the picture of a panda). The authors concluded that, in some cases, phonetic discrimination difficulties can lead to prolonged activation of competitors during non-native spoken-word recognition.

The incorrect perception of speech sounds can also lead to the momentary activation of phantom words, that is, words that are not actually present in the speech signal. Thus, concerning the pair of English vowels, /æ/-/ɛ/, some Dutch bilinguals might listen to "daffodil" and momentarily perceive the word "deaf" before the second syllable puts them back on the right track. Broersma and Cutler (2011) showed this was indeed the case when they tested the same kind of participants as in the preceding study. They first showed that these listeners who were asked to do a lexical decision task (i.e., say whether a sequence of sounds was a word or not), accepted near-words such as "daf" or "lemp" as real English words, thinking they were hearing "deaf" and "lamp", and this to a much greater extent than did English listeners (65% versus 38%, respectively). The researchers then asked another group of participants to do a cross-modal priming task. Here they heard parts of English words (e.g., "daf" taken from "daffodil") and immediately afterwards saw the written word "deaf" on a computer screen. Their task was to say whether what they saw was a word or a non-word. In a control condition, they would hear "hov" taken from "hovercraft" and see the visual word "deaf".

When the visual target was preceded by the auditory presentation of the same word, both the Dutch bilinguals and the English monolinguals were faster at giving their response, a well-known facilitation result obtained with this type of task. However, when a near-word (e.g., "daf") was presented, only the Dutch listeners showed a facilitation in the recognition of the visual word "deaf", thereby showing that they had heard "deaf". In general, near-words such as "daf" and "lemp" induced the activation of corresponding real words ("deaf", "lamp"). The researchers even found that when they presented untruncated spoken words such as "daffodil" (and not just "daf"), "deaf" remained a candidate, that is, it was still active. Even though the authors concluded that phantom competition may seriously hinder non-native word recognition, it should be recalled that this is just one level of processing that is involved when one is listening to continuous speech—syntactic, semantic, and pragmatic processing can correct the misperception at the lexical level and lead ultimately to a correct message representation. And, of course, not all sequences heard lead to phantom competition.

Processing Mechanisms and Strategies

In addition to misperceptions happening at the speech perception level and having an impact on the lexical level when listening to a second language, it can be the case that some processing mechanisms and strategies are not acquired because the first language did not have them and/or the second language was acquired later. We will illustrate this with two phenomena that have been studied quite extensively – the use of gender marking on words preceding the word to be recognized and the use of segmentation cues to help the word recognition process.

The Gender Marking Effect

Depending on the language, nouns may be characterized by gender, that is, they fall into classes such as masculine, feminine, neuter, animate, inanimate, etc. Thus, French, Italian, and Spanish have two genders (masculine and feminine), German has three (masculine, feminine, and neuter), whereas English has none. Other word classes such as adjectives, determiners, and pronouns do not have gender but will reflect the gender of the noun they are associated with in an utterance. In the French phrase, "la petite fille" (the little girl), both the article (la) and the adjective (petite) carry a feminine ending so as to agree with the feminine noun (fille). One talks of congruent gender marking on the words preceding the noun.

In one of the earliest studies examining the processing of gender marking in bilinguals, Guillelmon and Grosjean (2001) wanted to see if their recognition of nouns was speeded up by the congruent gender markings on preceding words (e.g., "la" and "petite" in the above example), and if incongruent markings slowed it down (e.g., "*le petit fille"). They tested two types of English–French bilinguals: early bilinguals who had started using their two languages when they were 5;4 years on average, and who used them on a regular basis, and late bilinguals who first spoke English only, had learned French at school, and had become regular users of French as adults at age 24;8 years on average. They were in their forties when testing took place. The task the participants were given was to repeat the noun at the end of short phrases where the gender marking was congruent with the noun (e.g., "le joli bateau" (the nice boat), incongruent ("*la jolie bateau"), or not present ("leur joli bateau")), that is, the control condition. In each case, the word to repeat was "bateau".

The early bilinguals showed both a congruency effect and an incongruency effect, a result also found in monolinguals. When compared to the control condition, they were faster when the gender marking was present and slower when it was absent. This showed that they had become sensitive to gender marking early in life. The late bilinguals, however, were insensitive to both gender congruency and gender incongruency, even though they produced very few gender errors in their speech production. They simply were not able to use the gender cues present ("le" and "la") to speed up or slow down the word recognition of the noun. The authors concluded that there might be a sensitive period to acquire such a mechanism and as their late bilinguals had acquired French after it, they were insensitive to gender marking. Of course, since they had good oral comprehension, they recognized the words being said, but they did so without being helped by gender marking.

The Guillelmon and Grosjean (2001) results were confirmed by Scherag et al. (2004) who also tested, among other participants, late bilinguals, this time English immigrants in Germany. They had started learning German after the age of 12 and had lived in Germany 15.5 years on average. They were asked to listen to two words, an adjective (the prime) followed by a noun (the target), and they had to decide whether the noun was a real word or a pseudo-word (non-word). The adjectives were correctly or incorrectly inflected for gender with respect to the noun (congruent or incongruent) and the pair were either semantically associated or not, that is, shared a meaning relationship with one another. Thus, in "faltiges Gesicht" (wrinkled face), the gender is congruent (neuter) and the semantic association is high. Examples of the other three possibilities were: "faltiges Haut" (wrinkled skin) where the gender is incongruent (neuter adjective and feminine noun) but the semantic association is high; "faltiges Gerücht" (wrinkled rumor) with congruent gender (neuter) but low semantic association; and "faltiges Lohn" (wrinkled reward) with incongruent gender (neuter adjective and masculine noun) and low semantic association. The results were clear: semantic priming was present in the English immigrant group but they did not show an effect for gender priming. The authors concluded, as had Guillelmon and Grosjean before them, that the full acquisition of some morphosyntactic functions, such as using gender cues to speed up the recognition of the noun, may be restricted to a limited period of life.

Ten years later, Montrul et al. (2014) undertook a study that included three different tasks, including a word repetition task that we report on here. Their participants were Spanish native speakers, Spanish heritage speakers in the United States who knew Spanish well but were not dominant in it, as well as learners of Spanish whose proficiency in that language was not very high. Like in Guillelmon and Grosjean (2001), participants were asked to listen to a series of determiner–adjective–noun phrases and to repeat the last word as quickly and as accurately as possible. There were three conditions: congruent (e.g., "la gran guerra" (the great war)), incongruent ("*el gran guerra"), and neutral ("su gran guerra"). The authors found that native speakers and heritage speakers had slower reaction times in the incongruent condition than in either the neutral and congruent conditions, the latter two giving similar results. (Obtaining a statistically significant congruency effect can be difficult experimentally, as Foote (2014) showed, even though the trend existed in her study.) What is important is that the incongruency effect was not found in the second language learners, showing once again that beyond a sensitive period, the use of gender cues will be difficult for late learners.

Do any studies show that late learners are able to use gender marking in certain circumstances? Dussias et al. (2013) give evidence that this might sometimes be the case. They used an eye-tracking paradigm in which participants looked at a two-picture scene in which a familiar object in each of them matched for gender (same-gender condition) or did not match for gender (different-gender condition). They embedded the name of the object (e.g. "el reloj") (the clock) in a sentence such as "El estudiante estaba dibujando el reloj que vio ayer" (The student was drawing the clock that he saw yesterday). The participants were simply asked to listen to each sentence and click on the picture of the object named in it while their eye movements were recorded. Both monolingual Spanish speakers and English-speaking learners of Spanish took part in the study. The latter who had learned Spanish during their childhood were split into two groups, low proficiency and high proficiency. The authors found that the monolingual Spanish speakers looked sooner at the object in the different-gender trials than in the

same-gender trials. As for the learners, the low-proficiency group showed no evidence that they used gender as a cue to facilitate online processing, but the high proficiency group did. Thus, it could be that gender marking can be used by late learners in particular tasks, when the sentence context is rich, and if they are highly proficient in the second language. Foote (2014) also found that highly proficient late learners of Spanish, who taught the language and paid attention to gender while doing so, were sensitive to incongruent gender marking in a word repetition task. Clearly more research needs to be done to fully understand under what circumstances gender marking can be used by late learners.

Segmentation Cues

At the beginning of this part, we stated that some processing mechanisms and strategies may not be acquired because the first language does not have them and/or the second language is acquired later. Some of these concern the use of segmentation cues, that is, acoustic-phonetic, phonotactic, lexical, and prosodic cues can help the listener identify word boundaries and/or modulate the activation and competition of lexical candidates. One such cue is segmentation by lexical subtraction, that is, the use of lexical knowledge (also known as lexicality) to impose a segmentation structure on the speech input (Mattys, White, and Melhorn 2005). A known word in the speech string gives information to the listener as to where the preceding and following word boundaries are situated. Thus, in the string of three spoken words, "… invidious person who …", since the word "person" is well known, the boundaries on either side are clearly signaled.

White, Melhorn, and Mattys (2010) were interested to see if second-language speakers of English whose first language was Hungarian used lexicality in the segmentation of spoken English the way English native speakers do. They were also interested in the use of stress (metrical segmentation) by these listeners since Hungarian always puts the word stress on the initial syllable of a word whereas English only does so 85–90% of the time. The Hungarian speakers they tested in Budapest, Hungary, had not started learning English before the age of 10 but had had several years of exposure to it and reported speaking it well. Two objective tests allowed the researchers to break them down into four levels of proficiency. In the experiment, they asked them to listen to five-syllable phrases over headphones. The phrases started with a three-syllable word (e.g., "anything") or a non-word (e.g., "imoshing") followed by two syllables (the prime) with stress on the first (e.g., "ˈcorri") or the second syllable (e.g., "conˈfu"). After each phrase (e.g., "anythingcorri", "imoshingcorri", etc.), the participants were presented with a visual letter string (e.g., "corridor") and were asked to indicate as quickly and as accurately as possible whether it was an English word or not.

The results showed that lexicality was an effective segmentation cue for all non-native speakers, whatever their level of proficiency, just as it was for native speakers. Thus, the first two syllables of "corridor" (i.e. "corri") were a more effective prime for visually presented "corridor" when heard in the phrase "anythingcorri" than in "imoshingcorri". According to the authors, the segmentation by lexical subtraction strategy appears to be a powerful and possibly universal word-finding mechanism. As for the stress pattern of the prime, it did not affect the degree of priming, neither in the native speakers nor in the second language speakers, showing thereby that stress is weighted less as a cue than lexical knowledge.

Other segmentation cues concern acoustic-phonetic characteristics such as allophonic variation (different phones are used to pronounce a given phoneme in different contexts) and duration (syllables are shorter in polysyllabic words than in monosyllabic words). Altenberg (2005) investigated the ability of second language speakers of English, whose first language was Spanish, to use two other cues, aspiration and glottal stop. Voiceless stops in English are aspirated at the beginning of words, that is, produced with a strong burst of air, whereas they are not in Spanish, and the author examined whether the second language speakers could tell the difference between such pairs as "lay speech" and "lace peach" (in the latter, the /p/ is aspirated). She also tested phrases containing glottal stops, which are characterized by a silent gap or period of creaky voice before the vowel at a word juncture (as in "like old" compared to "lie cold"). Stimuli such as these were placed within a carrier phrase, "Say ------ again", and were presented to the listeners, including a group of native speakers of English, who then had to choose which pair of words they had heard by circling their choice on an answer sheet.

Altenberg found that the second language learners obtained three out of four items correct (76.3%) whereas the native speakers were close to achieving a perfect score (97.3%). The learners did better with the glottal stop stimuli (88.4%) since glottal stops exist in Spanish in emphatic speech (words or utterances that are uttered with emphasis), but they had trouble with the aspiration stimuli (58.5%) since Spanish does not have aspirated consonants. (Some stimuli had both cues and there the second language learners did almost as well as the native speakers.) It would have been interesting to use participants with better proficiency in English since the ones tested had lived in the United States and had studied English for a bit more than five years only, on average.

Greater language proficiency and more language use can certainly result in the improved use of segmentation cues as Weber and Cutler (2006) have shown. They concentrated on a different type of sublexical cue, the phonotactic knowledge one has of a language, that is, knowledge of the permissible combination of phonemes in a language including syllable structure, consonant clusters, and vowel sequences. Phonotactic constraints are highly language-specific and it is therefore interesting to see how bilinguals manage in their second language. The authors asked whether German–English bilinguals, with excellent knowledge of English (they were students of translation and interpretation), could use the phonotactic constraints of their second language (English) and whether they were influenced by the constraints of their first language (German).

The researchers used a word-spotting paradigm in which participants attempt to find a word in a string of lexical elements. In their experiment, the words were at the end of nonsense sequences and followed one of four different conditions: a common boundary in which the phoneme before the word provided a phonotactically clear boundary in both English and German (e.g., the boundary between "moin" and "lecture" in "moinlecture" given that "nl" is not allowed in either language and must therefore contain a boundary); an English boundary where the preceding phoneme provided a clear boundary in English but not in German (e.g., the boundary between "thrarsh" and "lecture" in "thrarshlecture" given that English has no words that begin with a ch/sh + l initial cluster); a German boundary where the preceding phoneme provided a clear boundary in German but not in English (e.g., the boundary between "moyce" and "lecture" in "moycelecture", given that words in German may not begin with /s/ and therefore /sl/ must contain a word boundary); and, finally, a no-boundary condition in which the preceding phoneme did not provide a clear boundary in either language (e.g., the

boundary between "gork" and "lecture" in "gorklecture" since "kl" is a an acceptable cluster in both languages). In addition to the bilinguals, a group of American English monolinguals with no knowledge of German took part in the study.

The results, based on the data obtained for the first three conditions when compared to the fourth condition, were clear. When both English and German phonotactic constraints forced a boundary at word onset (the common boundary condition), the responses of both groups were equivalently facilitated. In the English boundary condition, the bilinguals were almost as strongly facilitated as the native English speakers, showing that they could make use of boundary constraints in their second language. As for the German boundary condition, the German listeners were significantly facilitated by contexts that forced a boundary in German but the English native speakers were not sensitive to the phonotactic sequences. The authors concluded that proficient second language listeners can indeed acquire the phonotactic probabilities of a second language and use them to good effect in segmenting continuous speech. This said, given the results in the German boundary condition, they may not be able to prevent interference from their first language constraints when listening to their second language. Had they been able to do so, their results would have been similar in this condition to those of native English speakers, but they were not.

The Activation of Candidates

We saw in the first part of this chapter that most models of word recognition agree that based on just a few milliseconds of a word being uttered, that word is activated in our internal lexicon along with other words that are similar. These candidates compete with one another, and with the word actually being uttered, and little by little, as more information arrives, the recognition system narrows down the possibilities and finally selects the word in question. The activation of candidates is thus a basic mechanism in word recognition and it is only normal that it has been a major topic of research where bilinguals are concerned.

Within-Language Activation

As concerns within-language activation, that is, the activation of candidates within just one language, only a few studies have examined how bilinguals fare. In the section entitled Lower Level Information, we mentioned problems that can occur when speech perception does not take place adequately and sounds are misperceived. This can lead to an increase in the number of candidates prior to word recognition and hence a delay in the process, the momentary activation of phantom words, that is, words that are not actually present in the speech signal, and even errors in recognition. Of course, if a second language is also not known very well, or a category of words are not familiar to a bilingual, then recognition problems will occur (see the first two sections of this chapter).

This said, most bilinguals have developed their languages to the extent that they need them, and within-language activation usually takes place quite smoothly. Blumenfeld and Marian (2011) give evidence for this. Their aim was to study the activation of within-language competitors during word recognition and the subsequent inhibition

(suppression, in their words) of irrelevant competing words. Their participants were English–Spanish bilinguals as well as English monolinguals. The former spoke English as a native language and did not differ from monolinguals in their self-reported English proficiency across comprehension, speaking, and reading modalities. They also had extensive Spanish experience (acquired before the age of 8), as well as substantial current exposure to the language. They were basically very fluent in both languages.

An adapted eye-tracking paradigm was used in which the participants listened to words in English and identified them among four pictures while their eye movements were tracked. Each target picture (e.g., that of a hamper) appeared together with a similar-sounding within-language competitor picture (e.g., a hammer) and two neutral pictures. The participants listened to the target word and identified its picture in the quadrant (cell) that appeared in front of them by pressing one of four keys. To probe inhibition of competitor words, the participants' key press was immediately followed by a priming probe trial in which the participants had to identify the quadrant containing a gray asterisk by pressing one of the same four keys (the other quadrants had black asterisks). The gray asterisk could appear in different quadrants. In the control probe trials, it appeared in the same location as a control picture in the preceding display; on competitor probe trials, it appeared in the location of the preceding competitor picture; and in the target probe trials, it appeared in the same location as the target in the preceding display. By comparing how participants reacted to the asterisks in each location, the researchers could study the inhibition of competitor words after recognition of the target word.

The researchers found that bilinguals were as efficient as monolinguals at identifying target words when within-language competitors were present, even though both were slowed down slightly by the latter. Both groups also coactivated similar-sounding competitors to an equal extent. As the authors write, within-language activation likely places equivalent demands on bilinguals' and monolinguals' cognitive systems. This is an important finding as it clearly shows that bilinguals can indeed process language efficiently and smoothly if they know it well and use it on a regular basis. The difference Blumenfeld and Marian found did not involve actual word recognition, which was the same for the two groups, but the inhibition of the competitors. Monolinguals responded slower to competitor probes than to control probes, suggesting thereby that they showed more residual inhibition than bilinguals. This could mean that bilinguals return to a baseline activation state faster after inhibiting irrelevant information. The authors venture the hypothesis that this ability to disengage more quickly from inhibiting irrelevant information may be especially important during bilingual language processing since the language not being used may become relevant at any point in time (e.g., when the interlocutor changes base language or code-switches).

In a later study, Marian et al. (2014) pursued this line of research by asking bilinguals and monolinguals to take part in an fMRI study in which they had to search for a picture representing an aurally presented word (e.g., "candy") from an array of four presented images. On competitor trials, the name of one of the objects in the display once again shared initial overlap with the target (e.g., "candle"). The results obtained showed that both monolinguals and bilinguals were very accurate in their responses, but once again they responded more slowly when the competitor picture was present than when it was absent, as was expected. There were no differences between monolinguals and bilinguals at this level. However, when the imaging results were compared, the researchers

found that bilinguals displayed substantially less cortical activation compared to monolinguals who showed greater activation in frontal regions (executive control areas) as well as the primary visual cortex. The conclusion the study arrived at was that both monolinguals and bilinguals experienced competition, as indexed by slower response times in competition conditions, whereas the two groups recruited different neural resources to manage this competition.

Between-Language Activation

The main topic of activation research in bilinguals has been between-language activation, that is, whether the other language(s) is (are) active when a particular language is being processed. To use the terminology employed over the years, is processing in bilinguals selective, that is, when one language is heard, only that language is active and is processed? This is what we have termed being in a monolingual mode (see Chapter 1). Alternately, is processing non-selective, that is, the bilingual's different languages intervene while processing is taking place? This is termed being in a bilingual mode. Recall that language mode is simply the state of activation of the bilingual's languages and language processing mechanisms at a given point in time. For a long while, researchers opted for non-selectivity and have produced at times rather categorical statements. Thus Green and Abutalebi (2013) stated that substantial evidence indicates that in bilingual speakers both languages are active, even when one is being used, and Weber and Broersma (2012) wrote that, during word recognition, the set of potential candidates is multiplied with parallel activation of words from the mother tongue and from the second language.

Admittedly, early research that examined this issue did seem to show the activation of both languages. A seminal study was conducted by Spivey and Marian (1999), who used the eye-tracking approach (visual world paradigm) for the first time on this issue with Russian–English bilinguals. Below we report on the Russian part of their study. Their participants looked at a 3 × 3 board that contained a number of objects: for example, a stamp was in the bottom right-hand square, a marker (or a ruler) in the top left-hand square, and two filler objects in the top-right square and the bottom-left square. The participants were given instructions in Russian to displace the target object on the board to the middle square: "Poloji marku nije krestika" (Put the stamp below the cross). In the interlingual competitor condition, an object on the board had an English name that shared initial phonetic characteristics with the onset of the name of the Russian target object. Thus when the target object was a stamp ("marku"), the interlingual competitor object was a marker, an object whose English name shares the same word beginning as "marku".

The researchers examined the eye movements made to this interlingual competitor object as compared to a control object, in exactly the same position, such as a ruler. In this case, the object's name bore no phonetic similarity with the name of the target object. The results obtained showed that the participants made significantly more eye movements to the interlingual competitor object (32%) than to the control object (7%). The authors concluded that the word onset of the target object (e.g., "marku") not only activated Russian words in the Russian lexicon but also English words in the English lexicon that began in a similar way ("marker" is very similar to "marku"). Based on this, the authors concluded that processing is non-selective. This first study had a large

impact on the field and for several years to come researchers were convinced that both the bilingual's languages were active during word recognition, the consequences being that there was an increase in the number of competitors, a higher density of neighbors, and slower word processing (see the work by Cutler and others previously mentioned).

New studies were undertaken and a more balanced picture slowly emerged that is more subtle but which also makes more sense. Basically, how much the other language is active depends on a number of factors and will lead to total activation all the way to total deactivation, as will be seen below. A first factor is quite simply the language proficiency a bilingual has in the language used in the study as opposed to the other language. If a study is done in the dominant or first language, and the other language is less well-known, then a more selective process will emerge. Weber and Cutler (2004) showed this very clearly. In the two studies that are of interest here (3 and 4), their participants were Dutch listeners who had started learning English at age 11 and had been using it for more than 7 years. They were presented with English spoken words while the visual display from which they had to select a target included a distractor item of which the Dutch name, but not the English name, made it a potential competitor. Thus, for example, they heard, "Click on the kitten. Now put it on top of the diamond", whilst they also saw a visual competitor whose name in Dutch ("kist", which means "chest") overlapped phonemically with the beginning of the target ("kitten"). The proportion of fixations obtained showed that the Dutch competitors were activated when the bilingual participants did the study but not when a control group of monolingual American speakers responded. They concluded, like Spivey and Marian, that non-native listeners experience spurious competition from native language candidates.

However, Weber and Cutler then asked themselves whether listeners would experience competition from their second language when listening to their first language. They therefore changed the language of the experiment and of the test items and ran a second group of similar bilinguals on the new stimuli (e.g., "kist" became the target and "kitten" the competitor). The result was clear: they found no activation of the English competitors! Their conclusion was that for listeners who use their second language less frequently than their native language, competition when listening to the latter is not increased by second language candidates. A few years later, Blumenfeld and Marian (2007) found a similar result.

Another factor that controls the activation of the other language is the bottom-up information heard by participants. For example, Ju and Luce (2004), who tested highly proficient Spanish–English bilinguals in Spanish and who also used the eye-tracking task, showed that even a subtle phonetic cue from the other language was enough to activate it. They manipulated the Voice Onset Time (VOT) of the first consonant of the Spanish target words, that is, the brief delay between the release burst and glottal pulsing, and replaced it with its English counterpart. Thus, for example, the Spanish /p/ of the word "playa" (beach) was in essence replaced with the English /p/ sound. This was enough to attract eye movements to the interlingual competitor object (a picture of "pliers") when the participants were asked to click on the picture that corresponded to the target word ("playa" said with the English /p/ sound). Basically, if bottom-up information from the other language enters the processing system, then that language gets activated.

This can also be clearly seen at the level above, the lexical level. Lagrou, Hartsuiker, and Duyck (2011) undertook a study showing that when interlingual homophones with

almost complete overlap (e.g., Dutch "lief" (sweet), English "leaf" /li:f/) are heard in isolation, word recognition becomes non-selective. They asked dominant Dutch–English bilinguals to decide whether spoken words pronounced in English (later the same experiment was conducted in Dutch) were words or non-words. Only 10% of the stimuli were interlingual homophones; the others were matched English control words, English fillers, and non-words. Despite being buried among other words in this way, homophones were recognized more slowly than control words and produced more errors. This was true when the authors ran similar bilinguals on the Dutch version of the study. What is interesting, though, is that in a later study, Lagrou, Hartsuiker, and Duyck (2013) preceded these words with low constraining sentences (e.g., "When you walk in the forest, there is a chance that you find a leaf") and high constraining sentences (e.g., "When the fall is coming in September most trees are losing more than one leaf"). They still found a homophone effect, but it was far weaker in the high-constraining sentences. Thus, when the semantic context points to words in the language being used in the study, cross-lingual interactions are reduced.

This was also clearly shown by Chambers and Cooke (2009) who used an eye-tracking technique and who asked English–French bilinguals to listen to French sentences. They preceded the target words (e.g., "poule" (chicken)) with non-restrictive and restrictive sentences. In the former case, such as in "Marie va décrire la poule" (Marie will describe the chicken), there was very little prior semantic constraint on the target word (here "poule") but in the restrictive case (e.g., "Marie va nourrir la poule" (Marie will feed the chicken)), the predicate constrained the noun. The competitor object was the picture of an interlingual homophone (a picture of a "pool" in our example). What was found was that consideration of the interlingual competitor object was greatly reduced when the context sentence was restrictive. Why was the number not reduced to zero? Quite simply because homophones were used in the study and participants were activating both the French lexicon and the English lexicon in a bottom-up manner. Can cross-language competition be removed totally during sentence comprehension? A study by Shook et al. (2015) would seem to show that it can. They observed no eye movements to cross-linguistic competitors in their eye-tracking study where targets were at the end of sentences. The latter most probably activated the language being used and deactivated the other language. Deactivation can also take place when interlocutors are known to be users of a particular language when communicating, even though they might be bilingual (see Molnar, Ibáñez-Molina, and Carreiras, 2015).

An important factor that will make word recognition selective or non-selective concerns the experimental context bilinguals find themselves in when doing word recognition studies (Grosjean, 1998, 2001). Several top-down factors can lead a participant to activate the language not being overtly used, such as: knowledge that the study relates to bilingualism; a laboratory that works on bilingual research; a bilingual university environment; reports from other bilingual participants who have just been in the study or who will do it soon; an experimenter who is bilingual, even though he or she only uses one language; the task that is used and/or the instructions that are bilingual; the two languages used in the experimental sessions; etc. As for bottom-up factors, we find the presence of cross-language homophones and shared word onsets in phonetically similar languages. In sum, just one factor, or a combination of factors, may well move the participants away from the monolingual end to the bilingual end of the language mode continuum, that is, from single- to dual-language activation.

Having become increasingly aware of these factors, Marian and Spivey (2003) criticized the so-called "monolingual mode" of their 1999 study with which we started off this section. They stated that a number of factors may have moved the participants away from the monolingual end of the continuum, factors such as the fact that the bilinguals knew they were taking part in an experiment on bilingualism, that they were tested by bilingual experimenters fluent in both languages, and that the two languages were tested in adjacent experimental sessions. We could add that the bilingual participants probably knew that the laboratory was doing bilingual research (in part, at least), that they may have received reports from other participants who had taken part in the experiment, and, a bottom-up factor, that the word onsets of the distractors may have activated the other language. In short, there were enough factors present for the required monolingual experimental session not to be present.

So as to put their participants in as close to a monolingual mode as possible, Marian and Spivey (2003) did a new study in which they used different experimenters who posed as monolingual speakers for the Russian and then the English sessions. (Note that what follows concerns the Russian session once again.) During testing, they used only the language of the session and participants only took part in one or the other session. The results they obtained were quite convincing. The participants looked only at interlingual English competitor objects in 8% of the trials as opposed to 5% for the control object, a non-significant difference. (Recall that in their first study, the percentages had been 32% and 7%, respectively.) Hence, in this case, the other language had been totally "closed out" and processing had now become selective.

Future research will probably confirm that factors such as these activate or deactivate the language not being tested, or find new factors. What is sure though is that the different languages of bilinguals (and accompanying processing systems) are available at all times. The input is processed by the language(s) that contain(s) elements of that input and this can lead to non-selective processing such as when homophones are involved (as seen above). Of course, if the input only contains elements of one language, then only one language may process it. Top-down variables will also activate or deactivate a language and sometimes even "contradict" the bottom-up information (as when, for example, the listener is "shocked" upon hearing the speaker say something in a language that is not expected). Things will also be complexified by the fluency bilinguals have in their different languages, their age of acquisition of their languages, the frequency of exposure to each language, the similarity of the two languages, etc. (Mercier, Pivneva, and Titone 2016; Costa et al. 2016). In sum, processing will be selective at times and non-selective at other times.

Summary

In this chapter an overview has been given of spoken word recognition in bilinguals. We have presented how word recognition takes place in real time and discussed the factors that play a role in how well bilinguals recognize words in their two or more languages. Among these, emphasis has been placed on the bilingual's language proficiency, language use and language history, the nature of the input from the speech perception level, the processing mechanisms and strategies that are influenced by the languages that are present, and the activation or deactivation of the language(s) not being processed.

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