Weber, A., & Broersma, M. (2012/in press). Spoken word recognition in second language acquisition. In C. A. Chapelle (Ed.), *The Encyclopedia of Applied Linguistics*. Bognor Regis: Wiley-Blackwell. DOI: 10.1002/9781405198431.

Spoken word recognition in second language acquisition

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In order to decode the message of a speaker, listeners have to recognize individual words in the speaker's utterance. Spoken word recognition involves two central processes: multiple word activation and competition. The incoming speech calls up a set of potential word candidates that match with the unfolding input, and the activated word candidates then compete for recognition (for models of spoken-word recognition see e.g., Gaskell & Marslen-Wilson, 2002; McClelland, 1991; Norris & McQueen, 2008). As the word *steak* is heard, for example, words with similar sounds like *stay*, *stale*, *stain*, *take*, and *ache* will be considered in parallel with *steak*. The fact that words resemble one another (e.g., *drunk* and *trunk* only differ in the voicing of the initial consonant), and short words may be embedded within longer ones (e.g., *ink* in *pink*), complicates the task for the listener.

Nevertheless, recognizing spoken words is usually effortless in one's native language (L1), but the same task can be much more demanding when listening to a second language (L2). Main issues in L2 word recognition research concern the involvement of the L1 and L2 lexica and the influence of the phonological structure of the listener's mother tongue, with the focus being on lexical representations of word form. (For a discussion of representation of word meaning in the L2, see the entry *Organization of the second language lexicon* by Judith Kroll.)

[A] More lexical activation for L2 listeners

The processes involved in spoken word recognition are presumably universal. The question is thus not whether multiple lexical activation and competition occurs in L2 spoken word recognition, but how much of it occurs. There is ample evidence by now that part of the effort of L2 listening is caused by an increase in the competitor set for L2 listeners.

[B] Words from the L1 lexicon

A major factor responsible for increasing the competitor set is that L2 listeners are not able to keep their two lexica apart. That is, when listening to their second language, they cannot prevent themselves from activating words from their native language. For example, when Dutch listeners hear the English word *leaf*, they not only activate *leaf* but also the similar-sounding Dutch word *lief*, meaning 'sweet' (Schulpen, Dijkstra, Schriefers, & Hasper, 2003). Words from their native language also activate when the overlap with the second language only concerns word onset. Dutch listeners experience activation of the Dutch word *deksel*, 'lid', when hearing the English word *desk* (Weber & Cutler, 2004), and Russian listeners activate the Russian word *marku*, 'stamp', when hearing the English word *marker* (Marian & Spivey, 2003).

For L2 listeners the set of activated words is therefore not restricted to words that are phonologically similar within the second language, but is enlarged by words that are similar across the first and second language. Although the speech signal contains enough phonetic-acoustic information for the L2 listeners to know which language is being heard (e.g., the /d/ in English *desk* and Dutch *deksel* differs in voice onset time), L2 word recognition is bedeviled by parallel activation of two lexica, even for highly proficient L2 listeners. There is a ray of hope, however. Recent findings suggest that activation of the L1 is much reduced when the L1 word is semantically incongruent with a sentence's context (e.g., English listeners activate English *pool* less strongly in the French sentence *Marie va nourrir la poule*, 'Marie will feed the chicken' (Chambers & Cooke, 2009; FitzPatrick & Indefrey, 2010).

[B] Words with easy sounds from the L2 lexicon

L2 listeners also suffer from an increase in lexical activation from within the second language itself. They are less efficient in deactivating unintended words than native listeners are, even when the speech does not contain any sounds that L2 listeners find particularly difficult. This is indirectly suggested by research showing that second-language listeners are more affected by neighborhood density than are native listeners. Both L1 and L2 listeners find it harder to recognize words coming from a high-density neighborhood (i.e., words for which a large number of other words exist in the mental lexicon that differ by a single sound) than words from a low-density neighborhood. The more words are activated because they sound similar to the speech input, the harder it is to recognize the intended word. For L2 listeners, however, the difference between words with high- and low-neighborhood density is much larger than for native listeners (Bradlow & Pisoni, 1999).

More direct evidence for L2 listeners being less efficient in deactivating unintended words comes from a study by Rüschemeyer, Nojack, and Limbach (2008). They found that when Russian learners of German hear the German word *Tisch*, 'table', they activate *Fisch*, 'fish', long enough for its meaning and word associations to be retrieved, whereas this is not the case for native listeners of German. Interestingly, Russian listeners activate the unintended word *Fisch* even though they can easily hear the difference between the onset of *Fisch* and *Tisch*.

[B] Words with difficult sounds from the L2 lexicon

Perceiving differences between similar-sounding words is not always easy for L2 listeners. This is due to the fact that L2 sound perception is often inaccurate (for an overview, see Bohn & Munro, 2007). In particular discrimination of second-language sound contrasts that are ignored in the listeners' native language may never reach native standards. Japanese listeners, for example, have notorious difficulty in distinguishing English /r/ and /l/, which both map (badly) to a single Japanese category which is phonetically between /r/ and /l/, and Dutch listeners find it difficult to perceive the difference between the English /æ/ (the vowel in *cat*) and /ɛ/ (the vowel in *desk*). These perceptual difficulties with L2 sounds affect L2 word recognition in at least three ways.

First, the distinction between minimal pairs can get lost. Dutch learners of English do not treat minimal pairs such as *flash* and *flesh* as two different words; rather, hearing *flash* also leads to the activation of *flesh* (Cutler & Broersma, 2005). Similarly, even highly fluent Spanish-Catalan bilinguals who have acquired both languages early in life show the same effect when listening to Catalan minimal pairs differing in sounds that are not contrasting in Spanish (Pallier, Colomé, & Sebastián-Gallés, 2001). Luckily, this is not a frequent problem. The number of minimal pairs in the English lexicon, for example, is relatively small, especially when compared to the number of homophones (e.g., *rain - reign*) that listeners have to handle anyway (Cutler, 2005). An increase in lexical competition due to the misperception of minimal pairs therefore occurs only rarely.

Second, words with different onsets are treated as matching in onset when perceptually difficult sounds are involved. When listeners hear a word, all words with overlapping onsets are initially activated. Thus, upon hearing the first syllable of *panda*, English L1 listeners activate not only *panda* but also *panel*, *panic*, and *pantry*, among others. As soon as more than the first syllable is heard, the activation of the incorrect word candidates decreases, and by the time the whole word *panda* has been heard, no activation of the incorrect candidates remains (Zwitserlood, 1989). For L2 listeners, however, this initial set of competitor words is expanded by words that differ in a perceptually difficult sound contrast in the initial portion of a word. That is, for Dutch listeners, hearing English *pan-* additionally activates words like *pencil*, *penny*, and *pension* (Weber & Cutler, 2004). Similarly, for Japanese listeners, hearing *rocket* causes temporary lexical activation of *locker* (Cutler, Weber, & Otake, 2006). Since the overlap in these cases is only temporary, the initial confusion will not lead to a lasting misinterpretation of which word is being heard. Nevertheless, the extended availability of incorrect interpretations slows down the L2 word recognition process. Analysis of the English vocabulary has shown that this type of confusion occurs frequently and causes substantial added lexical competition for L2 listeners (Cutler, 2005).

Third, parts of one or more words might be mistaken for another word that the speaker did not say at all. When English L1 listeners hear the word *DEFinite*, this also temporarily activates the embedded word *deaf*. For L2 listeners, however, this can

extend to cases where the speech signal does not actually contain an embedded word. Thus, for Dutch L2 listeners who hear English *DAFfodil*, the nearly embedded word *deaf* is also activated, while this is not the case for English L1 listeners (Broersma & Cutler, in press). Similarly, native listeners of Dutch, which distinguishes voiced and voiceless consonants but not in word-final position, activate *groove* when they hear the near-word *groof* in biG ROOFs (Broersma & Cutler, 2008). As well, Spanish-Catalan early bilinguals do not distinguish accurately between Catalan words and near-words differing in Catalan-only contrasts (Sebastián-Gallés, Echeverría, & Bosch, 2005). Besides sounds, perception of suprasegmentals can be difficult for L2 listeners as well, and has been shown to affect word recognition. Spanish, for example, has minimal pairs that only differ in the location of stress, but in French, stress is not used contrastively. French learners of Spanish have great difficulties rejecting a near-word (for example *gorró*) as a word, when it is created from an existing Spanish word (e.g., *górro*, 'hat') by changing the location of stress (Dupoux, Sebastián-Gallés, Navarrete, & Peperkamp, 2008). Listeners will eventually solve the misunderstanding because an erroneous parsing of the speech signal leads to meaningless leftovers (e.g., a person who hears *deaf* in *daffodil* will be left with *–odil* as a meaningless leftover), but this still requires a time-consuming detour. Again, analysis of the English vocabulary has shown that the problem of nearly-embedded words occurs very frequently (Cutler, 2005).

[A] Difficulties of segmenting speech into individual words for L2 listeners

The phonological similarity of words would be less problematic if the beginning and ending of words was as clearly marked in speech as it is in written language, where white spaces indicate word boundaries. But speech is a continuous stream of sounds, and listeners have to segment the stream into recognizable units (i.e., words) themselves. Since pauses in speech regularly occur within words and are missing between words, listeners have to use other information to locate word boundaries in an utterance. Information sources for L1 listeners include rhythmic structure, phonotactics, lexical knowledge, and fine phonetic detail. Listeners are often less efficient in

exploiting these language-specific information sources in their L2, mostly because their L1 segmentation strategies interfere.

[B] Rhythmic structure

One strategy listeners use to facilitate segmentation of running speech is based on the specific rhythmic structure of their L1. In English and Dutch, for example, most words begin with a stressed syllable, and native listeners of those languages use stress to find word boundaries. For example, English listeners find the embedded word *mint* much faster when it is followed by a strong syllable with full vowels (as in *mintayf*) compared to when it is followed by a weak syllable with reduced vowels (as in *mintef*) (Cutler & Norris, 1988). Comparable segmentation strategies of native listeners have been found for syllable-timed and mora-timed languages like French and Japanese, respectively (Cutler, Mehler, Norris, & Seguí, 1986; Sebastián-Gallés, Dupoux, Seguí, & Mehler, 1992).

When listening to an L2, listeners tend to use the segmentation strategy they know from their L1. French listeners use the syllable-based segmentation strategy that is appropriate for French even when they are listening to English, and English listeners are not using that strategy when listening to French (Cutler, et al., 1986). Similarly, native listeners of English or French persist in using L1 segmentation strategies when listening to Japanese (e.g., Otake, Hatano, Cutler, & Mehler, 1993).

[B] Constraints on sound sequences

Constraints on sound sequences within syllables (so-called 'phonotactic' constraints) are another information source used for speech segmentation (for L1 listening research, see McQueen, 1998). For example, in English, /sl/ as in *sleep* is a legal syllable onset but /ʃl/ ('shl') and /ml/ are not, and while a boundary between /s/ and /l/ is possible but not required, /ʃl/ and /ml/ clearly mark a syllable boundary and possibly also a word boundary in English. German, on the other hand, requires a syllable boundary between /s/ and /l/ and between /m/ and /l/ but not between /ʃ/ and /l/. Highly proficient German learners of English use both L1 and L2 specific knowledge to segment English speech. Their knowledge of English phonotactics helps them detect the English word *lunch* in

glarshlunch, but their interfering German phonotactic knowledge also leads to facilitated detection of *lunch* in *moycelunch* (Weber & Cutler, 2006).

[B] Lexical knowledge

Recognizing one word helps listeners find other words. When listeners recognize a word they know, especially when it is a longer word that is not likely to be part of another word, they expect the onset of a new word to follow. Thus, when listeners hear *anythingcorri*, they expect *corri* to be the beginning of a new word following *anything* (e.g., 'corridor'). Both native and non-native listeners use such lexical knowledge for segmentation (White, Melhorn, & Mattys, 2010). Beneficial effects are, however, smaller for L2 listeners than for L1 listeners (Mattys, Carroll, Li, & Chan, in press). This may be because L2 listeners usually know fewer words than L1 listeners, and because L2 listeners are less certain about which stretches of speech are words and which are not.

[B] Phonetic detail

Fine phonetic differences in how a sound is pronounced can also provide information about word boundaries. For example, the /t/ is pronounced with aspiration in the phrase *keeps talking*, but without aspiration in *keep stalking*. English listeners use these pronunciation differences to decide which phrase they heard. L2 learners, on the other hand, cannot use this information as efficiently. Thus, both Spanish and Japanese learners of English distinguish between the two interpretations much less accurately than English native listeners do (Altenberg, 2005; Ito & Strange, 2009).

[A] Summary and outlook

Recognizing spoken words in one's mother tongue is easier than recognizing words in a second language, learned later in life. Of course, with a restricted vocabulary it is very difficult and sometimes impossible to understand a second language. But even if a listener knows all the words and is highly proficient in the L2, it is still harder to recognize spoken words in the L2 than in the L1. Although L1 listeners are usually not aware of the complex processes underlying word recognition, L2 listeners are often painfully aware of the complexity of the task of speech comprehension. Difficulties

with L2 word recognition become even more evident during noisy listening conditions, for example when an L2 listener tries to follow a conversation in a crowded pub. (For research on L2 listening in noise see, e.g., Golestani, Rosen, & Scott, 2009).

As described above, one major factor responsible for the difficulty of L2 listening is that more words are competing for recognition for L2 listeners than for L1 listeners. For L2 listeners, the set of potential word candidates is multiplied with parallel activation of words from the mother tongue and of words from the second language that native listeners would not consider during recognition. The processes of lexical activation and competition in spoken word recognition are determined by phonological overlap between the speech input and words in the lexicon. But in L2 listening, the notion of phonological overlap gets a different meaning, as L2 listeners can experience overlap where L1 listeners do not.

Another factor contributing to the difficulty of L2 word recognition is that L2 listeners are less efficient than native listeners in segmenting the continuous speech stream into individual words. For L1 listeners, the task of segmentation is facilitated by numerous indications to word boundaries such as rhythmic cues, phonotactic constraints, lexical knowledge, and phonetic detail. Although L2 listeners can exploit these cues to some extent, they often cannot do so as successfully as L1 listeners.

An explanation for the difficulties of L2 listening is that listeners have already learned to speak and understand their mother tongue, and the experience with their L1 interferes with L2 acquisition (e.g., Birdsong, 1999); other explanations are biologically- or socially-based (see, e.g., Bialystok, 1997; Hyltenstam & Abrahamsson, 2003). Infants tune their perception very early to characteristics of their mother tongue in order to make speech processing as efficient as possible. When a second language is learned later in life, understanding the new language is then aggravated by this specialization in the mother tongue.

Yet, having an L1 already can also be beneficial for second language acquisition. Adult L2 learners have a wealth of linguistic and non-linguistic knowledge that they can bring to the task of acquiring a second language. For example, they have a set of phonemic categories that will partially overlap with the L2, they also know about

words and how they are structured, they have conceptual representations for concrete and abstract objects, and they can draw on orthographic knowledge for learning new word forms. L2 learners can and do exploit all these sources for the learning task, as shown, e.g., by recent research on the use of orthographic information in learning new words in an L2 (Kaushanskaya & Marian, 2009; Escudero, Hayes-Harb, & Mitterer, 2008). Luckily, the capacity for implicit learning also turns out to be larger for adult L2 learners than previously thought. Adult learners can successfully extract segmental, phonotactic, and lexical knowledge about an unknown language after few minutes of uninstructed listening to an unfamiliar the language (Gullberg, Roberts, Dimroth, Veroude, & Indefrey, in press).

Further, L2 listeners benefit from their L1 knowledge when listening to L2 speech produced with an L1 accent. L2 listeners recognize words more easily when the L2 speaker has the same native language as the listeners. Thus, Russian learners of Hebrew recognize Russian-accented Hebrew words faster than Arabic-accented Hebrew words (Leikin, Ibrahim, Eviatar, & Sapir, 2009), and Dutch learners of English recognize Dutch-accented English better than Japanese-accented English (Broersma, Aoyagi, & Weber, in press; Weber, Broersma, & Aoyagi, under revision) or German-accented English (Hanulikova & Weber, under revision). These effects have been explained as long-term adaptation to the accent that the L2 listeners hear the most (i.e., the accent typical of the speakers around them).

The flexibility of lexical processing for L2 listeners still needs to be more fully understood. Currently, research on L1 listening has provided us with ample evidence for a dynamic account of spoken word recognition. L1 listeners' ability for short-term adaptation to speaker- and language-specific aspects of speech (e.g., adaptation to a bad telephone connection, a speaker with a lisp, or a regional accent), and their ability for long-term learning, now needs to be investigated in detail for L2 listeners. The outcome of this research will inform us about individual differences in language learning, and will provide insights into the interplay of flexibility and stability in the speech recognition system.

Cross references

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2. Bilingualism and Cognition; de Groot, Annet

3. Bilingualism and Speech Perception; Sebastián-Gallés, Núria

4. Brain Activity during Second Language Processing (ERP); Davidson, Douglas

5. Lexical Access in Visual Word Recognition in Second Language Processing; Dijkstra, Ton

6. Organization of the Second Language Lexicon; Kroll, Judith

7. Spoken Word Production in Second Language Acquisition; Costa, Albert

8. Word Recognition;

9. Second Language Speech Perception and the Brain; Wang, Yue

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