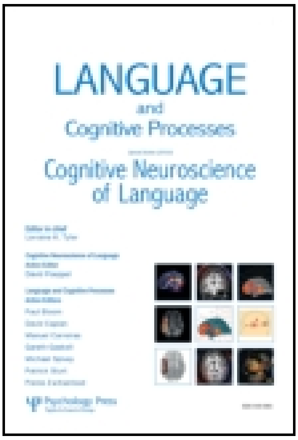

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Increased lexical activation and reduced competition in second-language listening

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Increased lexical activation and reduced competition in second-language listening

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This study investigates how inaccurate phoneme processing affects recognition of partially onset-overlapping pairs like *DAFFOdil-DEFIcit* and of minimal pairs like *flash-flesh* in second-language listening. Two cross-modal priming experiments examined differences between native (L1) and second-language (L2) listeners at two stages of lexical processing: first, the activation of intended and mismatching lexical representations and second, the competition between those lexical representations. Experiment 1 shows that truncated primes like *daffo*- and *defi*- activated lexical representations of mismatching words (either *deficit* or *daffodil*) more for L2 listeners than for L1 listeners. Experiment 2 shows that for minimal pairs, matching primes (prime: *flash*, target: *FLASH*) facilitated recognition of visual targets for L1 and L2 listeners alike, whereas mismatching primes (*flesh, FLASH*) inhibited recognition consistently for L1 listeners but only in a minority of cases for L2 listeners; in most cases, for them, primes facilitated recognition of both words equally strongly. Thus, L1 and L2 listeners' results differed both at the stages of lexical activation and competition. First, perceptually difficult phonemes activated mismatching words more for L2 listeners than for L1 listeners, and second, lexical competition led to efficient inhibition of mismatching competitors for L1 listeners but in most cases not for L2 listeners.

Keywords: Word recognition; Activation; Competition; Second language.

The comprehension of speech in a second language (L2) is difficult in many ways. Some of the difficulties involved, like the listener's unfamiliarity with a word, the confusability of two speech sounds, or the inability to segment the incoming speech stream into separate words, may be clearly noticeable to the listener. Other difficulties may be less noticeable, but they may nevertheless severely complicate the speech perception process. One of those unnoticed but serious difficulties in non-native listening is the increased number of activated lexical competitors due to perceptual difficulty. This paper assesses how difficulties of sound perception affect the recognition of words in an L2.

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Which sounds are difficult to distinguish for non-native listeners depends on the phoneme inventories of the first language (L1) and the L2, as described in a large body of research (see, e.g., the collected papers in Bohn & Munro, 2007; Strange, 1995). The most famous example of a difficult consonant pair is that of the English /r/-/l/ contrast, which is absent in Asian languages like Chinese and Japanese (Aoyama, Flege, Guion, Akahane-Yamada, & Yamada, 2004; Goto, 1971). Similarly, as Dutch does not have the English vowels /æ/ and /ɛ/, this English vowel contrast is difficult for Dutch listeners to perceive (Broersma, 2005; Schouten, 1975). Further, contrasts that do exist in the native language, but in the L2 occur in positions where they are not contrastive in the L1 can also pose a problem for non-native listeners. Thus, Dutch listeners, who have native language experience with voiced versus voiceless obstruents, but not in word-final position, use different phonetic cues to recognise English voiced versus voiceless obstruents in phonetic categorisation tasks than native English listeners do (Broersma, 2005, 2008, 2010), and do not use the voicing distinction accurately during word recognition (Broersma & Cutler, 2008). Such mismatches between the phoneme inventories of the L1 and the L2 can hinder word recognition in at least three ways.

First, minimal pairs can become difficult to distinguish. Thus, presentation of *write* led to the joint activation of *write* and *light* for Japanese listeners, and presentation of *cattle* led to the joint activation of *cattle* and *kettle* for Dutch listeners, in an auditory repetition priming task (Cutler & Otake, 2004). Similar results were found for highly fluent early Spanish-Catalan (but Spanish-dominant) bilinguals for Catalan minimal pairs which differed in contrasts that were difficult for them to perceive (e.g., */nɛtə/-/netə/*) (Pallier, Colomé, & Sebastián-Gallés, 2001). The inaccurate recognition of minimal pairs might disrupt speech comprehension, as listeners might have to resort to contextual information to determine the intended meaning of a word.

Second, partially overlapping competitors with similar onsets except for one difficult to distinguish contrast, like *rocket* and *locker*, can become temporarily confusable. Thus, for Japanese listeners, hearing *rocket* temporarily activated *locker* as well (Cutler, Weber, & Otake, 2006), and for Dutch listeners, hearing *panda* temporarily activated *pencil* (Weber & Cutler, 2004). Disambiguating information towards the end of the word will eventually resolve the confusion, but the extended availability of competitors might slow down word recognition.

Third, L2 listeners can experience phantom competition from "near-words" embedded in the speech signal. Fluent Spanish-Catalan bilinguals do not distinguish well between words and near-words differing in Catalan-only contrasts such as */finestrə/-/finɛstrə/* (Sebastián-Gallés, Echeverría, & Bosch, 2005), and Dutch listeners do not distinguish well between English words and near-words like *lamp-lemp* and *deaf-daf*, differing in the difficult to distinguish /æ/-/ɛ/ contrast (Broersma & Cutler, 2011), or between *groove-groof* or *flight-flide*, differing in final consonant voicing (Broersma & Cutler, 2008). Hearing a carrier fragment containing such a near-word (e.g., *DAFfodil*) led to strong activation of the real word (*deaf*) for the Dutch listeners, which even remained after the full carrier word had been heard (Broersma & Cutler, 2011). Near-words thus have the potential to add large numbers of lexical competitors to the lexical selection process that are very resistant to deactivation.

Of course, the activation of multiple lexical representations and the competition between them is a necessary part of speech comprehension, both in the L1 and in the L2. The number of phonemes that a language has at its disposal is limited, whereas the number of possible words built up of those phonemes is very large. One consequence is that a large majority of polysyllabic words have shorter words embedded in them (McQueen, Cutler, Briscoe, & Norris, 1995), another that many words partially overlap with others. When listeners hear a word containing an embedded word, both the longer word and the embedded word are activated (Davis, Marslen-Wilson, & Gaskell, 2002; Salverda, Dahan, & McQueen, 2003), and when listeners hear a word which partially overlaps with another word, the partially overlapping lexical competitor is also activated (Zwitserlood, 1989). Activated word forms actively compete for recognition (McQueen, Norris, & Cutler, 1994), all current models of speech recognition agree (for a review, see McQueen, 2005). As lexical competition should lead to the deactivation of competitors and to the selection of the intended word, it is conducive to speech comprehension. However, the other side of the coin is that words are harder to recognise when more lexical competitors are active; it is more difficult to recognise words when the number of words that partially match the input is larger (Norris, McQueen, & Cutler, 1995; Vroomen & De Gelder, 1995) and when they have more lexical neighbours, and thus more lexical competitors (Luce, Pisoni, & Goldinger, 1990). Thus, an increase in the number of active lexical competitors due to inaccurate phoneme processing may hinder word recognition for L2 listeners.

This paper further investigates how inaccurate phoneme processing affects the recognition of partially onset-overlapping pairs like *daffodil*-*deficit* and of minimal pairs like *flash*-*flesh*. In particular, it examines differences between L1 and L2 listeners at two stages of lexical processing: first, the activation of intended and mismatching lexical representations by perceptually difficult phonemes and second, the competition between those lexical representations. The studies that have investigated recognition of L2 minimal pairs so far (Cutler & Otake, 2004; Pallier, et al., 2001) used the auditory repetition priming paradigm. They showed that for L2 listeners presentation of one word of a minimal pair led to activation of the competitor as well, but the paradigm used does not provide specific information about the processes of lexical activation versus competition.

The present study therefore examines the occurrence of lexical activation and competition in non-native listening with an experimental paradigm particularly suited for the task: the auditory-visual cross-modal priming paradigm (Zwitserlood, 1996), which has been shown to be a powerful tool to provide insight into lexical activation and competition, and which has been used successfully to investigate effects of perceptual ambiguity (Connine, Blasko, & Wang, 1994) and of mismatch (Soto-Faraco, Sebastián-Gallés, & Cutler, 2001) on the amount of lexical activation, and to provide insight into the strength of lexical competition (Gaskell & Marslen-Wilson, 2002; Vroomen & De Gelder, 1995).

Partially overlapping words and minimal pairs are used which differ in contrasts that have been shown to lead to lexical confusion for Dutch listeners (Broersma & Cutler, 2011; Cutler & Otake, 2004; Escudero, Hayes-Harb, & Mitterer, 2008; Weber & Cutler, 2004), namely the British English vowel contrast of /æ/ and /ɛ/, and word-final obstruent voicing contrasts.

The vowel contrast is difficult to distinguish even for Dutch listeners with a high level of proficiency in English (Broersma, 2005; Schouten, 1975). As Dutch has only one vowel in the phonetic space of the English /æ/ and /ɛ/ (Booij, 1995), the two English categories are perceptually assimilated into a single L1 category (cf. Best & Tyler, 2007). Note that the Dutch vowel is represented by /ɛ/ in the International Phonetic Alphabet, but its acoustic realisation falls between that of the British English /æ/ and /ɛ/ (see Adank, Van Hout, & Smits, 2004; Deterding, 1997 for Dutch and

English, respectively). The word-final consonant voicing contrasts pose a problem for Dutch listeners because Dutch neutralises voicing distinctions in syllable-final, prepausal position (Booij, 1995). Even though Dutch and English share four pairs of voiced and voiceless obstruents, namely the alveolar and labiodental fricatives /z/-/s/, /v/-/f/, and the bilabial and alveolar stops /b/-/p/, and /d/-/t/, Dutch only allows for /s/, /f/, /p/, and /t/ (as well as /k/; Dutch has no /g/) word-finally, and thus has no word-final voicing contrasts. Dutch listeners have been shown to use perceptual cues differently than native English listeners do for phonetic categorisation of the word-final voicing contrasts in English (Broersma, 2005, 2008, 2010), and to experience lexical activation of words that mismatch with the speech input in final voicing (Broersma & Cutler, 2008).

Experiment 1 investigates how perceptually difficult phonemes affect the *activation* of intended and mismatching words for Dutch listeners, and Experiment 2 investigates the lexical *competition* between such words. Dutch listeners' results are compared with those of native listeners of British English.

In Experiment 1, the element of lexical competition was removed, so that the extent to which the mismatching phonemes contributed to the activation of the target words could be investigated on its own. To this end, listeners were presented with the initial portions of words, which were short enough not to cause lexical competition. Lexical representations are expected to receive less activation upon presentation of an incomplete word than upon presentation of a full word (Gaskell & Marslen-Wilson, 2002), and after presentation of a relatively short word fragment, lexical representations are unlikely to be activated strongly enough to exert strong inhibitory effects on other active lexical representations.

Pairs of trisyllabic words were selected which had similar onsets, except for the vowels /æ/ and /ɛ/ in the first syllable (e.g., *daffodil-deficit*). Listeners only heard the initial portion of each word, up to and including the second vowel (i.e., *daffo* or *defi*). The experiment assessed the activation of the words *daffodil* and *deficit* after hearing the onsets *daffo* and *defi*.

In the cross-modal priming experiment, listeners first heard an auditory prime, followed by a visually presented target word that the listeners needed to make a lexical decision about. The prime either matched the onset of the target (e.g., prime: *daffo,* target: *DAFFODIL*) or mismatched the target (*defi, DAFFODIL*), or it formed an unrelated control (*moni, DAFFODIL*). For the English listeners, Match primes should facilitate recognition of the visual targets more than Mismatch primes. For the Dutch listeners, due to perceptual confusion, this difference between the activation of target words after Match and Mismatch primes might be smaller than for the English listeners.

Next, Experiment 2 investigates Dutch and English listeners' recognition of English minimal pairs, differing in the /æ/-/ɛ/ contrast (e.g., *flash-flesh*), or in a word-final obstruent voicing contrast (e.g., *robe-rope*), and in particular the competition between the members of a pair after hearing one of the words.

EXPERIMENT 1

Experiment 1 was designed to investigate Dutch and English listeners' perception of English words with partially overlapping onsets, and to assess whether the difference between the activation of target words like *daffodil* after Match primes (*daffo*) and Mismatch primes (*defi*) was smaller for Dutch listeners than for English listeners.

Method

Participants

Participants were 72 native speakers of Dutch and 72 native speakers of British English. The Dutch participants (mean age: 20.6) had a high level of proficiency in English as an L2. They had received on average 7.0 years of English instruction in primary and secondary education. The English participants (mean age: 21.0) did not know any Dutch. The majority of the English participants knew at least one L2 (see Results and discussion). The Dutch participants were recruited from the participant pool of the Max Planck Institute for Psycholinguistics (the Netherlands), and the English participants from the participant pool of the Laboratory of Experimental Psychology of the University of Sussex (UK). None reported any hearing loss, visual loss, or reading disability. All were volunteers and received a small fee for participation.

Materials

As experimental visual target words, 24 pairs of trisyllabic English words with stress on the first syllable were selected. For each pair, the two words were identical from the beginning up to and including the vowel of the second syllable, except that one word had an /æ/ in the first syllable and the other an /ɛ/ (e.g., *daffodil*-*deficit*). Due to the limited availability of suitable pairs, the frequency of the selected items was not very high; the mean logarithmic lemma frequency per million, determined with the CELEX lexical database (Baayen, Piepenbrock, & Gulikers, 1995), using the full corpus including written and spoken sources, was 0.93 (0.98 for the words with an /æ/ and 0.89 for those with an /ɛ/; not significantly different from one another, $F(1, 23) < 1$). For each pair, a phonologically and semantically unrelated trisyllabic word was selected (mean frequency: 1.05; not different from the target pairs, $F(2, 46) < 1$).

Both items of a minimal pair occurred as visual targets, and all items occurred in three conditions, illustrated in Table 1. For each experimental target word (e.g., *daffodil*) the beginning of the same word (i.e., *daffo* from *daffodil*) served as Match prime, the beginning of the other word of the pair (i.e., *defi* from *deficit*) served as Mismatch prime, and the beginning of the unrelated word (i.e., *moni* from *monitor*) served as Control prime. When the visual target was the other word of the pair, i.e., *deficit*, the Match and Mismatch primes were reversed; thus, the Match prime was now *defi* from *deficit* and the Mismatch prime was *daffo* from *daffodil*. The experimental target words and their primes are listed in Appendix 1.

TABLE 1
Experiment 1: Experimental stimuli; examples, lexical frequency (mean logarithmic lemma frequency per million words), and number of trials per participant for visual target words and three types of auditory primes

	Visual target word	*Control prime*	*Match prime*	*Mismatch prime*
Example pair 1	Daffodil	Moni[tor]	Daffo[dil]	Defi[cit]
	Deficit	Moni[tor]	Defi[cit]	Daffo[dil]
Example pair 2	Family	Princi[ple]	Fami[ly]	Femi[nine]
	Feminine	Princi[ple]	Femi[nine]	Fami[ly]
Lexical frequency	0.93	1.05	0.93	0.93
Number of trials per participant	24	8	8	8

As fillers, there were 24 visually presented words with truncated Match primes (e.g., *inno[cent]-INNOCENT*), 24 words with Control primes (e.g., *sorce[rer]-MINIMAL*), and 24 words with Mismatch primes that differed from the visual targets in one vowel, but never in the /æ/-/ɛ/ contrast (e.g., *noti[fy]-NIGHTINGALE*). Further, there were 32 visually presented nonwords with Match primes (e.g., *nota[ble]*-NOTAROUS), 32 with Control primes (e.g., *memo[ry]-FUNDALISE*), and 32 with Mismatch primes that differed from the visual targets in one vowel but, again, never in /æ/-/ɛ/ (e.g., *dino[saur]-DENIMENT*).

All primes were the beginning of a real word. None of the stimuli existed in Dutch. All auditory stimuli were recorded by a male native speaker of British English. The speaker read the words one by one, separated by a pause, in a clear citation style. The recording was made in a soundproof booth using a high quality microphone and stored onto a computer at a sample rate of 16 kHz. With the speech editor Praat, the first part of each recorded word up to and including the vowel of the second syllable was excised to serve as an auditory prime.

Design

The experimental target items were divided into six lists (2 words per pair * 3 conditions). Each participant saw only one word of each of the 24 experimental pairs, 12 with an /æ/ and 12 with an /ɛ/, equally distributed over the three conditions: Match condition (preceded by auditory presentation of the first two syllables of the same word), Mismatch condition (preceded by the first two syllables of the paired word which overlapped with the first two syllables of the target word, except that an /æ/ in the target was an /ɛ/ in the prime and vice versa), and Control condition (preceded by the first two syllables of the unrelated word) (Table 1). Each participant was presented with all of the filler words and filler nonwords, so that each participant saw a total of 96 words and 96 nonwords, with 64 presentations in each of the three conditions. Items were presented in a semi-random order, such that maximally five visually presented words or five visually presented nonwords occurred in succession, and two experimental targets were separated by at least one filler item.

Procedure

Participants were tested one at a time in a quiet room. They received written instructions in their native language, informing them that on each trial they would hear part of an English word, directly after which an English word or nonword would appear on a computer screen. They were asked to press a green response button, labelled "yes", with their dominant hand if they thought the visually presented item was an English word, and a red response button, labelled "no", with their nondominant hand if they thought the visually presented item was not an English word. Participants were asked to respond both as fast and as accurately as possible. The task started with eight practice trials and was controlled with Nijmegen Experiment Set-Up (NESU) software. On each trial, an auditory stimulus was presented and at offset of that, a visual stimulus was presented. The auditory materials were presented binaurally over closed high quality headphones at a comfortable listening level and the visual materials appeared in large font on a computer screen in front of the participants. No time limit was imposed for the responses. After each button press, the next trial started.

Results and discussion

In this experiment and the following, reaction times (RTs) were measured from auditory item offset (i.e., from the onset of visual item presentation), and RT analyses were performed on the RTs of the correct responses. To improve the homogeneity of variance, an arcsine transformation was applied to the proportions of correct responses, and a logarithmic transformation to the RTs (Ferguson & Takane, 1989). The results of one experimental pair had to be excluded due to an error in the item lists. Responses with RTs longer than 1,500 ms were considered outliers; 40 responses (1.5% of the experimental trials in the RT analysis) were removed.[1]

Relevant differences between the two groups were found both in the proportions of correct responses and in the RTs. As Figure 1 shows, for the English listeners, there were more correct responses in the Match condition than in the Mismatch condition, $F1(1, 71) = 16.9$, $p < .001$, *partial* $\eta^2 = .19$; $F2(1, 45) = 12.4$, $p < .001$, *partial* $\eta^2 = .22$, whereas there was no difference between the two conditions for the Dutch listeners, $F1(1, 71) = 1.2$, $p > .1$; $F2(1, 45) < 1$. Indeed, there was a significant interaction between native language and condition for the conditions Match versus Mismatch, $F1(1, 142) = 11.0$, $p < .001$, *partial* $\eta^2 = .07$; $F2(1, 45) = 4.4$, $p < .05$, *partial* $\eta^2 = .09$. Further, in the Match condition, there was priming for both groups alike (i.e., there were more correct responses in the Match condition than in the Control condition), $F1(1, 142) = 4.7$, $p < .05$, *partial* $\eta^2 = .03$; $F2(1, 45) = 20.5$, $p < .001$, *partial* $\eta^2 = .31$.

The RTs of the correct responses mirror this pattern (Table 2). For the English listeners, RTs were shorter in the Match condition than in the Mismatch condition, $F1(1, 71) = 9.1$, $p < .01$, *partial* $\eta^2 = .11$; $F2(1, 44) = 4.8$, $p < .05$, *partial* $\eta^2 = .10$. For the Dutch listeners, on the other hand, RTs in the Match and Mismatch conditions did not significantly differ; note that there was a trend showing shorter RTs in the Match condition than in the Mismatch condition for the Dutch listeners, which just escaped significance in the by subjects analysis but was far from reaching significance in the by items analysis, $F1\ (1, 71) = 3.2$, $p = .078$; $F2(1, 45) < 1$. In the Match condition, there was again priming for both groups alike (i.e., RTs were shorter in the Match condition than in the Control condition), $F1(1, 142) = 16.9$, $p < .001$, *partial* $\eta^2 = .11$; $F2(1, 44) = 8.8$, $p < .01$, *partial* $\eta^2 = .17$.

Overall, the English listeners gave more correct responses than the Dutch listeners did, $F1(1, 142) = 130.6$, $p < .001$, *partial* $\eta^2 = .48$; $F2(1, 45) = 33.4$, $p < .001$, *partial* $\eta^2 = .43$, and RTs were shorter for the English listeners than for the Dutch listeners, $F1(1, 142) = 18.4$, $p < .001$, *partial* $\eta^2 = .12$; $F2(1, 43) = 80.3$, $p < .001$, *partial* $\eta^2 = .65$.

Bilingual listeners, while listening to their L1, have been found to overcome inhibition and to return to baseline activation faster than monolingual listeners (Blumenfeld & Marian, 2011). In the present study, while all Dutch participants knew at least one L2 (i.e., English), some of the English participants did not know an L2. To ensure that the differences between the Dutch and English participants were not due to general differences in inhibitory control between monolinguals and bilinguals, the English listeners who did not know any L2 were assessed separately. The majority of the English participants knew at least one language other than English (with German being the most common L2). Only 20 out of the 72 English participants did not know an L2. The pattern of results of those 20 participants did not differ from the pattern found for the overall group of English participants. With respect to the percentage of

[1] Neither in the analysis of the proportion of correct responses nor in the RT analysis was there an interaction with or main effect of vowel (/æ/ versus /ɛ/).

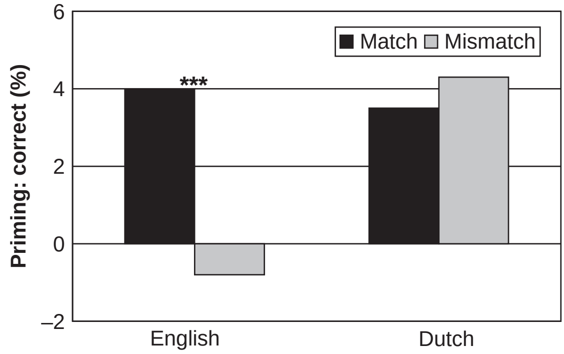


Figure 1. Experiment 1: English and Dutch listeners' priming results, computed as the difference between the percentage of correct responses in the Match or the Mismatch condition and the Control condition, with positive values indicating facilitation. *** denotes $p < .001$ for the *proportion correct* (rather than the priming) in the Match versus Mismatch condition. (Mean percentage correct in the Control condition: 91.8% for the English listeners; 70.2% for the Dutch listeners.)

correct responses, they showed facilitation in the Match condition (9.0%) and not in the Mismatch condition (−3.4%) (with an average of 88.5% correct in the Control condition). With respect to the RTs, they also showed facilitation in the Match condition (33.2 ms) and not in the Mismatch condition (−12.5 ms) (with an average of 637.2 ms in the Control condition). Thus, the subgroup of monolinguals among the English participants was not responsible for the difference between the Dutch and English listeners' results.

Note that the Dutch listeners' results differed from the English listeners' results only for the experimental items, where mismatching primes differed from the onset of the target words in a difficult to distinguish phoneme; for the filler words, where mismatching primes differed from the onset of the target words in an easy to distinguish phoneme (e.g., *noti[fy]-NIGHTINGALE*), the Dutch listeners' percentage correct was higher, $F1\ (1, 71) = 102.5$, $p < .001$, *partial* $\eta^2 = .59$; $F2(1, 47) = 4.3$, $p < .05$, *partial* $\eta^2 = .09$, and RTs were shorter, $F1(1, 71) = 110.7$, $p < .001$, *partial* $\eta^2 = .61$; $F2(1, 47) = 6.9$, $p < .05$, *partial* $\eta^2 = .13$, in the Match condition than in the Mismatch condition (Table 2), similar to the English listeners' results for the experimental items as well as for the filler words (Table 2).

In short, the results of Experiment 1 show that the lexical activation of words like *daffodil* and *deficit* after hearing onsets like *daffo* and *defi* was more similar for Dutch

TABLE 2
Experiment 1: English and Dutch listeners' percentage of correct responses and RTs of correct responses for visual target words in Control, Match, and Mismatch condition, separately for experimental and filler words

		Correct (%)		*RT (ms)*	
Items	*Condition*	*English*	*Dutch*	*English*	*Dutch*
Experimental	Control (e.g., moni[tor]-DAFFODIL)	91.8	70.2	667.8	741.8
	Match (e.g., daffo[dil]-DAFFODIL)	95.8	73.7	634.0	713.4
	Mismatch (e.g., defi[cit]-DAFFODIL)	91.0	74.5	658.7	729.8
Filler words	Control (e.g., sorce[rer]-MINIMAL)	95.5	87.3	672.7	717.5
	Match (e.g., inno[cent]-INNOCENT)	95.3	87.4	609.6	663.3
	Mismatch (e.g., noti[fy]-NIGHTINGALE)	92.2	76.1	668.5	730.3

listeners than for English listeners. Whereas there was clearly more lexical activation after Match primes than after Mismatch primes for the English listeners, both in the percentage correct and in the RTs, the difference between those conditions was not statistically significant for the Dutch listeners. A nonsignificant trend in the RTs suggests that the Dutch listeners may have processed the difference between the two vowels to some extent.

Given the differences in lexical *activation* between the Dutch and the English listeners, it seems likely that there will also be differences in lexical *competition* between the groups upon hearing items with phonemes that are difficult to distinguish for the Dutch listeners. Whereas Experiment 1 investigated the stage of lexical activation, by removing the element of lexical competition, Experiment 2, to the contrary, aims to address the stage of lexical competition. It investigates the occurrence of lexical competition between the two items of minimal pairs differing in the /æ/-/ɛ/ contrast (e.g., *flash-flesh*) or in a word-final obstruent voicing contrasts (e.g., *robe-rope*).

To assess lexical competition, listeners were now presented with full, untruncated words as primes. Primes were either identical to the target (e.g., prime: *flash,* target: *FLASH*), or mismatched the target (*flesh, FLASH*), or formed an unrelated control (*spite, FLASH*). For the English listeners, Match primes should facilitate recognition of the visual targets, whereas Mismatch primes should inhibit recognition. For the Dutch listeners, there are three possible outcomes:

First, both Match and Mismatch primes might inhibit recognition of the visual target. This would indicate that for the Dutch listeners both word forms of the minimal pairs are activated and compete with one another upon hearing either word. Thus, hearing either *flash* or *flesh* would lead to activation of both, and the competition between the lexical representations would hinder recognition of the visual target *flash* or *flesh*. This outcome would, however, be contrary to the findings of Cutler and Otake (2004) and Pallier et al. (2001), who found that presentation of one word of a minimal pair also led to facilitated recognition of the other word for L2 listeners in repetition priming tasks.

Second, both Match and Mismatch primes might facilitate recognition of the visual target. Such a pattern would indicate that both word forms of the minimal pairs are activated, but that the word forms do not compete with one another. This might be the case if the words are stored as homophones or, possibly, if they are phonologically distinct but imprecise perception does not clearly favour one interpretation over the other. It is conceivable that in such cases, both words might remain activated without competing until, for example, the context provides disambiguating information about the meaning of the word.

Third, there might be priming after Match primes and anything between priming and inhibition after Mismatch primes. Such an outcome would point to a combination of two patterns; it would indicate that in some cases, the Dutch listeners show similar results as the native English listeners, with facilitation after Match primes and inhibition after Mismatch primes, whereas in other cases they experience facilitation after Match as well as Mismatch primes.

EXPERIMENT 2

Experiment 2 assesses Dutch and English listeners' recognition of minimal pairs like *flash-flesh* and *robe-rope*, and in particular the occurrence of facilitation, inhibition, or a combination of the two after a mismatch between prime and target.

Method

Participants

Again, 72 native speakers of Dutch (mean age: 21.8) and 72 native speakers of British English (mean age: 21.0) took part. The participants met the description given for Experiment 1. The Dutch participants had received an average of 7.5 years of English instruction, and were again recruited from the participant pool of the Max Planck Institute for Psycholinguistics (the Netherlands). The English participants were now recruited at the University of Birmingham (UK). None had participated in Experiment 1.

Materials

As experimental stimuli, 21 mono- or disyllabic English minimal pairs were selected as visual target words. For six pairs, one word contained an /æ/ and the other an /ɛ/ (e.g., *flash*-*flesh*). For 15 pairs, one word contained a voiced final consonant and the other a voiceless final consonant (e.g., *robe*-*rope*). All words had a high frequency and were expected to be familiar for the Dutch listeners; the mean logarithmic lemma frequency per million, determined with the CELEX lexical database (Baayen et al., 1995) (again using the full corpus), was 1.70 (1.32 for words with an /æ/, 1.65 for words with an /ɛ/, 1.66 for words with a voiced final consonant, and 1.93 for words with a voiceless final consonant; frequencies did not significantly differ from each other, $F(1, 41) = 2.1$, $p > .1$). For each pair, a phonologically and semantically unrelated word was selected with the same number of syllables as the target words (mean frequency: 1.83; not significantly different from the minimal pairs, $F(1, 62) < 1$).

Like in Experiment 1, both items of a minimal pair occurred as visual targets, and all items occurred in three conditions, illustrated in Table 3. Each experimental visual target word (e.g., *flash*) had an auditory Match prime (the same word, *flash*), a Mismatch prime (the other word of the pair, *flesh*), and a Control prime (the unrelated word, *spite*). When the visual target was the other word of the pair, i.e., *flesh*, the Match and Mismatch primes were simply reversed; thus, the Match prime was now *flesh* and the Mismatch prime was *flash*. The experimental target words and their primes are listed in Appendix 2.

Further, 21 visual filler words with Match primes (e.g., *purchase*-*PURCHASE*), 21 with unrelated Control primes (e.g., *guide*-*SCHEME*), and 21 with Mismatch primes were selected; six Mismatch primes differed from the visual targets in the vowel (e.g., *follow*-*FELLOW*) and 15 in the final consonant (e.g., *sharp*-*SHARK*), like in the experimental items (but never in the /æ/-/ɛ/ contrast or a final consonant voicing

TABLE 3
Experiment 2: Experimental stimuli; examples, lexical frequency (mean logarithmic lemma frequency per million words), and number of trials per participant for visual target words and three types of auditory primes

	Visual target word	*Control prime*	*Match prime*	*Mismatch prime*
Example minimal pair 1	Flash	Spite	Flash	Flesh
	Flesh	Spite	Flesh	Flash
Example minimal pair 2	Robe	Suck	Robe	Rope
	Rope	Suck	Rope	Robe
Lexical frequency	1.70	1.83	1.70	1.70
Number of trials per participant	21	7	7	7

contrast). The number of mono- and disyllabic items was proportional to the experimental items. All primes, including those for nonword targets, were real words. For that reason, there were no Match primes for nonwords. Rather, there were 42 visual filler nonwords with Mismatch primes, again differing in one vowel or one consonant, never involving one of the crucial contrasts (e.g., *sister-SOSTER*), and 42 with unrelated Control primes (e.g., *snatch-PLORN*). None of the stimuli existed in Dutch. All words were recorded by the same speaker and in the same manner as described for Experiment 1.

Design

Like in Experiment 1, the experimental target items were divided into six lists (2 words per pair * 3 conditions), with vowel items and consonant items distributed evenly over the lists, and the target consonants distributed as evenly as possible. Each participant thus saw only one word of each of the 21 experimental minimal pairs, with seven items in each of the three conditions: Match condition (preceded by auditory presentation of the same word), Mismatch condition (preceded by the paired word which mismatched with the target in one phoneme), and Control condition (preceded by the unrelated word) (Table 3). Each participant was also presented with all of the filler words and nonwords, so that each participant saw a total of 84 words and 84 nonwords as visual targets. Items were presented in a random order.

Procedure

The procedure was as described for Experiment 1, except that the participants were now instructed that they would hear a word (rather than part of a word).

Results and discussion

Based on the distribution of the Dutch and English listeners' RTs, responses with RTs shorter than 300 ms or longer than 1,600 ms were considered outliers for the Dutch listeners, and responses with RTs shorter than 300 ms or longer than 1,300 ms were considered outliers for the English listeners; 42 responses (1.5% of the experimental trials in the RT analysis) were removed.[2]

As Figure 2 shows, in the Mismatch condition, in the RTs, there was inhibition for the English listeners but not for the Dutch listeners. Indeed, there was a significant interaction between native language and condition for the conditions Mismatch versus Control, $F1(1, 142) = 5.6$, $p < .05$, *partial* $\eta^2 = .04$; $F2(1, 20) = 12.4$, $p < .01$, *partial* $\eta^2 = .38$; for the English listeners, there was significant inhibition (i.e., RTs were longer in the Mismatch condition than in the Control condition), $F1(1, 71) = 10.6$, $p < .01$, *partial* $\eta^2 = .13$; $F2(1, 20) = 12.0$, $p < .01$, *partial* $\eta^2 = .38$, whereas there was none for the Dutch listeners (i.e., there was no difference between the Mismatch and Control conditions), $F1(1, 71) < 1$; $F2(1, 20) < 1$. Further, in the Match condition, there was priming for both groups (i.e., RTs were shorter in the Match condition than in the Control condition), $F1(1, 142) = 110.9$, $p < .001$, *partial* $\eta^2 = .44$; $F2(1, 20) = 46.6$, $p < .001$, *partial* $\eta^2 = .70$.

[2] Neither in the RT analysis nor in the analysis of the proportion of correct responses was there an interaction involving vowel versus consonant items. When vowel items and consonant items were analyzed separately, there were no interactions with or main effects of vowel (/æ/ versus /ɛ/) or final consonant voicing.

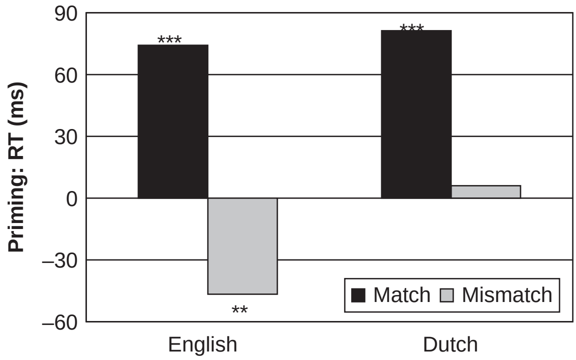


Figure 2. Experiment 2: English and Dutch listeners' priming results, computed as the difference between the reaction times of correct responses in the Match or the Mismatch condition and the Control condition, with positive values indicating facilitation. ** denotes $p < .01$, *** denotes $p < .001$ for the Match or the Mismatch condition versus the Control condition. (Mean reaction time in the Control condition: 623.1 ms for the English listeners; 725.6 ms for the Dutch listeners.)

Assessing the percentage of correct responses (Table 4), for both groups alike, the percentage correct was lower in the Mismatch condition than in the Control condition, $F1(1,\ 142) = 11.5$, $p < .001$, *partial* $\eta^2 = .08$; $F2(1,\ 20) = 32.3$, $p < .001$, *partial* $\eta^2 = .62$. The Dutch listeners had a lower percentage of correct responses on experimental trials (87.2%) than the English listeners did (95.0%), $F1(1,\ 142) = 20.1$, $p < .001$, *partial* $\eta^2 = .12$; $F2(1,\ 20) = 20.1$, $p < .001$, *partial* $\eta^2 = .50$.

Overall, RTs were longer for the Dutch listeners than for the English listeners (Table 4), $F1(1,\ 142) = 22.0$, $p < .001$, *partial* $\eta^2 = .13$; $F2(1,\ 20) = 177.4$, $p < .001$, *partial* $\eta^2 = .90$. In order to make sure that the difference between the Dutch and English listeners in the Mismatch condition, in particular the lack of inhibition for the Dutch listeners, was not due to the Dutch listeners' overall slower responses, the analyses were repeated, removing the 16 fastest English participants (i.e., with the shortest overall RTs for correct responses in the experimental trials) and the 16 slowest Dutch participants. For the remaining 112 participants, the Dutch and English listeners' RTs did not significantly differ [English: 629.5 ms, Dutch: 636.2, $F1(1,\ 110) < 1$; $F2(1,\ 20) < 1$]. The pattern of results did not change. Importantly, there was still an interaction between native language and condition for the conditions Mismatch versus Control, $F1(1,\ 110) = 5.1$, $p < .05$, *partial* $\eta^2 = .04$; $F2(1,\ 20) = 9.6$, $p < .01$, *partial* $\eta^2 = .32$, with significant inhibition for the English listeners [RTs were 37.8 ms longer in the Mismatch condition than in the Control condition; $F1(1,\ 55) = 12.1$, $p < .001$, *partial* $\eta^2 = .18$; $F2(1,\ 20) = 15.5$, $p < .001$, *partial* $\eta^2 = .44$] and none for the Dutch listeners [RTs were 0.7 ms shorter in the Mismatch condition than in the Control condition; $F1(1,\ 55) < 1$; $F2(1,\ 20) < 1$]. There was still Match priming for English and Dutch listeners alike [70.4 and 97.7 ms, respectively; $F1(1,\ 110) = 101.4$, $p < .001$, *partial* $\eta^2 = .48$; $F2(1,\ 20) = 42.8$, $p < .001$, *partial* $\eta^2 = .68$]. Thus, in the overall data set, the difference between the Dutch and English listeners' results in the Mismatch condition was not due to the overall RT difference between the groups.

Like in Experiment 1, while all Dutch participants knew at least one L2 (i.e., English), some of the English participants did not know any L2. Like in Experiment 1, however, the differences between the Dutch and the English listeners' results were not due to general differences between monolingual and bilingual participants. Again,

TABLE 4
Experiment 2: English and Dutch listeners' percentage of correct responses and RTs of correct responses for visual target words in Control, Match, and Mismatch condition, separately for experimental and filler words

		Correct (%)		*RT (ms)*	
Items	*Condition*	*English*	*Dutch*	*English*	*Dutch*
Experimental	Control (e.g., *spite-FLASH*)	96.6	89.8	623.1	725.6
	Match (e.g., flash-FLASH)	98.0	90.7	548.8	644.3
	Mismatch (e.g., *flesh-FLASH*)	90.5	81.0	669.7	719.6
Filler words	Control (e.g., *guide-SCHEME*)	97.9	89.5	613.7	691.5
	Match (e.g., purchase-PURCHASE)	98.0	83.3	562.5	638.0
	Mismatch (e.g., *follow-FELLOW*)	94.2	84.4	658.4	726.0

most English participants knew at least one L2 (now with French being the most common L2). Only 26 out of the 72 English participants did not know a L2. The results of those 26 participants did not differ from the pattern found for the overall group of English participants: they showed priming in the Match condition (51.7 ms) and inhibition in the Mismatch condition (46.0 ms) (with an average RT of 606.1 ms in the Control condition). Thus, the presence of monolingual participants in the English group did not explain the difference between the Dutch and English listeners' results.

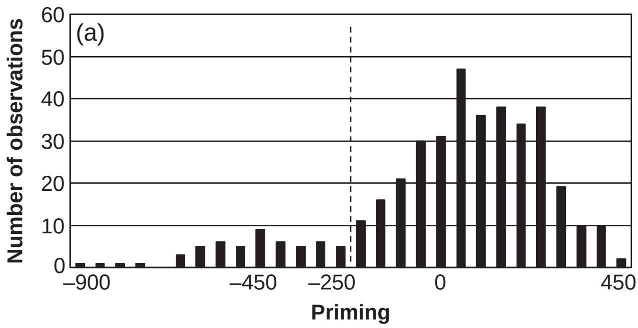
Note also that the Dutch listeners' pattern of results, with RTs in the Mismatch condition being similar to those in the Control condition, only occurred in the experimental trials, where the mismatching primes differed from the target in a difficult to distinguish phoneme. For the filler words, where mismatching primes and targets differed in an easy to distinguish phoneme, Dutch listeners showed facilitation in the Match condition and inhibition in the Mismatch condition, like the English listeners did for the experimental items as well as for the filler words (Table 4).[3]

Three possible outcomes for the Dutch listeners' results were sketched: first, inhibition in both the Match and the Mismatch condition, second, facilitation in both the Match and the Mismatch condition, or third, facilitation in the Match condition and anything between facilitation and inhibition in the Mismatch condition. The results clearly show the third pattern. They thus suggest that the Dutch listeners sometimes experienced facilitation in the Mismatch condition and sometimes inhibition.

Figure 3a shows that the Dutch listeners' RTs in the Mismatch condition were indeed the result of a combination of facilitation and inhibition. The figure represents the frequency distribution of ranges of priming in the Mismatch condition (i.e., of difference scores of Control – Mismatch RTs), with positive values indicating facilitation and negative values indicating inhibition. Difference scores were distributed bimodally, with a major mode at 0–50 ms and a minor mode at -500 to -450 ms. There were more

[3] For the filler words, for the Dutch listeners, both the facilitation in the Match condition and the inhibition in the Mismatch condition were statistically significant in the by subjects analysis [Match versus Control: $F1(1, 71) = 34.8$, $p < .001$, *partial* $\eta^2 = .33$; Mismatch versus Control: $F1(1, 71) = 30.5$, $p < .001$, *partial* $\eta^2 = .30$], but not in the by items analysis. Note that as filler words each occurred in only one condition (in contrast with the experimental items, for which condition was varied within items), the statistical power of the by items analysis was relatively low.

The Dutch and English listeners' results for the filler words did not significantly differ; there were no interactions between native language and condition [interaction with native language for Match versus Control: $F1(1, 142) < 1$; $F2(1, 154) < 1$; interaction with native language for Mismatch versus Control: $F1(1, 142) = 2.1$, $p > .1$; $F2(1, 178) = 1.1$, $p > .2$].



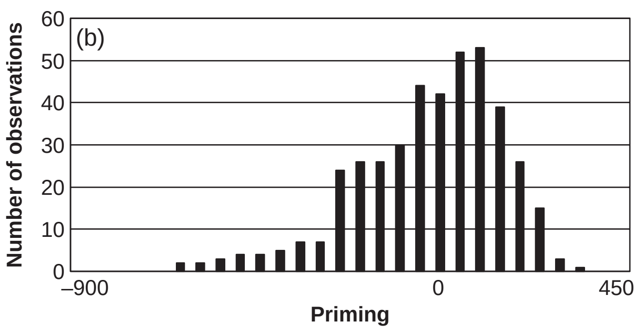


Figure 3. Experiment 2: frequency distribution of priming results in the Mismatch condition. Priming was computed as the difference between the reaction times of individual observations of correct responses in the Mismatch condition and the average reaction time (for the two language groups separately) of correct responses to the same target word in the Control condition, with positive values indicating facilitation and negative values indicating inhibition. Values on the x-axis indicate the upper limit of each 50 ms bin. (a) Dutch listeners' results; the dotted line indicates the assumed boundary between the two subsets of the bimodal distribution; (b) English listeners' results.

observations in the range of facilitation than in the range of inhibition, but the amount of inhibition was larger than the amount of facilitation (i.e., 450–500 ms of inhibition versus 0–50 ms of facilitation at the modes). Taking -250 ms as the border between the two subsets (see Figure 3a), there was significant inhibition on the left side of the border and significant facilitation on the right side of the border: RTs of trials with minimally 250 ms of inhibition were longer than RTs in the Control condition, $F1(1, 36) = 201.0$, $p < .001$, *partial* $\eta^2 = .85$; $F2(1, 28) = 613.6$, $p < .001$, *partial* $\eta^2 = .96$, and RTs of trials with maximally 250 ms of inhibition were shorter than RTs in the Control condition, $F1(1, 71) = 18.5$, $p < .001$, *partial* $\eta^2 = .21$; $F2(1, 41) = 40.0$, $p < .001$, *partial* $\eta^2 = .49$. Further, RTs of trials on the right side of the border did not differ from RTs in the Match condition, with mean RTs of 644.9 in the Mismatch condition and 644.3 in the Match condition, $F1(1, 71) = 1.3, p > .2$; $F2(1, 41) = 1.0, p > .3$. The frequency distribution thus clearly shows that the Dutch listeners' RTs in the Mismatch condition resulted from two distinct processes of facilitation and inhibition, averaging out at an RT which was not significantly different from that in the Control condition. For the subset of trials in the Mismatch condition that showed facilitation, this facilitation was exactly as strong as that in the Match condition. Note that, as expected, the English listeners' results did not show such a bimodal distribution (Figure 3b).

The Dutch listeners' results in the Mismatch condition were not due to two subsets of participants showing opposite patterns. Assessing the results per participant revealed no evidence for a bimodal distribution. Figure 4 shows the frequency distribution of ranges of priming in the Mismatch condition after averaging the results of each participant. The distribution approaches normality, with a mode at 0–100 ms. Thus, it was not the case that some of the Dutch listeners consistently showed facilitation whereas others consistently showed inhibition in the Mismatch condition (as this would have resulted in a bimodal distribution). Rather, all listeners experienced a combination of facilitation and inhibition. Similarly (not represented in Figure 4), it was not the case that some of the minimal pairs consistently showed facilitation whereas other minimal pairs consistently showed inhibition in the Mismatch condition. Rather, all mismatching primes sometimes facilitated and sometimes inhibited recognition of the competitor word.

GENERAL DISCUSSION

The two experiments presented in this paper showed differences between native and non-native listeners at two stages of lexical processing. The results indicate that the set of activated lexical competitors might be much larger in non-native than in native listening, due to an increased activation of mismatching lexical competitors as well as less efficient inhibition of such lexical competitors in L2 as compared to L1 listening. Experiment 1 showed that primes like *daffo* or *defi* activated both target words with minimally different onsets (*daffodil* and *deficit*) to a more similar extent for the Dutch listeners than for the English listeners. Experiment 2 showed that hearing a word like *flash* led to inhibition of its minimal pair *flesh* for the English listeners, but to a combination of facilitation and inhibition for the Dutch listeners.

The results of both experiments show that the Dutch listeners did recognise the difficult to distinguish phonemes better than chance. In Experiment 1, there was a nonsignificant trend with faster responses, showing more lexical activation, in the Match condition than in the Mismatch condition. In Experiment 2, if the phonemes were fully ambiguous for the listeners, this should have led to identical results in the Match and the Mismatch conditions whereas, to the contrary, the Dutch listeners' results in the two conditions clearly differed.

In Experiment 2, the Dutch listeners' responses in the Mismatch condition that showed inhibition, similar to the English listeners' responses, seem to result from accurate phoneme perception and a native-like competition process. Such responses

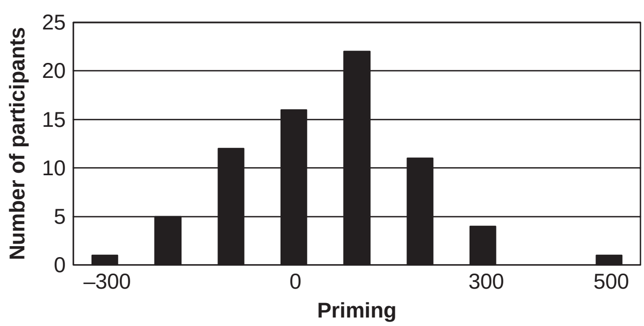


Figure 4. Experiment 2: frequency distribution of Dutch listeners' priming results in the Mismatch condition, after averaging results per participant. Priming was computed as the difference between the reaction times of correct responses in the Mismatch condition and the Control condition for each Dutch listener separately, with positive values indicating facilitation. Values on the x-axis indicate the upper limit of each 100 ms bin.

formed a minority of the Dutch listeners' responses. On the remaining trials, recognition of both words of a pair was facilitated to the same extent. Thus, primes activated both lexical representations equally, and they did not compete for recognition. There might be several reasons for this.

One explanation for this lack of competition between two activated word forms could be that those minimal pairs were stored as homophones (i.e., they might have identical phonological representations, or share a single phonological representation) and therefore did not compete for recognition. Another possibility is that two (nonhomophonous) lexical representations might sometimes be activated without competing for non-native listeners. It is conceivable that for L2 listeners the decision which word they have heard might sometimes be postponed and that there might be no competition between the lexical representations. This could, for example, depend on the listeners' confidence about which phoneme each word of a particular pair should contain, or on their confidence in their own perception of the crucial phonemes. When listeners are insecure about either of those, lexical selection might be postponed until further disambiguating information has been gathered from the continuation of the word or from the sentence context. The present study did not aim to distinguish between those possible explanations.

Both at the stages of lexical activation and competition, Dutch listeners' results differed from those of native English listeners. First, perceptually difficult phonemes activated mismatching words more for Dutch listeners than for English listeners and second, lexical competition led to the efficient inhibition of mismatching competitors for English listeners but in most cases not for Dutch listeners. Deactivation of unintended competitors has been shown to be very efficient for native listeners. Upon a mismatch between the incoming speech signal and an activated lexical candidate, that lexical candidate is almost immediately deactivated (Soto-Faraco et al., 2001; Zwitserlood, 1989). For L2 listeners, this process was thus found to be less efficient in the present study, both due to an increase in bottom-up activation of competitors compared to native listening, and due to a lack of inhibition of those competitors.

There is evidence that L2 listeners are less efficient in deactivating unintended words than native listeners are even when those words do not contain any sounds that the L2 listeners find particularly difficult. This is indirectly suggested by research showing that L2 listeners are more affected by neighbourhood density than native listeners are. Both L1 and L2 listeners find it harder to recognise words from a high-density neighbourhood than words from a low-density neighbourhood, but for L2 listeners, the difference between words with high- and low-neighbourhood density is much larger than for native listeners (Bradlow & Pisoni, 1999; Marian, Blumenfeld, & Boukrina, 2008). 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 heard the German word *Tisch*, "table", they activated *Fisch*, "fish", long enough for its meaning and word associations to be retrieved, whereas this was not the case for native listeners of German. Interestingly, Russian listeners activated the unintended word *Fisch* even though they could easily distinguish between the onset of *Fisch* and *Tisch*.

Even in the absence of perceptual confusion, the lexical competitor set might thus be increased for L2 listeners as compared to L1 listeners. Further, the possible effect of only one ambiguous contrast can already be considerable, as lexical statistics show. Cutler (2005) computed the upper bounds of the effects of perceptual ambiguity on the activation of lexical competitors. Lexical statistics were computed to determine the potential number of competitors added by perceptual ambiguity of the /æ/-/ɛ/ contrast in English. If the /æ/-/ɛ/ contrast was perceptually fully ambiguous, the number of nonwords which occurred embedded in other words and which might be perceived as real words would be considerable, with more than 78,000 occurrences per million words. The number of minimal pairs that would be perceived as homophones was relatively small, with 137 cases. The number of temporarily overlapping competitors, on the other hand, was very large, with an average of 274 added competitors per word. For the Dutch listeners in the present study, the /æ/-/ɛ/ contrast was not fully ambiguous (as found in both experiments), and the number of added lexical competitors due to misperception of this contrast is likely to be smaller than the maximum that Cutler (2005) computed. But listeners may be confronted with many perceptually ambiguous contrasts while listening to an L2, and the number of possible lexical competitors may increase sharply due to the combination of several of these contrasts within a single word. For example, presentation of the word *bad* may not only activate the lexical representation of *bed* for Dutch listeners, but it may activate *bat* and *bet* as well.

In L1 listening, it is more difficult to recognise a word when more lexical competitors are active, and therefore an increased competitor set is harmful to speech recognition. Although the activation of lexical competitors is a necessary part of speech comprehension (see e.g., McQueen, 2005), an increase in the competitor population has been shown to complicate the recognition of spoken words in the L1 (Luce et al., 1990; Norris et al., 1995; Vroomen & De Gelder, 1995). The results from the present study suggest, however, that an increase in the activation of mismatching lexical representations due to perceptual confusion in L2 listening might not be as detrimental to word recognition, because the activated lexical representations did not compete for recognition (possibly because they were stored as homophones, or because nonhomophonous lexical representations might be activated without competing in L2 listening, as outlined above).

The increase of lexical activation and the lack of efficient deactivation of lexical competitors might, however, slow down the retrieval of word meanings. In the case of partially overlapping words, at some point the speech input will clearly deviate from one of the lexical representations, which will solve the ambiguity. The competitor may remain active much longer for non-native listeners than for native listeners, but might not compete with the intended word and might thus not hinder word recognition. For minimal pairs, however, in the worst case, non-native listeners may not be able to determine on the basis of the phonetic input which word they have heard, and they may have to rely on the conversational context to select one interpretation. Thus, while such minimal pairs may be relatively rare (Cutler, 2005), they may slow down the spoken word recognition process considerably.

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APPENDIX 1
Experimental stimuli used in experiment 1

Target 1	*Target 2*	*Control prime*
accident	execute	poverty
adequate	editor	permanent
adjective	educate	cylinder
allergy	eloquent	formula
amorous	emerald	optimist
animal	enemy	property
animate	enervate	vocalise
antelope	entity	sinister
appetite	epilogue	civilise
avalanche	evident	immigrant
banister	benefit	incident
character	kerosene	article
clarify	clerical	symphony
daffodil	deficit	monitor
family	feminine	principle
janitor	genitive	prosody
lavender	levitate	fundament
massacre	messenger	orthodox
parasite	periscope	barbecue
patronise	petrify	fulminate
sacrifice	secretary	realise
salary	celebrate	funeral
tantalise	tentacle	mutiny

Note: Underlined fragments served as primes. Within each triplet the onset of each target served both as the Match prime for that target and as the Mismatch prime for the other target.

APPENDIX 2
Experimental stimuli used in experiment 2

Target 1	*Target 2*	*Control prime*
cattle	kettle	fever
flash	flesh	spite
mansion	mention	bottle
mantle	mental	passage
marry	merry	dozen
tan	ten	blood
lose	loose	judge
phase	face	home
rise	rice	chief
cab	cap	stiff
robe	rope	suck
bride	bright	shave
code	coat	mouse
fade	fate	pipe
grade	great	home
greed	greet	flush
hard	heart	touch
hide	height	youth
slide	slight	trap
thread	threat	fresh
wide	white	close

Note: Within each triplet each target served both as the Match prime for that target and as the Mismatch prime for the other target.