Accident – execute: Increased activation in nonnative listening

Mirjam Broersma

Max Planck Institute for Psycholinguistics
Nijmegen, The Netherlands
mirjam.broersma@mpi.nl

Abstract

Dutch and English listeners' perception of English words with partially overlapping onsets (e.g., *accident - execute*) was investigated. Partially overlapping words remained active longer for nonnative listeners, causing an increase of lexical competition in nonnative compared with native listening.
Index Terms: spoken word recognition, nonnative listening, lexical activation, phonetic contrast

1. Introduction

This study examines the occurrence of increased lexical activation in nonnative listening during perception of word pairs with partially overlapping onsets.

The activation of multiple lexical representations is a necessary part of speech comprehension, both in the native language and in second languages. Activated word forms actively compete for recognition (McQueen, Norris, & Cutler, 1994). As lexical competition may lead to the deactivation of competitors and to the selection of the target word, it is conducive to speech comprehension. However, the other side of the coin is that words are harder to recognize when more lexical competitors are active. Thus, it is more difficult to recognize words when the number of words that partially match the input is larger (Luce, Pisoni, & Goldinger, 1990; Norris, McQueen, & Cutler, 1995; Vroomen & De Gelder, 1995).

This threatens to be a severe problem in nonnative listening. There is a growing body of evidence that there is more activation of lexical competitors in nonnative listening than in native listening. First, Broersma (2002; 2005b; submitted) and Sebastián-Gallés, Echeverría, and Bosch (2005) showed that even highly skilled nonnative listeners sometimes perceived non-words as real words. Second, for nonnative listeners, minimal pairs sometimes activate each other (Broersma, 2002, 2005b; Cutler & Otake, 2004; Pallier, Colomé, & Sebastián-Gallés, 2001). Third, there is some evidence that partially overlapping competitors remain active longer in nonnative listening than in native listening (Cutler, Weber, & Otake, in press; Weber & Cutler, 2004).

The present study investigates Dutch and English listeners' perception of English words with partially overlapping onsets. Word pairs had a similar onset, except for the vowels /æ/ and /ɛ/ (e.g., *accident - execute*). The experiment consisted of two tasks, a cross-modal fragment priming task and a phonetic categorization task. The phonetic categorization task was included to obtain information about the nonnative listeners' ability to distinguish the /æ/-/ɛ/ contrast.

The /æ/-/ɛ/ contrast was expected to be perceptually difficult for the Dutch listeners. Dutch has only one phoneme in the phonetic space of English /æ/ and /ɛ/. Dutch listeners have been found to have difficulty distinguishing between these vowels. In a phonetic categorization experiment in which the vowels were presented in a non-word context, Dutch listeners categorized the vowels with a level of accuracy which was amply above chance but significantly lower that that of native listeners of English (Broersma, 2005a).

2. Method

2.1. Participants

Seventy-two native speakers of Dutch and 72 native speakers of British English took part. The Dutch participants had a high level of proficiency in English as a second language. They had received on average 7 years of English instruction in primary and secondary education. The English participants did not know any Dutch. The Dutch participants were recruited from the Max Planck Institute participant pool, and the English participants from the participant pool of the Laboratory of Experimental Psychology of the University of Sussex. None reported any hearing loss, visual loss, or reading disability. All were volunteers and received a small fee for participation.

2.2. Materials

For the cross-modal priming task, 24 pairs of trisyllabic English words with stress on the first syllable were selected as visual target words. For each pair, the first parts of the two words, up to and including the vowel of the second syllable, were identical, except that one word had an /æ/ in the first syllable and the other an /ɛ/ (e.g., *accident - execute*). For each pair, a phonologically and semantically unrelated trisyllabic word was selected.

All words were recorded by a male native speaker of British English. The speaker read the items 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 directly 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 to the visual targets. Each experimental target word (e.g., *accident*) had an Identity prime, taken from the same word (*acci* from *accident*), a Mismatch prime, taken from the other word of the pair (*exe* from *execute*), and a Control prime, taken from the unrelated word (*pove* from *poverty*). Note that the

Identity prime for one word (*acci* for *accident*) served as the Mismatch prime for the other word of a pair (*acci* for *execute*).

Further, 24 filler words and 32 filler non-words with Identity primes, and the same number of words and non-words with Mismatch primes and with Control primes were selected and constructed as described for the experimental items. Mismatch primes differed from the visual targets in one vowel, but never in /æ/ or /ɛ/. All primes, including those for non-word targets, were the beginning of a real word. Items selected for visual presentation were not spelled like existing Dutch words, and items selected for auditory presentation did not sound like existing Dutch words.

For the phonetic categorization task, the 24 pairs of experimental Identity and Mismatch primes were used.

2.3. Design

For the cross-modal priming task, the target items were divided into six lists (2 words per pair × 3 conditions). There were 24 pairs of experimental visual target words. Each participant saw only one word of each pair, 12 with an /æ/ and 12 with an /ɛ/. Each participant was presented with eight of the experimental visual targets in each of the three conditions: Identity 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). Each participant was presented with all of the filler words and filler non-words, so that each participant saw a total of 96 words and 96 non-words, 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 non-words occurred in succession, and two experimental targets were separated by at least one other item.
In the phonetic categorization task, participants were presented with four repetitions of the 48 stimuli which served as Identity and Mismatch primes in the previous task. The items were semi-randomized such that the same phoneme occurred maximally five times in succession, and minimally two other stimuli separated the two items of one pair.

2.4. Procedure

Participants were tested one at a time in a quiet room. All participants did both the cross-modal priming task and the phonetic categorization task, with a short break in between.

First, for the cross-modal priming task, the participants 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 non-word would appear on a computer screen. They were asked to press a green response button, labeled "yes", with their dominant hand if they thought the visually presented item was an English word, and a red response button, labeled "no", with their non-dominant 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 12 practice trials and was controlled with NESU (Nijmegen Experiment Set-Up) 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 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.

After having finished the cross-modal priming task, participants received written instructions for the phonetic categorization task. They were informed that they would hear parts of words containing either an /æ/ or an /ɛ/. They were instructed to decide which of these two sounds they had heard, and to press a green response button, labeled "E", with their dominant hand when they had heard an /ɛ/ and a red response button, labeled "A", with their non-dominant hand when they had heard an /æ/. The participants were asked to respond both as fast and as accurately as possible. Before the task started, the participants heard some examples of non-words containing /æ/ or /ɛ/. The task started with 8 practice trials and was controlled with NESU software. Stimuli were presented binaurally over closed headphones at a comfortable listening level, one at a time. No time limit was imposed for the responses. After each button press, presentation of the next item started.

3. Results

Reaction times (RTs) were measured from item offset, outliers were removed, the proportions of correct responses were arcsine transformed prior to analysis, and RT analyses were performed on the logarithms of the RTs of the correct responses. The results of one experimental pair had to be excluded due to an error in the item lists.

3.1. Cross-modal priming

The hypothesis being tested was that hearing the first part of a word would cause more activation of a word mismatching in the /æ/-/ɛ/ contrast for the nonnative listeners than for the native listeners. Mismatch primes were predicted to facilitate the recognition of visual targets more for the Dutch listeners than for the English listeners. For the English listeners, less facilitation was expected in the Mismatch condition than in the Identity condition, or possibly no facilitation at all. For the Dutch listeners, the amount of facilitation in the Mismatch condition might be similar to that in the Identity condition. Figure 1 shows that this was exactly the pattern found in the proportion of correct responses.

3.1.1. Proportion correct

Table 1 shows the percentage of correct responses and the RTs of the correct responses. First, the proportions of correct responses were analyzed.

The interaction between native language and condition was significant by subjects but not by items ($F1$ (2, 284) = 4.00, $p < .05$; $F2$ (2, 90) = 1.52, $p > .1$). For the conditions Identity versus Control, there was no interaction between native language and condition ($F1$ (1, 142) = 1.90, $p > .1$; $F2$ (1, 45) < 1) and there were more correct responses in the Identity condition than in the Control condition ($F1$ (1, 142) = 4.71, $p < .05$; $F2$ (1, 45) = 20.46, $p < .001$). For the conditions Mismatch versus Control, there was no interaction between

native language and condition (*F1* (1, 142) = 1.63, $p > .1$; *F2* (1, 45) < 1) and no main effect of condition (*F1* (1, 142) < 1; *F2* (1, 45) < 1).

The crucial comparison was between the Identity and the Mismatch conditions. As expected, for these conditions, there was an interaction between native language and condition (*F1* (1, 142) = 10.96, $p < .001$; *F2* (1, 45) = 4.38, $p < .05$). For the Dutch listeners, there was no difference between the Identity and the Mismatch condition (*F1* (1, 71) = 1.23, $p > .1$; *F2* (1, 45) < 1). For the English listeners on the other hand there were more correct responses in the Identity condition than in the Mismatch condition (*F1* (1, 71) = 16.90, $p < .001$; *F2* (1, 45) =12.44, $p < .001$).

A main effect of phoneme was significant in the analysis by subjects but not by items (*F1* (1, 138) = 7.46, $p < .01$; *F2* (1, 44) < 1) and there were no interactions involving phoneme. Thus, the results were similar for words with an /æ/ and words with an /ɛ/.

Overall, the English listeners gave more correct responses than the Dutch listeners (*F1* (1, 142) = 130.55, $p < .001$; *F2* (1, 45) = 33.43, $p < .001$).

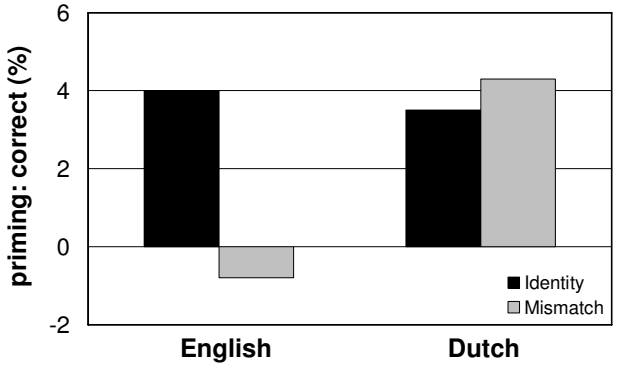

Figure 1. English and Dutch listeners' priming results, computed as the difference between the percentage of correct responses in the Identity or the Mismatch condition and the Control condition, with a positive value indicating facilitation.

3.1.2. Reaction time

In the analysis of the RTs of the correct responses, there were no interactions between native language and condition. There was a main effect of condition (*F1* (2, 284) = 5.54, $p < .01$; *F2* (2, 86) = 4.66, $p < .05$), but pairwise comparisons of the three conditions did not yield significant differences. RTs were shorter for the English listeners than for the Dutch listeners (*F1* (1, 142) = 21.11, $p < .001$; *F2* (1, 43) = 63.07, $p < .001$). There was no main effect of phoneme (*F1* (1, 125) = 2.17, $p > .1$; *F2* (1, 42) < 1), and there were no interactions involving phoneme.

Note that the analysis of the RTs of the correct responses was performed with a considerably reduced data set, due to the large proportion of errors made by the Dutch listeners. This may explain why there were no interactions involving native language, as has been observed in the analysis of the proportion correct.

Table 1. *English and Dutch listeners' percentage of correct responses and RTs of correct responses for target words in Control, Identity, and Mismatch condition, separately for target words containing /æ/ or /ɛ/. Examples are given in brackets.*

Target word	Condition (prime)	English	Dutch
		correct (%)	
/æ/ *(accident)*	Control *(pove)*	95.8	70.2
	Identity *(acci)*	99.1	74.7
	Mismatch *(exe)*	92.9	73.5
/ɛ/ *(execute)*	Control *(pove)*	88.0	70.3
	Identity *(exe)*	92.6	72.8
	Mismatch *(acci)*	89.1	75.4
		RT (ms)	
/æ/ *(accident)*	Control *(pove)*	682	828
	Identity *(acci)*	680	751
	Mismatch *(exe)*	684	771
/ɛ/ *(execute)*	Control *(pove)*	729	782
	Identity *(exe)*	692	786
	Mismatch *(acci)*	692	801

3.2. Phonetic categorization

The phonetic categorization task was included to assess the Dutch listeners' categorization of the /æ/-/ɛ/ contrast, and to compare their performance with that of the English listeners. It was expected that the Dutch listeners would categorize the phonemes less accurately than the English listeners, in line with Broersma (2005a).

The results were as expected. The percentage of correct responses to items containing an /æ/ was 85.6 % for the English listeners and 54.6 % for the Dutch listeners, and the percentages correct for items containing an /ɛ/ were 91.7 % and 66.9 %, respectively. The Dutch listeners made more errors than the English listeners did (*F1* (1, 142) = 938.66, $p < .001$; *F2* (1, 44) = 141.95, $p < .001$).

Further, there were more correct responses for the items containing an /ɛ/ than for the items containing an /æ/ (*F1* (1, 142) = 57.68, $p < .001$; *F2* (1, 44) = 5.25, $p < .05$). Thus, there was a bias towards perception of /ɛ/.

The Dutch listeners' proportion of correct responses was significantly above chance (50 % correct) (*t* (71) = 14.31, $p < .001$ by subjects; *t* (22) = 7.42, $p < .001$ by items). However, when the responses to /æ/ and /ɛ/ were assessed separately, the Dutch listeners' proportion of correct responses was significantly above chance for /ɛ/ (*t* (71) = 13.37, $p < .001$ by subjects; *t* (22) = 3.87, $p < .001$ by items) but not for /æ/ (*t* (71) = 3.75, $p < .001$ by subjects; *t* (22) = 1.38, $p > .1$ by items).

4. Discussion

As expected, there was more activation of competitors with partially overlapping onsets for the Dutch listeners than for the English listeners. In the cross-modal priming task, the presentation of Mismatch primes had different effects for the two groups of listeners. Both for native and for nonnative listeners, presentation of an Identity prime facilitated the recognition of the target word. For the English listeners, Mismatch primes did not facilitate the recognition of the target words. For the Dutch listeners on the other hand, Mismatch

primes facilitated the recognition of the target words, resulting in as many correct responses in the Mismatch condition as in the Identity condition.

The results from the categorization task showed that, as predicted, the Dutch listeners recognized the vowels less accurately than the English listeners did, in line with Broersma (2005a). Further, there was a bias towards perception of /ɛ/ for Dutch and English listeners alike. The Dutch listeners categorized the items with an /ɛ/ but not those with an /æ/ with a level of accuracy above chance. The Dutch listeners' low level of perceptual accuracy can explain the finding that presentation of the onset of words activated competitors with partially overlapping onsets more for Dutch than for English listeners.

5. General discussion

The results of the cross-modal priming study show that partially overlapping words cause more competitor activation for nonnative listeners than for native listeners.

The phonetic categorization task confirmed that the Dutch listeners recognized the vowels /æ/ and /ɛ/ with a level of accuracy just above chance, which seemed to be due to their categorization of /ɛ/ rather than their categorization of /æ/. They categorized the vowels less accurately than the English listeners did. Both the English and the Dutch listeners had a bias towards perception of /ɛ/. These results are consistent with previous studies (Broersma, 2005a, submitted).

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 temporarily overlapping competitors 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, 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. However, the statistics indicate that the possible effect of one ambiguous contrast only is already considerable. Of course listeners may be confronted with many perceptually ambiguous contrasts while listening to a second language. Processing of all of these contrasts may simultaneously increase the number of activated lexical representations. Further, the number of possible lexical competitors may increase sharply due to the combination of several of these contrasts within a single word. Thus, the increase of lexical activation may be very large in nonnative listening.

As it is more difficult to recognize a word when more lexical competitors are active, an increase in lexical activation is harmful to speech recognition. Although the activation of lexical competitors is a necessary part of speech comprehension (see e.g., McQueen, 2004), it has also been found to complicate the recognition of spoken words for native listeners (Norris et al., 1995; Vroomen & De Gelder, 1995). An increase in lexical activation extends this problem for nonnative listeners. The results from the present study show that the increase of competitor activation in nonnative listening may be very large and may seriously complicate the recognition of speech in a second language.

6. References

Broersma, M. (2002). *Comprehension of non-native speech: Inaccurate phoneme processing and activation of lexical competitors [oral]*. Proceedings of the 7th International Conference on Spoken Language Processing (pp. 261-264), Center for Spoken Language Research, University of Colorado, Boulder (CD-ROM).

Broersma, M. (2005a). Perception of familiar contrasts in unfamiliar positions. *Journal of the Acoustical Society of America, 117*, 3890-3901.

Broersma, M. (2005b). *Phonetic and Lexical Processing in a Second Language.* Unpublished doctoral dissertation, Radboud University Nijmegen, The Netherlands.

Broersma, M. (submitted). Spurious lexical activation in nonnative listening. *Cognition*.

Cutler, A. (2005). *The lexical statistics of word recognition problems caused by L2 phonetic confusion*. Proceedings of the 9th European Conference on Speech Communication and Technology, Lisbon, September 2005.

Cutler, A., & Otake, T. (2004). *Pseudo-homophony in non-native listening*. Poster presented at the 75th meeting of the Acoustical Society of America, New York.

Cutler, A., Weber, A., & Otake, T. (in press). Asymmetric mapping from phonetic to lexical representations in second-language listening. *Journal of Phonetics*.

Luce, P. A., Pisoni, D. B., & Goldinger, S. D. (1990). Similarity neighborhoods of spoken words. In G. T. M. Altmann (Ed.), *Cognitive Models of Speech Processing: Psycholinguistic and Computational Perspectives* (pp. 122-147). Cambridge, MA: MIT.

McQueen, J. (2004). Speech perception. In K. Lamberts & R. Goldstone (Eds.), *The Handbook of Cognition* (pp. 255-275). London: Sage Publications.

McQueen, J., Norris, D., & Cutler, A. (1994). Competition in spoken word recognition: Spotting words in other words. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20*, 621-638.

Norris, D., McQueen, J. M., & Cutler, A. (1995). Competition and segmentation in spoken-word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*, 1209-1228.

Pallier, C., Colomé, A., & Sebastián-Gallés, N. (2001). The influence of native-language phonology on lexical access: Exemplar-based versus abstract lexical entries. *Psychological Science, 12*, 445-449.

Sebastián-Gallés, N., Echeverría, S., & Bosch, L. (2005). The influence of initial exposure on lexical representation: Comparing early and simultaneous bilinguals. *Journal of Memory and Language, 52*, 240-255.

Vroomen, J., & De Gelder, B. (1995). Metrical segmentation and lexical inhibition in spoken word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 21*, 98-108.

Weber, A., & Cutler, A. (2004). Lexical competition in non-native spoken-word recognition. *Journal of Memory and Language, 50*, 1-25.