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*Voornaam is not (really) a Homophone: Lexical Prosody and Lexical Access in Dutch**

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KEY WORDS

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ABSTRACT

Four experiments examined Dutch listeners' use of suprasegmental information in spoken-word recognition. Isolated syllables excised from minimal stress pairs such as *VOORnaam/voorNAAM* could be reliably assigned to their source words. In lexical decision, no priming was observed from one member of minimal stress pairs to the other, suggesting that the pairs' segmental ambiguity was removed by suprasegmental information. Words embedded in nonsense strings were harder to detect if the nonsense string itself formed the beginning of a competing word, but a suprasegmental mismatch to the competing word significantly reduced this inhibition. The same nonsense strings facilitated recognition of the longer words of which they constituted the beginning, but again the facilitation was significantly reduced by suprasegmental mismatch. Together these results indicate that Dutch listeners effectively exploit suprasegmental cues in recognizing spoken words. Nonetheless, suprasegmental mismatch appears to be somewhat less effective in constraining activation than segmental mismatch.

1. INTRODUCTION

The President of the United States from 1993 to 2000 rejoiced in the first name Bill, a name which in Dutch is homophonous with the word *bil* 'buttock'. Whatever respect the Dutch felt for Mr. Clinton, they might have been justified in saying: *Hij was niet vanwege zijn voornaam voornaam.* 'He was not due-to his first-name respectable.'.

Is that Dutch sentence a pun, an imperfect pun, or no pun at all? To answer this question we need to decide what meanings are activated for a Dutch listener by the two occurrences of the string *voornaam* in the example sentence. The two words are identical segmentally, but differ suprasegmentally: stress falls on the first syllable of the noun, but on the second syllable of the adjective.

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If lexical access in Dutch is equally sensitive to any type of pronunciation information — specifically, both to segmental information and also to the suprasegmental information which signals stress pattern — then the members of a "minimal stress pair" such as *VOORnaam* and *voorNAAM* (upper case henceforth denotes a stressed syllable) will each activate separate lexical representations. In this case the example sentence might have very little punning potential, as is the case with most sequences of quite similar words (consider as an English example of such a not very successful pun the following description of a media-happy bishop: *You would certainly not call him a private primate*).

On the other hand, if lexical access in Dutch were to be sensitive only to segmental information, the two suprasegmentally differing pronunciations of *voornaam* might each activate the lexical representations of both "first name" and "respectable." In that case the example sentence might work quite well as the kind of pun which contains two unrelated homophones (as one might in English say of a superannuated fruit: *This is not exactly a current currant*).

In recent years considerable experimental attention has been devoted to assessing the relative contribution of segmental and suprasegmental information to lexical access. A constraining role of suprasegmental structure in word recognition has been demonstrated for Chinese (e.g., Fox & Unkefer, 1985, for Mandarin); and associative priming studies in Cantonese (Chen & Cutler, 1997; Cutler & Chen, 1995) have shown exactly parallel effects of the segmental and tonal structure of a syllable's rime in constraining priming. Pitch accent patterns in Japanese are also important for word recognition; thus gating experiments in Japanese (Cutler & Otake, 1999) have shown that listeners who have heard the onset and just half the vowel of a stimulus word's first syllable produce 80% word guesses with the same initial pitch accent pattern as the stimulus. Priming studies in the same language (Sekiguchi & Nakajima, 1999) have shown that segmentally ambiguous but suprasegmentally unambiguous word fragments activate only the words which they match both segmentally and suprasegmentally.

Analogous priming studies in Spanish (Soto, Sebastián-Gallés, & Cutler, 2001) have led to the same result; and an explicit comparison by these authors of the relative weight of segmental versus suprasegmental information showed that each was equivalently powerful. A single mismatch favoring one word over another had the same effect irrespective of whether the mismatch concerned a vowel, a consonant, or stress placement.

All these findings (and see Cutler, Dahan, & van Donselaar, 1997, for more) suggest a strong role for suprasegmental information in word activation. However, the languages involved are all ones in which segmental and suprasegmental structure are relatively independent. Mandarin and Cantonese are tone languages, in which the rime of every syllable incorporates one of the language's tones, realized via a characteristic F0 contour. Pitch accent in Japanese is likewise realized via F0 alone. Stress in Spanish is lexical stress, but it has no major consequences for vowel realization since Spanish has no vowel reduction.

In some languages there is greater interdependence between suprasegmental and segmental structure. Stress in English, for example, is not independent of vowel quality: only unreduced vowels can bear stress. Experimental evidence from English suggests that in that language segmental information outweighs suprasegmental information in lexical activation.

For example, Slowiaczek (1991) presented listeners with a sentence context and a stress pattern and asked them to judge a target word for acceptability; she found that the stress pattern information was often ignored, in that listeners responded yes to words which were semantically acceptable in the context but did not have the target stress pattern. A cross-splicing study by Fear, Cutler, and Butterfield (1995) confirmed that listeners pay more attention to the distinction between full and reduced vowels than to stress distinctions among full syllables. Listeners in this study heard tokens of words such as *audience, auditorium, audition, addition*, in which the initial vowels had been exchanged between words; they rated cross-splicings among any of the first three of these as insignificantly different from the original, unspliced tokens. Lower ratings were received only by cross-splicings involving an exchange between the initial vowel of *addition* (which is reduced) and the initial vowel of any of the other three words.

Studies of the perception of mis-stressed English words confirm the dominance of segmental information. Bond and Small (1983) found that word recognition in shadowing was achieved despite mis-stressing as long as the mis-stressing did not result in an alteration of vowel quality; Slowiaczek (1990) found the same for word identification in noise. Small, Simon, and Goldberg (1988) found that mis-stressing did not inhibit word recognition if it effectively created the target word's stress pair (e.g., *INsert* pronounced as *inSERT* or vice versa), though it significantly inhibited recognition if it created a nonword (e.g., *chemist* pronounced *cheMIST*, or *polite* pronounced *POlite*). Cutler and Clifton (1984) found that shifting stress without altering vowel quality had a much smaller adverse effect on recognition than stress shifts which changed full vowels to reduced or vice versa. The most disruptive effect on word recognition results from distortion of a stressed syllable. Bond (1981) compared the effects of several types of segmental mispronunciation (e.g., the alteration of a single feature, such as voicing); most disruptive, she found, was distortion of vowels in stressed syllables. Likewise, Mattys and Samuel (1997) showed that noise distortion in stressed syllables inhibited phantom word recognitions resulting from combination of dichotically presented input (e.g., *gar-* in one ear and *-lic* in the other).

The weakness of suprasegmental information in lexical access in English was underlined by an experiment by Cutler (1986), in which presentation of either of the two members of a minimal stress pair — for instance, either *FORbear* or *forBEAR*, or *trusty* or *trustee* — activated words associated to both of them. In a cross-modal priming task, Cutler presented listeners with sentences containing such words, and measured their response time to make lexical decisions about words presented visually coincident with offset of the critical word, that is, the member of the minimal stress pair. The sentences were neutral prior to the occurrence of the critical pair, for example: *The person that she was hurrying to see was the trusty/trustee*… Cutler found that whichever member of the stress pair had been heard, listeners' responses to associates of both members of the pair were facilitated in comparison to control words. Cutler argued that the suprasegmental differences between, for instance, *FORbear* and *forBEAR* were ineffective in constraining lexical activation, so that for English listeners *forbear* was effectively a homophone.

Clearly the evidence across languages is not uniform. In some languages the contribution of suprasegmental and segmental information in lexical access appears to be equivalent; in English, the evidence suggests a stronger role for segmental information. However, although the vast majority of studies in this area (as in most areas of psycholinguistics) have been conducted in English, it is far from clear that English is the most appropriate language for the purpose. Many other languages allow experiments which would be ruled out for English by the constraints of English phonological structure (for instance, one could not directly replicate the stress experiments of Soto et al., 2001, in English). Even some languages in which suprasegmental and segmental structure are interdependent allow for greater experimental flexibility than English does. Dutch is such a language.

Like English, Dutch has stress rhythm, an opposition between strong syllables (with full vowels) and weak syllables (with reduced vowels), and syllable weight effects in stress placement (Booij, 1995; Trommelen & Zonneveld, 1999). Dutch has lexical stress, that is, one syllable of any polysyllabic word is marked for higher stress than the other(s). Minimal pairs of words which differ in stress but not in vowel quality, such as *VOORnaam/voorNAAM* exist though they are very rare. In both these characteristics Dutch patterns like English. According to Trommelen and Zonneveld (1999), five rules suffice to account for the assignment of stress placement within words in each language, and the English and Dutch rule sets are identical except that the definition of what constitutes a heavy syllable is "a closed syllable" for Dutch and "a closed syllable or a syllable with a long vowel" for English.

Word prosody however also shows differences between English and Dutch. In English, the correspondence between stress and vowel quality is pervasive: vowels in stressed syllables are always full, while vowels in unstressed syllables are nearly always reduced. In Dutch, the correspondence is looser. Many more Dutch words than English words contain unstressed syllables with full vowels. Consider, for instance, the English words *cobra* and *cigar*: each is usually spoken with a reduced vowel in the unstressed syllable. The counterpart words in Dutch — *CObra*, *siGAAR* — have stress on the same syllables as the English forms, but have full vowels in the unstressed syllables. In fact, unstressed initial syllables of monomorphemic bisyllabic words of the *cigar* type hardly ever contain reduced syllables in Dutch (Booij, 1995; Schreuder & Baayen, 1994), but virtually always do in English.

This difference has consequences for the investigation of spoken-word recognition. Because Dutch contains many such words with unstressed syllables containing full vowels, it is relatively easy to construct Dutch experiments in which stress varies independently of segmental structure — that is, experiments of the kind that Soto et al. (2001) performed for Spanish. Thus Dutch allows useful further exploration of the role of suprasegmental structure in lexical access. Does suprasegmental information exercise as strong a constraint on lexical access as segmental information only when the two are independent? If so, then Dutch, where the two are not independent, will produce results more like those from English than those from Spanish.

What evidence there is for Dutch so far is mixed. An attempt by Jongenburger (1996; see also Jongenburger & Van Heuven, 1995a) to replicate Cutler (1986) in Dutch produced no evidence of facilitation by any type of prime, so that no conclusion could be drawn. In gating studies by the same author (Jongenburger, 1996; Jongenburger & Van Heuven, 1995b), listeners' word guesses displayed correct stress judgments for the initial syllable of a stimulus word only once the whole of that initial syllable and part of the following vowel had been presented. These results do not suggest strong constraints by suprasegmental information on word activation in Dutch. However, another gating study, in which the words were presented in sentence context and listeners were given a forced choice between two alternatives, showed that listeners could correctly assign a syllable to one of two words in which it was respectively stressed versus unstressed (e.g., *si-* to *silo* vs. *sigaar*; Van Heuven, 1988). Experiments on the perception of mis-stressed words (using gating: Van Heuven, 1985; Van Leyden & Van Heuven, 1996; or a semantic judgment task: Cutler & Koster, 2000; Koster & Cutler, 1997) have shown that mis-stressing harms word recognition in Dutch, and at least in Koster and Cutler's (1997) study the effects of mis-stressing were of similar magnitude to the effects of segmental mispronunciation. All of these findings are consistent with a significant role for suprasegmental information in Dutch word activation.

Only three of the above studies used a speeded response ("on-line") task to examine the use of suprasegmental information in Dutch word recognition, and in one of these (Jongenburger's [1996] cross-modal priming study) the results were inconclusive, while in the others (the two studies with a semantic decision task) the focus was chiefly on the effects of incorrect pronunciation.

In the present paper we describe four experiments, three of which use speeded-response paradigms. In the first two experiments we consider minimal stress pairs such as *VOORnaam/voorNAAM*. Is *voornaam* effectively a complete homophone, or an imperfect homophone, or not a homophone at all? In the third and fourth experiments we exploit the empirical possibilities of Dutch outlined above; we ask whether stress pattern information constrains activation in any word beginning with two full syllables, not necessarily a member of a minimal stress pair. To do this, we make use of a diagnostic for lexical competition — can suprasegmental information suffice to rule out a potential competitor word?

To examine the recognition of minimal stress pairs such as *voornaam*, we first examine the informativeness of the suprasegmental information in each syllable of the same minimal stress pairs. In Experiment 1, listeners performed a two-alternative forced-choice assignment of parts of words such as *VOORnaam* and *voorNAAM*. The words were recorded in isolation so that the same tokens could be used in the lexical decision task in Experiment 2. If Van Heuven's (1988) results for pairs such as *silo-sigaar* presented in sentence context can generalize to members of minimal stress pairs presented in isolation, then listeners should be able to tell to which member of the pair a syllable belongs.

2. EXPERIMENT 1

2.1 Materials

In all lexical-stress languages, minimal stress pairs are very rare. Cutler (1986) identified 11 clear pairs for English and conducted her experiment with eight pairs. A search in the Dutch component of the CELEX lexical database (Baayen, Piepenbrock, & Van Rijn, 1993) produced 13 clear pairs for Dutch. Several further potential pairs discovered in CELEX were rejected because the two members of the pair did not have distinct meanings (these were nearly all separable verbs vs. inseparable verbs with the same prefix), or because one member was a nonce-form or a slang form or an inflected word or of very low frequency (examples of pairs rejected for one or more of these reasons are *koopie-copie* 'bargain; copy', *misdadiger* 'a criminal; more felonious', *automaat* 'car size; automaton').

Twelve pairs were chosen for use in Experiments 1 and 2. They were *achterruit/achteruit* 'rear window; backwards'; *avonduur/avontuur* 'eveningtime; adventure'; *canon/kanon* 'canon; cannon'; *doorlopen* 'run on; proceed through'; *ondergaan* 'sink; undergo'; *onderhouden* 'keep down; maintain'; *overweg* 'crossing; along'; *Plato/plateau* 'Plato; plateau'; *Servisch/servies* 'Serbian; crockery set'; *uitstekend* 'projecting; excellent'; *voorkomen* 'appearance; prevent'; *voornaam* 'first name; respectable'. The thirteenth potential pair was *voorruit/vooruit* 'front windscreen; forwards', which was dropped because of its semantic similarity to *achterruit/achteruit* and because the selected set contained two other pairs with *voor-*. The pairs were recorded onto Digital Audio Tape by a female native speaker of Dutch, and the recordings stored on disc. Mono- and bisyllabic fragments were extracted from all 24 words. In two of the minimal pairs (ach#ter#ruit/ach#ter#uit; a#vond#uur/a#von#tuur), some syllabic boundaries differed in the initial- versus the final-stress members; the differing syllables were not used, so that these pairs were represented in the experiment by corresponding initial fragments only (*ach-, achter-; a-*). The four bisyllabic pairs were represented by initial and final syllables. The remaining five trisyllabic pairs were represented by three fragments, namely the monosyllabic foot, the bisyllabic foot, and the monosyllabic fragment comprising the stressed syllable of the bisyllabic foot; thus for *voorkomen* the fragments were *voor-*, *-komen* and *-ko-*. The four-syllable pair *onderhouden* was represented, correspondingly, by four fragments. Thus there were in total 60 experimental fragments. Syllables were also extracted from four further pairs for use as practice materials in Experiment 1; these were *voorruit/vooruit*, *omspoelen* ('rinse out; wash around'), *buitendienst* ('outside service; out of service') and *onderdrukken* ('press down; oppress').

Two tapes of the experimental fragments were made, each containing a different ordering of all 60 fragments. Each ordering was random except for the following constraints: no successive presentations of fragments from the same pair occurred; and the ordering of any two segmentally identical fragments on Tape A was reversed on Tape B. Thus, for example, where on tape A *ca-* from *canon* occurred earlier than *ka-* from *kanon*, on tape B *ka-* from *kanon* occurred earlier than *ca-* from *canon*.

An answer sheet was constructed for each tape. For each fragment the two words of the appropriate word pair were listed, with their stressed syllables capitalized, and each word was illustrated with a short example sentence. For instance, a subject who heard *lo-* from *doorlopen* could see on the answer sheet:

DOORlopen	doorLOpen
Om op tijd te komen moest ze hard doorlopen	Ze heeft de lagere school goed doorlopen.

Glosses for these sentences would be: 'To get there in time she had to run fast', and 'She got through primary school satisfactorily'. The example sentences for each pair were always the same, but the left-right placement of the two alternatives was counterbalanced such that on 50% of trials the correct choice was on the left, and the ordering for a given fragment differed on answer sheets A and B. A similar answer sheet was used for the practice set.

2.2 Subjects

Twenty-four Nijmegen University undergraduate students were tested; all were native

TABLE 1

Percent correct choice of source word, Experiment 1, as a function of stress, position of fragment in word, and first versus second presentation

	1st half of word		*2nd half of word*		*Mean*
	Stressed	Unstressed	Stressed	Unstressed	
1st presentation	86.9	82.0	87.6	71.4	82.0
2nd presentation	88.7	92.5	94.8	85.7	90.4
Mean	87.8	87.2	91.2	78.6	86.2

speakers of Dutch, with normal hearing. They received a small payment for their participation. Twelve subjects heard Tape A then Tape B, the other 12 Tape B then Tape A. The results from two subjects who reported that they had misunderstood the task were not analyzed.

2.3 Procedure

Subjects heard the fragments over closed headphones. One second before each fragment on the tape a 500 ms bleep was played as alerting signal. The rate of presentation was one fragment each ten seconds. Subjects were asked to circle on the answer sheet the word from which they thought the fragment had been extracted. The experiment began with 17 practice fragments after which subjects had a chance to ask questions. The two experimental blocks were then presented, with a short break between them.

2.4 Results and Discussion

The responses were scored by hand and percent correct scores ascertained for each subject and each item. The overall percent correct was 86.2%; Table 1 shows the mean percent correct, collapsed across fragment types, for word half, stress, and presentation order. Analyses of variance, with the factors syllable stress (stressed, unstressed), position in word (first half, second half) and presentation (first time, second time) were conducted separately across the two random factors subjects and items. The analyses revealed that subjects' judgments were more often correct on second than on first presentations, $F_1(1,21)=11.18$, $p<.01$; $F_2(1,29)=39.82$, $p<.001$, and were more often correct when a fragment consisted of a stressed syllable than an unstressed syllable; $F_1(1,21)=4.16$, $p=.05$; $F_2(1,29)=4.59$, $p<.05$. Presentation order and stress interacted across items, $F_1(1,21)=3.63$, $p<.075$; $F_2(1,29)=5.66$, $p<.03$; the improvement on second presentation was largely accounted for by unstressed syllables. There were no effects of the position of the fragment in the word.

The most noticeable result of Experiment 1 was, however, the high scores overall; even in the least well-judged condition (first presentation of unstressed syllables: 77% correct) listeners performed significantly above chance at choosing the correct member of the stress pair. Dutch listeners can thus in general very easily judge whether a syllable or bisyllable presented in isolation comes from a word in which it bears stress or from a word in which it does not bear stress, even when the two words in question are members of a minimal stress pair. Preceding sentence context, as used in Van Heuven's (1988) study, is not necessary for performance of the identification, nor is it necessary that the two choice words diverge segmentally after the first syllable.

Experiment 2 examines the recognition of the full-form minimal stress pairs. The task used was a repetition priming paradigm. In word recognition experiments, repetition effects are robust: responses are facilitated when an item has been heard earlier. This repetition effect may be used as a sort of diagnostic of homophony. This was demonstrated by Pallier, Sebastián-Gallés and Colomé (1999), in a study of word perception by Spanish-Catalan bilinguals. Some Catalan phonetic contrasts (e.g., /s/-/z/) are difficult for Spanish-dominant bilinguals to discriminate. In a repetition priming experiment, Spanish-dominant bilinguals showed repetition priming for members of a Catalan word pair such as *casa-caza* when the other member of the pair had been presented earlier in the experiment. Catalan-dominant bilinguals showed no repetition priming in this case, and neither group showed priming between pairs of words differing in contrasts appearing in both languages (e.g., /m/-/n/). Pallier et al. argued that pairs like *casa-caza* are effectively homophonous for the Spanish-dominant listeners, such that presentation of either activates the lexical representations of both. By analogy to their experiment, we can use the task to examine whether minimal stress pairs in Dutch are effectively homophonous. If both members of such a pair are activated when either member is heard then repetition priming should occur for, say *VOORnaam* given an earlier presentation of either *VOORnaam* or *voorNAAM*. On the other hand, if Dutch listeners use the suprasegmental cues to stress to constrain activation to only the uttered member of the pair, then repetition priming should occur for *VOORnaam* given an earlier presentation of *VOORnaam* but not given an earlier presentation of *voorNAAM*.

3. EXPERIMENT 2

3.1 Materials

The 12 minimal stress pairs used in Experiment 1 also formed the material for Experiment 2. In the same recording session as for Experiment 1, 240 further words and nonwords were recorded. One hundred and forty-four of these formed the material for a separate experiment on priming effects of phonological similarity (Cutler, Van Ooijen, & Norris, 1999).

Six presentation orders were constructed, each consisting of a short practice set followed by an experimental list of 132 words and 132 nonwords. Each presentation order contained 12 target words distributed throughout the experimental list; each member of each minimal pair occurred as target in three of the orders, with stress (initial, final) counterbalanced across orders. The items appearing 12 items earlier in the list than each target were defined as the prime items, and could be (a) the same item as the target (e.g., for *VOORnaam, VOORnaam*), (b) the target's minimal pair (e.g., for *VOORnaam*, *voorNAAM*), or (c) a control word (e.g., for *VOORnaam*, *camping*). Identity priming is robust at a lag of 12 items (Monsell, 1985). Each presentation order contained, for each stress pattern, two items in each prime condition. The rate of presentation was approximately one item per three seconds.

The phonological similarity in the matrix experiment always involved segmental differences, such as the word *lepel* 'spoon' preceded (immediately or with intervening items) by the nonword *lopel*, or the word *kaper* 'pirate' preceded by *kamer* 'room'. The phonological similarity experiment contained no repeated items, so that the four identical prime-target pairings in each order, and the four pairings of stress pair prime and target, were the only segmentally faithful repetitions in 264 items.

3.2 Procedure

Subjects were tested individually or in groups of up to four. They heard the practice and experimental lists over headphones and were instructed to decide for each item whether or not it was a real word of Dutch and to signal their decision by pressing one of two response keys labeled YES and NO. YES responses were made with the preferred hand. A pause for questions occurred after the practice set.

The items were presented from disc by a computer running the NESU experimental control software. Timing began at the onset of each item, and was stopped by the keypress responses or by a timeout window of 2500 ms. Response times were collected and stored by the computer.

3.3 Subjects

Seventy-eight members of the Nijmegen University community participated in the experiment in return for a small payment. All were native speakers of Dutch with no reported hearing problems; none had participated in Experiment 1. The six presentation orders were heard by 14, 14, 14, 12, 12, and 12 participants respectively. Data of two further subjects were discarded for technical reasons.

3.4 Results and Discussion

The missing-response rate was low, the highest error score being for the word *canon*, which was missed by four of the 36 subjects who received it as target. Mean error rate for the identity prime (repetition) condition was 1.8%, for the stress-pair prime condition 2.5% and for the control condition 3.6%, but the intercondition differences were not statistically significant. The response times (RTs) were adjusted for measured item duration to give, as is conventional for auditory lexical decision, times from target offset. Because many of the words were quite long and became unique before their final phoneme, this resulted in quite short mean RTs. Accordingly we subjected both the RTs from onset and the RTs from offset to analyses of variance, with the factors prime condition (identity, stress-pair or control prime) and target stress pattern (first- or second-syllable stress), and in each case with subjects and with items as random factors. Both analyses in fact produced the same pattern of significance. We report the results from offset, and Figure 1 shows the corresponding means.

The results were very clear. The analysis of variance showed a main effect of prime condition significant in both analyses, $F_1(2,144)=20.99, p<.001$; $F_2(2,44)=8.58, p<.001$. T-tests showed that RTs were significantly faster in the identity prime condition than in the control condition, $t_1(77)=5.65, p<.001$; $t_2(23)=2.98, p<.01$, or the stress-pair prime condition, $t_1(77)=5.49, p<.001$; $t_2(23)=4.38, p<.001$, whereas the latter two did not differ

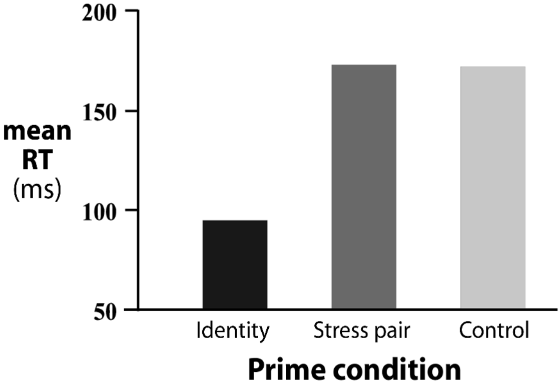

Figure 1

Mean response times (ms) from word offset in each of the three conditions of Experiment 2: prime identical to target (e.g., *VOORnaam — VOORnaam*), prime stress pair of target (e.g., *voorNAAM — VOORnaam*) or control prime (e.g., *camping— VOORnaam*)

(t_1, $t_2 < 1$). The main effect of stress pattern and the interaction of stress pattern with prime condition did not reach significance.

Thus Experiment 2 has shown no evidence that a member of a minimal stress pair activates both its own lexical representation and that of the other member of the pair; *VOORnaam* apparently activates only *VOORnaam* and not *voorNAAM*, while *voorNAAM* activates only *voorNAAM* and not *VOORnaam*. In Dutch, a mismatching stress pattern rules out the activation of a lexical entry which otherwise matches the segmental structure of the input.

This suggests that Dutch listeners ought also to be able to exploit stress mismatches to rule out activation of words other than the members of minimal stress pairs. As we pointed out in the introduction, Dutch (unlike English) contains many polysyllabic words of which both the first and second syllables are strong, so that either of the first two syllables could potentially bear stress. If stress information did not constrain activation, then an initial strong syllable might activate potential candidate words with stress on that syllable or with stress on the following syllable, and these words would compete for recognition until subsequent segmental information arrived to favor one over the other. Competition would be reduced, however, if initial portions of words activated only candidate words with a particular stress pattern. The results of Experiment 2 certainly suggest that competition is restricted in just this way.

To test this proposal further, we exploit in Experiment 3 a paradigm which is known to show effects of inter-word competition. In the word-spotting task, listeners detect real words embedded in a minimal nonsense context. McQueen, Norris and Cutler (1994) showed that detection of English words is harder if the context in which they are embedded forms the onset of another real English word — e.g., English *mess* is harder to spot in *domes* [dəmɛs] than in *nemes* [nəmɛs]. Competition from the other word (in this case, *domestic*) activated by its first two syllables interfered with detection of the embedded word. This competition effect for target words embedded within strings which are the onsets of longer words has been replicated for Dutch by Van der Lugt (1999). Experiment 3 asks whether such competition can be fully removed, in Dutch, by stress mismatch. We compare the detection of words like *zee* ('sea'), embedded in strings which are potential word onsets (*muzee*, the beginning of *museum*), in versions in which the stress pattern of the competing word is preserved (*muZEE*, as in *muSEum*) or mismatched (*MUzee*).

4. EXPERIMENT 3

4.1 Materials

To construct the experimental items for the word-spotting study, trisyllabic words were first selected from the CELEX (Baayen et al., 1993) lexical database of Dutch according to the following criteria: Both the first two syllables of each word had full vowels; primary stress of the word fell on the second syllable; neither the first syllable nor the first two syllables of the word were themselves a word; no other Dutch word began with the same two syllables differently stressed; the second syllable of the word was itself a word, unrelated to the trisyllabic matrix word; and neither matrix nor embedded word had very low frequency. Examples are *museum* ('museum'), of which the second syllable is homophonous with *zee* ('sea'); *abstraktie* ('abstraction'), containing *strak* ('taut'), and *annonce* ('announcement'), containing *non* ('nun'). Twenty-two such words were found of which 20 were selected for the experimental materials. They are listed in the appendix.

For each embedded word two nonsense strings were constructed, one which corresponded to the first two syllables of the matrix word (e.g., *muzee, abstrak, annon*), and another in which segmental alteration in the first syllable produced a string corresponding to the first two syllables of no existing Dutch word (e.g., *luzee, upstrak, tunnon*). Thus the target words occurred at the end of two nonsense strings, of which one could be expected to produce competition from the matrix word while the other should produce no competing activation. Two stress versions were created of each nonsense string: Stress on the second syllable, as in the matrix word (*muZEE, luZEE*) and stress on the first syllable *(MUzee, LUzee*), producing a total of four items containing each embedded word.

Sixty bisyllabic filler items were constructed. Forty of these contained no words or word onsets; ten began with real-word onsets but contained no embedded words; and ten contained embedded words but did not begin with a word onset. Fourteen further practice items were constructed, of which four contained embedded words. Half the fillers and half the practice items had stress on the first syllable, half on the second syllable.

All experimental items, fillers and practice items were recorded onto Digital Audio Tape by a female native speaker of Dutch. Four experimental presentation orders were constructed, each containing all filler items and one version of each of the 20 experimental word targets. For the experimental word targets, the two independent variables Onset Condition (Word Onset, Nonword Onset) and Stress (Second Syllable, First Syllable) were counterbalanced across orders. Thus for our example word we compare how often listeners report spotting *zee* in the competitor string *muZEE* (Word Onset, Second Syllable Stress) compared with the stress-mismatch string *MUzee* (Word Onset, First Syllable Stress), the segmental mismatch string *luZEE* (Nonword Onset, Second Syllable Stress) and the control string *LUzee* (Nonword Onset, First Syllable Stress).

4.2 Procedure

Subjects were tested in groups of two to four. They were seated in separate sound-attenuated cubicles and heard the stimuli binaurally over closed headphones. They were instructed to listen to the stimuli and to press a response key as fast as possible whenever they detected a real Dutch word embedded at the end of any stimulus; after pressing the response key they were to pronounce the word they had detected. They first heard the practice items, after which they had an opportunity to ask questions; then they heard one of the experimental presentation orders. Their vocal responses were recorded onto Digital Audio Tape; keypress responses, timed from stimulus onset, were recorded within a window of 2500 ms. Presentation of the stimuli and recording and storage of responses were controlled by a computer running NESU experimental control software.

4.3 Subjects

Fifty-nine participants were tested, from the same population as in Experiments 1 and 2. All were native speakers of Dutch with no reported hearing problems; none had taken part in Experiments 1 and 2. They were paid a small sum for participating. The data for one subject who failed to detect most targets were discarded. Two further subjects (those with the highest error rate in their respective conditions) were excluded to counterbalance the design at 14 subjects per condition.

4.4 Results and Discussion

The subjects' spoken responses were checked and keypress responses for which there had been no spoken word, or an incorrect response, were treated as missing data. Analyses of variance across subjects and across items were carried out for both the RTs and the miss rates; the factors in these analyses were stimulus onset (word, nonword) and stress pattern (second syllable stress, first syllable stress). The overall miss rate (14.3%) was (by comparison with other word-spotting studies) quite low, perhaps because the embedded words were in general of high frequency. There was a tendency for words to be missed less often when the syllable in which they occurred was stressed (11.1% miss rate for items stressed on the second syllable vs. 17.5% for items stressed on the first syllable), but there was no difference between the miss rate in word onsets and nonword onsets (both just over 14%), and in the analysis of miss rates, no effect reached significance across both subjects and items.

For the analysis of RTs, the item durations were subtracted from the measured times from target onset, to give RTs from word offset. The mean RTs in the four conditions are shown in Figure 2. The analyses of variance showed a significant main effect of the word onset versus nonword onset comparison, $F_1(1,52)=21.89, p<.001; F_2(1,19)=9.74, p<.01$, no significant main effect of stress pattern, but an interaction between these two variables (which narrowly failed to reach significance across subjects: F_1 $(1,52)=3.76$, $p<.06$; $F_2(1,19)=5.04, p<.04$. T-tests showed that the 111 ms difference between word onset and nonword onset for items stressed on the second syllable was highly significant, $t_1(55)=$ 3.83, $p<.001$; t_2 $(19)=3.29$, $p<.005$, whereas the 43 ms difference between word versus nonword onsets for items stressed on the first syllable was significant across subjects, $t_1(55)=2.44$, $p<.02$, but not significant across items, $t(19)=1.89$.

In this experiment the predicted competition effect, previously reported by McQueen et al. (1994) for English and Van der Lugt (1999) for Dutch, was thus once again observed: *zee* was harder to detect in *muZEE*, which simultaneously activates the competitor word *museum*, than in *luZEE*, which activates no other Dutch word. When the string *muzee* was stressed on the first syllable, however, the resulting input *MUzee* did not activate the

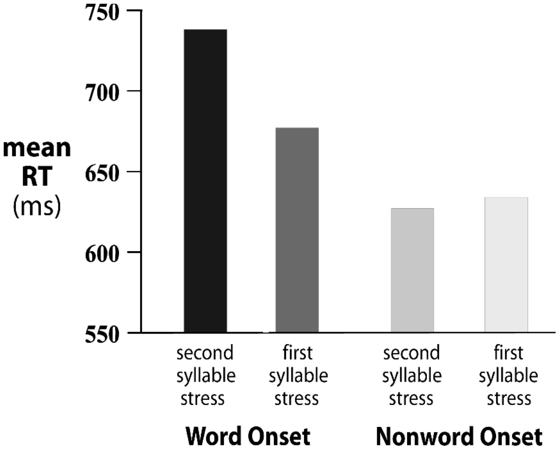

Figure 2

Mean response times (ms) in each of the four conditions of Experiment 3: Word onset versus nonword onset, second syllable stress (matching the matrix word) versus first syllable stress (mismatching the matrix word)

competitor as effectively: detection of *zee* in *MUzee* was much faster than it had been in *muZEE*, and the difference in speed of detection for *zee* in *MUzee* versus *LUzee* was not statistically reliable.

An alternative way of viewing the two-way interaction is that there is a reverse stress effect for the word onset items, where UNstressed targets were detected 61 ms faster than stressed targets, $t_1(55)=1.91$, $p=.06$; $t_2(19)=2.26$, $p<.04$, but there are no stress effects in the nonword onset items, in which stressed targets were detected on average 7 ms faster than unstressed targets (t_1, $t_2<1$). Note that any acoustic advantages which might have accrued to the embedded word when the item was stressed on the second syllable (*muZEE* vs. *MUzee*) would in effect have acted to attenuate the competition effect. Stress on the embedded word in such items has been shown to lead to faster RTs (Quené & Koster, 1998). Despite any such acoustic benefits, however, *muZEE* remained the hardest stimulus type; the word onset items showed a reverse stress effect.

Experiment 3 has thus shown that word activation in Dutch is sensitive to suprasegmental as well as to segmental information in the input. The input *MUzee* does not reliably activate *museum*. Note, however, that the results for *MUzee* could actually be considered intermediate between those for *muZEE* (the hardest stimulus) and those for *luZEE* and *LUzee* (the two easiest conditions, of apparently equivalent effect). That is, *luZEE* (which differed from the onset of *museum* in segmental structure but not in stress pattern) did not appear to produce any degree of activation different from that produced by *LUzee*, while *MUzee* (which differed from the onset of *museum* in stress pattern but not in segmental structure) may perhaps have produced partial activation, albeit not sufficient to lead to a statistically reliable effect of competition from *museum*. This is an important observation if it is generalizable, because it suggests that a segmental mismatch may be more effective than a suprasegmental mismatch in ruling out unwanted lexical activation.

In our final experiment, we examine this latter issue directly. Experiment 4 is a follow-up experiment to Experiment 3, using the same materials in a task designed to assess activation of the matrix word itself. This final experiment used a version of the cross-modal priming task (see Zwitserlood, 1996, for a review). In this task, lexical decision responses to a visually presented word are speeded by prior auditory presentation of the same word. Prior auditory presentation of a fragment of the word will also facilitate responses. In Experiment 4 we checked the relative facilitatory effect on visual lexical decision responses of prior auditory presentation of correctly stressed versus mis-stressed initial fragments of the target words.

5. EXPERIMENT 4

5.1 Materials

The prime materials were selected from Experiment 3, and included three of the four versions of each experimental target item, plus 40 of the filler stimuli. Since there was no longer any need for the control prime condition to match the other prime conditions in its second syllable (as had been the case for the word-spotting materials), a completely unrelated control condition could be created for this experiment. Accordingly, for each experimental target item the Experiment 3 control prime with both stress and segmental mismatch was replaced by a new bisyllabic control prime which was stressed on the first syllable (and hence was a stress mismatch with the target) and shared no or virtually no segments with the target. Thus *LUzee* was replaced by *VIba*, *UPstrak* by *DOmo*, *TUNnon* by *POEmu*. Again four presentation orders were created, each of which contained all fillers plus one version of each of the experimental stimuli, with the four prime conditions counterbalanced.

Target stimuli for visual lexical decision were chosen for each prime stimulus. The target words for the experimental stimuli were the original trisyllabic items whose bisyllabic onsets had provided the experimental items: Thus the target for *muzee/luzee/viba* was MUSEUM, for *abstrak/upstrak/domo* ABSTRAKTIE, for *annon/tunnon/poemu* ANNONCE. One of the Experiment 3 items which had a potentially confusing visual target was replaced by one of the two other available items. The filler prime-target pairs were made up of ten real-word onsets followed by nonword targets (e.g., *abor* OKTIBAL), ten nonword onsets followed by dissimilar nonword targets (e.g., *muktro* VAGOFIEL), ten nonword onsets followed by overlapping nonword targets (e.g., *oeskar* OESTIGO) and ten nonword onsets followed by real words (e.g., *ato* MARINE). Twelve practice items with a similar makeup were constructed.

5.2 Procedure

Subjects were tested in groups of two or three in sound-attenuated carrels. They were instructed to listen to the nonsense bisyllables and to watch the screen in front of them, on which a letter string would be presented at the offset of each nonsense item; they should decide as rapidly as possible whether or not the letter string was a real word of Dutch, and signal their decision by pressing one of two response keys, labeled YES and NO. The auditory primes were presented through closed headphones and the targets were presented in upper case on a high resolution display screen, for a one-second interval beginning at offset of the prime.

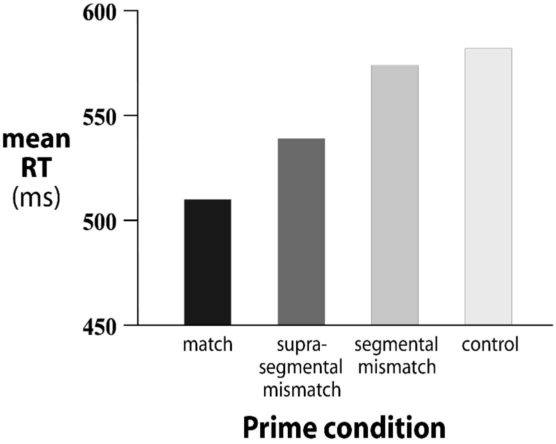

Figure 3

Mean response times (ms) in each of the four conditions of Experiment 4: Matching fragment, stress mismatch, segmental mismatch, control

Prime and target presentation and the collection and storage of responses were controlled by a computer running NESU software. Response times were measured from prime offset with a timeout of 2500 ms. Prime-target pairs were presented at a rate of one pair per 3.5 s.

5.3 Subjects

Fifty-six subjects were tested, from the same population as before and, again, all native speakers of Dutch with no reported hearing problems. None had taken part in any of Experiments 1 to 3.

5.4 Results and Discussion

The error rate was low (4.7%, including responses after timeout) and an analysis of the errors showed no significant effects at all. Figure 3 shows the mean lexical decision RTs for each condition.

Analyses of variance were conducted across subjects and across items, to assess the four-way factor prime condition (matching, suprasegmentally mismatching, segmentally mismatching, or control prime). The main effect of prime condition was highly significant, $F_1(3,156) = 28.95, p < .001$; $F_2(3,57) = 12.14, p < .001$: Target words (e.g., MUSEUM) were responded to fastest when the prime matched the first two syllables of the target both segmentally and suprasegmentally (*muZEE*), and least rapidly when the prime had no match with the target (*VIba*), while the other two prime conditions (suprasegmental mismatch: *MUzee*, and segmental mismatch: *luZEE*) fell in between. Post hoc tests across both subjects and items showed that all conditions differed significantly from one another at at least the .01 level, except the segmental mismatch (*luZEE*) and control (*VIba*) conditions, which did not differ.

Of the 20 items, four had more than a single segment mismatching the target in the segmental mismatch condition (e.g., *tunnon* ANNONCE). An analysis excluding these four items however revealed exactly the same pattern of results in ANOVAs and post-hoc tests; the mean difference between the match and the segmental mismatch condition reduced from 64 ms to 53 ms but was still significant beyond the .001 level.

Experiment 4 has thus confirmed that the fragment *muZEE* really does activate *museum*; the long RTs to *zee* in *muZEE* in Experiment 3 reflect competition from the partially present matrix word. A fragment with suprasegmental mismatch (*MUzee*) produces significantly less activation of the target that a matching fragment does, confirming once again that Dutch listeners make use of suprasegmental information in the lexical activation process.

However, the suggestion from Experiment 3 that segmental mismatch weighs rather more heavily than suprasegmental mismatch in activation reduction was confirmed via the significant difference between the two mismatching prime conditions; while both produced significantly less facilitation than the matching fragment, the segmental mismatch also produced significantly less facilitation than the suprasegmental mismatch and indeed no more facilitation than the control prime. The implications of this final finding will be considered below.

6. GENERAL DISCUSSION

Our four experiments have clearly shown that Dutch listeners can effectively use suprasegmental information in the recognition of spoken words. Experiment 1 showed that unambiguous information is available in individual syllables extracted even from members of minimal stress pairs, and that listeners can use that information to tell, for instance, whether an isolated syllable *voor-* came from *VOORnaam* ('first name') or *voorNAAM* ('respectable'). Experiment 2 showed no trace of facilitation from one member of a minimal stress pair to the other in auditory lexical decision, although reliable repetition priming occurred. *Voornaam*, it may be concluded, is not a homophone for Dutch speakers; *VOORnaam* activates the lexical representation of *VOORnaam*, and *voorNAAM* activates the lexical representation of *voorNAAM*, but they do not activate each other to a sufficient extent to produce repetition priming. The Dutch listeners produced a response pattern resembling that of Pallier et al.'s (1999) Catalan-dominant bilinguals — for whom *casa-caza* formed a distinct pair of words — rather than their Spanish-dominant bilinguals — for whom *casa-caza* was effectively a single form repeated.

Experiment 3 extended the scope of this conclusion by assessing the activation of potential competitor words in a word-spotting task, and Experiment 4 examined these words' activation directly. In both studies there was clear evidence that mismatching suprasegmental information reduced word activation. In other words, the lexical representation of *museum* clearly received a greater degree of activation from the fragment *muZEE* than from the segmentally matching but suprasegmentally mismatching fragment *MUzee*, just as the lexical representation of *voornaam* (N) received greater activation from *VOORnaam*, and the lexical representation of *voornaam* (Adj) received greater activation from *voorNAAM*. Dutch listeners can constrain the activation of lexical representations by early use of the suprasegmental characteristics of spoken words.

Constraints on lexical activation of all sorts contribute to the efficiency of human spoken-word recognition. Languages construct tens of thousands of separate words out of just a few dozen phonetic segments (Maddieson, 1984), with the inevitable result that words resemble one another, occur embedded within one another, and potentially create ambiguous segmentations when strung together in continuous utterances. Multiple activation of candidate words consistent with a spoken input is a phenomenon reliably attested in psycholinguistic laboratories (Connine, Blasko, & Wang, 1994; Gow & Gordon, 1995; Marslen-Wilson & Zwitserlood, 1989; Shillcock, 1990; Tabossi, Burani, & Scott, 1995). Nevertheless word recognition is a highly efficient process and the spuriously activated candidates rarely reach the listener's consciousness; human listeners have an arsenal of procedures for ensuring that the recognition process runs as smoothly as the constraints of the language and the exigencies of the listening situation allow.

One of these is the competition process via which simultaneously activated word candidates inhibit one another so that the string of words with the best match to the input ultimately receives the greatest accumulated activation; again, experimental evidence amply documents the inhibitory effects (Goldinger, Luce, & Pisoni, 1989; Goldinger, Luce, Pisoni, & Marcario, 1992; McQueen et al., 1994; Slowiaczek & Hamburger, 1992). Competition speedily disposes of spuriously activated words. Even more effective, of course, is maximal use of the information in the input to reduce activation of spurious lexical representations. Recent research has shown that coarticulatory information which signals the nature of an upcoming phonetic segment constrains word activation levels (Marslen-Wilson & Warren, 1994; McQueen, Norris, & Cutler, 1999), indicating that segmental information is exploited as early as listeners can obtain it. Suprasegmental information is, our results confirm, also exploited rapidly and effectively.

Just as the findings from other languages such as Japanese, Chinese, and Spanish (reviewed by Cutler et al., 1997) attest, the present findings show that in Dutch, too, suprasegmental information in the input is used by listeners to constrain the lexical activation process. As Experiments 1 and 2 showed, it can rule out one of two segmentally ambiguous options in minimal stress pairs; and as Experiments 3 and 4 further demonstrated, it also allows competitors to be disposed of.

An important consequence of the present findings and the analogous findings from other languages is thus that models of spoken-word recognition should incorporate a role for suprasegmental information in lexical activation. Although all currently leading models in this area are computationally implemented (and hence allow detailed simulations of word recognition experiments with human listeners), none has at present either a real-speech input facility or a representation of suprasegmental structure in artificial input. To illustrate this point, we simulated our findings in Shortlist (Norris, 1994), a computational model of spoken-word recognition based on simultaneous activation and interword competition. As input we presented the model with the two fragment primes (in suprasegmentally unmarked form, e.g., *muzee, luzee*), as well as, for comparison, with the embedded and matrix words themselves. Shortlist takes as input strings of phonetic segments, and allows simulations to be conducted with a realistically sized lexicon; we carried out our simulations with a 20,000 word Dutch lexicon based on the CELEX lexical database (Baayen et al., 1993).

The mean activation values at the end of each input string and one segment of silence later are shown in Table 2. The simulations effectively reflected the competition process of which Experiments 3 and 4 provided evidence. It can be seen that at the end of the matching fragment (e.g., *muzee*) the matrix word (activation value .164 using the model's standard parameters) is actually rather more highly activated than the embedded word (.099); the

TABLE 2

Mean activation values of embedded word and matrix word (a) after final segment of input and (b) after additional segment of silence in Shortlist simulations of Experiment 3 and 4 input

Input		*Activation of embedded word* (e.g., *zee*)	*Activation of matrix word* (e.g., *museum*)
Matrix word	(e.g., *museum*)		
	(a)	–.031	.642
	(b)	–.096	.758
Matching fragment	(e.g., *muzee*)		
	(a)	.099	.164
	(b)	.475	–.121
Mismatching fragment	(e.g., *luzee*)		
	(a)	.289	not in shortlist
	(b)	.502	not in shortlist
Embedded word	(e.g., *zee*)		
	(a)	.373	not in shortlist
	(b)	.535	not in shortlist

latter wins the competition process only after silence has indicated that the input has ended. The mismatching fragment (e.g., *luzee*), which never constituted the beginning of a Dutch word, consequently produces less competition and hence higher activation of the embedded word (.289) at input offset (though again an additional segment of silence leads to a considerable rise in the embedded word's activation level). Indeed, the pattern of activation of the embedded word given the mismatching fragment as input (.289, .502) is not very different from the pattern (.373, .535) given the embedded word itself as input. In neither of the latter two cases did the matrix word receive sufficient activation, either at input offset or later, to gain entrance to the shortlist (the competition set, which in the simulations was allowed to grow as large as 30 words, the Shortlist model's standard limit).

These simulations thus accurately capture much of the pattern of the data in Experiments 3 and 4. At the end of the matching fragment the embedded word (the targeted response in Experiment 3) is less active than it is at the end of the mismatching fragment; and indeed, the RTs to the embedded word in Experiment 3 were longer after matching than after mismatching fragments. In contrast, the activation of the matrix word (target in Experiment 4) is higher after the matching fragment than after the mismatching fragment, and again in Experiment 4 we observed faster RTs to the matrix word after matching than after mismatching fragments. In the matrix word's shortlist, finally, the embedded word itself, though present, hardly offers serious competition.

What our simulations however fail to capture is the difference between the suprasegmentally matching and mismatching fragments (*muZEE* vs. *MUzee*) in Experiments 3 and 4. No computational model, Shortlist included, as yet offers a realistic simulation of the processing of suprasegmental features of the speech input; nor, for that matter, do lexical databases of European languages currently code suprasegmental information in a manner appropriate for such simulation. Our results suggest that current computational models of spoken-word recognition are in this respect deficient; suprasegmental information can be used by listeners in Dutch, and adequate modeling of Dutch spoken-word processing should reflect this.

As a variety of different results, reviewed in the introduction, combine to indicate, listeners do not make optimal use of suprasegmental information in word recognition in English — for English listeners, suprasegmental alterations affect word recognition less strongly than segmental changes. Thus despite the general similarity of Dutch and English prosodic structure, the evidence suggests a difference in Dutch versus English spoken-word processing with regard to the weighting given to this aspect of speech structure. In related aspects of spoken-word recognition, parallel results have been reported for the two languages. Thus the stress-based rhythm of English is exploited by listeners in segmentation of speech into words (Cutler & Butterfield, 1992; Cutler & Norris, 1988), and both sets of findings have been replicated in Dutch (Vroomen, Van Zon, & De Gelder, 1996).

Underlying the segmentation results is the fact that in both languages, a strategy of assuming that strong syllables are likely word onsets will be quite efficient, since in both, most words begin with strong syllables (Cutler & Carter, 1987; Schreuder & Baayen, 1994; Van Heuven & Hagman, 1988; Van Kuijk, 1996; Vroomen & De Gelder, 1995). Similar distributional arguments can be adduced for why the weighting of suprasegmental information in the two languages should be different. With a view to quantifying the contribution of stress in the determination of word identity, Van Heuven and Hagman (1988) analyzed a 70,000 word lexical database of Dutch. They discovered that approximately half of all syllables in Dutch could occur in either stressed or unstressed form, suggesting that stress specification could narrow the field of potential word candidates for a wide range of input sequences. When they computed the point at which each word (counting in phonemes from word onset) could be uniquely identified, they found that this point was reached on average after 80% of the word's phonemes; when stress information was included, however, a forward search was successful on average given only 66% of the phonemes. Although to our knowledge such an analysis has not been performed for English, we predict that including stress information would lead to considerably less advantage in that language than in Dutch. Consider for instance the fact that English versions of our Experiments 3 and 4 cannot be constructed. Although the English vocabulary does contain some words beginning with two full syllables, the prerequisites listed above in the materials section of Experiment 3 cannot be met such that a comparable set of materials with spuriously embedded words can be constructed. (Thus the English word *museum* has the right initial prosodic structure; but in English *museum*, the first syllable, *mew*, constitutes a word, and the second, *zee*, does not.) Relevant performance information on this issue is available from a gating study carried out in both languages by Van Leyden and Van Heuven (1996); in their study, listeners benefited more from correct stress information (as measured by the point at which word recognition occurred) in Dutch than in English.

In short, the simple difference in the patterning of unstressed syllables in the two languages, such that in Dutch unstressed syllables with full vowels (*si-* in *sigaar*) are reasonably common while in English they are rare, seems to have direct consequences for processing. In Dutch, stress information can reasonably regularly be called upon to distinguish between strings which are segmentally identical, and listeners do use it to this effect. In English, opportunities for this use of stress information are rarer, and listeners have thus presumably accumulated less experience with it. The present results do not in themselves directly demonstrate a cross-linguistic difference, but the balance of the evidence from our experiments, set against the balance of the evidence from the many experiments with English, suggests a stronger role for suprasegmental information in lexical activation in Dutch than in English. Such a difference is fully explicable in the light of the distributional patterning of stress in the two languages.

Finally, we consider the implications of our results for the relative weight of suprasegmental information versus segmental information in determining word activation levels. The results of Experiments 3 and 4 certainly point to a somewhat stronger contribution from segmental than from suprasegmental information; in both experiments, fragments mismatching the matrix word in only a single segment (e.g., *luZEE*) patterned like the control conditions with greater mismatch to the target (*LUzee, VIba*), while fragments which mismatched the matrix word only suprasegmentally (*MUzee*) produced an intermediate result. In Experiment 3, *MUzee* produced significantly less inhibition than *muZEE*, but also a (marginally significant) greater degree of inhibition than *LUzee*. In Experiment 4, *MUzee* facilitated MUSEUM significantly less than *muZEE* did, but also significantly more than *luZEE* and *VIba* did.

Systematic exploration of such effects is necessary before a definite conclusion can be drawn. For instance, it is arguable that segmental information (about vowel identity, at least) is more rapidly available to constrain activation than suprasegmental information is; even the transition from a preceding consonant into a vowel suffices to enable listeners to identify that vowel (Strange, 1989). Mismatch between two Chinese syllables in tone is detected less rapidly than segmental mismatch, by native Chinese or non-native listeners (Cutler & Chen, 1997). However, it is interesting to contrast the pattern in the present Experiment 4 with cross-modal fragment priming experiments reported for Spanish by Soto et al. (2001). In those experiments the effects on priming (of a visual target by an auditory word fragment) arising from a mismatch in stress, in a single vowel or in a single consonant were compared, and found to be absolutely parallel. In Spanish, that is to say, there was no evidence of a stronger role for segmental mismatches than for suprasegmental mismatches. As we mentioned earlier, Spanish has no vowel reduction and any syllable can be either stressed or unstressed; thus stress variation will never be correlatively signaled by segmental variation. Spanish thus contrasts with Dutch (in which stress variation very often goes together with segmental variation) and even more so with English (in which stress variation is almost always accompanied by segmental variation). In other words, one could imagine a continuum of segmental consequences of stress on which Spanish fell towards the minimal end and English towards the maximal end, with Dutch occurring somewhere in between. In this respect it is perhaps indeed the case that Dutch also falls somewhere between Spanish and English in the relative weight of segmental and suprasegmental information in lexical activation: the two are fully equivalent in Spanish, segmental information somewhat outweighs suprasegmental in Dutch, while in English segmental information is usually sufficient to do all the work.

Note that no cross-linguistic difference in processing mechanisms need be postulated to explain this weighting; the only cross-linguistic differences are those concerning the available cues for making an early distinction between two alternative words. In Spanish, listeners' experience has led them to realize that suprasegmental information alone can frequently distinguish one word from another; in Dutch, the equivalent experience suggests that suprasegmental information will sometimes convey such a distinction alone, but it can also often function in tandem with a segmental distinction. Segmental distinctions on the other hand occur overwhelmingly without accompanying suprasegmental distinctions, making, for Dutch listeners, the experience of exploiting segmental information alone considerably stronger.

Furthermore, models of spoken-word recognition such as Shortlist could conceivably accommodate a weighting difference of this type with little difficulty. The strength of the mismatch effect (reduction in a provisional candidate word's activation consequent upon incoming information mismatching that word) is one of the parameters in Shortlist. Shortlist works in essentially the same way with input in (and a lexicon of) any language, but allows for language-specific information to influence its operation. Thus the implementation in Shortlist of the Possible Word Constraint (PWC; Norris, McQueen, Cutler, & Butterfield, 1997) makes reference to knowledge about rhythmic structure and its relation to word boundaries, and to permissible phonetic sequences within syllables; both these types of information differ across languages, so that the PWC will necessarily operate language-specifically. In a similar way, the mismatch parameter could be more heavily weighted for segmental than for suprasegmental mismatch in some languages but not in others. Of course, this could only be instantiated once the initial step, as discussed above, had been taken: the model must incorporate the processing of suprasegmental information in lexical access, in principle for all languages.

For the present, it is thus clear that in Dutch, *voornaam* is not (really) a homophone; to call Clinton's *voornaam voornaam* is not (really) a joke.

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APPENDIX

Materials used in Experiments 3 and 4

The nine items on each line represent, for each experimental stimulus: (a) the embedded word which was the target in Experiment 3; (b) its English gloss; (c) the matrix word which was the putative competitor in Experiment 3 and the target in Experiment 4; (d) its English gloss; (e) the matching fragment; (f) the stress-mismatching fragment; (g) the segmentally mismatching fragment; (h) the control fragment in Experiment 3; (i) the control fragment in Experiment 4. Note that although Dutch orthography is in general transparent, it is not always possible to see the embedded word in the written form of the matrix (e.g., *rups* in *corruptie*, *zee* in *museum*).

strak *taut* abstraktie *abstraction* abSTRAK ABstrak upSTRAK UPstrak domo
ver *far* aversie *aversion* aVER Aver uVER Uver orni
pas *passport* impasse *impasse* imPAS IMpas emPAS EMpas firmo
rups *caterpillar* corruptie *corruption* corRUPS CORrups kerRUPS KERrups opif
mens *person* clementie *clemency* cleMENS CLEmens kreMENS KREmens tori
dop *top* adoptie *adoption* aDOP Adop eDOP Edop plinus
man *man* amandel *almond* aMAN Aman oeMAN OEman heda
dij *thigh* andijvie *endive* anDIJ ANdij onDIJ ONdij klebu
pen *pen* appendix *appendix* apPEN APpen iPPEN IPpen goempi
nek *neck* connectie *connection* conNEC CONnec ganNEC GANnec akta
jas *coat* fiasco *fiasco* fiJAS FIjas siJAS SIjas werdu
zee *sea* museum *museum* muZEE MUzee luZEE LUzee viba
vin *fin* provincie *province* proVIN PROvin droVIN DROvin lepti
thee *tea* prothese *prosthesis* proTHE PROthe bluTHE BLUthe tuiki
non *nun* annonce *announcement* anNON ANnon tunNON TUNnon poemu
ga *go* bagage *baggage* baGA BAga buGA BUga fiti
bar *bar* embargo *embargo* emBAR EMbar umBAR UMbar gantus
nis *niche* cynisme *cynicism* cyNIS CYnis muNIS MUnis pambo
gen *gene* agenda *diary* aGEN Agen eGEN Egen libra
mes *knife* trimester *trimester* triMES TRImes greMES GREmes --
ton *barrel* rotonde *roundabout* roTON ROton woTON -- orkus