MPI SERIES
IN PSYCHOLINGUISTICS

THE OPEN-/CLOSED-CLASS DISTINCTION IN SPOKEN-WORD RECOGNITION

Alette Haveman

THE OPEN-/CLOSED-CLASS DISTINCTION IN SPOKEN-WORD RECOGNITION

ISBN: 90-76203-04-0
Cover design: Linda van den Akker
Photographs: Alette Haveman
Printed and bound by: Ponsen & Looijen bv, Wageningen

THE OPEN-/CLOSED-CLASS DISTINCTION IN SPOKEN-WORD RECOGNITION

een wetenschappelijke proeve
op het gebied van de Sociale Wetenschappen

Proefschrift
ter verkrijging van de graad van doctor
aan de Katholieke Universiteit Nijmegen,
volgens besluit van het College van Decanen
in het openbaar te verdedigen
op donderdag 18 december 1997
des namiddags om 1.30 uur precies

door
Alette Petra Haveman
geboren op 13 September 1967 te Warfstermolen

Promotor: Prof. dr. A. Cutler

Manuscriptcommissie: Prof. dr. A. D. Friederici (Max-Planck-Institute, Leipzig)
Prof. dr. H. H. J. Kolk (Katholieke Universiteit Nijmegen)
Dr. J. M. McQueen (Max-Planck-Institute, Nijmegen)

The research reported in this thesis was supported by a grant from the Max-Planck-Gesellschaft zur Förderung der Wissenschaften, München, Germany.

Aan mijn ouders
Voor Bart

DANKWOORD

De weg naar een proefschrift gaat over bergen en door dalen. Veel mensen ben ik dank verschuldigd: zij duwden mij een berg op, of trokken me uit een dal. Ergens aan het begin van deze weg staat Pim Levelt die mij vol vertrouwen het Max-Planck Instituut heeft binnengehaald. Pim, Antje Meyer, Harald Baayen, Ger Desserjer en de leden van de productiegroep hebben mij ingewijd in de raadselen der psycholinguistiek en mij grondig voorbereid op het produceren van een proefschrift.

Anne Cutler, mijn onderzoeksmoeder, heeft mij vervolgens als PhD.-studente opgenomen in haar 'phonological structure in comprehension' familie en mij gevoed met haar enthousiasme en kennis over taalbegrip. Dank Anne, voor 'always having an open door and an open mind'. Veel dank ook aan James McQueen, de andere leden van de comprehension group en mijn collega-PhD. studenten die vaak het nuttige met het aangename verenigden. Ook ben ik dank verschuldigd aan de leden van de technische groep (met name John Nagengast, Christa Hausmann, Ad Verbunt en Inge Doehring), de administratie (vooral Rian Zondervan), de bibliothecaresses, Hans Gerrits - voor duizend en één karweitjes en Richard Piepenbrock voor zijn ondersteuning met Celex. En dan natuurlijk Marlies Wassenaar die in haar keurig ABN belangeloos honderden zinnen en woordjes in wilde spreken en Paul Verleg die zorgde dat de deur 'vanzelf' open ging en die vele proefpersonen voor me heeft opgebeld en ontvangen.

Een speciaal woord van dank gaat ook uit naar mijn paranimfen Leonore Biegstraten waarmee naast wetenschap ook al het andere besproken kon worden en Mariëtte Koster die als kamergenote heel wat te verduren heeft gehad. Ook zou ik Joost van de Weijer, David van Kuijk en Kay Behnke willen noemen als mijn kamergenoten tijdens de laatste periode, en Arie en Dirk zonder wie deze fase beduidend minder leuk zou zijn geweest. En verder, dank aan al die anderen die onder andere door hun vrienschap aan dit onderzoek hebben bijgedragen: Maarten van Casteren (voor zijn hulp en gezelligheid), Julie Christiansen (voor haar stimulans en haar correcties in mijn Engels), Delphine Dahan (die altijd persoonlijk of via de e-mail beschikbaar was) en Nancy Liebrand (voor het tolereren van al die vieze kopjes op het aanrecht als het proefschrift weer eens belangrijker was). Aan het eind van een proefschrift staat een manuscriptcommissie. Ik ben James McQueen, Herman Kolk en Angela Friederici dankbaar voor het kritische oog waarmee zij dit proefschrift hebben gelezen.

En tenslotte mijn ouders, mijn zussen, en Bart, die ogenschijnlijk niets met dit alles te maken hebben, maar aan wie ik meer te danken heb dan aan wie dan ook

TABLE OF CONTENTS

GENERAL INTRODUCTION

CHAPTER 1

ABSTRACT

Incoming continuous speech needs to be segmented into words before it can be understood, a process which is based on the individual characteristics of a language. After a brief presentation of the realization of segmentation in the model of spoken-word recognition Shortlist (Norris, 1994), this chapter discusses how a processing distinction between the open-class vocabulary (nouns, verbs, adjectives, and adverbs) and the closed-class vocabulary (e.g., articles and pronouns) could be of use in the segmentation of Dutch. This discussion will be followed by a short review of experimental evidence for two distinct processing vocabularies, and leads to the formulation of three research questions: 1) what is the role of word frequency in the recognition of open- and closed-class words, 2) is stress an indicator of vocabulary class in Dutch and are Dutch listeners able to use this cue in the segmentation of continuous speech, and 3) are listeners able to use the syntactic context of a sentence to predict upcoming closed-class words? The introduction ends with an overview of the contents of the other chapters.

1.1 SEGMENTATION

Imagine that you listen to a foreign language you do not speak. Take for instance the sentence *jinzhanhuazaiyangguangxiashengkai.* What you hear is a stream of speech sounds. You do not perceive individual words, and are thus not able to assign meaning. When you listen to this language more often and learn some word meanings and grammar, it will become obvious that this Chinese sentence consists of the five words *jinzhanhua zai yangguang xia shengkai* roughly meaning *the marigolds flourish in the sunshine.* Although the segmentation of sentences into individual words might seem trivial once you know the language, it is still not entirely clear how listeners know where in a continuous stream of speech certain words end, and others begin.

Early models of spoken-word recognition (Cole & Jakimik, 1978, 1980; Marslen-Wilson & Welsh, 1978) assumed the segmentation process to be strictly sequential - the end of a word that has been recognized indicates the start of a new word. In the case of the sentence *the marigolds flourish in the sunshine,* this means that once the word *marigolds* has been recognized, a listener will know that the next word starts with the /f/. However, sequential processing poses a problem for the recognition of words in which other words are embedded. For instance, since *marigolds* contains the words *marry, go, goal, gold,* and *old* these words may be recognized before the entire word has even been heard (evidence for the on-line activation of embedded words has been presented by Gow and Gordon, 1995; Shillcock, 1990; Tabossi, Burani, & Scott, 1995; Vroomen & De Gelder, 1995; Zwitserlood, 1989; and by Zwitserlood & Schriefers, 1995). Recognition of the appropriate meaning thus requires backtracking, which is, however, not possible in sequential models without the addition of extra processing machinery.

More recent models of spoken-word recognition such as SHORTLIST (Norris, 1994) therefore assume that multiple interpretations of words are considered in parallel, and in these models, late disambiguating information can be used to obtain a final unique interpretation.[1] The crucial assumption of

---

[1] *The TRACE model (McClelland & Elman, 1986) assumes a similar mechanism with respect to word recognition as SHORTLIST. However, since the TRACE model has an highly inefficient architecture (for a discussion see Norris, 1994; McQueen, Cutler, Briscoe, & Norris, 1995), the findings of the current thesis will be discussed in the framework of SHORTLIST. For an extensive comparison between these two models and the COHORT model of speech recognition (Marslen-Wilson, 1987), see Frauenfelder (1996).*

the SHORTLIST model is that segmentation is achieved by means of competition between a shortlist of words whose selection is based on their match with the incoming acoustic signal. The activation of the nodes of the shortlisted words can be decreased by incompatible acoustic information (the /r/ in *marigold* can decrease activation of *man*, which would be activated by the initial /mae/), and by competition from fellow-shortlist members which have a large degree of overlap (*goal* and *gold*). The word which eventually has the highest level of activation will win the competition procedure, and can be recognized. Experimental evidence for competition of embedded words with their carrier word has been presented by McQueen, Norris, and Cutler (1994). They showed that listeners made fewer errors in recognizing the word *sack* in the string /saekrək/ than in the string /saekrəf/, because in the latter case the word *sack* has to compete with the word *sacrifice*. Similar results were found for embedded words which were not aligned with the onset of the larger word; the word *mess* appeared harder to detect in the word /dəmɛs/, which is the onset of *domestic*, than in the word /nəmɛs/.

In a later version of SHORTLIST by Norris, McQueen, Cutler and Butterfield (in press) the competition process is assumed to be biased by a so-called possible-word constraint. Listeners do not segment the speech stream in such a way that part of the input will be left as an impossible syllable or word. Whenever a candidate word is misaligned with a clear syllable boundary, this candidate will be penalized by a decrease in its activation. The possible-word constraint was based on a finding by Norris and colleagues that listeners had more problems recognizing a word like *apple* in /faeppəl/ than in /vʌfaeppəl/, because in the /faeppəl/-case segmentation before the /ae/ would leave the impossible word /f/. Since *apple* is thus misaligned with a possible word boundary, its activation is decreased.

In the /faeppəl/-example, the possible-word constraint uses the silent interval before the /f/ as a segmentation cue. However, the possible-word constraint can also exploit phonotactic constraints, that is, the possible sequential arrangements of phonological units (McQueen & Cox, 1995; McQueen, submitted). For instance, since syllables in English are not allowed to start with the cluster /ld/, a listener will know that /ld/ in *gold* cannot be the beginning of a word. Another set of segmentation cues that can be exploited by the possible-word constraint are the metrical properties of a language. In 1987, Cutler and Carter argued that in English, listeners use a metrical segmentation strategy (MSS) in which strong syllables (i.e., those having a full vowel) are used for the placement of word boundaries in continuous speech. Experimental evidence for the importance of strong syllables in segmentation was provided by Cutler and Norris (1988). They demonstrated that the word *mint* was easier to recognize in the nonsense string /mɪntəf/ having a strong-weak pattern (i.e., containing a full vowel and a reduced vowel), than in the nonsense string /mɪnteɪf/ having a strong-strong pattern. In the latter case, the second strong syllable /teɪf/ triggers segmentation, and the /t/ will therefore be taken as the initial consonant of /teɪf/ instead of the last consonant of *mint*. Assembly of /min/ and /t/ across a segmentation boundary is thus required, which will slow down the detection time of *mint*.

Further evidence for a metrical influence in speech segmentation was provided by Cutler and Butterfield (1992) who observed that the metrical structure of English plays a role when unclear speech is wrongly interpreted (i.e., 'slips of the ear'). Interaction of competition and metrical effects was demonstrated by Norris, McQueen, and Cutler (1995), who showed that effects of metrical segmentation were only significant when a large numbers of competitors were aligned with the onset of a strong syllable.

The principle of metrical segmentation in English was originally implemented into SHORTLIST by both boosting the activation of word candidates with a strong onset which also begin at a strong syllable in the input (e.g., when the input is /mɪn-teɪf/ and the candidate is *tape*), and by decreasing the activation of word candidates with a strong onset which are not aligned with a strong onset in the input - such as the candidate *mint* in the input /mɪn-teɪf/ (McQueen, Norris, & Cutler, 1994; Norris, McQueen, & Cutler, 1995). However, Norris, McQueen, Cutler, and Butterfield (in press) showed that all of the experimental effects mentioned above (i.e., Cutler & Norris, 1988; McQueen, Norris, & Cutler, 1994; Norris, McQueen, & Cutler, 1995; McQueen & Cox, 1995) can be simulated sufficiently when the metrical effects were incorporated into the possible-word constraint simply by penalizing word candidates which were misaligned with metrically-determined boundaries. It should be noted that in SHORTLIST, the strength of a syllable does not control when a lexical access attempt takes place. Syllable strength can only influence the amount of bottom-up evidence, penalizing word candidates with a strong onset which are misaligned with a strong onset in the input.

To summarize, SHORTLIST assumes that the competition process - on which the segmentation procedure is based - can be influenced by cues such as silence, phonotactic constraints, and metrical characteristics. However, this model has been developed primarily for the segmentation of the stress-timed language English. Since languages have different metrical properties, it is likely that listeners use language-specific cues for the segmentation of their language. For instance, listeners of Dutch - a stress-timed language like English - also seem to use vowel quality as a metrical cue for segmentation (Vroomen, van Zon & de Gelder, 1996; see chapter 3), and the possible word constraint for Dutch seems to be quite similar to that for English (Norris, McQueen, Cutler & Butterfield, in press). However, in syllable-timed languages such as French, Spanish, and Catalan, the syllable is an important metrical cue (Cutler, Mehler, Norris & Segui, 1986, 1992; Mehler, Dommergues, Frauenfelder & Segui, 1981; Pallier, Sebastián-Gallés, Felguera, Christophe & Mehler, 1993; Sebastián-Gallés, Dupoux, Segui & Mehler, 1992). Furthermore, in mora-timed languages such as Japanese (a mora is a sub-syllabic unit), segmentation appears to be based on the mora (Cutler & Otake, 1994; Otake, Hatano, Cutler & Mehler, 1993).

Languages can also differ with respect to the type of words used to built a sentence. For instance, whereas languages such as Chinese mainly use open-class words such as nouns and verbs[2], languages such as English and Dutch use both open-class words and closed-class words such as determiners and conjunctions. As will be discussed below, Cutler and Carter (1987) have argued that speakers of English are able to use this distinction between open- and closed-class words in the segmentation of their language. Since Dutch differs from English with respect to the phonological realization of words, the current thesis explores whether the distinction between open- and closed-class words can also be used in the segmentation of Dutch. In the next section, I will describe the individual characteristics of both the open- and the closed-class item sets, and how the open-/closed-class distinction could be important for the segmentation procedure.

1.2 THE OPEN-/CLOSED-CLASS DISTINCTION

Traditionally, the vocabulary of English has been assumed to consist of a group of words having a clear meaning or referent (nouns, main verbs,

---

[2] *For instance, a literal translation of the Chinese sentence jinzhanhua zai yangguang xia shengkai does not involve the closed-class determiner the. That is, jinzhanhua means marigold, zai xia means in, and yangguang means sunshine, shengkai means flourish.*

adjectives, and most of the adverbs), and of a group of items that are used to indicate grammatical relations (e.g., determiners, pronouns, number, case, and tense markers). This distinction has traditionally been reflected in the terms *content* versus *function* words. Returning to *the-marigolds-flourish-in-the-sunshine* example, the three words *marigold, flourish* and *sunshine* belong to the content word item set. The other elements of the sentence (the determiners *the*, the plural marker *-s*, and the preposition *in*) are examples of function words.

This distinction between content and function words might seem rather clear-cut at first sight. Yet closer inspection of especially the function word group suggests that this is not the case. For instance, although pronouns traditionally belong to this group, these words seem to have a clear referent. Furthermore, as indicated by Friederici (1988), prepositions can be used in such a way that they indeed bear virtually no semantic information (as the preposition *on* in *The drinks are on me*[3]), but they can also be used in a way that they do bear some semantic information (as in *Peter stands on the chair*). The two classes of words might therefore be better captured by another characteristic, namely the degree to which they allow new words to become a member of their group. For instance, whereas new nouns or verbs often evolve in a language, new pronouns or prepositions hardly ever originate. Based on the differing flexibility of the content and function word groups to allow for new members, the term content words has gradually be replaced by the term *open-class* words, and the term function words has been changed into *closed-class* words. In English, the closed-class item set consists of about 200 words (Petocz & Oliphant, 1988), and the closed-class set has about 400 members in Dutch (Van Wijk & Kempen, 1980).

The amount of flexibility with respect to new members is, however, not the only characteristic of the open- and closed-class item groups. For instance, whereas open-class words are highly variable in length, closed-class words are usually rather short. In addition, both classes differ with respect to their phonological realization; in English, open-class words must contain at least one full vowel, while closed-class words can have only a reduced vowel. Probably the most salient distinction between open- and closed-class words is their difference in frequency of usage. That is, whereas most open-class words are used with a rather low-frequency, closed-class words are used very

---

[3] *In this case the sentence should be interpreted such that the speaker is paying for the drinks.*

often. This difference in frequency of occurrence between open- and closed-class words makes it difficult to study processing of open- and closed-class words, since observed processing differences between open- and closed-class words might actually be effects of frequency. Because the influence of frequency in the recognition of spoken open- and closed-class words has not been systematically investigated, the impact of this difference in frequency will play a major role in the present thesis; the first research question concerns the role of frequency on the perception of open- and closed-class words.

Consider now the possible role of the open-/closed-class distinction in the segmentation procedure. This distinction can only be of help if there would be some cue in the speech signal indicating whether an incoming word belongs to the open- or to the closed-class vocabulary. If these vocabularies are differently marked or can somehow be predicted from previous speech, a listener will know that either an open- or a closed-class word will come up. Open-class words could then be looked up in a mental lexicon (where previously learned information about words is stored) for open-class words, and closed-class words could be looked up in a closed-class lexicon. This could speed up the recognition process since in the case of a closed-class word target, all acoustically matching open-class words will be excluded as possible word candidates. Over the last couple of decades, it has indeed repeatedly been argued that the small set of closed-class words is stored in a mental lexicon separate from that for open-class words (e.g., Bradley, 1978; Cutler & Carter, 1987; Friederici, 1985; Swinney, Zurif & Cutler, 1980).

On-line classification of speech into open- and closed-class words might furthermore serve the purpose of speeding the process of locating the onsets of open-class words (Cutler, 1993; Cutler & Butterfield, 1992). Since open-class words are more complex than closed-class words in that they usually have more than one meaning, fast access of open-class words in the mental lexicon would speed the selection of the appropriate meaning representation, and hence speed overall computation of sentence semantics. However, on-line categorization could also help to quickly locate the closed-class words, because the interpretation of the open-class words largely depends on the closed-class sentence context (Garrett, 1978). Either way, on-line classification of speech into open- and closed-class items implies that the two vocabularies are processed differently before access to the mental lexicon has taken place. The next section reviews some of the evidence for and against such a pre-lexical processing difference between the open- and closed-class vocabularies as it is available from earlier studies on language production, language acquisition, and language perception.

1.3 THE STATE OF THE ART

1.3.1 Language Production

In production, the open-/closed-class distinction played a major role in Kean's (1977, 1979) description of the speech produced by agrammatic Broca's aphasics. Since the speech of these patients often lacks unstressed inflectional endings and closed-class words (*Marigold* .. eh .. *flourish* .. *sun*), Kean proposed that agrammatism is actually a phonological deficit in which lexical items ('non-clitics') are produced while unstressed items (phonological 'clitics') are omitted. However, later studies have shown that this view of agrammatism is untenable (e.g., Kolk, 1977; Klosek, 1979), and that agrammatism results from a syntactic or morphological disorder.

The distinction between open- and closed-class words in speech production has also been studied by Garrett (1975; 1980; 1982), demonstrating that the two vocabulary classes were involved in different types of speech errors. For example, whereas open-class words are often involved in transpositions or word exchanges such as in *the* ***sunshines*** *flourish in* ***marigold***, closed-class words are not very likely to switch their order over such a long distance (the occurrence of ***in*** *marigold flourish* ***the*** *sunshine* is highly improbable). Instead, closed-class items more often exchange with directly adjacent closed-class words, or participate in shifts in which only one item changes its position (*a marigold grow in the suns* instead of *a marigold grows in the sun*). Garrett therefore argued that whereas open-class words are retrieved from the mental lexicon in a rather late stage of the production of a sentence, closed-class words might already be specified as features on a sentence frame which indicates the serial order of a sentence.

The results of a later experimental study on the production of closed-class words did not provide any evidence, though, for such immanence of free-standing closed-class morphemes in structural frames of English sentences (Bock, 1989). The assumption of distinct processing vocabularies in speech production has also been challenged by Jescheniak and Levelt (1994) in a study of word frequency effects in speech production, and by some recent studies on several types of speech errors: namely particular types of structural errors (Stemberger, 1984), and phonological speech errors of normal (Dell, 1990) and language-impaired speakers (Kohn & Smith, 1993).

As will be argued in chapter 4, however, it might not be possible to generalize the results from speech production to speech perception, since the sequential nature of speech perception might encourage different processing of open- and closed-class words. In speech production, on the other hand, the process of mapping a concept to syntactic and phonological representations is not necessarily sequential, reducing the likelihood that open- and closed-class words are differently processed.

1.3.2 Language acquisition

The open-class/closed-class distinction has also received attention in the language acquisition literature. For instance, Gleitman and Wanner (1982) speculated that children might learn the distinction between open- and closed-class words because of the correlation between stress and vocabulary class. Valian and Coulson (1988) have furthermore shown that learning of a miniature artificial language by an adult depends on both the reliability of a closed-class word as an anchor point around which to organize lexical material, and also on the frequency of these markers. The miniature language consisted of closed-class words of three letters beginning with a vowel, and of open-class words of four to six letters long starting with a consonant (an example of a sentence is *alt deerch erd hift*, with *alt* and *erd* being closed-class words and *deerch* and *hift* being open-class words). When the closed-class words occurred six times as often as open-class words, subjects could easily learn the language, but when the closed-class words occurred only one and a half time as often, subjects only learned the superficial properties of this language. However, when the words were accompanied by a figure as a reference field, both groups of subjects learned the more detailed properties of the language, with the subjects who received the high-frequency variant learning the artificial language faster. Valian and Coulson suggested therefore that the high frequency of closed-class elements could facilitate language learning in general.

Furthermore, the learning pattern in children is different for the open- versus the closed-class vocabulary. First, closed-class words are acquired later in the acquisition process than open-class words (e.g., Flores d'Arcais, 1981).[4] Second, closed-class words have a distinct pattern of development in that they are learned item-by-item in a rather particular order over a relatively long period of time (Brown, 1973). Finally, the learning rate depends on the properties of the input corpus more for closed-class than for open-class words (Newport, Gleitman & Gleitman, 1977).

In addition, many studies have shown that children exhibit different patterns of performance on open- versus closed-class words in experimental situations, for example in repetition (e.g., Chafetz, 1994; Gerken & McIntosh, 1993; Katz, Baker & Macnamara, 1974), and in monitoring experiments in which listeners monitor for a previously specified word (Friederici, 1983b, 1993). The latter monitoring studies indicated that the automatic procedures via which closed-class words are accessed by adults are not yet available during language acquisition - whereas young children were faster to monitor for open-class words than for closed-class words both presented in a sentence context, older children showed a similar pattern to adults in that monitoring for closed-class words was faster.

However, it has been questioned in the acquisition literature whether the apparently different patterns for open- and closed-class words indeed reflect the open-/closed-class distinction itself. Slobin (1996), for instance, argues that it is quite unclear where the line between lexical and grammatical words should be placed. First, the lexicon for verbs in English can be subdivided into smaller relatively ‘closed’ groups of words from which it is possible to find systematic sets of semantic components. For example, in the domain of object destruction, distinctions can be made as to the nature of the object destroyed (e.g., *break*, *tear*, *smash*), or to the texture of the object (e.g., *crumple*, *crumble*, *shatter*). Second, it is unclear which specific notions can receive grammatical expression in a language, and how these notions are organized. Slobin therefore argued that, with respect to the learning task in language acquisition, identical learning mechanisms are likely to apply across the mental lexicon, including both open- and closed-class words.

Language acquisition data might furthermore not necessarily inform us about prelexical processing of open- and closed-class words in perception. For instance, part of these data is actually based on the utterances that children produce, and, as has been argued before, processing of open- and closed-class

---

[4] *Valian and Coulson's (1988) proposal that closed-class words aid in learning open-class words might be especially valid for a later stage of language acquisition, since only then has the child acquired some of the closed-class words.*

words in speech production might be different from that in speech perception.

1.3.3 Language perception

The majority of the language perception studies on storage and processing of open- and closed-class words compare normal language processing with the impaired processing of agrammatic Broca's aphasics. Abnormal patterns with respect to their comprehension of closed-class words have frequently led to the assumption that these agrammatic patients cannot utilize the special, fast and automatic pre-lexical routine to access closed-class words used by normal listeners. The processing of open- and closed-class words in language perception has been investigated both in the perception of visually presented stimuli, and in the perception of auditorily presented materials.

Visual perception

One of the most influential studies on the open-/closed-class distinction in visual language processing was presented by Bradley in 1978 (see also Bradley, Garrett & Zurif, 1980). She demonstrated that whereas for normal subjects the speed of retrieval of closed-class words did not depend on the frequency of usage of these words, agrammatic subjects did show frequency effects on closed-class retrieval. The insensitivity of closed-class retrieval to frequency of occurrence in normal language use could not be replicated, however, in later studies (Gordon & Caramazza, 1982, 1983; Segui, Mehler, Frauenfelder & Morton, 1982; Gordon, 1983; Garnsey, 1985; Segui, Frauenfelder, Lainé & Mehler, 1987). A second finding of Bradley concerned the time needed to make a decision on the word or nonword status (i.e., a lexical decision) of nonwords - lexical decisions to disyllabic nonwords starting with a monosyllabic open-class word (*THINage*) were faster than decisions to disyllabic nonwords starting with a monosyllabic closed-class word (*THANage*). Although this result also suggested differential processing of open- versus closed-class words, later studies attributed this finding to other effects such as the composition of the lexical decision word list (Kolk & Blomert, 1985), or to effects that occur at a later stage in language processing than lexical access (Matthei & Kean, 1989; Petocz & Oliphant, 1988).

Visual processing of the open- and closed-class vocabulary has also been studied with a letter cancellation paradigm (i.e., subjects read a text and circle each instance of a target letter). Rosenberg, Zurif, Brownell, Garrett, and Bradley (1985), for example, reported that normal readers were better in detecting letters in open- than in closed-class words, but Broca's aphasics did not show such a difference. Although this finding again indicated special retrieval of the closed-class vocabulary, recent studies pointed to the actual functional role of open- versus closed-class words in sentence processing as an alternative explanation for the difference between open- and closed-class words in letter cancellation tasks (Colé & Segui, 1994; Greenberg & Koriat, 1991; Greenberg, Koriat & Shapiro, 1992; Koriat & Greenberg, 1993). In addition, Moravcsik and Healy (1995) showed that semantic differences between words (i.e., within and between members of the two vocabulary classes) have a large influence on letter detection responses, and they argued that the visual processing of letters occurs during a late stage, the access of semantic information.

The observation that agrammatic Broca's aphasics fail to recognize closed-class words in the same way as normal subjects suggests that Broca's area in the left hemisphere is crucial for the operation of a possible special access system for the closed-class vocabulary. Bradley and Garrett (1983) therefore presented open- and closed-class words to both the right visual field (RVF) and the left visual field (LVF) with the use of a tachistoscope. Since they observed more accurate naming latencies for open-class than for closed-class words in the RVF (connected to the left hemisphere) but not in the LVF (connected to the right hemisphere), Bradley and Garrett argued that closed-class words are dealt with by a special mechanism in the left hemisphere, but that a single mechanism operates over both vocabulary classes in the right hemisphere.

However, two later studies (Chiarello & Nuding, 1987; Mohr, Pulvermüller & Zaidel, 1994) failed to replicate Bradley and Garrett's finding. They found faster processing of the open-class words in the LVF (instead of the RVF), and no difference in the RVF. Yet the indication that open- and closed-class words were processed differently in the left and the right hemispheres was also in these studies taken as evidence for separate processing vocabularies.

Separate processing of open- and closed-class words in visual-field studies has also been shown by Shapiro and Jensen (1986) who used Bradley's (1978) lexical decision paradigm on open- and closed-class-headed nonwords. They found that lexical decisions to nonwords headed by an open-class word were slower than lexical decisions to complete nonwords, but only when these nonwords were presented to the RVF. This effect appeared absent for the those nonwords that were headed by closed-class words. However, as raised by Matthei and Kean (1989) and Petocz and Oliphant (1988) in relation to Bradley's study, the effects presented by Shapiro and Jensen might also be due to a post-access difference between open- and closed-class words.

The processing of open- versus closed-vocabulary classes by the two hemispheres has also been studied in normal readers with the event-related brain potential (ERP) method. In this method, EEG recordings are synchronized to the presentation of a stimulus and averaged over a large number of trials. The results of these ERP studies do not, however, unanimously point towards distinct processing. However, Kutas and Hillyard (1983) observed a larger N400 in the right versus the left hemisphere for open-class words presented in semantically anomalous sentences (the N400 is a negative peak occurring 400 ms. after the onset of the stimulus, and typically reflects semantic processing). In contrast, no interhemispheric difference with respect to the N400 was observed for the closed-class words.

But although the open-class result was replicated in a study by Neville, Nicol, Barss, Forster, and Garrett (1991), the closed-class result was not replicated; both a N125 and a N400 were found to be more pronounced over left anterior hemisphere sites for closed-class words. Yet when words of both vocabulary classes were presented in random sequences of items (Van Petten & Kutas, 1991) or isolated and used in a lexical decision task (Garnsey, 1985), ERP's of both open- and closed-class words were quite similar. Furthermore, a small difference between the two vocabulary classes occurring about 400 ms. after stimulus onset was interpreted by Garnsey (1985) as the reflection of a late process following lexical access, such as the integration of context or response preparation.

One reason for the diversity in these ERP results might be the fact that some of the studies neglected to take some important factors into account, such as matching of open- and closed-class items for frequency and word length. In addition, the studies differed with respect to the hemisphere sites where the signals were measured, and the type of sentence context that was used. Two studies, however, which were carried out under quite similar conditions did show similar results - both Neville, Mills and Lawson (1992), who recorded ERPs to open- and closed-class words in well-formed sentences, and Pulvermüller, Lutzenberger and Birbaumer (1994), who used isolated open- and closed-class words in a lexical decision task demonstrated equal activity over both hemispheres for open-class words, and more negativity over the left than the right hemisphere for closed-class words. This result suggests that open-class words correspond to neuronal assemblies that are equally distributed over both hemispheres, but assemblies corresponding to the closed-class vocabulary are more strongly lateralized to the left hemisphere. Pulvermüller and colleagues furthermore reported this difference in activation for the two vocabulary classes arose as early as 160 ms. following stimulus onset, which indicates that this difference is likely to reflect an early process in word recognition.

Other evidence for separate processing vocabularies is provided by double dissociations between language disturbances (Pulvermüller, Lutzenberger & Birbaumer, 1994). For instance, whereas agrammatic aphasics are often unable to produce closed-class items but are able to produce open-class words, so-called anomic patients appear unable to produce open-class words and can only produce closed-class words. A similar double dissociation can be observed between patients with acquired dyslexia (reading difficulties). Whereas patients with surface dyslexia mainly have problems reading open-class words (e.g., Fromkin, 1987), patients with deep or phonological dyslexias show problems in particular with the closed-class vocabulary (e.g., Coltheart, 1980).

Auditory perception

Open-/closed-class processing has received considerably less attention in studies on spoken language. In a set of studies by Friederici (1983a, 1985, 1988, 1993), the word monitoring task was used. She observed that language unimpaired adults processed closed-class words such as the German *nur* (only) faster than open-class words such as *Geld* (money) when these words were presented in a sentence context. Yet agrammatic aphasics processed open-class words faster. However, in both the normal and the agrammatic condition, monitoring of open-class words and not of closed-class words turned out to be influenced by the preceding semantic context. For instance, the monitoring latencies for the word *Geld* in the sentence *Der Mann hoffte, Geld zu gewinnen* ('the man was hoping to win money') were found to be faster after the semantically related sentence context *Der verarmte Spieler entschloss sich, ins Kasino zu gehen* ('The impoverished man decided to go to the casino') than after a preceding unrelated sentence context such as *Der verliebte Student entschloss sich, ins Grüne zu fahren* ('The student who was in love decided to drive to the open country'). Friederici therefore argued that although agrammatic patients may have lost their ability to automatically access closed-class words (see also Friederici & Schoenle, 1980), the process of closed-class retrieval is likely to be still autonomous since it remained unaffected by semantic factors. The loss of the automatic retrieval of closed-class words by agrammatic patients has also been supported by a word monitoring study by Swinney, Zurif and Cutler (1980), who found no effect of vocabulary class for normal listeners, but faster monitoring times for open-class than for closed-class words for agrammatic patients. However, a drawback from the monitoring task is that one cannot be sure that subjects have indeed accessed the mental lexicon when they respond, and that we thus might be measuring at a different level than we are actually interested in.

Other studies have furthermore argued that it is not the distinction between open- and closed-class words *per se* that causes a difference in processing between these words, but rather their saliency. For instance, Grosjean and Gee (1989) assume the vocabulary to be a continuum of words ranging from open-class words carrying new or old information, via stressed and unstressed closed-class words, to several types of affixes and inflections, and ending with unstressed syllables in polysyllabic words. This continuum thus runs from forms that typically have high content, carry stress, and retain a lot of their phonological identity in the speech stream, to forms that have a more grammatical meaning, bear less stress, and retain less of their phonological identity. Grosjean and Gee therefore argued that the distinction between salient, stressed or strong syllables versus non-salient, weak or unstressed syllables is crucial for assigning incoming words to either an open- or a closed-class lexicon. If a closed-class word is stressed, it will thus be looked up in the main lexicon which contains both open- and closed-class words (instead of in the separate closed-class part).

The absence of two clearly definable sets of words has also been illustrated by data on the processing of prepositions presented by Friederici (1985). This study showed that whereas subcategorized prepositions (such as the German preposition *auf* in *Peter hofft auf den sommer* "Peter hopes for the summer") were processed similar to closed-class words, but lexical prepositions (such as *auf* in *Peter steht auf dem Stuhl* "Peter stands on the chair") were processed similar to open-class words. This result might be due to the observation that the latter group of prepositions has more semantic content than the other closed-class items, since these prepositions primarily refer to locations (an argument which also holds for pronouns in that they refer to persons, e.g., Friederici, Weissenborn and Kail, 1991).[5]

A clear-cut distinction between open- and closed-class words has also been disputed by Bates and Wulfeck (1989). They argued that the two vocabulary classes might actually be better described as 'fuzzy sets' with only a few prototypical open- or closed-class words and a majority of borderline cases. Bates and Wulfeck therefore suggested that all lexical items (open- and closed-class items, bound and free) are stored in one mental lexicon. Based on cross-linguistic studies with aphasic patients, they argued that the observed dissociations between open- and closed-class words are likely to be due to differences in the perceptual/motor and cognitive/semantic processing mechanisms that are involved in the retrieval of words from the mental lexicon rather than to differences in the storage of the two classes of words in separate lexicons.

1.4 SEGMENTATION CUES

Given these diverse results on processing and storage of open- and closed-class words obtained from language production, language acquisition, and language perception, the sceptical attitude on the reality of an open-/closed-class distinction that has emerged recently might not be surprising. The present study sought to help resolve this matter since the use of separate vocabularies in the segmentation of spoken language would provide strong evidence for a division in the vocabulary at other levels of processing.

However, as can be concluded from the previous section, the most convincing evidence for different processing of open- versus closed-class words is available from studies on visual rather than on auditory language processing. On-line classification of open- versus closed-class words in reading could be based on the length of words since written words are clearly separated by blanks, and since closed-class words are usually very short (see for example Valian and Coulson's (1988) artificial language study in which

---

[5] *In the present study, both prepositions and pronouns have been treated as closed-class words, since they pattern with the other closed-class words with respect to stress.*

closed-class words are suggested by 3-letter combinations). Obviously, word length as a cue to vocabulary class can not be used in spoken language, since spoken words are not nicely separated by silences. In this thesis, I will therefore investigate two possible indicators of vocabulary class in spoken word recognition: a word's phonological realization, and its predictability from the syntactic (grammatical) context.

A first indicator of vocabulary class could be the phonological realization of words. In English, for instance, open-class words contain at least one full vowel and closed-class words usually contain a reduced vowel. Cutler and Carter (1987) therefore argued that the metrical segmentation strategy used by English speakers involves pre-lexical identification of strong syllables, and that these strong syllables triggers a lexical access attempt in an open-class lexicon. When a word has been recognized and the next syllable is weak, lexical access takes place in a closed-class lexicon. The involvement of the open-/closed-class distinction in the metrical segmentation process was supported by Cutler and Carter's observation that over 90% of the open-class words in a corpus of English text had a strong onset, and that 75% of all strong syllables were onsets of open-class words.

In English, the relationship between vocabulary class, vowel quality, and stress is quite clear. That is, open-class words contain at least one strong vowel which is likely to be stressed (e.g., the /ɛ/ in *ahead* and *lesson)*, and closed-class words are normally pronounced with an unstressed weak vowel (e.g., the /ə/ in *the* or *a*). Since vowel quality is an absolute characteristic, and stress is a more relative property (one syllable can be more stressed than another), it might not be surprising that English speakers base their segmentation on vowel quality rather than on stress (Cutler & Norris, 1988; Cutler, 1993). However, in Dutch, the correspondence between vocabulary class, vowel quality and stress is more variable, since strong vowels are quite often unstressed (e.g., the /ɑː/ in *cobra* 'cobra' and *salon* 'saloon').

Since there are some recent indications that Dutch listeners are able to use the stress pattern of a word to access the mental lexicon despite the fact that stress has a relative character (van Donselaar, Koster & Cutler, in preparation). The crucial question - and the second research question of this thesis - is whether stress in Dutch serves as an indicator of vocabulary class (open-class words are stressed, closed-class words are unstressed). Only if the relationship between vocabulary class and stress proves to be a stable one, should Dutch listeners be able to use this correspondence in the segmentation of their language. This question will be addressed in a series of experiments investigating whether open-class words are recognized faster when they are stressed than when they are unstressed, and whether the reverse pattern holds for the recognition of closed-class words.

On-line classification of open- and closed-class words based on metrical characteristics might be assisted by the predictability of words from the syntactic context. In this case, lexical access would not be encapsulated from syntactic information, allowing context to determine which words in the mental lexicon to access (i.e., interactive processing). The alternative would be that context has its influence at a post-access level and can only be used to decide on the appropriate candidate after access of the mental lexicon has already taken place (i.e., modular processing). Although several studies have demonstrated lexical access of open-class words to be insensitive to the syntactic context (e.g., Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982; Tanenhaus, Leiman & Seidenberg, 1979), Shillcock and Bard (1993) have shown that this might not be the case for closed-class words. They found that lexical decisions to a visually presented synonym of the open-class meaning of a homophone such as /wʊd/ were only facilitated when the syntactic context biased the low-frequency open-class meaning and not when the context biased the high-frequency closed-class meaning (*timber* was primed by *wood* but not by *would*). Shillcock and Bard therefore concluded that whereas listeners are able to predict upcoming closed-class words from the syntactic context, they are not able to predict upcoming open-class words.

However, this conclusion deserves some further investigation for at least two reasons. First, the results seemed to be unaffected by the large difference in frequency between the open- and closed-class meanings. However, there is an increasing amount of experimental evidence in favour of a role of frequency in spoken-word recognition. For instance, Zwitserlood (1985) and Marslen-Wilson, Brown, and Zwitserlood (both reviewed in Marslen-Wilson, 1987) demonstrated that the auditorily presented syllable *cap-* activated semantic associates of both *captain* (*ship*) and *captive* (*guard*). Lexical decisions on these associates turned out to be faster for the associates of the high-frequency word *captain* than for the associates of the low-frequency word *captive*. This suggests that high-frequency words have a higher level of activation than low-frequency words. Because closed-class words in general have a much higher frequency of occurrence than open-class words, the present studies on the relation between vocabulary class and stress or context thus also clearly bear on the role of frequency in spoken-word recognition.

Another reason for further investigation of Shillcock and Bard's conclusion is the fact that their conclusion was based on an incomplete design - they only used synonyms of the open-class meanings of homophones. The third research question of this thesis therefore concerns whether syntactic context can indeed be used to predict upcoming closed-class words. This question will be studied in a series of experiments in which listeners make lexical decisions on semantic associates of both the open- and the closed-class meanings of homophones.

A final remark should be made on the implications of the possible use of stress and context in speech segmentation for the SHORTLIST model. As already mentioned, the use of stress and context outlined above implies that these factors are able to influence the activation of words in the mental lexicon; they determine where in the incoming speech a lexical access attempt takes place and which words are accessed. Such an influence of stress and context is, however, not incorporated in the current version of the SHORTLIST model, in which only the incoming speech signal can determine which words are activated. With respect to metrical information, SHORTLIST already includes the distinction between strong and weak syllables by influencing the degree of activation of candidate words. If stress appears to be crucial in speech segmentation, the model would require only minor adaptation by adding information on degrees of lexical stress. Furthermore, in the current version of SHORTLIST, the syntactic context does not influence which word candidates will be accessed, neither does context have an influence on the level of activation with which the candidate word will enter the competition process. Again, both possibilities require only minor adaptation of the model.

In summary, the open-/closed-class distinction could be relevant for the segmentation of Dutch. A prerequisite for reliable research on this distinction is to exclude word frequency as a major determinant of the outcome. Since open-class words have intrinsically lower frequencies than closed-class words, effects of frequency might otherwise mistakenly be taken as a result of different processing of open- and closed-class words. The role of frequency in auditory perception will therefore be the first research question of the present thesis. If Dutch listeners indeed use the open-/closed-class distinction in speech segmentation, they should be able to use metrical and/or syntactic cues as indicators of vocabulary class. The second research question thus concerns whether the correspondence between stress and vocabulary class allows for a strategy in which incoming stressed items are classified as open-class words and unstressed items are classified as closed-class words. Open-class words could then be looked-up in an open-class lexicon, and closed-class words could be looked up a closed-class lexicon. The third research question relates to the issue of whether syntactic context can be used to predict upcoming closed-class words. If a closed-class word is predicted, the closed-class lexicon could be accessed, otherwise, words could be looked-up in the open-class lexicon. The use of the two vocabulary classes in word segmentation would have implications for the SHORTLIST model of spoken word recognition, and would also support the psychological reality of the open-/closed-class distinction.

1.5 ORGANIZATION OF THE CHAPTERS

The structure of the remaining contents of this thesis is as follows.[6] In *Chapter 2*, I investigate the first research question - what is the impact of frequency on the recognition of spoken open- and closed-class words? In three experiments, open- and closed-class words are used in isolation, and studied in two different experimental tasks (lexical decision and single-word shadowing). These experimental methods are discussed with respect to their implications for open-/closed-class research.

In the third and fourth chapter, the second research question is the central topic - does stress serve as an indicator to vocabulary class in Dutch? The main focus of *Chapter 3* is whether Dutch listeners assume a monosyllabic stressed word belongs to the open-class vocabulary, and assign unstressed monosyllabic words to the closed-class vocabulary.[7] I describe two word-

---

[6] *Since most chapters have been submitted to journals, some overlap between the contents of the chapters could not be avoided.*

[7] *All the experimental open- and closed-class words used in this thesis are monosyllabic. Since the large majority of prototypical Dutch closed-class words are monosyllabic, effects of metrical segmentation should be strongest for these words. Although open-class words exhibit much more variation with respect to their number of syllables, the length of these words was matched with the length of the closed-class words.*

spotting experiments in which listeners listen for stressed and unstressed open- and closed-class words embedded in nonsense words. The results are compared to the results of a third word-spotting experiment in which the quality of the vowels was independently manipulated. In *Chapter 4*, the focus shifts from metrical segmentation to the likelihood of separate storage of open- and closed-class words in the mental lexicon. In three experiments (word-spotting, lexical decision, and cross-modal priming), the influence of stress on the recognition of open- and closed-class words in a nonsense context is compared to recognition of these words in meaningful phrases and sentence contexts.

The third research question is the central theme of *Chapter 5* - can syntactic context be used to predict upcoming closed-class words? The influence of syntactic context on the processing of open- and closed-class words in short meaningful phrases is examined (using lexical decision, auditory priming, and cross-modal priming paradigms). *Chapter 6* contains a general discussion of the results of chapter 2-5, and a final general conclusion.

EFFECTS OF FREQUENCY ON THE AUDITORY PERCEPTION OF OPEN- VERSUS CLOSED-CLASS WORDS

CHAPTER 2

(This chapter is based on a publication in the Proceedings of the Fourth International Conference on Spoken Language Processing, Oct 3-6, 1996, H. T Bunnell & W. Idsardi (Eds.), Vol 1, p. 78-81 New Castle, Delaware Citation Delaware. This publication concerns the results of the first experiment; experiment 2 and 3 are additional)

ABSTRACT

Over the past couple of decades, it has been repeatedly investigated whether open-class items are processed in a different way from closed-class items. Most studies, however, have been bedevilled by difficulties in controlling all relevant distinctions between open- and closed-class items. For example, whereas open-class items have a relatively low frequency of occurrence, closed class words have a very high frequency. The current chapter investigates auditory lexical decision on open- versus closed-class items when the effect of frequency is controlled for. Results revealed faster responses to high-frequency open-class items compared to closed-class items of similar frequency. Furthermore, responses to both low-frequency open-class items and nonwords were significantly different from the responses to the high-frequency open-class items, but not from responses to the high-frequency closed-class items. Similar latencies for closed-class items and nonwords suggest that the open/closed- class distinction might be due to the clear lexical meaning of open-class items as opposed to the more grammatical function of closed-class words. This conclusion was supported by the results of a single-word shadowing task. Since both lexical decision and shadowing thus seem to be influenced by a meaning component, these tasks are probably not ideally suited for a comparison between two sets of words which intrinsically differ on kind and amount of meaning.

2.1 INTRODUCTION

The vocabularies of languages like English and Dutch fall into two classes: an open-class item set consisting of nouns, verbs, adjectives, and adverbs, and a closed-class item set that contains minor lexical categories like pronouns and articles. One of the most striking distinctions between open- and closed-class items is their different frequency of occurrence. In contrast to the low frequency of occurrence of most open-class items, closed-class items are used with a much higher frequency. Since word frequency effects are likely to influence lexical access (Gordon, 1985), these effects received a great deal of attention in research on possible processing differences between open- and closed-class items on an access and retrieval level. For example, based on the absence of a frequency effect for closed-class items in visual lexical decision, Bradley (1978) argued for a specialized lexical access routine for the retrieval of closed-class elements during speech processing. Later studies, however, did not succeed in replicating this result. Not only were frequency effects found for both open- and closed-class items with similar frequencies (Gordon & Caramazza, 1982; Segui, Mehler, Frauenfelder, & Morton, 1982), both classes also showed a non-linear function of reaction time with logarithmic frequency (Gordon & Caramazza, 1985). The flattening of the frequency distribution in the higher ranges (higher than 400 occurrences per million or 2.5 log frequency), though, turned out to be significant for the closed-class items only. This discrepancy between the two item sets was attributed to word-specific influences (corresponding to the visual word form or to the configurational properties of the words) on lexical decision speed in general.

Although the open and closed class words presented under normal conditions exhibited equal effects of frequency, Gordon and Caramazza (1985) showed that under masked conditions, responses to open-class items were somewhat faster than responses to closed-class items of comparable frequency. Gordon and Caramazza interpreted this result as evidence against the existence of a specialized processing routine for closed-class items, since they assumed that the closed-class items rather than the open-class items should benefit from such a routine. Taken together, the results of these studies seem to indicate that distinctions between open- and closed-class items do not manifest themselves at the level of lexical access and retrieval.

This conclusion seemed to be confirmed by findings presented by Matthei and Kean (1989), using auditory instead of visual lexical decision. With open- and closed-class items from different frequency ranges (mean log frequencies of 2.18 and 3.11, for the open- and closed-class items, respectively), Matthei and Kean found frequency-dependent reaction times in both lexical classes. However, no non-linearities could be shown in their reaction time versus frequency analysis. For the lack of a frequency saturation effect for high frequency items, two possible explanations were given. First, strong effects of duration were found, which might have interacted with the effect of frequency. Second, the lack of a frequency saturation effect might have been due to the difference in the modality of presentation. Auditory presentation could prevent floor effects from occurring. In addition to the frequency sensitivity of closed-class items, the results of Matthei and Kean showed similar reaction times for the open- and closed-class item sets (507 ms. and 490 ms., respectively). Given the considerably higher frequency of most of the closed class items, however, faster reaction times for the closed-class item set ought to have been found. Because of the different frequency ranges of the open- and closed-class items, it is fairly hard to disentangle the influence of frequency from other factors like meaning.

Using Dutch as a language that allows for a comparison between open- and closed-class items of similar frequency, the present study investigates auditory lexical decisions on open- versus closed-class words when the effect of frequency is controlled. The results will be discussed with respect to Gordon and Caramazza (1982; 1985). They suggested that faster responses to open-class items than to comparable closed-class items would not only argue against a specialized access routine for closed-class items, it would also make it difficult to explain the frequency insensitivity of closed-class items as the trivial expression of a reaction-time floor effect.

2.2 EXPERIMENT 1: AUDITORY LEXICAL DECISION

2.2.1 Method

Subjects

The twenty undergraduate students taking part in this experiment were drawn from the subject pool of the Max-Planck-Institute for Psycholinguistics. Three students were replaced by other students because of their extreme high error rates (>40%). Most of these errors were due to responses that were given before item offset. The participants (15 females and 5 males) ranged in age between 20 and 35 years old, with a mean age of 25. All students were native speakers of Dutch, and they were paid for their participation.

Materials

The target item set contained 12 monosyllabic high-frequency open-class items and 12 monosyllabic high frequency (HF) closed-class words. Open-class items were either nouns, main verbs, or adjectives. The closed-class item set was composed of articles, conjunctions, pronouns, and quantifiers. The open- and closed-class items were matched as closely as possible for their initial phonemes and their number of phonemes (mean length of 3 phonemes). The items were furthermore matched for their lemma based frequency (i.e., the frequencies of all word forms from an inflectional paradigm were summed) according to the Dutch version of the CELEX lexical database. The frequency of the open-class items ranged from 11 to 2321 occurrences in a million, with a mean frequency of 719 (i.e., 2.86 log frequency). The closed-class items covered a range from 16 to 2438 occurrences in a million (mean frequency of 683; i.e., 2.83 log frequency).

An additional filler item set was selected, consisting of 48 legal nonwords. These nonwords were constructed by changing one phoneme of 24 randomly selected open class words and 24 randomly selected closed class words. In roughly half of the cases, the altered phoneme was at the beginning of the word, in the other half, the change was made at the end of the word. To prevent listeners to be biased towards a nonword response on the closed-class items (when only a small number of closed-class words are used, these words might become 'nonword-like'; see also Kolk and Blomert, 1985), 24 low-frequency (LF) open-class fillers were also selected. Although these words are less familiar to listeners, they still require a word response. The LF open-class fillers were either nouns (12 items) or adjectives (12 items), varying in length from 3 to 5 phonemes. The mean lemma frequency of occurrence of the open-class fillers was 1 in a million. The open- and closed-class items are presented in Appendix A, the nonwords in Appendix B.

Presentation

The items were presented in two blocks, each block consisting of 6 HF open-class items and 6 HF closed-class items intermixed with 12 filler LF open-class items and 24 filler nonwords. The order of the presentation of the blocks was counterbalanced across subjects, with the order of the individual items pseudo-randomized for every two participants. This randomization was restricted by four factors: 1) no more than three words or nonwords in succession, 2) no more than three successive experimental items, 3) no successive items with identical initial phonemes, and 4) the first four items of each block were filler items. A practice block of 14 items was also constructed. This block contained 7 randomly selected open- and closed-class items, and 7 legal nonwords.

Procedure

A list with both the words and the nonwords in random order was read by a trained female speaker of standard Dutch, and recorded in a sound attenuated booth using a Sony 670 DAT-recorder and a Sennheiser HMD224 microphone.

Participants were tested either individually or in pairs, in sessions of about ten minutes. They were seated in a sound proof booth, and listened to the stimuli over headphones. A written instruction was given to listen to the items carefully, and decide whether an item was a word or a nonword after hearing the entire word. A button labelled "yes" had to pressed with their dominant hand where an item was judged to be a word. A button labelled "no" was used for the nonword responses. Participants were encouraged to respond as fast and accurately as possible. Subjects could respond to a presented word for 2000 ms., measured from the onset of this item. The next trial was presented after 660 ms.

Presentation of the practice items was followed by a short break in which the participants had an opportunity to ask questions. After this break, two blocks of experimental items were offered, separated from each other by a short pause.

2.2.2 DATA ANALYSIS AND RESULTS

Lexical decision response latencies were measured from the offset of the items. Responses were excluded from the analysis if: 1) the push-button response was given before the offset of an item or after the time-out period

(4% open class responses, 11 % closed class responses), and 2) the push-button latency exceeded the mean RT per condition plus or minus 3 SD (0.3%). The missing data and outliers were replaced by a value based on the mean of the item at hand plus the subject's mean RT deviation from the mean of the RTs of the other subjects.

Reaction times and percentages of errors are shown in Table 2.1. An analysis of variance with the factor item-type (HF open class; HF closed class; LF open class; nonwords) showed a significance difference, both when this analysis treated subjects as the repeated measure (F1) and when items were treated as the repeated measure (F2) ($F1(3,57) = 20.85$, $p < .01$, $MSe = 3306.12$; $F2(3,92) = 3.83$, $p < .05$, $MSe = 17727.29$).

A post-hoc Newman-Keuls revealed significantly faster latencies for the HF open-class items than for the HF closed-class items ($p < .01$). In addition, significantly fewer errors were made in the open-class versus the closed-class item set ($p < .01$). The latencies of the LF open-class words and nonwords differed significantly from the mean latency of the HF open-class items ($p < .01$), but not from the latencies of the HF closed-class items. Although the LF open-class words were not matched with the HF open-class words for their number of phonemes, the obtained difference between these groups of words indicates the occurrence of a normal frequency effect in the open-class items.

To assess whether the difference between the high-frequency open- and closed-class words are influenced by other factors, additional correlation analyses using Pearson correlation tests were carried out with the factors item frequency, item duration, uniqueness points (UPs), and cohort size.

Table 2.1 *Results of experiment 1. Mean decision latencies, and percentages of errors (in brackets)*

High-frequency open-class words	304 ms.	(4)
High-frequency closed-class words	407 ms.	(11)
Low-frequency open-class words	371 ms.	(18)
Nonwords	442 ms.	(6)

Statistical examination of the frequency ranges with a t-test showed that the open- and closed-class item sets did not significantly differ in their lemma based frequencies. Furthermore, no significant correlation could be shown between the lemma based frequencies of the open- or the closed-class items and their corresponding decision latencies.

The duration analysis showed a minimal, non significant difference between the mean duration of the open-class items (680 ms.) and the mean duration of the closed-class items (683 ms.). These durations did not influence the decision latencies of either the open- or the closed-class item set.

Another factor that might have influenced the decision latencies are the points at which the open- and closed-class items can be uniquely identified, i.e., their uniqueness point or UP. Examination of the UPs revealed no such difference between the two item sets. In fact, except for the closed-class word *zulks* ('such a thing' / 'this'), none of the items could be uniquely identified at its offset.

To compute the cohort size of an item, the longest possible word starting with this item was selected. Successively, the cohort of this word was determined on a phoneme basis (one phoneme equalled a vowel, a consonant, a long vowel, a diphthong, or an affricate) using the lemma lexicon of the CELEX database. For the open-class item set, a cohort size of 6042 words was found; the closed-class item set had a cohort of 5169 words. The difference between the item sets did not reach the level of significance on a t-test. Although the mean frequency of the members of the closed-class cohorts was somewhat higher than the mean frequency of the members of the open-class cohorts (136 versus 110, respectively), this difference did not turn out to be significant. Because of the shape of frequency distributions in general, the median frequencies of the open- (1.0) and closed-class (1.2) item set were also determined. Again, a t-test did not show any significant difference. Finally, the decision latencies of both the open and the closed class items did not correlate with either the absolute cohort size or with the cohort size corrected for frequency.

2.3 DISCUSSION

The primary goal of the present experiment was to compare auditory lexical decision responses to open- versus closed-class words of similar frequency. Results revealed faster reaction times for the high-frequency open-class items than for the high-frequency closed-class items, independent of item durations, uniqueness points, and cohort sizes. Furthermore, subjects tended to make fewer errors in the open-class items when compared to the closed-class items. These findings confirm earlier results obtained with a visual paradigm where open- and closed-class items were presented under masked conditions (Gordon & Caramazza, 1985).

One might wonder, however, whether the slow reaction times for the closed-class vocabulary words indeed argue against a special retrieval mechanism for these items (as proposed by Gordon and Caramazza, 1985). Since closed-class items mainly indicate grammatical relationships between open-class words, closed-class words cannot serve their normal function when presented in isolation. Open-class items, on the other hand, have a clear lexical meaning, both when presented in running speech and in isolation. This difference between the two vocabulary types does, in fact, predict an advantage for the recognition of open- versus closed-class items in a lexical decision task, since word recognition in such a task is largely based on the meaning of the items (Taft, 1990).

The difference in responses found for open- and closed-class items of similar high frequency, however, indicates that one cannot simply state that high-frequency closed-class items show frequency insensitivity as a result of a reaction time floor effect. The analysis of the relationship between reaction times and frequencies of occurrences in the current study showed that neither the open- nor the closed-class latencies corresponded with their frequency of occurrence. This result again confirms findings from visual lexical decision. Therefore, the absence of a frequency saturation effect in Matthei and Kean's (1989) auditory lexical decision study is not likely to have be caused simply by the use of the auditory modality.

How can the slower responses to the closed-class items be explained? In previous lexical decision studies on open- and closed-class distinctions, only responses to the real words have been analyzed. However, since open- and closed-class items differ in the amount of meaning they convey (open-class items have an obvious lexical meaning, closed-class items tend to indicate the grammatical relations between open-class items), a comparison with items having no lexical meaning could possibly shed some light on the cause of the obtained result. Whereas high-frequency open-class words showed different responses from nonwords, high-frequency closed-class words did not differ from the nonwords. This suggests that the open/closed-class distinction is indeed due to the difference in lexical meaning between the two vocabulary classes.[8]

2.4 EXPERIMENT 2: SINGLE-WORD SHADOWING

Although meaningfulness is thus likely to affect the outcome of a lexical task, Taft (1990) pointed out that lexical decision might also be affected by the degree as to which words are functionally constraint. For example, whereas the open-class words that are used in a visual lexical decision task are usually words that stand alone without reference to other words (e.g., *communion*, *digest*), the closed-class words sometimes can stand alone (e.g., *those*, *again*), but more frequently cannot stand alone (e.g., *thus*, *am*). In order to investigate whether functional constraint has an influence on lexical decision, Taft used both functionally constrained and functionally unconstrained open- and closed-class words in a series of visual lexical decision experiments. Lexical decisions on functionally unconstrained open-class words turned out to be equally as fast as decisions on functionally unconstrained closed-class words, but faster than decisions on both functionally constrained closed-class and functionally constrained open-class words (e.g., *verge*, *depend)*. Taft therefore concluded that it is easier to recognize a word when it constitutes a functional unit in its own right than when it does not, independent of the vocabulary class that word belongs to.

Although functional constraint thus seems to have an influence on the speed of a lexical decision, in Taft's study, this factor was confounded with the meaningfulness of words; functionally unconstrained words have more meaning than functionally constrained words (the latter words can either only be defined in syntactic terms (e.g., *than)*, or they are part of a larger lexical item (e.g., *upside* in *upside down*)). In order to determine whether functional constraint or meaning is the most important factor in determining decision latencies, Taft also compared lexical decisions to functionally constrained open-class words with a clear lexical meaning (e.g., *contain* - this word

---

[8] *One could argue that the comparison between words and nonwords involves two different types of responses: a 'yes'-response for the words, and a 'no'-response for the nonwords. However, since 'yes'-responses are usually faster than 'no'-responses, the slow responses to the closed-class words precisely show how slow these words are processed by the listeners.*

always requires an object when used in a sentence, and clearly means *include*) with lexical decisions to functionally unconstrained open-class words also having a clear meaning (e.g., *justice* - this word does not require an object). Since these two types of open-class words showed similar latencies, he concluded that the factor that affects lexical decision is not functional constraint per se, but rather the meaningfulness of words.

Taft furthermore argued that the influence of meaning is more likely to occur post-access rather than (pre-)access, since no effect of functional constraint was found when a naming task was used (naming involves lexical access without the involvement of a decision stage; Balota & Chumbley, 1984). The absence of this effect in naming agreed with an earlier finding of Chumbley and Balota (1984) showing that meaningfulness of open-class words has an effect on visual lexical decision reaction times but not on naming latencies. However, other studies have suggested that word meaning is also involved in naming - Seidenberg, Waters, Sanders, and Langer (1984) found a semantic priming effect on naming, and Bleasdale (1987) reported longer naming latencies for abstract versus concrete words. Taft therefore argued that the latter effects of meaning are of a different nature (the nature of the representation of a word's meaning) from those of meaning in relation to his data (the link between the orthographic form of a lexical entry and its meaning).

The importance of word meaningfulness in auditory lexical decisions has been demonstrated in Experiment 1. When high-frequency open- and closed-class words were auditorily presented, lexical decisions to the open-class words were significantly faster than the decisions to the closed-class words. In fact, the high-frequency closed-class words showed similar latencies to nonwords (which have no lexical meaning). It was therefore concluded that the open-class/closed-class distinction is likely to result from the clear lexical meaning of high-frequency open-class words as opposed to the more grammatical function of closed-class words. Although these results agree with Taft's (1990) observations for visual lexical decision, experiment 1 did not include a condition comparable to the naming task in which meaning is not explicitly involved. An equivalent of the naming task for auditory word recognition is the single-word shadowing task (Slowiaczek, 1990) in which spoken words have to be repeated both fast and accurately.

Shadowing of words, however, can theoretically take place via two different routines; a pre-lexical routine in which the mental lexicon is not contacted, and a lexical routine in which lexical representations are accessed (Howard & Franklin, 1988). If words are repeated via the pre-lexical routine, no conclusions can be drawn about differences between open- and closed-class words at the level of lexical access. Yet Slowiaczek (1990) observed a difference in the shadowing latencies of correctly and incorrectly stressed words. She therefore argued that subjects automatically access a lexical representation when the shadowing task is performed, since otherwise no difference would have been found.

The involvement of the lexicon in a shadowing task was also suggested by the results of Goldman (1991) who reported faster shadowing latencies for open-class words than for closed-class words. For this reason, Goldman stated that open- and closed-class words are probably identified using different mechanisms. However, the open- and closed-class words used in this study were not matched for their frequency of occurrence. Furthermore, Goldman reported faster latencies for low-frequency than for high-frequency words. This finding runs counter to the common observation that high-frequency words are shadowed faster than low-frequency words (e.g., Forster, 1976; Scarborough, Cortese, & Scarborough, 1977).

Experiment 2 will therefore investigate whether shadowing latencies are different for open- versus closed-class words when these words are matched for their frequency of occurrence. To check for effects of frequency, open-class words of a rather low frequency were included. Since a normal frequency effect is supposed to reflect lexical access (e.g., Gordon, 1985), such an effect would show involvement of the lexicon.

2.4.1 Method

Subjects

Twenty students drawn from the subject pool of the Max-Planck Institute took part in the experiment. None of the students had previously participated in experiment 1. All participants had normal hearing abilities, and were paid Fl. 8.50 for their participation.

Materials, presentation, and procedure

The experimental item set consisted the same words used in experiment 1 with the exception of the nonwords: 12 HF open-class, 12 HF closed-class, and 24 LF open-class words. A written instruction was presented to listen to the items carefully, and to repeat the items as fast and accurately as possible after hearing the entire word. After a practice block of 14 items, two blocks of 24 words were presented (6 HF open-class words, 6 HF closed-class words, 12 LF open-class words) each headed by 4 practice words. The order of presentation of these blocks was counterbalanced across listeners. Furthermore, the order of the individual words was pseudo-randomized for every two participants with the constraint that no succeeding items with identical initial phonemes were allowed. Speech-onset latencies were measured with a voice-key connected to a Hermac AT-computer. All sessions were recorded with a Sony DTC 55 ES DAT-recorder. If subjects were tested in pairs, so that on-line monitoring was not possible, these recordings were used to score the responses afterwards.

2.4.2 Results and discussion

Four types of responses were excluded from the analysis: 1) repetitions that were incorrect, 2) responses starting with a disfluency, 3) responses preceded by a non-speech sound, and 4) responses given after the 2000 ms. time-out period. These responses (6% of the data set) and the reaction times that exceeded the mean reaction per condition with plus or minus three standard deviations (0.6%) were replaced by the overall mean per condition. All latencies were measured from item offset. The mean repetition latencies are presented in Table 2.2.

Table 2.2 *Results of experiment 2. Mean reaction times, and percentages of errors (in brackets)*

High-frequency open-class words	235 ms.	(7)
High-frequency closed-class words	263 ms.	(5)
Low-frequency open-class words	250 ms.	(8)

A one-way analysis of variance with the factor item-type (HF open class; HF closed class; LF open class) showed a significant difference when the analysis was performed across subjects (F1), but not across items (F2) ($F1(2,38) = 5.93$, $p < .01$, $MSe = 633.74$; $F2(2,45) = .52$, $p > .05$ ns., $MSe = 4322.60$). Posthoc Newman-Keuls analysis revealed a significant difference between HF open-class words and LF open-class words when the data were analysed across subjects ($p < .05$), but not when the data were analysed across items. In addition, decisions to HF closed-class words were significantly slower than decisions to HF open-class words, but again only in the by-subject analysis ($p < .05$).

However, Radeau and Morais (1990) demonstrated that word shadowing latencies are influenced by the uniqueness points of these words, and also by their duration and their frequency of occurrence. To check for possible influences of these variables on the latencies of the high-frequency words, a series of correlation analyses were performed.

First, as shown in experiment 1, no difference between the uniqueness points of the HF open-class and the HF closed-class words was found. Second, the duration of the HF open-class (680 ms.) and HF closed-class words (683 ms.) did significantly correlate with their reaction times (open-class items: $r = -.6894$, $p < .05$, two-tailed; closed-class items: $r = -.67788$, $p < .05$, two-tailed). Thus, the longer the duration of an item, the faster this item was repeated. An analysis of co-variance with duration as co-variate was performed to check whether elimination of the factor duration would result in a difference between the HF open- and closed-class items. However, controlling for item duration did not lead to a significant difference between the open- and closed-class items. A third factor that could have influenced the shadowing latencies is frequency of occurrence. However, the frequency of the items did not correlate with the mean latencies found for either the HF open-class ($r = -.5189$, $p > .05$, two-tailed) or the HF closed-class items ($r = -.2207$, $p > .05$, two-tailed). A last factor that could have influenced the responses to the HF open- or closed-class words is that some of the subjects reported problems in determining whether a specific item had already ended or not. However, experiment 1 showed no significant difference between the two vocabulary classes with respect to their cohort.

The percentages of errors (presented in Table 2.2) did not significantly differ from one another in a one-way analysis of variance.

To summarize, these results suggest that single-word shadowing involves lexical access - faster latencies were observed for the HF open-class versus the HF closed-class words, and a normal frequency effect was found for the HF versus the LF open-class words. The weakness of these effects in the by-item analysis is probably due to the small number of items that was used.[9] To be able to determine the influence of the meaning difference between the HF open- and closed-class words on the shadowing latencies, nonwords were added to the experimental item set, in a subsequent experiment. If meaning is somehow involved, the shadowing latencies of the meaningless nonwords might be more similar to the latencies of the closed-class words than to the latencies of the open-class words since these closed-class words also convey little lexical meaning.

2.5 EXPERIMENT 3: SHADOWING OF NONWORDS

2.5.1 Method

Subjects

Twenty-two paid students took part in the experiment. None of these students had also participated in the previous experiments. The data of one participant was excluded from the analysis because of an extremely high error score (>10%); the data of another participant was excluded because of extremely fast reaction times.

Materials and procedure

The items for the current experiment consisted of the same HF open- and closed-class words and the LF open-class used in the previous two experiments. In addition, the 48 nonword fillers of experiment 1 were also included. The items were presented in two blocks of 48 items starting with 4 filler items. The practice block of 7 open- and closed-class items was extended with 7 nonwords. The procedure for this experiment was identical to the procedure described for the previous experiment.

---

[9] *Note that Goldman only reported F1 values (analysis over subjects), and no F2 values (analysis over items).*

2.5.2 Results and discussion

The repetition latencies were measured from target offset. Three types of responses were excluded from the analysis: 1) erroneous repetitions, 2) disfluent repetitions, and 3) responses in which the voice key failed to trigger (open class 3%; closed class 1%; open-class low-frequency fillers 3%; nonword fillers 5%). Both these missing data and responses that exceeded the mean reaction time per condition plus or minus 3 standard deviations (.6%) were replaced by the overall mean reaction time per condition.

A one-way analysis of variance with the factor item-type (HF open class, HF closed class, LF open class, nonword) showed a significant effect in the by-subject analysis only (F1(3,57) = 6.51, $p < .05$, MSe = 273.66; F2(3,92) = .56, $p > .05$ ns., MSe = 2022.13). The mean repetition latencies for each item group are presented in Table 2.3.

A series of posthoc Newman-Keuls analyses showed that the HF open-class words were repeated significantly faster ($p < .05$) than the HF closed-class words, the LF closed-class words, and the nonwords, but only in the by-subject analysis. The differences between the latter three groups, however, did not reach significance. In Table 2.3, the percentages of errors that were made are also presented. These percentages did not significantly differ from each other in an analysis of variance.

The results indicate that in the current single-word shadowing task a meaning component was involved; meaningless nonwords tended to be repeated as slowly as the HF closed-class words. The non-significant difference between the high-frequency open- and closed-class words is thus more likely to be caused by a difference in meaning rather than by a distinction in lexical access.

Table 2.3 *Results of experiment 3. Mean reaction times, and percentages of errors (in brackets)*

High-frequency open-class words	246 ms.	(2)
High-frequency closed-class words	269 ms.	(0)
Low-frequency open-class words	258 ms.	(1.5)
Nonwords	261 ms.	(5)

2.6 GENERAL DISCUSSION AND CONCLUSION

To summarize, the first auditory lexical decision experiment showed that when open- and closed-class items have a similar frequency and are therefore equally familiar to listeners, closed-class items are harder to recognize. In fact, high-frequency closed-class items appear to be processed in a similar way to nonwords. To investigate whether this effect was indeed due to a difference in meaning rather than to an access difference between open- and closed-class words, the second and third experiment used a single-word shadowing task in which no explicit meaning decision is required. Although faster shadowing latencies were observed for the open-class words than for the closed-class words, the closed-class latencies were demonstrated to be as slow as the shadowing latencies of nonwords (both effects did, however, not reach significance). The latter finding suggests that the meaning of words is still involved in the shadowing task. Automatic involvement of lexical access and of the meaning of words in the shadowing task was also supported by the occurrence of a normal frequency effect (i.e., responses to high-frequency open-class words tended to be faster than responses to low-frequency open-class words).

Based on the results of the lexical decision and shadowing tasks, it can be concluded that in both tasks a meaning-component is involved. Lexical decision and shadowing are therefore probably not ideally suited to investigate differences between two sets of words that intrinsically differ in the type and amount of meaning they convey. This finding has direct implications for the current research program; the experiments reported below carefully take the intrinsic differences between the two sets into account and focus on comparisons within rather than between each of these two vocabulary classes.

The current results also suggest that the obtained difference between the high-frequency open- and closed-class words is more likely to evolve at a post-access rather than at an pre-access or access level. However, if the open-/closed-class distinction is used in the segmentation of speech, the information should already be available before the mental lexicon is accessed. The next chapter investigates whether the stress pattern of words serves as a cue to vocabulary class, and whether this cue can be used to access the mental lexicon.

STRESS AS AN INDICATOR OF VOCABULARY CLASS

CHAPTER 3

(This chapter is based on an article submitted to Language and Speech)

ABSTRACT

Previous studies have argued that English listeners use syllables with a full vowel for the segmentation of continuous speech (Cutler & Norris, 1988; Cutler, 1993). Whenever such a syllable is detected, a lexical access attempt will take place in an open-class lexicon. When the word is recognized and the next syllable is weak, a lexical search through a separate closed-class lexicon will be started. Since the correspondence between the vocabulary class of a word and its vowel quality is less clear for Dutch than for English, the present study investigated whether for Dutch listeners stress rather than vowel quality serves as a cue to vocabulary class, and whether the information about the stress pattern of a word can be used to access the mental lexicon. The results of three word-spotting experiments in which the stress pattern of both open- and closed-class words was manipulated showed that whereas stress slightly facilitated the recognition of open-class words, it delayed the recognition of closed-class words. Because these effects varied both with frequency of occurrence and with the position of the words in the phrases, it is argued that stress in Dutch is not a reliable cue to vocabulary class. The results are explained by a mis-stressing account rather than by a dual-lexicon hypothesis.

3.1 INTRODUCTION

Languages such as English and Dutch are characterized by the alternation of stressed and unstressed syllables. Not only is the stress pattern of a word important to distinguish between minimal stress pairs like *TRUSty* and *trusTEE*, stressed syllables are in general also easier to perceive than unstressed syllables because of their longer durations and their higher amplitudes (Nooteboom & Cohen, 1984). Stressed syllables are therefore often defined as strong syllables, whereas unstressed syllables are usually considered to be weak. However, the terminology strong versus weak has also been used to describe the quality of a vowel; whereas strong syllables are syllables with a full vowel, weak syllables contain a reduced vowel (usually a schwa). Although both definitions of strong and weak syllables characterize syllables with a stressed full vowel as strong and syllables with an unstressed reduced vowel as weak, they do make different predictions about the status of syllables with an unstressed full vowel (as the *au* in *audition).* Whereas the stress-based definition would identify such a vowel as being weak, it would be strong according to the vowel-based definition (Fear, Cutler, & Butterfield, 1995).

Exact definition of strong versus weak syllables is relevant for the metrical segmentation theory developed by Cutler and Norris (1988). Since word boundaries in continuous speech are usually not clearly marked, Cutler and Norris argued that listeners of a stress-timed language adopt a strategy for the segmentation of their language that is based on the occurrence of strong syllables (a metrical segmentation strategy, or MSS). After detection of the onset of a strong syllable, a lexical access attempt will take place. Potential success of the strategy of treating strong syllables as possible word onsets was supported by the observation that the large majority of both English (Cutler & Carter, 1987) and Dutch words (Baayen & Schreuder, 1994) indeed start with a strong vowel. However, whether metrical segmentation is based on either full or on stressed vowels seems to depend on the phonological characteristics of each stress-timed language individually. For example, as the next sections describe, whereas metrical segmentation of English seems to be mainly based on vowel quality, the role of stress is likely to be larger for Dutch.

3.1.1 Metrical segmentation in English

The absence of a direct influence of stress on the access of English words has been demonstrated by Cutler and Clifton (1984). Not only did they show that prior knowledge of the stress pattern of a word does not help English listeners to reduce the number of potential word candidates, they also demonstrated that words presented with their canonical stress pattern (strong-weak for nouns, and weak-strong for verbs) were not easier to recognize than words presented with these stress patterns reversed. Additional evidence that, in English, stress itself does not serve as an access code to the mental lexicon was provided by Cutler (1986). In a priming study, she showed that words with two different meanings depending on their stress pattern (e.g., *forbear*) basically behave like normal homophones in that responses to semantic associates of both meanings (*ancestor* and *tolerate*) were primed when these words were presented visually to subjects shortly after the homophonous prime had been presented in a spoken sentence. If stress had been used in the lexical access procedure, priming would have occurred for the contextually appropriate associates only.

Although the above studies thus indicate that English listeners do not use stress in their lexical access procedure, these listeners do seem sensitive to the distinction between full and reduced vowels. In a recent study, Fear, Cutler, and Butterfield (1995) showed that listeners group syllables with unstressed full vowels (e.g., the first syllable of *audition*) together with stressed syllables that also have a full vowel (e.g., the first syllables of *audiences* and *auditoria*) rather than with unstressed syllables having a weak vowel (e.g., the first syllable of *addition*). The relational distinction between stressed and unstressed syllables is thus less important for English listeners than the absolute quality of a vowel (full versus reduced).

Not only do English listeners make a categorical distinction between full and reduced vowels, two additional studies by Cutler and her colleagues indicated that these listeners also use this distinction in their segmentation of continuous speech. In the first study, Cutler and Norris (1988) asked subjects to detect a word in a disyllabic nonword. The results revealed that a word like *mint* was easier to detect when the nonword had a strong-weak pattern as in /mɪn-təf/, than when the pattern was strong-strong, as in /mɪn-teɪf/. Cutler and Norris explained this difference as a result of segmentation; if a second syllable is strong, listeners will segment this syllable from the first one. To detect *mint* in /mɪn-teɪf/ subsequent assembly of /min/ and the /t/ across a segmentation position is required, which will result in slower detection times.

A second study by Cutler and Butterfield (1992) furthermore showed that both in laboratory-induced and in spontaneous misperceptions of speech, listeners are more likely to insert an erroneous word boundary before a strong syllable (e.g., hearing *some pill* instead of *uphill*) than before a weak syllable (e.g., hearing *effect of* instead of *effective*). On the other hand, erroneous deletion of word boundaries occurred more often before weak syllable (e.g., hearing *my gorgeous* instead of *my gorge is*) than before strong syllables (*Israeli* instead of *is he really*). Furthermore, whereas boundaries inserted before strong syllables tended to produce following open-class words (lexical words like nouns, verbs, adverbs, and adjectives), boundaries before weak syllables were more likely to produce closed-class words (grammatical words like pronouns, conjunctions, and auxiliaries). The observation that in English strong syllables are more likely to be initial syllables of open-class words and weak syllables are usually closed-class words (Cutler & Carter, 1987; Cutler, 1993), indicates that listeners might develop heuristic segmentation procedures based on the structure of their language.

The statistical correspondence between strong and weak syllables and vocabulary class has led to the hypothesis that strong syllables will trigger a lexical search through a lexicon that only consists of open-class words (Cutler & Carter, 1987; Cutler, 1993). When the recognition of such an open-class word is completed and the following syllable is weak, the next lexical access attempt will be carried out in a separate closed-class lexicon. Again, vowel quality rather than stress seems to be of importance. For example, Cutler and Foss (1977) showed that phonemes were easier to detect in sentences when they carried a sentence-level accent than when main sentential stress was on another word causing the target word to be unstressed, irrespective of whether a word belonged to the open-class or to the closed-class vocabulary. A similar result was obtained by Swinney, Zurif and Cutler (1980) using a word-monitoring paradigm. They showed that both open- and closed-class words were easier to detect when they carried sentential stress than when they did not, but this tendency was only significant for the closed-class words. Therefore, Swinney and colleagues argued that speakers usually expect stress to fall on open-class items, and treat all the stressed words as potential carriers of important information. If closed-class items are stressed instead, these words will then receive the special attention that is normally reserved for open-class words.

Although the syllable carrying sentence level accent is usually the same syllable that also carries the main stress of the word, Grosjean and Gee (1987) defended that word-level stress in general facilitates the recognition of words independent of whether a word belongs to the open- or to the closed-class vocabulary. They argued that stressed syllables initiate a complex lexical search through the mental lexicon. Unstressed syllables, on the other hand, are recognized through a pattern-like recognition system which is helped by phonotactic and morphemic rules. Because unstressed syllables are most likely to be closed-class words, these words will be looked-up in an additional closed-class lexicon. Grosjean and Gee furthermore assumed that the distinction between stressed and unstressed words is more crucial than the distinction between open- and closed-class words. They suggested that all words of both vocabulary classes can be arranged in a continuum from high to low saliency, depending on the pitch, amplitude and duration they are usually produced with. Whereas words with a high saliency are processed via the lexical search method, words with a low saliency are more likely to be processed via pattern-matching. This implies that closed-class words with a high saliency can also be processed via a lexical search, just like high-saliency open-class words.

The independence of stress and word class effects has furthermore been argued for by Goldman (1991). In the first part of her study, subjects were asked to shadow passages containing stressed and unstressed open- and closed-class words. Although both open- and closed-class words were repeated faster when they carried stress, the facilitatory effect of stress was larger for the closed-class words. In addition, a main effect of word class was found in that open-class words were repeated significantly faster than closed-class words. These results were interpreted as evidence against the possibility that the difference between open- and closed-class words solely depends on their stress pattern (the word class stimuli were balanced for stress), and that open- and closed-class words are processed by different mechanisms.

3.1.2 Metrical segmentation in Dutch

The fact that, in English, stress does not serve as an access code to the mental lexicon might arise from the fact that in this language information on stress can always be derived from the segmental structure (Cutler, Dahan, & van

Donselaar, 1997). That is, weak vowels are always unstressed, and full vowels are usually stressed. However, this correspondence is less clear for Dutch, where full vowels are quite often unstressed. Based on this difference between the two languages, it could be predicted that Dutch listeners are able to use stress prelexically, and that they are thus able to rely more on stress while segmenting their language than English listeners are. The results of several recent experiments on the role of stress in Dutch indeed seem to support this prediction.

When minimal stress pairs like *CAnon* (*song*) and *kaNON* (*gun*) were embedded in a sentence context and used in a gating paradigm, Dutch listeners needed at least the entire first syllable and the beginning of the second syllable to determine whether the initial syllable was stressed or unstressed (Jongenburger & van Heuven, 1995a; Jongenburger, 1996). Nevertheless, these listeners seemed able to use the information on stress patterns in a prelexical stage of word recognition. When the embedded minimal stress pairs were used as primes in a cross-modal priming paradigm (Jongenburger, 1996), lexical decisions on semantic associates of either member of such a pair (e.g., *to sing* or *war*) were not facilitated by initially-stressed primes like *CAnon*. However, initially-unstressed primes such as *kaNON* did facilitate lexical decisions on the associates of both members.

Further evidence of a pre-lexical role of stress in Dutch, has been presented by van Donselaar, Koster, and Cutler (in preparation; see also Koster and Cutler, 1997). Subjects were faster to spot the word *zee* (*sea*) in the nonsense string *luzee* than in the nonsense string *muzee*, but only when the second syllable of the nonsense string was stressed. When the first syllable was stressed, *zee* was spotted equally fast in both nonsense strings. Because *muzee* is the beginning of the Dutch word *museum* (which carries stress on its second syllable), van Donselaar and colleagues argued that this word was activated when *muzee* was stressed on its second syllable, and competition between the words *zee* and *museum* hindered recognition of the word *zee*. They also argued that the word *museum* was not activated when *muzee* carried initial stress. These results suggest that mis-stressing a word in Dutch prevents lexical activation.

The use of strong syllables in the segmentation of Dutch has been investigated by Vroomen, van Zon, and de Gelder (1996). A replication of Cutler and Norris' (1988) experiment in which subjects had to spot an embedded word like *melk* (*milk*) in nonsense strings with either a strong-strong pattern (*mel-*

koos) or a strong-weak pattern (*mel-kəs*) showed that subjects made more errors spotting *melk* in strong-strong strings than in strong-weak strings. This result supported Cutler and Norris' assumption that a strong syllable will trigger segmentation which, in these cases, requires reassembly of speech materials across segmentation boundaries. However, their finding was only replicated for the error data and not for the reaction time data. Furthermore, as in Cutler and Norris' study, Vroomen and his colleagues did not vary stress independently of vowel quality, in that second syllables were always unstressed irrespective of a full or a reduced vowel.

In a later study by Koster and Quené (submitted), though, vowel quality and stress were independently manipulated. The second syllable of a disyllabic nonsense string could contain either a full vowel or a schwa, and stress could be placed either on the first or on the second syllable. As in Vroomen et al.'s (1996) study, the results showed an effect of vowel quality in the error data, but not in the latency data. A further effect of stress - target words followed by a stressed syllable were harder to identify than targets followed by an unstressed syllable - was argued to be due to the high acoustic saliency of the stressed syllables, since similar results were found when the targets were spliced out of their context. To verify whether the effect of vowel quality was weakened by a stronger stress effect, Koster and Quené carried out an additional study in which the target word contained a stressed full vowel, and the second syllable was unstressed irrespective of the quality of the vowel (e.g., /BER-kəf/ versus /BER-kɪf/ and /BER-kif/). Again, results showed an effect of the quality of the vowel of the second syllable in the error data, but not in the reaction time data. Based on these results, Koster and Quené concluded that the role of vowel quality is probably weaker for Dutch than for English. They furthermore argued that the fact that stressed syllables are acoustically more salient than unstressed syllables might obscure the true role of stress in speech segmentation.

Strong support for the use of a metrical segmentation strategy by Dutch listeners was provided by the results of a replication of Cutler and Butterfield's (1992) study on laboratory induced mis-segmentations (Vroomen, van Zon, & de Gelder, 1996). Like English listeners, Dutch listeners were more likely to insert an erroneous word boundary before a syllable with a full vowel (e.g., hearing *de zang* 'the song' instead of *gezang* 'singing') than before a syllable with a weak vowel (e.g., hearing *geurt de* 'smells too' instead of *geurde* 'smelled'). They also tended to delete boundaries more often before syllables with a reduced vowel (e.g., hearing *zelfbeheer* 'self-management' instead of *zelf beweerd* 'self asserted') than before syllables with a full vowel (e.g., hearing *kreukeloos* 'wrinkleless' instead of *kreupel loopt* 'limpingly walks'). Furthermore, as for English, erroneously inserted word boundaries tended to produce open-class words, and erroneously deleted boundaries more often resulted in a closed-class word.

Although in English the relation between vocabulary class and vowel quality seems to be stronger than the relation between class and stress, this does not necessarily also have to be the case for Dutch. Not only is the relation between the two vocabulary classes and the respective quality of their vowels more variable, the role of stress in general also seems to play a more important role in the lexical access procedure of Dutch versus English words. Consequently, the general correspondence between vocabulary class and stress (Cutler, 1993; Cutler & Foss, 1977; Grosjean & Gee, 1987; Swinney, Zurif, & Cutler, 1980) might cause Dutch listeners to expect stressed words to be open-class words and unstressed words to belong to the closed-class vocabulary. The present study therefore aims to investigate whether stress rather than vowel quality gives a cue to Dutch listeners as to whether a word belongs to either the open- or the closed-class vocabulary. Three word-spotting experiments will be presented in which the relation between vocabulary class, stress and vowel quality are investigated. The first experiment is focused on the question of whether the facilitatory influence of stress is identical for open- versus closed-class words. In the second experiment, the interaction between stress and the recognition of open- and closed-class words in relation to their position in the phrase is further investigated. The last experiment deals with the influence of stress versus the influence of vowel quality.

3.2 EXPERIMENT 4

In general, stressed syllables are easier to recognize than unstressed syllables, because of their higher acoustical salience. Bond and Small (1983), for example, showed that stressed syllables contribute more to word recognition than unstressed syllables. Stressed syllables are furthermore easier to recognize than unstressed syllables when they are not presented in their original context (Lieberman, 1963), and word-initial phonemes are easier to spot in stressed versus unstressed syllables of spontaneously produced utterances (Mehta & Cutler, 1988).

In continuous speech, open-class words are more likely to be stressed than closed-class words, and thus listeners might assign stressed words to the open-class vocabulary and unstressed words to the closed-class vocabulary. To investigate whether stress has indeed a different impact on the recognition of open- versus closed-class words, both stressed and unstressed versions of these items were used in a word-spotting paradigm. If stress has a facilitatory influence independent of vocabulary class, the stressed versions of both open- and closed-class words are expected to be recognized faster than the unstressed versions. However, if stress does interact with vocabulary class, open-class words are more likely to be recognized faster when they are stressed, and closed-class words will probably be processed faster when they are unstressed.

3.2.1 Method

Participants

Forty-one students participated in the current experiment. All participants were drawn from the subject pool of the Max-Planck Institute for Psycholinguistics, and were paid Dfl. 8.50. The data of five students were excluded, either because of a technical failure (1 student) or because of relatively high error percentages (> 20% errors). The remaining students were divided over two groups of eighteen participants each. The first group consisted of 15 females and 3 males with a mean age of 23. The participants of the second group, 13 females and 5 males, had a mean age of 24. None of the students participated in more than one of the experiments reported in this paper.

Materials

30 monosyllabic Dutch open-class words (nouns and adjectives) and 30 Dutch monosyllabic closed-class words (articles, conjunctions, pronouns, quantifiers, and prepositions) served as experimental item sets. Both sets contained 15 words with a relatively high frequency of occurrence and 15 words with a low frequency of occurrence (frequency was included as a variable to be able to check for a basic frequency-effect). However, the

frequency range of the open-class item set was much lower than the frequency range of the closed-class items. The mean logarithmic frequencies of the low- and high-frequency open-class words (0.60 and 1.46 logfreq, respectively) were based on the frequency counts of the Celex lexical database (1990)[10], and were shown to be significantly different on a t-test (t(28) = -3.72, p < .01, two-tailed). The difference in frequency between the low- and the high-frequency closed-class words (2.38 and 3.92 logfreq, respectively) was also significant (t(28) = -8.14, p < .01, two-tailed). The items of the open- and closed-class set were pairwise matched on their relative frequency, their number of phonemes and their structure (i.e., consonants and vowels). Furthermore, they were pairwise combined with the same legal CVVC nonsense syllable (e.g., *muts-deul* 'bonnet-deul' versus *mits-deul* 'provided that-deul'). The initial phonemes of the nonsense syllable could not form a legal word onset with the last phoneme of the preceding word. All experimental items are listed in Appendix C.

The filler item set consisted of 30 additional words (15 open class, 15 closed class) combined with a CVVC nonsense syllable, and 90 disyllabic nonsense strings. As in the experimental item set, these nonsense strings were constructed in pairs with identical second CVVC syllables (e.g., *geum-kaaf* versus *huim-kaaf*).

3.2.2 Procedure

Two lists with all items in randomized order were read by a trained female speaker of standard Dutch in a sound-attenuated cabin. In the first list, stress was placed on the first syllable. In the second list, the second syllable was stressed. All words were recorded using a Sony 670 DAT-recorder and a Sennheiser HMD 224 microphone. Inspection of the individual wave-forms showed higher amplitudes for those syllables that were intended to bear stress compared to those items that were not intended to bear stress. Furthermore, since duration is a correlate of stress (Lehiste, 1970), the durations of the stressed and unstressed versions of the open- and closed-class words were compared. Not only were the stressed versions of the open-class words significantly longer than their unstressed versions on a t-test (348 ms. versus

---

[10] *The CELEX lexical database (1991) is based on 42,380,000 word tokens of Dutch. The reported frequencies were extracted from the word-form frequency counts.*

314 ms.; $t(29) = 4.50$, $p < .01$, two-tailed), the duration of the closed-class words was also significantly longer in their stressed than in their unstressed versions (340 ms. versus 288 ms.; $t(29) = 5.24$, $p < .01$, two-tailed).

The items were divided over two list versions in such a way that each version of an item (stress on the first or on the second syllable) was assigned to a different list. Both lists furthermore contained items of both high- and low-frequency open- and closed-class words and were presented to different groups of subjects. The items of each list were randomly divided over 3 blocks, all blocks starting with four practice words and containing sixty target items. Item blocks were presented in counterbalanced order, with the order of the individual items pseudo-randomized for every three subjects. Four criteria were used for this randomization: 1) items starting with identical phonemes were not presented immediately after each other, 2) no more than three succeeding items contained a real word, 3) no more than three open- or closed-class words appeared in succession, and 4) no more than three items with similar stress patterns appeared in succession.

The participants were individually tested in a sound-attenuated booth in sessions of about fifteen minutes. They were seated in front of a microphone and listened to the items over headphones. Subjects were given written instructions to listen to the items carefully, and decide as fast and as accurately as possible whether an item contained a real word as its first syllable. As soon as such a real word was detected, a response button labelled 'yes' had to be pressed with the dominant hand. If no word was detected, no response was required. It was further emphasized in the instructions that real words could not only be nouns, but for example, also articles or prepositions. After a real word had been detected, subjects were asked to repeat the detected word as soon as a star appeared on the computer screen in front of them. After a practice block of thirty-six items, subjects were allowed to ask questions. A short break was given after each of the following blocks.

Both the presentation of the stimuli and the on-line data collection was controlled by a Hermac AT-computer. Starting from the onset of an item, a push-button was enabled for 2500 ms. After 900 ms., a star appeared on the computer screen for an additional 900 ms. A voice key was enabled for 3400 ms. from the appearance of the star. If no response was given, the next trial started after 2500 ms. All spoken responses were recorded using a Sony DTC 55 ES DAT-recorder. Scoring of the repetition responses was done on-line by the experimenter. In case of an unclear response, the recordings were consulted.

3.2.3 Results and discussion

Word-spotting latencies were measured from the onset of each item. Latencies were excluded from the analysis if the word was not detected within the time-out period (13% of the data) or if a response was followed by a faulty repetition (1%). Furthermore, latencies exceeding the mean RT per condition by plus or minus three standard deviations were discarded (2%). Empty cells were replaced by the overall mean reaction time per condition.

Results were analyzed using two-way analyses of variance with the two within-subject factors stress (stressed versus unstressed) and frequency (low versus high). Because of the different frequency ranges of the open- and closed-class words, the two types of words were analyzed separately. Analyses were performed both across subjects (F1) and across items (F2). The mean latencies of both the open- and the closed-class words are represented in Figure 3.1.

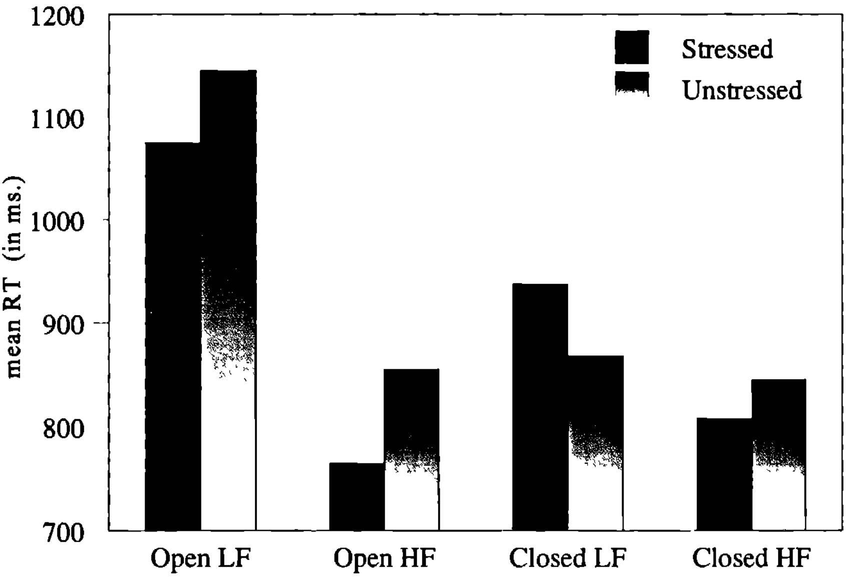

Figure 3.1 *Results of experiment 4. Mean word-spotting latencies for stressed and unstressed open- and closed-class words of low (LF) and high frequency (HF), with word targets being the first syllable of a disyllabic nonword.*

In the open-class item set, a main effect of stress was found in that the stressed versions were recognized faster than the unstressed versions (902 ms. and 998 ms., respectively; $F1(1,35) = 24.69$, $p < .01$, $MSe = 8877$; $F2(1,28) = 34.06$, $p < .01$, $MSe = 2697$).

Furthermore, high-frequency words were recognized faster than low-frequency words (810 ms. and 1108 ms., respectively; ($F1(1,35) = 441.55$, $p < .01$, $MSe = 7238$; $F2(1,28) = 57.05$, $p < .01$, $MSe = 23396$). No interaction was found between stress and frequency. The analysis of the errors showed fewer errors for the stressed (10%) versus the unstressed (19%) versions of the open-class words ($F1(1,35) = 17.83$, $p < .01$, $MSe = .02$; $F2(1,28) = 11.78$, $p < .01$, $MSe = .01$). Fewer errors were also found for the high- (7%) versus the low-frequency words (21%) ($F1(1,35) = 39.64$, $p < .01$, $MSe = .02$; $F2(1,28) = 6.72$, $p < .05$, $MSe = .04$). Again, there was no interaction between stress and frequency.

High-frequency closed-class words were recognized faster than low-frequency closed-class words (826 ms. versus 912 ms., respectively; $F1(1,35) = 42.90$, $p < .01$, $MSe = .5790$; $F2(1,28) = 6.48$, $p < .05$, $MSe = 16768$). However, closed-class words revealed a different effect from the open-class words with respect to the influence of stress, in that they showed the tendency to be recognized faster when unstressed (873 ms.) than when stressed (866 ms.). This effect did not reach significance, though. However, because of a significant interaction between stress and frequency ($F1(1,35) = 7.34$, $p < .01$, $MSe = 10232$; $F2(1,28) = 8.21$, $p < .01$, $MSe = 3608$), the effect of stress was also inspected for the high- and low-frequency items separately. For the high-frequency item group, no significant difference between the stressed and the unstressed versions was found in a post-hoc Newman-Keuls analysis. For the low-frequency closed-class words, on the other hand, the unstressed versions were recognized significantly faster than the stressed versions ($F1(1,35) = 9.29$, $p < .05$, $MSe = 5646$; $F2(1,14) = 5.00$, $p < .05$, $MSe = 4034$). The amount of errors made in the stressed versions of the closed-class words (7%) did not differ significantly from the unstressed versions (6%), nor did the amount of errors differ for the high-frequency group (5%) versus the low-frequency group (8%).

However, since unstressed words tend to have shorter durations than stressed words (Nooteboom & Cohen, 1984), the faster latencies for the unstressed versus the stressed versions of the closed-class words might actually be due to their duration. Measurement of the durations indeed showed significantly longer durations for the stressed versions of the closed-class words (340 ms.) Than for the unstressed versions (288 ms.) on a t-test (t(29) = 5.24, p < .01, two-tailed). Nevertheless, Pearson correlation analyses showed no significant correlations between the duration of the closed-class words and their corresponding mean latencies.[11]

These results suggest that stress does not necessarily always have a facilitatory effect on the recognition of words - whereas the processing of open-class words is facilitated by stress, the recognition of relatively low-frequency closed-class words is actually hindered by the occurrence of stress. This observation thus seems to confirm the hypothesis that Dutch listeners indeed expect stressed words to belong to the open-class item set and unstressed words to be members of the closed-class item set.

However, the results might have been influenced by the position of the word in the nonsense string. Whereas in Dutch closed-class words normally occupy the initial position of a disyllabic phrase, open-class words are more likely to be in the final position (e.g., *het kind 'the child'* or *mijn huis 'my house'*). If the listeners perceived the disyllabic nonsense strings as two-word phrases, the effect of stress on the open-class words could have interacted with the unexpected occurrence of a string-initial open-class words. Therefore, a second experiment was carried out in which the order of the nonsense syllable and the real word was switched; the open- and closed-class words were now placed in the second syllable of the disyllabic nonsense strings (i.e., string-final). If stress is a reliable cue to which class a word belongs to - independent of the position of the item in the string and of the expectations of listeners - the results are expected to be similar to the findings of the previous experiment in that open-class words will be recognized faster

---

[11] *A pilot experiment in which 40 subjects were asked to respond right after the presentation of the nonsense strings, showed similar results for both the open- and the closed-class data. Both low- and high-frequency open-class words were recognized faster when stressed than when unstressed, but this result was only significant for the high-frequency open-class words. Furthermore, low-frequency closed-class words were recognized significantly faster when they were unstressed, and stress did not have any influence on the recognition of high-frequency closed-class words. Because of extremely high error values, however, some items were replaced by others for the main experiment, and four changes were made in the procedure: 1) the practice block was extended from 12 to 36 items, 2) subjects were told that the real words were not only nouns, 3) subjects were asked to respond after the appearance of a star, and 4) subjects were given more time to respond.*

when they are stressed, and closed-class words will be recognized faster when they are unstressed.

3.3 EXPERIMENT 5

3.3.1 Method

Participants

Forty-two students were drawn from the subject pool of the Max-Planck Institute for Psycholinguistics. The data of four students was excluded, because the error-score of these students exceeded the 20% cut-off. The remaining students participated in two groups of eighteen participants each: the first group of students consisted of 7 females and 11 males (mean age of 24 years old), and the second group contained 11 females and 7 males (mean age of 23). All students were paid Dfl. 8.50 for their participation.

Materials

The materials were identical to the materials used for the previous experiment, with the exception that the order of the syllables were switched. Thus, when an item contained a real word, this word now occupied the second instead of the first syllable (e.g., *deul-muts* 'deul-bonnet'). For the experimental items, nonsense syllables were replaced by new syllables if the last consonant of this syllable could function as a legal word onset with the first consonant of the following target word. The experimental items are listed in Appendix D.

Procedure

The procedure was as in the previous experiment, with two exceptions. First, new recordings were made to ensure a natural transition between the two syllables. Second, subjects were instructed to determine whether the second instead of the first syllable of an item was a real word or not. The items were presented in exactly the same orders as in the previously described experiment.

3.3.2 Results and discussion

Measurement of the word-spotting latencies was made from the onsets of the second syllables. Responses given after the time-out period (8%) and responses followed by a faulty repetition (1%) were discarded. Outliers were defined as those latencies that exceeded the mean reaction time per condition by plus or minus 3 standard deviations (4%). Both the missing values and the outliers were replaced by the overall mean reaction time per condition. The responses for the open- and closed-class item groups were analyzed using a two-way analysis of variance with the within-subject factors stress (stressed versus unstressed) and frequency (high versus low). Again, the analyses took place both across subjects (F1) and across items (F2). In Figure 3.2, the word-spotting latencies of both the open- and closed-class item groups are presented.

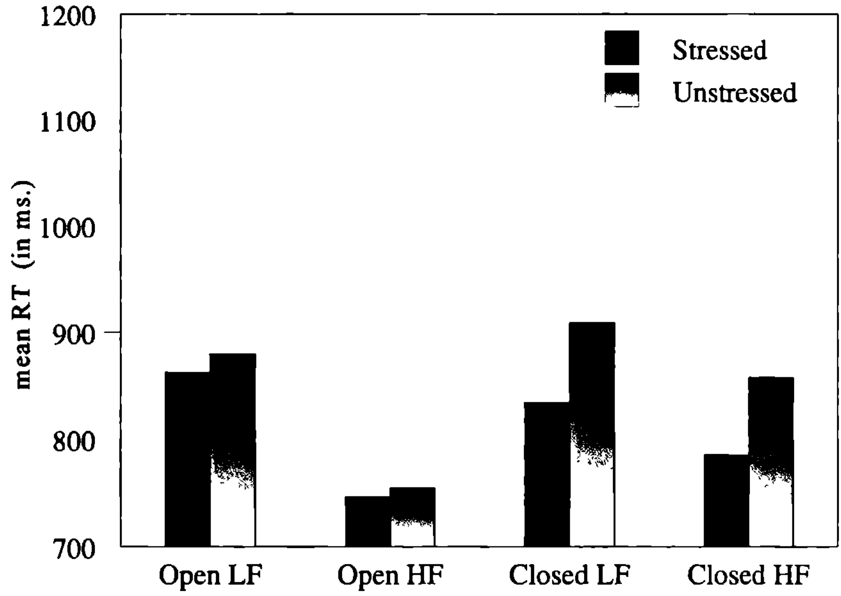

Figure 3.2 *Results of experiment 5. Mean word-spotting latencies for stressed and unstressed open- and closed-class words of low (LF) and high frequency (HF), with word targets being the second syllable of a disyllabic nonword.*

The results of the open-class item condition showed that although stressed words were recognized somewhat faster than unstressed words (805 ms. versus 818 ms.) this effect was not significant. There was no significant interaction between frequency and stress which indicated that the effect of stress was similar for open-class words of both high- and low-frequency. The effect of frequency, however, was highly significant in that the high-frequency items (751 ms.) were detected considerably faster than the low-frequency items (871 ms.) (F1(1,35) = 128.56, p < .01, MSe = 3902.46; F2(1,28) = 21.81, p < .01, MSe = 9995.17). The analyses of the error responses revealed a non-significant effect of stress (7% errors in both stressed and unstressed open-class words), but significantly more errors were made to the low-frequency words (11%) compared to the high-frequency words (3%) (F1(1,35) = 19.92, p < .01, MSe = .01; F2(1,28) = 8.07, p < .05, MSe = .01). Again, no interaction between stress and frequency was found.

For the closed-class words, a main effect of stress was found; stressed closed-class words were detected faster than unstressed closed-class words (786 ms. versus 858 ms.; F1(1,35) = 106.74, p < .01, MSe = 1855.86; F2(1,28) = 19.62, p < .01, MSe = 77488.24). Furthermore, an effect of frequency was found with high-frequency words recognized faster than low-frequency words (786 ms. versus 858 ms.; F1(1,35) = 82.37, p < .01, MSe = 4398.38; F2(1,28) = 7.48, p < .05, MSe = 20275.80). The pattern of the word-spotting latencies was mirrored in the error pattern. Not only were fewer errors found for the stressed items when compared to the unstressed items (5% versus 10%; F1(1,35) = 11.09, p < .01, MSe = .01; F2(1,28) = 5.75, p < .05, MSe = .01), there were also fewer errors found for the high-frequency items (7%) when compared to the low-frequency items (4%; F1(1,35) = 22.02, p < .01, MSe = .01; F2(1,28) = 4.06, p = .05, MSe = .02). The interaction between stress and frequency did not reach significance in the analysis of the errors.

These findings clearly show a different pattern from the results of the previous experiment; whereas stress had a large facilitatory effect on the recognition of open-class words in string-initial position, the effect of stress on the recognition of open-class words in string-final position was absent. Furthermore, whereas low-frequency closed-class words in string-initial position were recognized more slowly when they were stressed, this inhibitory effect of stress disappeared when they were presented in string-final position. In fact, stressed closed-class words were now recognized significantly faster than their unstressed variants. Although the previous results indicated some relationship between stress and vocabulary class, the present observation that the effect of stress on the recognition of a word varies with the position of this word in a string strongly suggests that stress in Dutch is not a reliable indicator of vocabulary class.

However, this interpretation should be viewed cautiously since it is possible that the results may (at least in part) have been caused by effects of vowel quality, since stress and vowel quality were not independently manipulated. Therefore, a third experiment was needed to disentangle the influences of both these factors.

3.4 EXPERIMENT 6

In English, unstressed words are more likely to have a reduced vowel and stressed words always have at least one full vowel (Altmann & Carter, 1989). However, there is no clear one-to-one correspondence for Dutch; unstressed words, for example, quite often have no reduced vowel. It is therefore hard to determine whether the previously reported effects are indeed due to stress or whether there is also some interaction with vowel quality. In the present word-spotting experiment, stress and vowel quality were therefore separately manipulated.

3.4.1 Method

Participants

The students taking part in this experiment were recruited from the subject pool of the Max-Planck Institute and received FL. 8.50 for their participation. The data of one subject out of 49 was excluded because of a technical failure. The remaining participants were randomly assigned to one of three subject groups of 16 students each. Two groups consisted of 11 females and 5 males, the other group contained 12 females and 4 males. The mean age of the participants of each group was 23 years.

Materials

The experimental item set consisted of three sets of words which differed with respect to their vowel quality. The first item set contained 11 open- and 11 closed-class words with a full vowel (e.g., *dom* 'stupid' and *per* 'by'). The items of the second set were variants of the words of the first set in that all vowels were reduced to a schwa (e.g., *dəm* and *pər*). In the third item set, the vowel of the 11 open- and 11 closed-class words was a lexicalized schwa (e.g., *dun* 'thin' and *de* 'the'). The items of the first and the final set, were presented to the subjects both when stressed and when unstressed. The words of the second set were only presented in their unstressed form.

Not only did the frequencies of the open-class words with a lexicalized schwa (0.67 logfreq) not differ significantly from the frequencies of the open-class words with a full vowel (0.82 logfreq), the frequencies of the closed-class items containing a lexicalized schwa (2.88 logfreq) also did not differ from the frequencies of the closed-class words having a full vowel (3.10 logfreq). The items of each group were as closely matched as possible on their number of phonemes. Except for the closed-class words with a lexicalized schwa, which had an average length of 2 phonemes, the mean length of the words was 3 phonemes.

All open- and closed-class words were combined with a legal nonword of a CVVC structure. Because many of the closed-class words with a lexicalized schwa are only used in their cliticized form (e.g., *geef-əm 'give him'*), all words were placed after the nonsense syllable, i.e., string-final. 74 filler/practice items were also constructed. These fillers consisted of two legal nonsense syllables. In Appendix E, all experimental phrases are listed.

Procedure

The items were read out from two randomized lists by a trained female speaker of standard Dutch. Whereas in the first list stress was placed on the first syllable, in the second list, the second syllable was stressed (the reduced words were only recorded as unstressed). The words were recorded in a soundproof booth using a Sennheiser HMD224 microphone and a Sony 670 DAT-recorder.

The experimental items were divided over three item lists in such a way that corresponding items with a full vowel (stressed or unstressed) or with this vowel reduced to a schwa belonged to a different list. This resulted in 36 experimental words for list 1 and 3, and 38 experimental words for the second list.[12] In each list, an equal number of nonsense filler items was added. All items of a list were randomly divided over two blocks starting with four practice items. The order of the words was adapted following four criteria: 1) no more than three stressed or unstressed words appeared in succession, 2) no items with identical initial phonemes appeared in succession, 3) only three items of the same vocabulary class were allowed to occur in succession, and 4) a maximum of 3 strings containing a real word appeared in succession. The practice block contained of 36 items. The instructions to the subjects and the testing procedure were the same as in experiment 5.

3.4.2 Data analysis and results

Word-spotting latencies were adjusted so as to measure from target word onsets. Trials were excluded from the analysis either when no response was given within the time-out period, i.e., the response was made after the critical cut-off, or the subject did not respond at all (35% of the data), or when the response was not followed by a correct repetition of the word (1%). Furthermore, data was also excluded when the mean reaction time per condition was exceeded by plus or minus 3 standard deviations (1%). All missing latencies were substituted by the overall mean reaction time per condition. Because subjects failed to recognize all the open-class words with reduced vowels and recognized only 3% of the reduced closed-class words, these data were not entered into the statistical analysis. Two-way analyses of variance with the two within-subject factors vowel quality (full versus schwa) and stress (stress versus unstressed) were performed on the remaining open- and closed-class data separately, that is on stressed and unstressed versions of words having either a full vowel or a lexicalized schwa. The mean word-spotting latencies for both the open- and the closed-class item group are presented in Figure 3.3.

---

[12] *Recall that the total number of items was 110: 11 open-class words with a full vowel (stressed and unstressed), 11 closed-class words with a full vowel (stressed and unstressed), 11 open-class words with a reduced vowel (unstressed), 11 closed-class words with a reduced vowel (unstressed), 11 open-class words with a lexicalized schwa (stressed and unstressed), and 11 closed-class words with a lexicalized schwa (stressed and unstressed).*

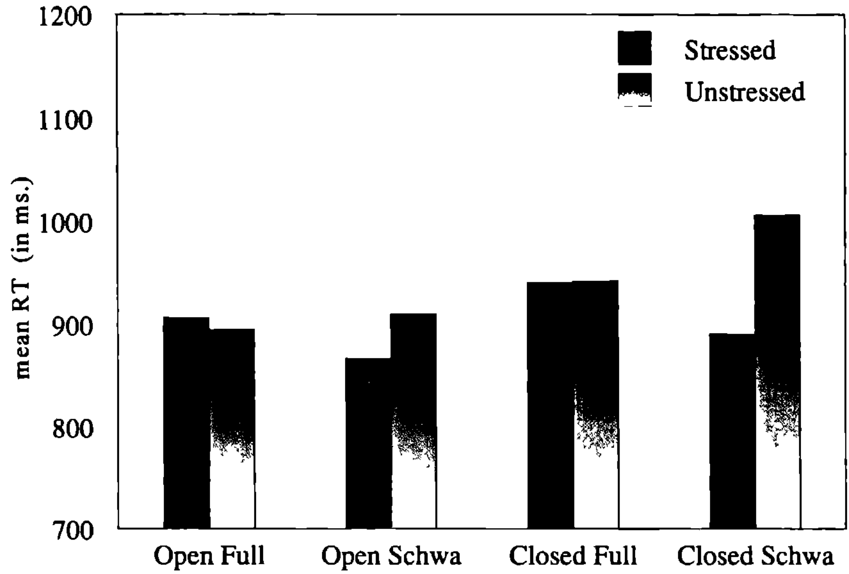

Figure 3.3 *Results of experiment 6. Mean word-spotting latencies for stressed and unstressed open- and closed-class words with either a full vowel (Full), or with a lexicalized reduced vowel (Schwa), with word targets being the second syllable of a disyllabic nonword.*

For the open-class item group, neither an effect of vowel quality, nor an effect of stress could be found in the detection latencies. However, significantly more errors were made in the open-class words containing a schwa (19%) than in the open-class words with a full vowel (10%) (F1(1,47) = 156.69, p < .01, MSe = 156.69; F2(1,20) = 5.05, p < .05, MSe = .21). This result is probably due to the fact that the schwa is acoustically less salient than the other vowels. Stress did not influence the amount of errors made in words with either vowel quality.

For the closed-class item group, both a significant main effect of stress (F1(1,47) = 11.08, p < .01, MSe = 13567.84; F2(1,20) = 9.48, p < .01, MSe = 3894.76) and a significant interaction between stress and vowel quality were found (F1(1,47) = 13.43, p < .01, MSe = 14514.83; F2(1,20) = 9.31, p < .01, MSe = 3894.76). Post-hoc Newman-Keuls analyses showed that whereas for closed-class words with full vowels stress did not have an influence on their recognition, for closed-class words with a lexicalized schwa stress did have a facilitatory effect. As with the open-class words, more errors were made in the closed-class words with a lexicalized schwa (46%) than on closed-class words with a full vowel (15%). This difference, however, only reached significance when analyzed over subjects ($F1(1,47) = 156.69$, $p < .01$, $MSe = 156.69$; $F2(1,20) = 1.30$, $p > .05$ ns., $MSe = .07$). Stress had no significant effect on the number of errors made on closed-class words.

To summarize, both open- and closed-class words were extremely hard to recognize when a full vowel was reduced to a schwa. In addition, the findings of the previous experiment were replicated in that stress did not have a large influence on the recognition of open-class words (with either a full vowel or a lexicalized schwa) when they were presented in second phrase position, but the recognition of closed-class words in this position was facilitated by stress when these words are normally produced with a schwa.

3.5 GENERAL DISCUSSION

Our mental lexicon might be split into separate open-class and closed-class lexicons. Such a dual lexicon assumption implies that the incoming speech contains a cue to which vocabulary class a word belongs. As proposed for English by Cutler and Norris (1988; Cutler, 1993), this cue might be the strength of the vowel of an incoming syllable - strong syllables will be looked up in the open-class lexicon and weak syllables will be submitted to the closed-class lexicon (i.e., a metrical segmentation strategy). The current study investigated whether in Dutch the relation between stress and vocabulary class is stable enough to indicate whether the open- or the closed-class store should be accessed. If this is stable, and words are stored in separate lexicons, open-class words should then be easier to recognize when they are stressed, and closed-class recognition should be faster when the words do not carry stress.

A first experiment in which monosyllabic open- and closed-class words were placed in the first syllables of disyllabic nonsense strings showed that the recognition of open-class words was indeed facilitated by stress. Furthermore, closed-class words were easier to recognize when they were unstressed, but only when they had a relatively low frequency of occurrence.

Although this experiment thus seemed to support dual storage, the results of a second experiment certainly did not. When the open- and closed-class words were presented in string-final position, stress had only a slight facilitatory influence on the recognition of open-class words, and an unexpected large facilitatory influence on closed-class recognition.

Although a dual-lexicon theory can explain why stressed open-class words are processed faster than unstressed open-class words (unstressed open-class words will first erroneously be submitted to the closed-class lexicon), such a theory cannot easily account for the finding that the recognition of only low-frequency closed-class words was delayed when the words were stressed. Because all closed-class words will be submitted to the open-class lexicon when they carry stress, the inhibitory effect of stress should appear for closed-class words of both high and low frequency. In addition to this discrepancy between items of different frequency, a simple dual-lexicon hypothesis also has problems explaining why the influence of stress on the recognition of both the open- and closed-class words varies with the position of these words in the string. If the correspondence between stress and word class were reliable, stress should have a stable effect on the recognition of these words.[13]

The dual lexicon hypothesis therefore seems not sufficient to explain the observed effects of stress. An alternative explanation for these effects might be the fact that stress in general has an acoustic facilitatory effect on the recognition of words. In the current experiments, open-class words in string-initial position where recognized faster when they carried stress (experiment 4), open-class words in string-final position were also recognized faster when they carried stress, although this effect did not reach significance (experiment 5), and closed-class words in string-final position also tended to be recognized faster when they were string-final (experiment 5, closed-class words with a lexicalized schwa in experiment 6). The larger effect of stress for open-class words in string-initial versus string-final position might be accounted for by the assumption that stress has a larger facilitatory influence on words that are perceptually less clear (because of following acoustic materials) than on words that are followed by silence.

---

[13] *The finding of faster reaction times for stressed closed-class words in string-final position also rules out a dual lexicon hypothesis in which closed-class words are listed in both the open- and the closed-class lexicon (as for example proposed by Grosjean and Gee, 1987), since the processor for unstressed closed-class words is expected to be faster than the processor for stressed closed-class words because of the absence of a lexical search through the lexicon.*

Although the acoustic facilitatory effect of stress thus seems able to explain most of the observed effects, string-initial closed-class words were not easier to recognize when they were stressed. This observation might be explained by an additional account of mis-stressing. In Dutch (as in English), the default word order of a two-word phrase is an unstressed closed-class word followed by a stressed open-class word, for example 'the chair' or 'my book'. Phrase-initial closed-class words are only stressed when they are used with emphatic stress or in a contrastive situation. Because such a situation was not created in the present experiment, a string-initial closed-class word which is stressed might thus sound mis-stressed to a listener, which will delay recognition of such a word. A mis-stressing account can also explain the discrepancy between the high- and low-frequency closed-class words. Mis-stressing will have the greatest impact on items which have a relatively low frequency of occurrence. Compensatory strategies based on frequency must be used to recognize high-fequency words, masking their slower recognition. Finally, open-class words clearly can appear in phrase initial position without appearing mis-stressed.

If our mental lexicon is divided into open- and closed-class words but the correspondence between stress and vocabulary class is too variable to determine which of these lexicons to access, there should be some other cue in the incoming speech which enables a choice between the two lexicons. The neglect of this important factor in previous studies of storage and access of open- versus closed-class words seems partly due to the fact that many of these studies focused on speech production rather than on speech perception. For example, in his study of the successive stages of speech production, Garrett (1975; 1980) observed that open- and closed-class words were distinctively affected by different types of errors, motivating the assumption of dissimilar processing in production of open- versus closed-class words. In addition, Golston (1991) showed that the production of open- and closed-class words meets different requirements on both the size of a prosodically well-formed word and on the involvement in word-formation processes such as affixation and compounding. Other studies that have concentrated on the perception of the two vocabulary types were often directed to the processing distinction per se, or otherwise aimed at proving the disfunctioning of a special retrieval system for closed-class words in language disturbed listeners (e.g., Bradley, 1978; Bradley, Garrett, & Zurif, 1980).

However, one study that did focus on cues that can be used to access the mental lexicon is the earlier mentioned investigation by Cutler and Carter (1987). They argued that, for English, the quality of the vowel is the crucial indication of vocabulary class since open-class words are nearly always produced with a full vowel and closed-class words are more likely to be produced with a reduced vowel. Yet, the present third experiment suggests that for Dutch listeners, vowel quality is not a better cue than stress to base lexical access on, since open-class words were not consistently recognized faster when their vowels were full, and recognition of closed-class words was not better when they had reduced vowels. The almost complete failure of these listeners to recognize words from both vocabulary classes when these words were presented in their reduced form furthermore indicates that the results of experiments 4 and 5 are true effects of stress - if the stress manipulation in these experiments had also caused a change in vowel quality, recognition of the unstressed open- and closed-class words would presumably have been considerably worse.

Syntactic context has been proposed as another possible cue to vocabulary class by Shillcock and Bard (1993). Based on the results of a cross-modal priming experiment, they suggested that closed class words are interactively processed, such that the syntactic context determines look-up of these words in a closed-class lexicon. Shillcock and Bard furthermore argued that since closed-class words are often realized as weak syllables and a poor acoustic input is likely to activate quite a large set of lexical competitors, syntactic information could be useful to constrain the set of word candidates to the most likely ones. Because the correspondence between stress or vowel quality and vocabulary class is rather incomplete, listeners might thus use the syntactic context as an additional cue to assign a word to the closed-class vocabulary.

This result seems to confirm the earlier study by Goldman (1991) in which open- and closed-class words preceded by a sentence context were used in a gating paradigm. Listeners not only needed a larger percentage of an open-class word than of a closed-class word for word identification, they also needed a larger percentage of an open-class word for a maximal acceptance score (i.e., when both the correct word was identified and the maximum confidence rating was given). Goldman therefore argued that recognition of open-class words is mainly based on acoustic information, but recognition of closed-class words is also highly influenced by higher-level processes such as knowledge of word classes and the structure of a language. However, since a recent priming study (see chapter 5) failed to replicate Shillcock and Bard (1993), and a gating paradigm does not investigate on-line processing, the use of the syntactic context as a cue to vocabulary class is left uncertain.

A remaining question is whether the distinction between open- and closed-class words should be implemented in current models of spoken word recognition, even if the vocabulary class of a word cannot completely be predicted from the acoustic signal. As outlined for English by Cutler and Carter (1987), the implementation of a dual lexicon would be rather simple. An initial scanning procedure places markers at the onset of every strong syllable. Successively, those items that are preceded by a marker are submitted to an open-class lexicon. All other items are looked-up in a closed-class store (see Cutler and Butterfield (1992) for a comparison between a rhythmic segmentation algorithm and other segmentation algorithms).

An advantage of the implementation of a dual lexicon into word recognition models could be at least a partial elimination of the problem of lexical embedding. For example, the high-frequency closed-class word *me* will interfere with the recognition of the low-frequency open-class word *medium*, unless the first strong syllable initiates a lexical search through an open-class lexicon. However, McQueen, Cutler, Briscoe, and Norris (1995) showed that even if this problem with embedded closed-class words is solved, there are still many words in which an open-class word is embedded. Although the frequency of these open-class words is usually lower than the frequency of closed-class words, recognition of the entire word will still suffer from interference with the embedded open-class word. Therefore, storage of closed-class words in a separate lexicon will reduce the problem of lexical embedding only little.

Furthermore, implementation of the dual storage hypothesis in spoken word recognition models is problematic since neither vowel quality or stress are reliable cues to the vocabulary class of a word. The system would thus have to deal with erroneous look-ups of closed-class words in the open-class lexicon and erroneous search for open-class words in the closed-class lexicon. In addition, it is rather unclear whether word recognition would indeed be a great deal faster when the vocabulary is divided into two separate sub-lexicons instead of storage of open- and closed-class words in one single lexicon. For example, if the frequency of words plays a role in word access, in that high-frequency words are accessed before low-frequency words (as for example proposed by frequency-based models like Forster's (1976, 1981) search model or Luce's (1986) Neighborhood Activation Model), high-frequency closed-class words will be accessed before low-frequency open-class words. Since the closed-class item group is a relatively small set of words - approximately 200 words for English (Petocz and Oliphant, 1988) and about 400 words for Dutch (van Wijk & Kempen, 1980) - recognition of open-class words would not be considerably slower for one versus two lexicons.

Although the role of stress in running speech might thus not be to direct lexical access to either an open- or a closed-class lexicon, stress might still be used as a probabilistic indicator to the onsets of words. The latter possibility has been implemented in the Shortlist model of spoken word recognition, originally developed by Norris in 1994 (Norris, McQueen, & Cutler, 1995). In the first stage of this model, a restricted set of candidate words or 'shortlist' is selected, based on both bottom-up activation and inhibition from the acoustic signal. Furthermore, continuous activation of candidate words takes place, irrespective of the starting point of these words in the input. In the second stage of the Shortlist model, the best fitting words enter an interactive activation network were they compete with each other via lateral inhibition. The greater probability of a strong syllable being a word onset is realized by an activation boost which is given to candidates which have a strong onset and which are also aligned with a strong onset in the speech signal. Candidates which do not have a strong onset where one is matched in the input are penalized. Thus in Shortlist, syllable strength is not able to determine which words are accessed, but it can influence the degree of activation of these words.

The present data are consistent with such a role of stress, because the correspondence between stress or vowel quality and the vocabulary class of a word was found not to be completely stable. The fact that the influence of stress depended on both frequency of occurrence and on the position of the word in the nonsense string furthermore indicates that these factors need to be properly controlled in further studies of effects of stress in general. In addition, the observation that stress tended to facilitate syllable recognition independently of the vocabulary class of a word is consistent with the higher likelihood of a stressed syllable to be a word-onset, since word-onsets should be perceptually salient. Moreover, the finding that stressed words are in general easier to perceive than unstressed words confirms the common view that stress has a facilitatory effect on word recognition.

The next chapter investigates whether the relationship between stress and vocabulary class is more stable when open- and closed-class words are used in meaningful phrases and sentences than in the nonsense context used in the present chapter. As mentioned above, a fairly stable relationship between stress and vocabulary class would be necessary if incoming open- and closed-class words are classified on-line and assigned to either an open- or a closed-class lexicon. The reality of such a dual lexicon is the focus of the next chapter. After a review of evidence for either a single or a dual lexicon, new data will be presented and discussed with respect to the storage of open- and closed-class words.

ONE OR TWO MENTAL LEXICONS? STRESS AS A PRE-LEXICAL CUE

CHAPTER 4

(This chapter is based on an article submitted to Memory and Cognition)

ABSTRACT

Whereas single-lexicon hypotheses assume open- and closed-class words to be stored in the same mental lexicon, dual-lexicon hypotheses claim storage in separate lexicons. Dual storage requires that there is an ambiguous cue to vocabulary type in the acoustic signal, and would be supported by evidence that listeners indeed use such a cue. The current study therefore investigated whether, for Dutch listeners, stress facilitates open-class recognition but hinders closed-class recognition. The results showed unstable effects of stress for words presented both in nonsense (in the word-spotting paradigm) and in meaningful contexts (in the lexical decision task). Furthermore, when open-class/closed-class homophones were embedded in carrier words, stress did not prevent the closed-class meaning of the homophone from being activated. These findings strongly suggest that stress is not a reliable cue to vocabulary class, and the results are inconsistent with storage of open- and closed-class words in separate mental lexicons.

4.1 INTRODUCTION

Searching for a particular word in our extensive mental lexicon is a highly complex procedure. One possible way to reduce the complexity could be efficient organization of all the stored words into sublexicons. Plausible candidates to base such an organization on are those groups of words that are rather distinctive from each other such as open- versus closed-class words. The open-class item group is an extendable, large set of words, consisting of nouns, verbs, adjectives, and most of the adverbs. The members of these groups have in common that they convey a rather clear lexical meaning, and most of these words contain at least one full vowel. The closed-class item group, on the other hand, has a fixed, small size. Its members are words with a more grammatical function, like pronouns, conjunctions, and determiners, usually with a reduced vowel. Since this small set of closed-class words are used with a fairly high frequency, the lexical search for closed-class words could be considerably faster if these words were stored separately from the enormous number of open-class words.

Although separate storage of open- versus closed-class words thus seems attractive, theories of language perception which incorporate the assumption of a dual lexicon have to provide an answer to several important questions. For instance, are the advantages of a dual lexicon in terms of faster speech processing real advantages if word retrieval turns out to be based on frequency, and what will happen if the wrong lexicon is accessed? And, above all, what are the cues in the acoustic speech signal that are used to decide which lexicon to access, and if there are no cues, on what basis could the decision be made? In the next sections, these questions will be discussed in the light of both single-lexicon approaches (which assume that all words are stored in just one mental lexicon) and of dual-lexicon approaches.

4.1.1 Single-lexicon hypotheses

One source of evidence for storage of open- and closed-class words in a single mental lexicon is effects of frequency. Forster (1981) compared naming latencies for high-frequency words presented in pure-frequency lists (only containing high-frequency words) versus responses to the same words presented in mixed-frequency lists (consisting of high-, medium-, and low-frequency words). Forster argued that faster reaction times for words in pure lists would suggest a dual lexicon; whereas for pure lists, lexical look-up will mainly take place in a limited lexicon with common high-frequency words (probably mostly closed-class words), for mixed lists, lexical look-up will take place both in this limited lexicon and in an additional complete lexicon. Because the limited lexicon will only be consulted in a certain proportion of words depending on the number of preceding high-frequency words in the list, latencies will be slower for the mixed lists compared to the pure lists. Although such a result was found by Glanzer and Ehrenreich (1979) in a lexical decision task, Forster (1981) did not find different naming latencies for high-frequency words in pure- versus mixed-frequency lists. He therefore concluded that a lexical search is more likely to be carried out in one single mental lexicon, starting at the entry with the highest frequency (a frequency-ordered search model of lexical access). These results are also in line with (currently more accepted) parallel processing models in which incoming information is simultaneously compared with all the relevant information in the lexicon (see Gordon (1983) for data supporting parallel processing models).

Frequency has also played a major role in the debate on processing and storage of open- versus closed-class words by agrammatic patients. Agrammatism is part of the larger syndrome of Broca's aphasia and is, in language production, characterized by the omission of both closed-class words and inflections. However, agrammatic patients also seem to be impaired with respect to the perception of open- versus closed-class words. For example, Bradley (1978) showed that for language unimpaired subjects, lexical decisions on open-class words depended on the frequency of occurrence of these words. For closed-class words no such relation was found. However, when agrammatic subjects performed the same task, the recognition of both open- and closed-class words turned out to depend on their frequency. Bradley therefore argued that normal subjects can access closed-class words both through a frequency-dependent routine (via the main lexicon) and through a frequency independent routine (via a closed-class lexicon). Yet this specialized access system for closed-class words cannot be used by agrammatic patients.

The relative importance of this type of evidence for both normal and abnormal language processing has triggered many attempts to replicate Bradley's findings, not only for English (Gordon & Caramazza, 1982), but also for French (Segui, Mehler, Frauenfelder, & Morton, 1982; Segui, Frauenfelder, Lainé, & Mehler, 1987). However, all studies failed to replicate

Bradley's finding of frequency independent access of closed-class words as predicted by the hypothesis of a dual lexicon.

A theory on agrammatism which incorporates the assumption of a single lexicon has been put forward by Bates and Wulfeck (1989). They proposed that the factors determining retrieval of open-class words from the mental lexicon are distinct from the factors that determine closed-class retrieval. Since these factors are differentially sensitive to stress or noise, it is not surprising to find dissociations between open- and closed-class words, even when these words are stored in a unified lexicon.

Bates and Wulfeck mentioned furthermore that division of words into open- and closed-class item sets is not easy, since the open-class/closed-class contrast is not as clear as it might seem on first sight. Instead of two clear-cut categories, the classes might be better described as 'fuzzy sets' containing a few prototypical words and a large set of borderline cases. In addition, closed-class words do not always show a homogeneous pattern in agrammatic sentence comprehension and production. For example, Friederici (1982) showed that the availability of prepositions to aphasic patients in speech production and perception depended on their functional role (syntactic/semantic) in the sentence. Furthermore, Friederici, Weissenborn and Kail (1991) demonstrated a relatively high level of agrammatic performance on the comprehension of pronouns. A more precise distinction than the open-class/closed-class difference thus seems needed to describe the language impairment of agrammatic patients.

4.1.2 Dual-lexicon hypotheses

The hypothesis that open- and closed-class words are differentially processed and separately stored has mainly been based on two types of evidence: the production of speech errors and observations from agrammatic patients. With respect to speech errors, Garrett (1975, 1980, 1982) postulated a theory of language production based on his observation that open- and closed-class words engaged in different types of speech errors. Open-class words, for example, are mainly involved in word-exchange errors such as *the room to my door* instead of *the door to my room*, which typically evolve at a functional level of sentence representation (where both phrasal membership and grammatical roles are determined). Other error types in which open-class words are frequently involved are word substitution errors, which can result both from retrieval based on meaning (e.g., *recent* instead of *near*) or retrieval based on form (e.g., *exhibition* instead of *expedition*). Whereas the first type of errors are most likely to arise when a message is mapped to the functional level, the latter type of errors probably originate when open-class words are inserted into phrasal planning frames of the positional level (where serial order and certain form aspects are specified).

Unlike open-class words, closed-class words are frequently involved in shift errors such as *here been once* instead of *been here once*. Garrett argued that these shifts are more likely to occur at a positional rather than at a functional level of sentence representation. In addition, Garrett argued that closed-class words are not retrieved via a lexical search (and are consequently not stored together with the open-class words), and that instead they appear as features of positional frames.

Evidence for differential processing and storage of open- versus closed-class words in language perception has been provided by Swinney, Zurif, and Cutler (1980). They showed that normal listeners and agrammatic patients differ with respect to the recognition of stressed and unstressed open- and closed-class words in a word-monitoring task. For normal listeners, stressed words were easier to recognize than unstressed words, with a larger effect of stress for open-class than for closed-class words. For agrammatic patients, stressed words were also recognized faster than unstressed words, but this effect was equally large for both classes. A second difference between the two groups was the observation that open- and closed-class words were recognized equally fast by normal listeners, but agrammatic patients recognized open-class words than closed-class words. Swinney and his colleagues therefore argued that, unlike normal listeners, agrammatic patients cannot use stress as a cue to distinguish between vocabulary classes due to a disruption of the special access and retrieval system for closed-class words.

This conclusion was supported by Friederici (1985) who compared the capacities of normal listeners and of agrammatic patients to monitor for open- versus closed-class words. When these words were presented in a sentence context, both groups of listeners showed facilitation on open-class words due to semantic context, but not on closed-class words. However, whereas the normal listeners reacted faster to closed-class words than to open-class words, agrammatic listeners reacted faster to open-class words.

Although these studies on agrammatic patients thus suggest different processing and storage of open- versus closed-class words, they do not explicitly discuss the question of which cue from the incoming speech listeners use to decide which sublexicon to access. This issue has, however, been addressed by Cutler and Carter (1987) in their description of the speech segmentation process. Since continuous speech lacks any consistent acoustic cues to the boundaries of individual words, the relatively distinct phonological characteristics of open- versus closed-class words might be helpful in the segmentation process. Whereas, in English, open-class words are always produced with at least one full vowel, closed-class words are often realized with their vowel reduced to a schwa. Cutler and Carter therefore proposed that when the incoming signal contains a full vowel, a lexical search will take place in an open-class lexicon. If a word is recognized and the next syllable is weak, this syllable will be submitted to a closed-class lexicon (see also Cutler and Norris, 1988, and Cutler, 1993). Evidence for such a segmentation strategy based on vowel quality was presented by Cutler and Butterfield (1992); both natural and laboratory-induced mis-segmentations showed that listeners often erroneously insert a word boundary before a strong syllable (e.g., misperceiving *and allergy* for *analogy*), but delete them before a weak syllable (e.g., misperceiving *my gorgeous* for *my gorge is*). Furthermore, boundaries inserted before strong syllables tended to produce open-class words, and boundaries inserted before weak syllables tended to produce grammatical words (e.g., misperceiving *effect of* for *effective*).

Limited relevance of stress for the parsing of English has been indicated by a further experiment in the study of Swinney, Zurif, and Cutler (1980). When both stressed and unstressed open- and closed-class words were used in a word-monitoring paradigm with non-impaired listeners, recognition of unstressed closed-class words was not faster than recognition of stressed closed-class words. If unstressed words are looked-up in a closed-class lexicon, and stressed words in the open-class words, stress should have had an inhibitory influence on he recognition of closed-class words.

The importance of vowel quality in stress assignment relative to stress was also investigated by Field (1996). In order to study the detachability of closed-class words, combinations of unstressed closed-class words with either one stressed nonword (weak-strong strings) or with two stressed nonwords (strong-weak-strong strings) were auditorily presented to a group of listeners. These listeners transcribed the sequences of words as accurately as they could. Although closed-class words in medial position were equally often segmented out when they contained a full vowel (*dealth on pive*) or a weak vowel (*rilt at sodge*), in initial position, closed-class words were easier to recognize with a full (*on fope*) rather than a weak vowel (*at kiff*). Since the latter pattern was also found for the two types of strings combined, Field argued that vowel quality instead of stress is the key factor for segmentation in English.

If open- and closed-class words are separately stored and words are assigned to one of these lexicons based on their vowel quality, the system would have to deal with closed-class words having a full vowel in their initial syllable that are submitted to the open-class lexicon, and also with weak open-class words that are submitted to the closed-class store. However, when false alarm rates were calculated for open- and closed-class words of the *London-Lund Corpus of English Conversation* (Svartvik & Quirk, 1980), these rates appeared to be rather low (Cutler and Carter, 1987). Of the strong syllables, 74% were indeed initial syllables of open-class words, 15% were non-word-initial syllables, and only 11% of the strong syllables were in fact initial syllables of closed-class words. Furthermore, 69% of the weak syllables were initial syllables of closed-class words and 26% were non-word-initial. Again, the false alarm rate was quite low - only 5% of the weak syllables turned out to be initial syllables of open-class words.

The problem of submitting closed-class words with a full vowel to the open-class lexicon is solved in dual-lexicon hypotheses which assume that closed-class words that can be strong are also listed in the main open-class lexicon. Such a dual-lexicon hypothesis has been proposed by Grosjean and Gee (1987). They argued that only salient syllables can trigger a lexical search through the main lexicon (with saliency defined as a combination of pitch, amplitude, and duration), since non-salient syllables do not provide enough phonetic information. In the main lexicon, both open-class words and closed-class words that can be salient are stored. Non-salient syllables are recognized via pattern recognition matching, and are thus first (partly) identified before the closed-class lexicon is contacted to obtain information about their meaning, syntactic class, and subcategorization. Such an analysis of nonsalient items would be less demanding for a processing system (and thus faster), since no complex lexical search has to be carried out. Whether the main lexicon or the closed-class lexicon is accessed when the speech signal contains a closed-class word depends in this model on the saliency of such a word.

In English, neither vowel quality nor saliency are strict cues to the vocabulary class of words. Therefore, it has been argued that other information, like the syntactic context, might help to assign incoming words to either the open- or the closed-class lexicon. The effect of stress on the recognition of open- versus closed-class words in a sentence context has been studied by Herron and Bates (1997). Homophones like /baɪ/ having both an open-class meaning (*buy*) and a closed-class meaning (*by*) were used in sentences which were read by both a male and a female speaker. Successively, the homophones read by the male speaker were spliced into the sentences read by the female speaker, such that the context was either appropriate to the meaning of the homophone (*can't BUY me love / stand by me*), appropriate to the other meaning of the homophone (*can't by me love / stand BUY me*), or neutral with respect to the meaning of the homophone (*say BUY now / say by now*). Whereas the open-class words were always produced with stress, the closed-class words did not carry stress.

When listeners were asked to repeat the different-voice word as fast as possible, the open- and closed-class words differed little in their shadowing latencies when they were presented in their appropriate context. In the context where the open- and closed-class words were swapped, the closed-class words - which can be viewed as unstressed open-class words, tended to be hard to recognize. This was not the case for swapped open-class words, though. In fact, these swapped open-class words - which can be considered as stressed closed-class words - were recognized more accurately and often faster than the unstressed closed-class words. In a neutral context, closed-class words were harder to recognize than open-class words, which might be due to the difference in acoustic saliency. Herron and Bates concluded that both acoustic and contextual cues are used simultaneously to access the appropriate entry.

Several other studies have suggested that the syntactic context can be used to predict upcoming words. For example, Shillcock and Bard (1993) used a cross-modal priming paradigm to show different processing of open- versus closed-class words. In their experiment, subjects were asked to listen to sentences which syntactically biased a homophone like /wʊd/ towards either its open-class meaning *wood* or towards its closed-class meaning *would*. At the offset of the homophone, they were asked to make a lexical decision on a semantic associate of the open-class meaning like *timber*. Because no facilitation was found for decisions on open-class associates presented after the context biased the closed-class meaning, Shillcock and Bard argued that whereas open-class words are processed in a modular way, closed-class words can be predicted from the syntactic context and are thus processed interactively.

A difference between the two classes with respect to the influence of the context was also indicated by the study of Friederici (1985). She observed that normal listeners were faster in monitoring for a closed-class word than for an open-class word when these items were presented in semantically unrelated sentence contexts. This indicates that the syntactic context is mainly useful for accessing closed-class words. However, recognition of the open-class words improved from the semantically unrelated to the semantically related condition. Semantic constraints thus seem to permit the preselection of open-class candidates.

Although the results of these studies seem to argue for interactive use of sentence context, it is hard to determine whether context indeed exercises its influence at a pre-lexical level (determining submission of incoming words to either the open- or the closed-class lexicon), or whether the contextual influence should rather be located at a later post-access level. For instance, a recent study by Colé and Segui (1994) showed that grammatical incongruency had a larger impact on lexical decisions to open-class target words preceded by a closed-class prime than on lexical decisions to open-class targets preceded by an open-class prime. They therefore argued that the grammatical link is more immediately computed when the first word is a closed-class word then when both words are open-class words. When the outcome from the syntactic processor is negative, lexical decision on a target can be delayed. Colé and Segui furthermore proposed that this effect of vocabulary type is related to the functional role of these words during sentence processing (i.e., a post-access interpretation) rather than to a difference in their retrieval mechanisms.

Another problem with a pre-lexical contextual influence concerns the contradictory results described in the literature of contextual influences on the access of ambiguous words (either homophones or homographs). Whereas several studies claim interactive, non-modular processing (e.g., Glucksberg, Kreuz, and Rho, 1986; Schwaneveldt, Meyer, and Becker, 1976; Simpson, 1981), other studies argue for modular processing (e.g., Forster and Bednall, 1976; Hogaboam and Perfetti, 1975; Holmes, 1979; Onifer and Swinney, 1981; Swinney, 1979). In addition, even if the syntactic context can be used to predict the vocabulary class of upcoming words, the recognition system will also have to deal with those words that cannot be predicted from the context, as in the sentence *Did you know that Mary quit...* which can equally likely be continued with an open-class word (like the verb *smoking),* as with a closed-class word (as the pronoun *her* in *her job*, or *to* in *to go on a world trip*).

Although a dual-lexicon approach thus seems attractive in explaining, for example, speech error data or results obtained with language disturbed speakers and listeners, there is so far no conclusive evidence for English as to which cue in the input could be used to access either lexicon; vowel quality does not have a one-to-one correspondence to open- or closed-class words, and the role of the syntactic context is unclear.

4.1.3 Stress as a pre-lexical cue in Dutch

In contrast to English, in which stress does not play a role on a pre-lexical level (Cutler, 1986), a recent experiment by van Donselaar, Koster, and Cutler (in preparation) indicated that, in Dutch, stress does play a pre-lexical role. When the Dutch word *zee* was embedded in the nonsense words *luzee* and *muzee*, subjects were faster to spot *zee* in *luzee*, but only when the second syllable was stressed. Van Donselaar and colleagues explained this finding by assuming that the Dutch word *museum* (stressed on its second syllable) was only activated when the nonsense word also carried stress on its second syllable. Competition between the words *museum* and *zee* would then delay recognition of *zee*.

Since if stress could be used pre-lexically it could make a viable cue to vocabulary class, the present study investigated whether Dutch listeners can use stress for accessing either an open- or a closed-class lexicon. Whereas a stressed word would then be assigned to the open-class store, unstressed words would be assigned to the closed-class store. In a first word-spotting experiment, the recognition of stressed and unstressed open- and closed-class words was investigated when these words were presented in a nonsense context. The results were compared with the results of a second - lexical decision - experiment in which open- and closed-class words were used in a meaningful phrase. In a third cross-modal priming experiment, the activation of stressed and unstressed open- and closed-class words was investigated when they were initial embeddings of open-class carrier words presented in a sentence context.

4.2 EXPERIMENT 7: WORD-SPOTTING IN A NONSENSE CONTEXT

To investigate whether open-class recognition will be facilitated by stress and closed-class recognition will be hindered by stress, open- and closed-class words were embedded as initial syllables of disyllabic nonsense strings (e.g., *huis-bool* "house-bool" and *hem-baaf* "him-baaf") and used in a word-spotting task (Cutler & Norris, 1988). The strings were manipulated with respect to their stress pattern. This experiment was in designed specifically to replicate the results of experiment 4 (chapter 3) with larger sets of items. In addition, to further investigate the effect of frequency on the recognition of open-class words, the open-class item group contained words of low, medium, and high frequency.

4.2.1 Method

Participants

Thirty-eight undergraduate students from the Max-Planck Institute subject pool took part. The data of two students was excluded because of their relatively large number of errors (more than 20%). All participants had normal hearing abilities and normal vision, and were native speakers of Dutch. The students participated in two groups of eighteen students each, and were paid Dfl. 8.50 for their participation. None of them participated in any of the other experiments reported in this article.

Materials

The experimental item set contained seventy-five open-class items (nouns, adjectives, and adverbs) and fifty items of the closed-class item set (pronouns, prepositions, conjunctions, articles, and interjections). Based on the frequency of occurrence of their word forms according to the CELEX (1990) lexical database, the open-class items were divided into a low-frequency item group of twenty-five words (less than 500 occurrences per 42 million, mean logarithmic frequency of .72), a medium-frequency group of twenty-five items (frequency between 500 and 7000, mean logfreq 1.66), and a high-frequency item group containing twenty-five words (frequency more than 7000, mean logfreq 2.61). The frequencies of the groups differed significantly from each other on an analysis of variance ($F(2,72) = 310.02$, $p < .01$, MSe = 22.745). The items of each group were as closely matched as possible with the members of the other item groups on their phoneme structure, their number of phonemes, and their word class. All items were monosyllabic and no other words were embedded in the experimental words from word onset.

The closed-class items were divided into two groups of twenty-five items each: a low-frequency item group with a frequency of less than 104000 occurrences per 42 million (mean logfreq 2.42) and a high-frequency item group with a frequency of more than 104000 occurrences (mean logfreq 3.81). A t-test analysis showed these frequencies to be significantly different from each other ($t(48) = 7.33$, $p < .01$, two-tailed). The items of the closed-class groups were matched on phoneme structure, number of phonemes, and word class.

Both the open- and closed-class experimental items were followed by a monosyllabic CVC nonsense syllable (e.g., *angst-deul* "fear-deul"). Items that were already matched for their phonemes and word class were combined with the same nonsense syllable (*bed-woem* "bed-woem" / *dak-woem* "roof-woem" / *pek-woem* "pitch-woem"). All experimental items are listed in Appendix F.

In addition to the experimental items, 125 filler nonwords were constructed. These fillers consisted of a combination of two nonsense syllables. Whereas the first syllable of these nonwords varied in phoneme structure, the second syllable always had a CVVC structure (e.g., *blim-fuul*; *kuk-jien*). Thirty-four practice and warm-up items were also constructed.

Procedure

A trained female speaker of standard Dutch read the items in randomized order both with stress placed on the first syllable and with stress on the second syllable. The recordings were made with a Sony 670 DAT-recorder and a Sennheiser HMD 224 microphone in a sound-attenuated room. Since both amplitude and duration are correlates of stress (e.g., Nooteboom and Cohen, 1984; Lehiste, 1970), both these factors were inspected. As expected, waveforms of the items showed higher amplitudes for stressed words than for unstressed words. Furthermore, the durations of the stressed open-class words (mean 923 ms.) were significantly longer from the durations of the unstressed open-class words on a t-test (mean 900 ms.) ($t(74) = 2.45$, $p < .05$, two-tailed), as were the durations of the stressed (mean 873 ms.) versus the unstressed (mean 844 ms.) closed-class words ($t(49) = 2.82$, $p < .01$, two-tailed).

The participants were tested individually in sessions lasting about twenty minutes. They received written instructions to decide whether the first part of an auditory presented nonsense string was a real word or not. It was mentioned in the instruction that words could be not only nouns, but also other words like articles and prepositions. As soon as the listeners detected a real word, they had to press a button with their dominant hand. 900 ms. after their response, a star appeared on the computer screen in front of them. When this star appeared, the word had to be repeated into a Sennheiser microphone which was activated for 3400 ms. If the first syllable was not a word, no response had to be made and the next trial started after 2500 ms.

All subjects first listened to a practice block of twenty items. The items were presented over headphones. After a short break in which questions could be asked, three blocks of forty-five experimental items and forty-five filler nonwords were presented, each block headed by four warm-up items. The items were divided over the two subject groups in such a way that each subject listened to items belonging to each frequency item group, and to either the stressed or the unstressed variant of each word. The items of each block were presented in counterbalanced order, with the order of the individual items pseudo-randomized for every three subjects. The randomization took place according to four criteria: 1) no more than three succeeding items containing a real word, 2) no items with identical initial consonants in succession, 3) no more than three succeeding open- or closed-class items, and 4) no more than three succeeding items with identical stress patterns. A Hermac AT-computer was used both for the stimuli presentation and the on-line data collection (both the push button and the voice-key responses). On-line scoring of the repetition responses was done by the experimenter. In case of an unclear response, recordings were checked afterwards.

4.2.2 Results and discussion

The word-spotting latencies were measured from the onset of the items. Three types of responses were not analyzed: 1) push-button responses given after the time-out period (10% of the data), 2) wrong repetitions (3%), and 3) push-button latencies exceeding the overall mean reaction time per condition plus or minus 3 standard deviations (1%). These missing data and outliers were substituted by the overall mean reaction time per condition. The mean detection latencies for both open- and closed-class words are presented in Figure 4.1.

The open-class data was analysed both across subjects (F1) and across items (F2) using an analysis of variance with stress (stressed and unstressed) and frequency (low, medium, high) as within-subject factors. The results revealed a significant interaction between stress and frequency when the data were analyzed over subjects (F1(2,70) = 5.31, p < .05, MSe = 2369.42; F2 (2,72) = 1.32 p > .05 ns., MSe = 9723.10). Therefore, separate post-hoc Newman-Keuls analyses were performed to study the effect of stress within the different frequency groups. It was shown that stressed open-class words were detected faster than unstressed open-class words, but this effect was only significant for the open-class words with a low frequency of occurrence (F1(2,70) = 11.73, p < .01, MSe = 4720.58; F2(2,72) = 1.32, p < .05, MSe = 9207.58).

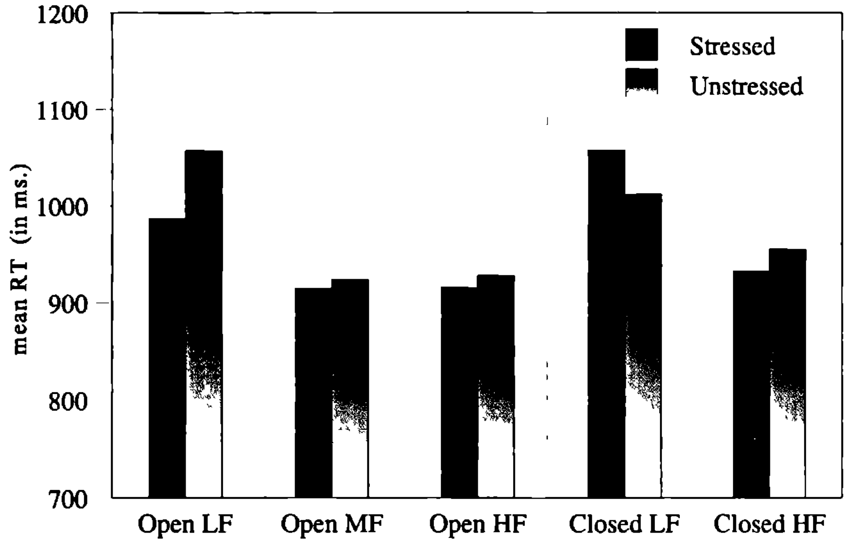

Figure 4.1 *Results of experiment 7. Mean word-spotting latencies for stressed and unstressed open-class words of low (LF), medium (MF), and high frequency (HF), and for stressed and unstressed closed-class words of low and high frequency. The targets were the first syllable of a bisyllabic nonsense string.*

Furthermore, low-frequency items were detected significantly more slowly than open-class items of both medium and high frequency ($F1(2,70) = 61.05$, $p < .01$, $MSe = 36.20$; $F2(2,72) = 10.69$, $p < .01$, $MSe = 14317.08$).

The analyses of the error responses showed fewer errors for stressed open-class words (7%) than for unstressed open-class words (14%) ($F1(1,35) = 50.85$, $p < .05$, $MSe = .00$; $F2(1,72) = 13.63$, $p < .01$, $MSe = .01$). The error analyses also indicated that subjects tended to make fewer errors when the frequency of occurrence of the items increased (high 7%, medium 11%, low 13%) ($F1(2,70) = 14.11$, $p < .05$, $MSe = .01$; $F2(2,72) = 1.08$, $p > .05$ ns., $MSe = .05$). The interaction between stress and frequency was not significant.

Closed-class words were similarly analysed with two-way analyses of variance, with the within-subject factors stress (stressed versus unstressed) and frequency (low versus high). Again, a significant interaction between stress and frequency was found when the data were analyzed over subjects ($F1(1,35) = 14.01$, $p < .01$, $MSe = 3015.05$; $F2(1,48) = 2.95$, $p > .05$ ns., $MSe = 8310.50$). Post-hoc Newman-Keuls analysis showed that in the subject analysis low-frequency closed-class words were detected faster when unstressed than when stressed ($F1(1,35) = 10.96$, $p < .05$, $MSe = 4053.02$; $F2(1,24) = 2.49$, $p > .05$ ns., $MSe = 10655.29$). Stress did not have any significant influence on high-frequency closed-class words. A highly significant effect of frequency was also found; high-frequency closed-class words were detected faster than low-frequency closed-class words ($F1(1,35) = 60.28$, $p < .01$, $MSe = 5285.96$; $F2(1,48) = 10.98$, $p < .01$, $MSe = 20034.29$). Although the unstressed closed-class words were significantly shorter than the stressed closed-class words, these durations did not correlate with the word-spotting latencies. Duration can thus be excluded as a cause of the faster reactions to the unstressed words.

The analysis of the error responses showed that although stress did not influence the recognition of closed-class words in general, subjects made fewer errors to the unstressed high-frequency closed-class words (8%) than to the stressed high-frequency closed-class words (15%) ($F1(1,35) = 11.10$, $p < .01$, $MSe = .01$; $F2(1,24) = 4.29$, $p < .05$, $MSe = .01$). Furthermore, fewer errors were made in the high-frequency (11%) versus the low-frequency (25%) closed-class words ($F1(1,35) = 159.09$, $p < .01$, $MSe = .00$; $F2(1,48) = 4.01$, $p = .05$, $MSe = .11$).

The results show a rather clear pattern. As in experiment 4 described in chapter 3, stress had a facilitatory effect on open-class words and an inhibitory effect on the recognition of closed-class words, but only when these items had a relatively low frequency of occurrence. Although stress is thus not a reliable indicator of the vocabulary class of a word, the error data did indicate that stress and vocabulary class are somehow related; although listeners made fewer errors with stressed open-class words, they made more errors with stressed closed-class words. Whereas the faster and more accurate recognition of open-class words might be due to the higher acoustical salience of stressed words in general (e.g., Bond & Small, 1983), the slower recognition of stressed closed-class words might result from mis-stressing. Closed-class words are in daily speech not frequently produced with stress, and mis-stressed words are harder to recognize than words with their normal stress pattern (e.g., Bond & Small, 1983, and Cutler & Clifton, 1984 for English; van Heuven, 1985 for Dutch).

4.3 EXPERIMENT 8: LEXICAL DECISION IN MEANINGFUL PHRASES

Although the correspondence between the vocabulary class and the stress pattern of a word thus seems not to be reliable, the unstable effect of stress might be due to the fact that the open- and closed-class words were presented in a nonsense context. For example, Friederici (1985) has argued that open- and closed-class words should be studied in a normal sentence context, since only then might the specialized retrieval system for closed-class words come into play. To assess whether the relation between stress and vocabulary class would be more reliable in a meaningful context, a second experiment was designed in which stressed and unstressed open- and closed-class words were used in meaningful phrases consisting of two words (e.g., *mijn hond* "my dog"). Two groups of subjects were asked to make lexical decisions on either the closed-class words, or on the open-class words.[14] If stress is a reliable cue of vocabulary class, lexical decision are expected to be faster for closed-class words when they are unstressed, and for open-class words when they are stressed.

To provide more insight into possible effects of mis-stressing, the closed-class words were divided into two groups. The first group of words contained

---

[14] *Note that lexical decision requires a 'yes-no' response. Word-spotting is equivalent to a 'go-no go' lexical decision task. The latter task is used when words have to be located in a nonsense context).*

random combinations of determiners and pronouns with an open-class word (e.g., *ons kind* "our child", and *dat kalf* "that calf"). The second group consisted of relatively standard prepositional combinations of unstressed closed-class and stressed open-class words (e.g., *te voet* "on foot", *naar bed* "to bed", and *tot gauw* "see you soon"). Since these latter words are often produced together, with a weak-strong stress pattern, they might be more comparable to multisyllabic words with a weak-strong stress pattern than to random combinations of closed- and open-class words. Mis-stressing might thus have a larger effect on the standard propositional combinations than on the random combinations.

4.3.1 Method

Participants

Eighty-one paid students from the subject pool of the Max-Planck Institute participated in this experiment. The data of one student was excluded from the analysis, because the error cutoff of 20% was exceeded. The other students were randomly assigned to one of eight subject groups consisting of ten students each.

Materials

The experimental items included twenty-four closed-class items (determiners, pronouns) which were combined with twenty-four open-class items (nouns, verbs) into two-word phrases. To control for effects of frequency, the items were combined to make that four groups of twelve item combinations based on their frequency: low-frequency closed-class words (mean logfreq of 2.67) were combined with open-class words of both low (0.58 logfreq) and high (2.08 logfreq) frequency, like *geen hint* ("no cue") versus *geen hond* ("no dog"). Furthermore, high-frequency closed-class words (3.96 logfreq) were combined with open-class words of both low and high frequency, as in *de hint* ("the cue") versus *de hond* ("the dog"). T-tests showed significantly higher frequencies for the high- versus low-frequency open-class words ($t(22) = -2.78$, $p < .05$, two-tailed) and for the high- versus low-frequency closed-class words ($t(22) = -5.97$, $p < .01$, two-tailed).

Twenty low-frequency (2.37 logfreq) and twenty high-frequency (3.86

logfreq) prepositions were also combined with twenty open-class words (nouns, adverbs) (e.g., *van goud* "of gold", *per trein* "by train"). Again, the frequencies differed significantly from each other on a two-tailed t-test ($t(18) = 6.24$, $p < .01$). The open-class words all had a high frequency (2.02 logfreq), since not all prepositions allowed for combination with a low-frequency open-class word. Ninety-six filler nonwords were also constructed: half of them had a nonword in the first position (*kes big* "kes pig"), the other half had a nonword in the second position (*men traakt* "one traakt"). The frequencies of the real words were roughly matched with the frequencies of the experimental items. In Appendix G, the experimental phrases are listed.

Procedure

A trained female speaker of standard Dutch was asked to read two lists of the items. In the first list, stress was put on the first syllable (*DE hond*). In the second list, the second syllable was stressed (*de HOND*). The recordings were made in sound-attenuated cabin with a Sony DTC 55 ES DAT-recorder.

The items were divided over four item lists, in such a way that strings that only differed with respect to their stress pattern were assigned to different lists (e.g., *DE hond* and *de HOND*). Furthermore, strings that contained identical words were also assigned to a different list (e.g., *geen hint* and *geen hond*). The four lists were presented to four groups of subjects, who were asked to make lexical decisions on the items occurring in the first position in a phrase. An additional four groups of subjects had to make lexical decisions on the items in the second phrase position. The order of the phrases of each list was pseudo-randomized for every subject. For the randomization three criteria were used: 1) no more than 3 succeeding phrases with the same stress pattern, 2) no more than three target or filler phrases in succession, and 3) no succeeding items starting with the same phoneme. All lists started with a practice block of ten filler practice phrases. After a short break, subjects listened to two more blocks of thirty-four items, each beginning with an additional two filler warm-up items.

All participants were tested individually in a sound-isolated booth. Each participant listened to the stimuli over headphones while sitting in front of a computer screen and a microphone. The test sessions lasted about ten minutes each. Listeners made a word-nonword decision on either the first or the second syllable of the phrases, and pressed a button with their dominant hand as fast and accurately as possible when this syllable was a real word. 900 ms. after a response, a star appeared on the computer screen for 900 ms. and the detected word had to be repeated into the microphone. This microphone was activated for 3400 ms. In case no word was detected, the next trial started after 2500 ms.

A Hermac AT-computer was used to control both the stimuli presentation and the on-line data collection of the push button responses. The repetition responses were scored on-line by the experimenter. In the case of unclear responses, recordings were consulted afterwards.

4.3.2 Data analysis and results

The decision latencies were measured from phrase onset if the target was the first word of the phrase, and from the onset of the second word if the target was the second word. Push button reaction times were excluded from the analysis when: 1) reaction times were greater than the time-out value (open class 4%, closed class 6%), 2) the push button response was followed by an erroneous repetition (open class 3%, closed class 2%), and 3) reaction times exceeded the overall mean reaction time per condition by plus or minus 3 standard deviations (open class 1%, closed class 1%). The missing data and outliers were replaced by the overall mean reaction time per condition. The mean lexical decision latencies are presented in Figure 4.2.

A three-way analysis of variance involving the factors stress (stressed, unstressed) and frequency (low, high) as within subject factors, and vocabulary class (open, closed) as a between subject factor was performed. Because of a significant interaction between vocabulary class and stress ($F1(1,78) = 6.42$, $p < .05$, $MSe = 3364.46$; $F2(1,66) = 8.20$, $p < .05$, $MSe = 3276.93$), the influence of stress and frequency was separately analysed in the open- versus closed-class word sets. The analysis of the open-class words showed that stress did not have an influence on their recognition. Furthermore, high-frequency open-class words were recognized faster than low-frequency open-class words, but only when the data were analyzed over subjects ($F1(1,78) = 101.97$, $p < .01$, $MSe = 3768.48$; $F2(1,66) = .90$, $p > .05$, $MSe = 23948.11$). The error data showed that the listeners made fewer errors in stressed open-class words (3%) versus unstressed open-class words (7%) ($F1(1,78) = 6.94$, $p < .05$, $MSe = .01$; $F2(1,66) = 8.43$, $p < .01$, $MSe = .00$), but no effect of frequency was found.

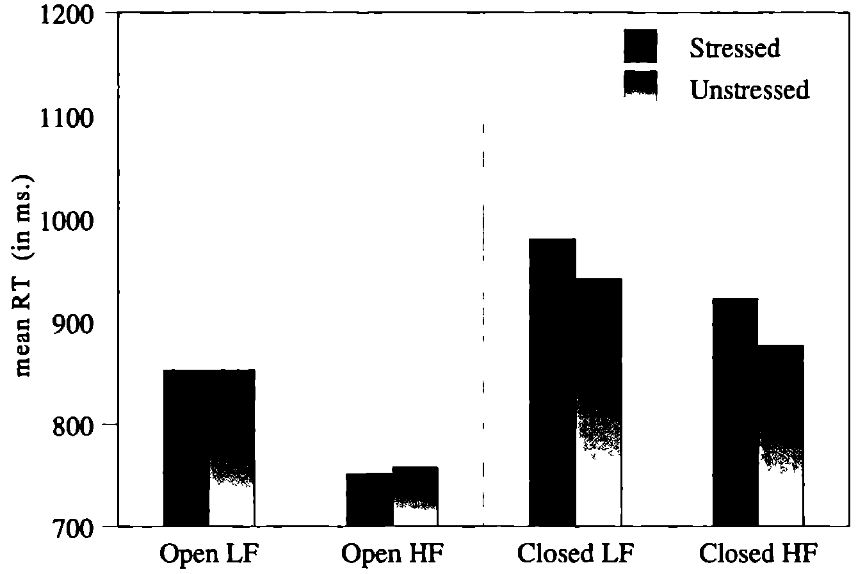

Figure 4.2 *Results of experiment 8. Mean word-spotting latencies for stressed and unstressed open-class words and closed-class words of low (LF) and high frequency (HF). The targets were presented in a meaningful phrase of two words, with closed-class words in the first position and open-class words in the second position.*

The detection latency analysis of the closed class items revealed that unstressed words were recognized significantly faster than stressed closed class words (F1(1,78) = 15.08, p < .01, MSe = 3364.46; F2(1,66) = 13.06, p <. 05, MSe = 4935.28). Furthermore, high-frequency closed-class words were detected significantly faster than low-frequency closed-class words (F1(1,78) = 29.65, p < .01, MSe = 3768.48; F2(1,66) = 11.30, p < .01, MSe = 11489.30). There was no interaction between stress and frequency in the closed-class words. The analysis on the closed-class errors showed no significant effect of stress. However, fewer errors were made in the high-frequency words (7%) when compared to the low-frequency words (10%) (F1(1,78) = 25.40, p < .01, MSe = .01; F2(1,66) = 10.30, p < .05, MSe = .05).

When the analysis of variance was performed over the determiners and pronouns only, low-frequency words were recognized faster when stressed

(956 ms.) than when unstressed (939 ms.), and high-frequency words were still recognized faster when unstressed (895 ms.) than when stressed (917 ms.). These differences were not significant, however. The separate analysis on the preposition combinations, on the other hand, showed a highly significant main effect of stress ($F1(1,77) = 43.55$, $p < .01$, $MSe = 4756.15$; $F2(1,18) = 19.49$, $p < .01$, $MSe = 5313.33$). Not only were the low-frequency prepositions recognized faster when unstressed (948 ms.) than when stressed (1044 ms.), high-frequency prepositions were also detected faster when they were unstressed (831 ms.) than when they were stressed (938 ms.).

The similar results of the previous word-spotting experiment and the present lexical decision experiment indicate that the influence of stress on the recognition of open- versus closed-class words is not drastically different in a nonsense versus a meaningful context. In the nonsense context, stress had a facilitatory influence on the recognition of low-frequency open-class words, and a inhibitory influence on the recognition of low-frequency closed-class words. In the meaningful context, subjects made fewer errors on stressed open-class words than on unstressed open-class words, and stress inhibited recognition of all closed-class words. The explanation that this result is due to mis-stressing rather than to differential processing or storage of open- versus closed-class words was furthermore strengthened by the observation that standard combinations of prepositions and open-class words showed a larger inhibition effect when the normal stress pattern was reversed than the random combinations of closed- and open-class words.

4.4 EXPERIMENT 9: CROSS-MODAL PRIMING IN SENTENCES

The results of the previous experiments suggest that stress plays no role in assigning words to either an open- or a closed-class lexicon. If this observation is indeed valid, both the open-class meaning (*wood*) and the closed-class meaning (*would*) of an open-/closed-class homophone like */wʊd/* should be accessed when this homophone is used in a neutral sentence context, irrespective of whether this homophone is stressed or unstressed. On the other hand, if stress does play a role in assigning words to either an open- or a closed-class lexicon, then the open-class meaning should be accessed when the homophone is stressed, and the closed-class meaning should be accessed when the homophone is unstressed (i.e., stress will thus prevent the closed-class meaning from being accessed).

In the current experiment, stressed Dutch homophones such as *hen* ("hen" / "them") were presented embedded in existing words like *HENdels* ("grips") as carrier. These carrier words were used as the last word of a complete sentence, and subjects were asked to make lexical decisions on semantic associates of the embedded words ("chicken" / "you"). Since both the semantic and the syntactic context could influence expectations of listeners with regard to the vocabulary class of this embedded word, the semantic context was neutral as to the meanings of both the embedded and the carrier words. Furthermore, the syntactic context was chosen such that the word preceding the embedded word could be followed by either an open- or a closed-class word. If stress does not influence access of either meaning of the homophone, the closed-class meaning is expected to receive more activation than the open-class meaning, since this meaning has the highest frequency of occurrence. However, if stress does influence lexical access, only the open-class meaning is expected to be activated.

4.4.1 Method

Participants

Forty-eight paid students from the Max-Planck Institute subject pool were asked to participate. They were randomly divided over four groups of twelve subjects each.

Materials

The experimental item set consisted of twelve sentences that ended in a plural noun of two to four syllables. This noun was never preceded by an article, because the use of an article would predict the next word to be an open-class word. The final nouns had a mean logarithmic word form frequency (logfreq) of .14, and they all contained a stressed monosyllabic open-class/closed-class homophone as their first syllable (e.g., *Kunstschilders verven HENdels* "Artists paint handles"). In their open-class meaning ("hen"), these homophones were either nouns or adjectives with a mean logfreq of .43. This frequency did not differ from the frequency of their carrier word on a t-test for paired samples. In their closed-class meaning ("them"), the homophones were conjunctions, prepositions, pronouns, and numerals with a mean logfreq 2.68. This frequency was not only significantly higher than the frequency of the carrier word ($t(11) = -8.44$, $p < .01$, two-tailed), but it was also higher than the frequency of the open-class meaning ($t(11) = 7.98$, $p < .01$, two-tailed).

All homophones served as primes for two target items that were semantic associates of either the open-class ("hen" - "chicken" or the closed-class meaning "them" - "you"). The associates of the open-class meaning were also open-class words themselves, and the closed-class meaning associates belonged to the closed-class vocabulary. None of the targets shared their initial phoneme with the prime, or were semantically related to the carrier noun.

For the control sentences, the embedded primes were all nonhomophonous open-class and closed-class words (24 cases each), half of these words carrying stress, the other half being unstressed. The embedded stressed open-class primes (logfreq .82) had significantly higher frequencies than their carrier words (logfreq .04; $t(11) = -5.68$, $p < .01$, two-tailed), as for example the embedded word *ban* ("excommunication") in *De vreemde artiest spaarde BANjo's* ("The weird artist collected banjo's"). The frequencies of the unstressed open-class primes (logfreq .79) were also significantly higher than the frequencies of their carrier words (logfreq .15; $t(11) = -2.75$, $p < .05$, two-tailed), as the embedded word *kar* ("cart") in *De firma importeerde karTONnen* ("The firm imported cardboard boxes"). Furthermore, higher frequencies were found for embedded stressed (logfreq 3.24) and unstressed (logfreq 3.30) closed-class primes relative to the frequencies of their carrier words (logfreqs of .39 and .20, respectively; $t(11) = .681$, $p < .01$, two-tailed, and $t(11) = -10.98$, $p < .01$, two-tailed). Examples of sentences containing stressed and unstressed closed-class primes are *De vreemde artiest spaarde DUSters* ("The weird artist collected dressing-gowns"; embedded word is *dus* ("so")) and *De firma importeerde meLOEnen* ("The firm imported melons"; embedded word is *me* ("me")).

The open-class primes were either nouns or adjectives which were embedded in carrier nouns; the closed-class primes were prepositions, conjunctions, adverbs, pronouns, and articles also embedded in carrier nouns. Again, the target associates belonged to the same word class as their primes. The carrier words of both the homophonous and nonhomophonous primes are listed in Appendix H.

One hundred and eight sentences served as filler and warm-up items. Eighteen of these sentences ended in a determiner plus a plural noun, another eighteen sentences ended in a determiner plus a singular noun. The word targets (18 open class; 18 closed class) were furthermore semantically unrelated to the prime. All other filler sentences were combined with a legal nonword target of 1 to 3 syllables. The sentences either ended in a determiner plus a singular or plural noun, or they ended in a singular (mass) or plural noun not preceded by a determiner.

Procedure

The sentences ending in carrier nouns with embedded prime words were read in a random order from two separate lists by a trained female speaker of standard Dutch. Recordings were made in a sound-isolated booth using a Sony 670 DAT-recorder and a Sennheiser HMD224 microphone.

The items were divided over four item lists. Each list started with fourteen practice items, followed by two blocks headed by four warm-up items. Both blocks contained thirty-six experimental and twenty-seven filler sentences followed by a word target, and sixty-three filler sentences followed by a nonword target. All word targets were also presented after unrelated base-line primes, which were also embedded in the last noun of a sentence. The sentences were divided over the lists in such a way that each subject listened to sentences from each condition, and that no identical sentences or primes were presented to the same subject group. The trials were pseudo-randomized in such a way that only three embedded nonwords were permitted in succession, and successive targets did not start with identical phonemes.

Subjects were tested individually while seated in a sound-attenuated booth at a comfortable distance from a computer screen. After a warning-tone of 300 ms. and an additional interval of 300 ms., a sentence with a prime word was presented over headphones. At the offset of each prime, a target word was visually presented. These targets were centered on the screen, in white (36 point arial font) against a black background. The participants were asked to press a button labelled YES as fast and as accurately as possible if this target was a real word. If the target was not a real word, they were to press a button labelled NO. The real word responses were made with the dominant hand. The next sentence was presented 805 ms. after a response, or if no response was given within a time-out period of 2000 ms.

4.4.2 Data analysis and results

Response latencies were measured from the onset of the target items. They were not analyzed when a wrong button was pushed (4%) or when the latency exceeded the overall mean reaction time per condition plus or minus three standard deviations (1%). These missing data and outliers were replaced by the overall mean reaction time per condition.

The analysis was based on difference scores that were calculated by subtracting the reaction time for an item from its baseline value (i.e., the mean reaction time for this item presented after an unrelated prime calculated over all subjects). Both the mean reaction times and the mean baseline values are presented in Figure 4.3. For the stressed homophonous primes, the difference scores were 14 ms. when followed by an associate of the open-class meaning (*HENdels- kip*), and 34 ms. when followed by an associate of the closed-class meaning (*HENdels - jou*).

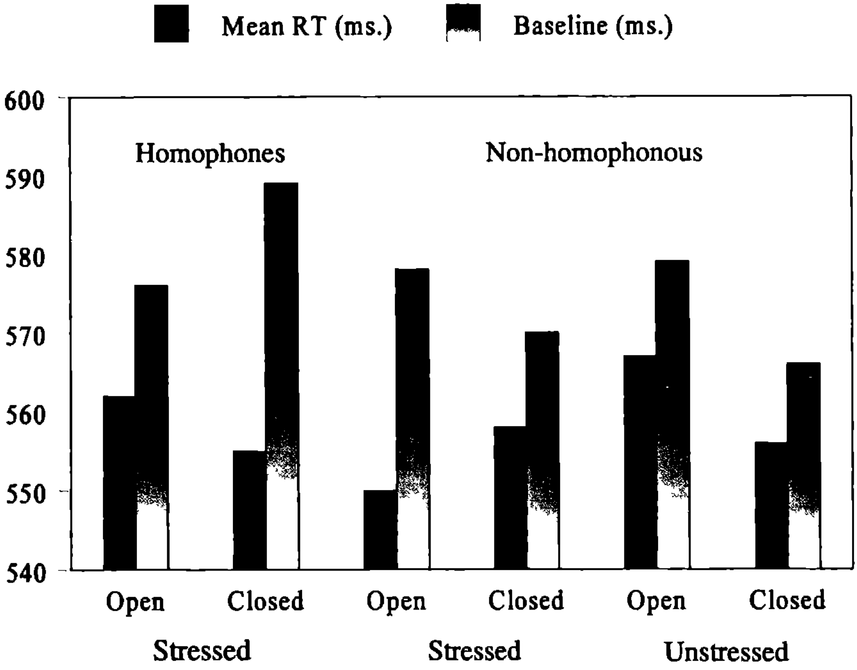

Figure 4.3 *Results of experiment 9. Mean lexical decision latencies to the associates of stressed and unstressed embedded open- and closed-class words, and corresponding latencies to these words when presented after an unrelated baseline word.*

Although a slight tendency towards priming was thus found for both meanings, only the associates of the closed-class meanings of the embedded homophones were significantly primed when analyzed over subjects (t-test for paired samples: t1(47) = -2.61, p < .05; t2(11) = -1.46, p >.05). The priming for associates of the open-class meanings of the embedded homophones was not significant. The analysis of the errors made in the homophonous condition showed more errors to the closed-class associates (8%) than to the open-class associates (0%), but this difference did not reach significance.

The difference scores for the stressed nonhomophonous primes were 28 ms. for the open-class associates (*BANjo's* - *vloek*), and 12 ms. for the closed-class associates (*DUSters* - *kortom*). For the unstressed nonhomophonous primes these values were 12 ms. and 10 ms for the open-class and closed-class associates, respectively (*karTONnen* - *wiel* and *meLOEnen* - *zich*). Only the associates of the stressed open-class words were significantly primed, and then only when the results analyzed over subjects (t1(47) = -2.08, p < .05; t2(11) = -1.23, p > .05). An additional analysis of variance with target class (open class associate / closed class associate) and stress (stress / unstressed) as within-subject factors was carried out on these difference scores. The result showed no main effects of target class or stress, and no interaction between these two factors.

The error analysis of the nonhomophonous condition showed 2% errors for the associates of the stressed open- and closed-class primes, and 2% for the associates of the unstressed open-class targets. In the associates of the unstressed closed-class primes, 4% errors were made. However, none of these differences reached significance.

These findings support the earlier conclusion that stress is not likely to be used as a pre-lexical cue to vocabulary class, since the semantic associates of the closed-class meaning of open-class/closed-class homophones appear to have been activated, despite the fact that these homophones carried stress. Although a tendency towards priming occurred in all conditions, this effect was not present for all subjects, nor for all items. A possible cause of the weakness of the priming effect might be a variable strength of the association between prime and targets. An influence of the duration of the carrier word can be ruled out, since the durations of the prime words did not differ significantly in the experimental versus the baseline condition. This was also the case for the durations of the carrier words. The obtained effects are thus not contaminated by effects of duration. The influence of the frequency of the carrier words relative to the frequency of the embedded prime words will be discussed in the next section.

4.5 GENERAL DISCUSSION

Support for the hypothesis that open- and closed-class words have separate stores in the mental lexicon would be provided by the presence of some unambiguous cue in the incoming speech on which the assignment of an incoming word to either of these stores could be based. The present study showed that Dutch listeners do not use stress as an indicator of vocabulary class, either when open- and closed-class words are presented in a nonsense context (experiment 7), or when these words are used in a meaningful context (experiment 8). Although the recognition of open-class words was expected to be facilitated by stress, this effect was not stable in that it interacted with other factors like word frequency. In addition, no consistent inhibitory effect of stress on the recognition of closed-class words was found. This effect was again influenced by word frequency, and also seemed to depend on the expectation of the listener with regard to the stress pattern of certain combinations of words. For example, the effect of stressing a closed-class word was larger for standard combinations of prepositions and nouns versus more random combinations of a closed-class word followed by a noun. These results support the assumption that delayed recognition of closed-class words due to stress results from an acoustic effect of mis-stressing rather (see also chapter 3) than from access of the wrong lexicon.

A tentative explanation for such a mis-stressing effect on the recognition of closed-class words might be provided by a context-sensitive lexicalist approach (MacWhinney, 1988). In this approach, each lexical item has a "valence description" indicating the type of items with which it can form a larger unit. A determiner, for example, can have a syntactic frame like (*post, noun*), indicating that this determiner can be followed by a noun. If a determiner is accessed during speech processing, this valence description will be activated. Successively, the processor will check whether the expectation is filled, also taking into account cues like word order, grammatical markings, lexical class information, and prosodic cues. The fact that stressed closed-class words are often recognized more slowly than unstressed closed-class words when followed by a noun, might thus be explained by a violation of a minus stress specification for a determiner in a DET-NOUN frame. Stress put on the determiner will then slow down recognition, and this effect is likely to be smaller for high-frequency than for low-frequency words. The larger effect of mis-stressing for the preposition+noun combinations versus the other closed-class+noun combinations might then result from the fact that combinations like *on foot*, *by train*, *to bed* or *on board* occur more frequently together (and are more likely to be lexicalized) than combinations like *I slept*, *that fish*, or *his helmet*. According to this explanation, the delayed recognition of stressed closed-class words is thus more likely to be a post-access effect of mis-stressing rather then a pre-lexical result of accessing an erroneous lexicon.

Additional evidence that stress in Dutch is not used as a pre-lexical cue to vocabulary class (even when open- and closed-class words are presented in a sentence context) is provided by the third experiment of the present study on the activation of homophones with both an open-class and a closed-class meaning. If stressed lexical items are looked up in the open-class lexicon, a stressed homophone like *hen* (having both an open-class meaning "hen" and a closed-class meaning "them") should activate semantic associates of the open-class meaning but not of the closed-class meaning. However, the results showed that when such homophones were used as the first syllable of a sentence final carrier word (*hendels* "handles"), the closed-class associates received more activation than the open-class associates. This not only indicates that stress cannot prevent closed-class meanings from being activated, it also shows that embedded words are activated in running speech, even if these words are not supported by the context.

This latter finding that embedded words receive activation agrees with the results of a number of other studies. Prather and Swinney (1977), for example, showed that semantic associates of carrier-initial embedded words such as *boy* in *boycott* were activated when these carriers were presented in isolation (as described in Swinney, 1981). The absence of activation of the syllable *cot* was explained by the prediction that listeners have a bias towards perceiving the longest candidate consistent with a phoneme string. However, two other studies did show activation for word-final embedded words. First, Shillcock (1990) demonstrated that carrier-final embedded words which are used in a sentence context prime their hyponyms (*bone* primed *rib* in the sentence *He carefully placed the trombone on the table*), and he argued that the magnitude of priming effects is modulated by the frequency of the onsets of words. Second, Gow and Gordon (1995) showed that listeners accessed both *tulips* and *lips* at the same time when presented with the string *two lips*. They also demonstrated that the pronunciation of a phoneme string by a speaker affects listeners' patterns of lexical access; no priming was found for *lips* when it was pronounced as part of *tulips*.

Multiple activation of words has also been shown by Zwitserlood (1989). In this study, subjects listened to the Dutch fragment *kapit-*, which can be the onset of the words *kapitein* ("captain") and *kapitaal* ("capital"). Priming occurred for lexical decisions on semantic associates of both meanings (respectively, *schip* "ship" and *geld* "money"). The observation that completely and partially embedded words are activated despite the fact that they are not supported by the context, provides evidence for current models of spoken word recognition in which simultaneously many (erroneous) words are activated that closely resemble the incoming signal.

For example, the TRACE model developed by McClelland and Elman (1986) allows for parallel activation of words if certain parameters which control mutual inhibition of competing words are set in such a way as to suppress each other's activation only slightly. Parallel activation of overlapping words which do not have synchronized onsets is also assumed in the revised version of the Cohort model by Marslen-Wilson (1987); word candidates are activated in parallel, and a word is recognized when its activation level becomes considerably higher than the level of activation of its closest competitor. Likewise, in the more recent model of spoken word recognition, Shortlist (Norris, 1994), a 'shortlist' of words having the best match with the input are activated and entered into a competition process. Whereas the occurrence of word-onset embeddings is a problem for sequential models in that word-onsets cannot be reliably rejected (for example, the word *property* can only be recognized if the word-onset embedding *proper* is rejected), models based on parallel activation of words can handle lexical embeddings by competition between lexical hypotheses.

In models for spoken word recognition like TRACE, Cohort, and Shortlist, frequency does not contribute to this competition process. Nevertheless, the influence of frequency on the competition between two word candidates is suggested by the present finding that associates of the high-frequency closed-class meaning of a homophone appear to receive more activation than associates of the low-frequency open-class meaning. Although this result might have been partly due to the frequency of the carrier word (i.e., the frequency of the carrier word was lower than the frequency of the closed-class meaning, but equal to the frequency of the open-class meaning), similar effects of frequency have been found by Zwitserlood (1985) and Marslen-Wilson, Brown, and Zwitserlood (both reviewed in Marslen-Wilson, 1987).

These studies not only showed that auditory input like *cap-* activates both *captive* and *captain*, they also indicated that the competition between these words is influenced by the difference in their frequency of occurrence; lexical decisions on semantic associates of the high-frequency word *captain* (*ship*) were faster than decisions on the associate of the low-frequency word *captive* (*guard*). When two words thus share their first syllable and have been accessed simultaneously, the word with the highest frequency of occurrence will receive more activation than the word with the lower frequency of occurrence.

If frequency indeed plays a role in the lexical access procedure for spoken words, one of the advantages of a dual lexicon over one single lexicon (namely faster retrieval of closed-class words due to the fact that open-class words are not included in the competitor set) is eliminated. Since the frequency of occurrence of most of the closed-class words is much higher than the frequency of occurrence of the open-class words, they will have a stronger activation than most of the open-class competitors.

Yet if all words are stored in a single lexicon, how can we account for the effects obtained from studies of aphasia and speech-error observations? As mentioned in the introduction, Bates and Wulfeck (1989) have argued that agrammatic speakers might suffer from a disorder of lexical access rather then from a 'central syntactic deficit' in which syntactic knowledge is lost. Because open- and closed-class words have such different characteristics with regard to their access properties, dissociations between these item classes are not unlikely to occur, even if both vocabulary classes are stored in the same lexicon. For example, open- and closed-class words are intrinsically different with respect to their semantic content (the set of semantic associations), phonological salience (stress, vowel quality, and number of syllables), assignability (local versus long-distance binding), and frequency of occurrence (high or low). Whereas the first three features tend to make open-class words easier to perceive and remember, the feature frequency will favour retrieval of the high-frequency closed-class words.

Not only are these individual properties of the open- and closed-class words likely to influence lexical access, there is also another set of extrinsic factors which favours access of either open- or closed-class words. Whereas a small cohort size and a high positional predictability facilitates access of closed-class words, a small within-cohort confusability and the possibility of inter-item priming in context favours access of open-class words. Since these factors thus have almost opposite effects on the retrieval of open- versus closed-class items, Bates and Wulfeck argued that it is not hard to imagine why closed-class morphemes are at a disadvantage when the processor is subjected to stress (e.g., a high memory load) or noise. In a later study, Blackwell and Bates (1995) provided evidence for this assumption by demonstrating that it is actually possible to evoke agrammatic profiles in healthy adults when their processing capacity is diminished (i.e., by the performance of a secondary (memory) task during a grammatical judgement task).

Separate storage and processing of open- and closed-class words has also been assumed to explain the different engagement of open- and closed-class words in speech errors (Garrett, 1978, 1980, 1988). A first point that should be addressed is that since speech error data result from speech production it is not clear whether these results can directly be generalized to speech perception. In speech production, a speaker has a concept in mind which needs to be mapped onto syntactic 'lemma' and phonological 'lexeme' representations (see Levelt's (1989) model of speech production). In speech comprehension, however, the latter representations have to be mapped on a conceptual representation. Since the input signal for a listener is sequential, the mapping problems might be different for speech comprehension versus speech production. This, in turn, might encourage distinct processing of open- and closed-class words in perception versus production.[15]

Second, Garrett supported his hypothesis that open- and closed-class words are differently processed and stored by citing data from agrammatic speech processing. However, as already pointed out, Bates and Wulfeck (1989) have argued that to explain dissociations between open- and closed-class words the assumption of a dual lexicon is not required.

A final remark with regard to speech error phenomena as evidence for differential processing and storage of closed-class words is that this assumption is solely based on Garrett's observation that closed-class words are only seldom involved in segmental errors. The crucial question therefore is whether this observation can be explained by the distinctive features of

---

[15] *The link between the production and comprehension of closed-class words with regard to agrammatic performance has recently been discussed by Garrett (1992). He argued that whereas the locus of the production problem would be the mapping from message or conceptual representations to syntactic representations (phrasal analysis and logical representations), the locus of the comprehension problem would be the mapping from the lemma to the conceptual representation.*

open- versus closed-class words as proposed by Bates and Wulfeck (1989). Perhaps, factors such as a small number of semantic associates and syllables, a small cohort size, high predictability from the context, and a high frequency of occurrence make these closed-class words less prone to errors than open-class words. Although such an explanation is still speculative, Dell (1990) has indeed argued that the open-class /closed-class contrast in phonological speech errors is due to their different frequency of usage. He therefore claimed that open- and closed-class morphemes are not distinguished in their pre-access processes in word recognition (see also Jescheniak & Levelt, 1994).

Two other studies have also argued that speech error data in fact demonstrate similar processing of open- and closed-class words. For instance, Stemberger (1984) argued that many errors can be described as instances of wrongly accessed morphological or syntactic structures. These structural substitutions are biased towards more frequent structures and towards minimal structures, both favouring structures without closed-class words. Since the loss of open-class words is less common, Stemberger stated that the assumption of distinct processing vocabularies is not needed. Furthermore, Kohn and Smith (1993) have reported that the production of closed-class words and of nouns by agrammatic patients is actually largely similar with respect to the occurrence of phonological errors. They therefore argue that closed-class words are stored along with the open-class words in the mental lexicon.

Given these alternative explanations for the agrammatic and speech error data, the storage of both open- and closed-class words in one single mental lexicon is not unlikely. In addition, the present findings that stress does not serve as a pre-lexical cue to vocabulary class and that frequency plays a role in the lexical access procedure are incompatible with a dual lexicon with separate access procedures for open- and closed-class words. However, listeners might use other cues than stress to assign open- and closed-class words to respectively an open- or a closed-class lexicon. The next chapter will focus on one of those alternative cues - the syntactic context.

MODULARITY IN LEXICAL ACCESS: EVIDENCE FROM WORD CLASS AND FREQUENCY EFFECTS

CHAPTER 5

(This chapter is based on an article submitted to the Quarterly Journal of Experimental Psychology)

ABSTRACT

Recent studies have suggested that whereas the processing of closed-class words can be influenced by the syntactic environment, lexical access of open-class items is not sensitive to this aspect of the sentence context. The present study investigated this difference between the two vocabulary classes by using homophones syntactically biased towards either their open-class or their closed-class meaning. In a first word-spotting experiment, the speed of retrieval of both meanings was found to correspond to their respective frequencies of occurrence. This might indicate that frequency effects arise in accessing the syntactic word (lemma) rather than the phonological word (lexeme). When the homophones were used in a cross-modal priming paradigm, priming was found for associates of the closed-class meaning when they were preceded by a homophone in a closed-class context, but not when they were preceded by a homophone in an open-class context. No priming effects were found for associates of the open-class meanings in either context. These results suggest that although both meanings of a homophone are initially activated, the meaning with the highest frequency will be passed on for a check against the context first. They furthermore support models of spoken word recognition in which the syntactic context plays a role at a later integration stage.

5.1 INTRODUCTION

Homophones like *checked* have a single phonological form but multiple meanings (*evaluated* or *having a square pattern*). Contextual information is thus needed to decide on which particular meaning is appropriate. There are, however, different accounts about the exact moment in time at which contextual information can play a role in the word recognition process. In an interactive account, context is assumed to activate the contextually appropriate meaning of the homophone only (*selective access*). Modular views on word processing, on the other hand, are based on the assumption that context does not influence the initial activation of word meanings. One version of this model claims that in an initial stage of the lexical access process only the meaning with the highest frequency will be selected for further processing. If it turns out that this meaning does not fit with the context, another meaning will be retrieved (*ordered access*). In a second version of the modular account, all meanings are initially accessed and context is used in a post-access selection process directing a listener to one single meaning (*exhaustive access*).

Experimental studies on this issue show rather contradictory results. Whereas some of the results argue for interactive processing (Glucksberg, Kreuz, & Rho, 1986; Schvaneveldt, Meyer, & Becker, 1976; Simpson, 1981), other results suggest modular processing (Forster & Bednall, 1976; Hogaboam & Perfetti, 1975; Holmes, 1979; Onifer & Swinney, 1981, Swinney, 1979) (for reviews, see Simpson, 1984, 1994). One of the factors that might be responsible for the discrepancy across these studies is variation in the type of context in which the homophones were presented. For instance, context can be semantically biasing towards a certain meaning of the homophone (if it contains a word which is semantically highly associated with this particular meaning), but the context might also provide pragmatic or syntactic cues to the meaning of the homophone (e.g., the homophone *play* in the sentence *The gifted man wrote a play* can be disambiguated into the meaning of *drama* by using the pragmatic information that a game is not very likely to be written. The syntactic context of the article preceding the ambiguous word furthermore indicates that this word is used in its noun-meaning rather than in its verb-meaning of the act of playing). Whereas a strongly semantically biasing context might help accessing a homophone in a directive way, other contexts - such as the pragmatic or syntactic context - are probably not restrictive enough to bias access of a certain meaning.

For instance, Seidenberg, Tanenhaus, Leiman, and Bienkowski (1982) used homophones with either two noun readings (e.g., *organ*) or with one noun and one verb reading (e.g., *watch*). These homophones were presented in both semantically and syntactically/pragmatically biasing contexts. For noun-noun homophones presented in semantically biasing context, naming responses to visual targets (presented at the offset of the homophone) were faster when these targets were related to the contextually biased meaning than when the targets were related to the unbiased meaning. For noun-verb homophones, no directive access was found. This difference between the two types of homophones was explained by a possible different representation in the mental lexicon. However, both types of homophones did show similar results when they were presented in a syntactically /pragmatically biasing context; all meanings were activated when targets were presented at the acoustic offset of the homophone. Furthermore, for both types of homophones, only the contextually appropriate meaning remained active when the targets were presented 200 ms. after the offset of the homophone.

The latter results agreed with an earlier study by Tanenhaus, Leiman, and Seidenberg (1979) who also used noun-verb homophones in syntactically biasing sentence contexts (e.g., *I bought the watch* versus *I will watch*). When a target was presented at the offset of the homophone, naming responses to targets related to both the noun and the verb readings were facilitated when compared to responses to an unrelated target. They also found that when targets were presented 200 ms. after the offset of the homophone, only responses to the target related to the contextually biased meaning were facilitated. Tanenhaus and colleagues therefore argued that in a syntactically biasing sentence context both meanings of the homophone are initially accessed, but the inappropriate meaning is rapidly suppressed.

Predicting words from the syntactic context might indeed not be very useful, since these predictions are not completely watertight. For example, the word *to* predicts that the next word is likely to be a verb (as in *to house*), but *to* can theoretically also be followed by a determiner plus noun (*to the/my house*). Furthermore, if such a prediction were to lead to higher activation of all verbs, an enormous number of verbs would be activated which would not even start with compatible acoustic information. It might therefore be more efficient to activate both the noun and the verb meaning of an ambiguous word, and successively use syntactic information to select the most appropriate one.

Yet Shillcock and Bard (1993) have argued that although this is probably true for open-class words (nouns, adjectives, verbs, and most adverbs), modular processing with respect to the syntactic context might not apply to closed-class words (such as determiners, prepositions, conjunctions, and auxiliaries). They argued that interaction between the syntactic context and the processing of closed-class words could in fact lead to both perceptual and computational efficiency. For instance, closed-class items tend to be perceptually different from open-class items in that open-class words tend to start with a stressed syllable having a full vowel, and closed-class words are often unstressed syllables containing a reduced vowel (Cutler & Carter, 1987). This phonological distinction could be the basis of a metrical segmentation strategy (MSS) in which a strong syllable initiates a lexical search in a sub-lexicon for open-class words (Cutler & Carter, 1987; Cutler & Norris, 1988; Cutler & Butterfield, 1992; Cutler, 1993). When the recognition of an open-class item is completed and the next syllable is weak, this will trigger a lexical search in the closed-class sub-lexicon. Since the phonological characteristics of a word do not always correspond to the general characteristics of either the open- or the closed- class vocabulary, Shillcock and Bard suggested that the syntactic context could provide additional cues for assigning a word to either vocabulary class.

From a computational angle, interaction of the syntactic context with the access of closed-class words could also be an advantage. Whereas the open-class item set is large and can easily be extended with new members, the closed-class item set is much smaller and new members are hardly ever added. If a closed-class item can be predicted from the syntactic context, only this small subset of lexical items would thus be activated and superfluous activation of open-class words would be prevented.

To investigate whether the syntactic context is indeed involved in the processing of closed-class words, Shillcock and Bard designed a cross-modal lexical decision study in which open-class/closed-class homophones such as /*wʊd*/ were used. These homophones typically have an open-class meaning of a relatively low frequency of usage (*wood*), and a closed-class meaning of a relatively high frequency (*would*). All homophones were presented in clause-final position in a sentence syntactically biasing the homophone towards either its open- or its closed-class meaning (e.g., *John said that he didn't want to do the job, with his brother's wood / but his brother would, as I later found out*). A synonym of the open-class meaning (*timber*) was visually presented at the acoustic offset of the homophonous prime. The results revealed that lexical decisions to such a synonym were facilitated when the sentences were biased towards the open-class meaning of the homophone (relative to an unrelated prime substituted for the homophone in the original utterance). However, decisions to these open-class synonyms were not facilitated when the utterance biased the closed-class meaning. Shillcock and Bard interpreted these results as evidence for modular processing of open-class words versus interactive processing of closed-class words.

In Shillcock and Bard's study, the high-frequency closed-class meanings did not seem to interfere with the access of open-class meanings, even though the closed-class meanings exhibited higher frequencies than the open-class meanings. Since previous results on frequency imbalanced open-class homophones suggest that dominant meanings are more strongly activated than subordinate meanings (in semantically non-biasing sentence contexts), this finding of Shillcock and Bard seems rather surprising. Hogaboam and Perfetti (1975), for instance, carefully selected open-class homophones such as *cold* with both a high-frequency meaning (i.e., the weather being cold) and a low-frequency meaning (i.e., having a cold). Subjects were faster to decide whether the last word of a sentence had more than one meaning when the homophones were contextually biased towards the low-frequency meaning. Hogaboam and Perfetti explained these results by assuming that dominant meanings of homophones are always accessed first, irrespective of the context (*ordered access*). Thus if the context is biased towards the subordinate meaning, the mismatch between the initially retrieved dominant meaning and the context will facilitate detection of ambiguity. However, if the context is biased towards the dominant meaning, the low-frequency meaning still has to be retrieved.

Additional evidence for faster processing of the dominant high-frequency meaning of a homophone was presented by Holmes (1979). In a semantic meaningfulness task (in which subjects had to decide whether a sentence was meaningful or not), reactions were faster to sentences biasing the dominant meaning of a homograph than to sentences biasing the subordinate meaning. That this effect was not merely due to longer comprehension times for subordinate meanings was shown in an additional experiment in which decisions were made on sentences containing unambiguous synonyms of the homographs (matched for the frequency of either meaning). Whereas similar reaction times were found for dominant meanings and their high-frequency controls, the processing of subordinate meanings took longer than the processing of their low-frequency control words. Although these results indicate ordered access for frequency imbalanced homophones, neither the ambiguity detection task nor the semantic correctness task are sensitive enough to determine the exact role of frequency on the lexical access procedure.

A more precise method to investigate the moment in time at which frequency plays a role in the lexical access procedure is the priming paradigm. Simpson (1981), for example, used a cross-modal priming paradigm to investigate the effect of semantic/pragmatic context on the perception of frequency-imbalanced open-class homophones. When the context did not bias a certain meaning, only the dominant meaning was facilitated when targets were presented 120 ms. after the acoustic offset of a homophone. Thus, in the absence of a biasing context, meaning retrieval seemed to be based on frequency. However, when the context was strongly biased towards either the dominant or the subordinate meaning, only the contextually appropriate meaning was facilitated. For weakly biasing contexts, the effects were different for dominant and subordinate meanings. When the context biased the dominant meaning, only this particular meaning was activated. Yet when the context weakly biased the subordinate meaning, both the subordinate and the dominant meaning were activated. Although this result suggests that the effect of frequency dominance can be altered by the context, a delay between prime and target of 120 ms. is still too long to decide whether initially only the dominant meaning is activated (*ordered access*) or whether initial activation of both meanings takes place (*exhaustive access*).

This difference between ordered access versus exhaustive search of frequency imbalanced homophones has more specifically been tested by Tabossi (1988). In a series of cross-modal lexical decision experiments, she used homophones with both a high-frequency and a low-frequency meaning. At the offset of these homophones visual targets that were related to either the dominant or the subordinate meaning were presented. The results showed that when the context biased the dominant meaning, the ambiguous word could be accessed both selectively or exhaustively depending upon the constraint the context placed on the semantic features of its contextually congruent meaning. Tabossi thus concluded that both dominance and context may have an effect on lexical access of an ambiguous word. In a later paper, Tabossi and Zardon (1993) showed that these findings do not indicate exhaustive access followed by a fast selection of either meaning, but they rather reflect genuine dominance and context effects.

These studies on open-class homophones thus clearly indicate a strong activation of dominant meanings in non-biasing sentence contexts. The absence of the interference from the high-frequency closed-class meaning in Shillcock and Bard's study might, however, be explained by the location of frequency in the mental lexicon. Because homophones have only one single phonological representation, access of the low-frequency open-class meaning could benefit from the higher-frequency of the closed-class meaning if frequency is located at this phonological node. This explanation will be investigated in experiment 10.

Furthermore, Shillcock and Bard (1993) did not include semantic associates of the closed-class meaning of the homophones in their study, which prevented verification of two other predictions of respectively modular and interactive processing accounts. First, a modular view in which both meanings of the homophone are initially accessed not only predicts activation of semantic associates of the open-class meaning, but also predicts activation of semantic associates of closed-class meanings (note that the alternative modular account in which only the meaning with the highest frequency is activated is not supported by Shillcock and Bard's results). Second, if closed-class words are indeed accessed in an interactive manner, we not only expect no priming effect for associates of the open-class meaning after accessing the closed-class homophone, but there should also be a positive priming effect for the associate of the closed-class meaning. These further predictions of the modular and the interactive account will be tested in experiments 11 and 12.

5.2 EXPERIMENT 10: LEXICAL DECISION

In the early fifties, it was shown that the speed with which words are retrieved from the mental lexicon depends on their frequency of occurrence; for speech perception by Solomon and Postman (1952), and for production by Oldfield and Wingfield (1965) and by Wingfield (1968). It is still not clear, however, at what level of the speech perception process frequency becomes important when homophones with both an open-class and a closed-class meaning are processed. If frequency plays a role at the level of phonological representations, the two meanings of a homophone might be retrieved equally fast since they share their phonological node. However, if frequency is important at some other level of the speech perception process where these two meanings have separate representations, high-frequency closed-class meanings are expected to be retrieved faster than low-frequency open-class meanings. Several studies on ambiguous words have indeed indicated that the retrieval speed of two open-class meanings of an ambiguous words like *arms* (*limbs* or *weapons*) is based on their separate frequencies of usage (Jastrembski, 1981; Morton, 1979; Rubenstein, Garfield, & Millikan, 1970). For example, Forster and Bednall (1976) showed that in a syntactic function decision task where subjects had to decide on the correctness of certain noun and verb phrases (e.g., the correct phrases *the house* or *to house* versus the incorrect phrases *the eat* or *to ear*), reaction times on correct phrases were faster for the meaning of the homophone with the highest frequency (in this case the noun-meaning of *house*). None of the previous studies on storage and access of open- and closed-class items has, however, explicitly addressed the question of how ambiguous open-class/closed-class words are represented, and at which level of the perception procedure frequency becomes important.

The present experiment therefore investigated lexical decisions on Dutch open-class /closed-class homophones that were biased towards either their open- or their closed-class meaning by a preceding word (respectively *groen haar* 'green hair' and *voor haar* 'to her'). The frequencies of the closed-class homophones were higher than the frequencies of the open-class homophones. If frequency is important on a phonological level, lexical decision latencies of the open-class readings should be similar to the decision latencies of the closed-class readings. However, if frequency is influential at another level, different latencies can be expected.

In order to study access of homophones that are not preceded by a biasing context, the two-word phrases were also presented in their reversed order (e.g., *haar groen* 'hair green'). In addition to this variation in order, the phrases were further varied with regard to their stress pattern (e.g., weak-strong and strong-weak). Because open-class items tend to contain a strong or metrically stressed syllable and closed-class items tend to be weak, unstressed syllables (Cutler & Carter, 1987), the use of one particular stress pattern could favor the retrieval of one class over the other. In case of a weak-strong stress pattern, for example, recognition of closed-class items in initial position could be easier than recognition of open- class items in this position.

5.2.1 Method

Participants

Eighty students were recruited from the subject pool of the Max-Planck Institute for Psycholinguistics. All students were native speakers of Dutch with normal hearing abilities and normal vision. The participants were randomly assigned to one of eight groups of ten subjects and received Dfl. 8.50 for their participation. None of the students participated in more than one of the experiments reported here.

Materials

The experimental item set consisted of forty phrases consisting of two words. Twenty of these phrases ended in a monosyllabic homophone. These homophones were biased towards either their open- or their closed-class meaning (10 cases each) by the first word of the phrase. The other twenty phrases ended in a non-homophonous word (10 open class; 10 closed class). These non-homophonous controls were matched with the homophones for both their number of phonemes (homophones 2.3; open-class controls 2.6; closed-class controls 2.4) and their frequency of occurrence. Mean word-form frequencies were 523 per 42 million for the homophonous open-class items and 649 for the open-class controls (according to the frequency counts of the Celex lexical database). Word-form frequencies were 1109099 and 93018 per 42 million, for the closed-class homophones and the closed-class controls, respectively. In Appendix I, all experimental items are listed. In addition to the experimental phrases, sixty-eight filler phrases were constructed. These filler items all consisted of a combination of a word and a legal nonword (e.g., *het nint* 'the nint'; *rood suik* 'red suik'). The experimental and filler items were presented both in their normal and their reversed order. The nonwords in the filler phrases occupied the second position when these phrases were presented in their normal order. However, when the phrases were presented in their reversed order, the nonwords were on the first position (34 cases, each).

Procedure

A list containing both the experimental and the filler items was randomized four times. A trained female speaker of standard Dutch was asked to read the resulting four lists with a natural intonation. In the first list, stress was put on the first word of the phrase (e.g., *KORT haar* 'short hair'), and in the second list stress was placed on the second word (e.g., *kort HAAR*). In the other two lists, the order of the words was also altered (e.g., *HAAR kort / haar KORT* 'hair short'). Recordings were made in a sound-isolated booth using a Sony 670 DAT-recorder and a Sennheiser HMD 224 microphone.

The phrases were assigned to eight lists which were presented to eight different groups of subjects. The assignment of phrases to different lists took place when: 1) these phrases differed in stress pattern only (e.g., *KORT haar* and *kort HAAR*), 2) the phrases contained a homophone (e.g., *kort haar* and *voor haar*), and 3) they consisted of identical words, as for the normal and the reversed order (e.g., *kort haar* and *haar kort)*. In each list, target and filler items were assigned to three blocks. The first block was a practice block of ten filler phrases, the second and third block each started with two filler phrases followed by ten target and ten filler phrases in pseudo-randomized order. For the randomization, the following three criteria were used: 1) no more than three target or filler phrases in succession, 2) no more than three successive items with identical stress patterns, and 3) no successive items having the same initial phoneme. Samples of the experimental phrases in their different conditions are presented in Table 5.1.

Subjects were tested one at a time, while seated in a sound-proof booth in front of a computer screen and a microphone. They were given written instructions to listen to the phrases over headphones, and decide as fast and accurately as possible whether this phrase contained a real word in its first position (or in its second position, in case of the reversed order).

Table 5.1 *Example of experimental phrases in their different conditions used in Experiment 10*

	Normal order		**Reversed order**	
	Homophones	Controls	Homophones	Controls
Open class (-stress)	KORThaar	WITbier	haarKORT	bierWIT
Open class (+stress)	kortHAAR	witBIER	HAARkort	BIERwit
Closed class (-stress)	VOORhaar	NAASThem	haarVOOR	hemNAAST
Closed class (+stress)	voorHAAR	naastHEM	HAARvoor	HEMnaast

The participants responded by pressing a button marked YES with their dominant hand. 900 ms. after a push-button response, a star was shown on the computer screen for an additional 900 ms. As soon as the star appeared, a voice key was activated for 3400 ms. and the participants had to repeat the word they had detected. If no real word was detected, no push-button response had to be made. In this case, the next trial started after 2500 ms. Stimulus presentation and on-line data collection was controlled by a Hermac AT-computer. Word repetitions were recorded with a Sony DTC 55 ES DAT-recorder. Scoring of the repetition responses was done on-line by the experimenter. However, when these repetition responses were unclear, the recordings were consulted afterwards.

5.2.2 Results and discussion

Decision latencies were measured from the onset of the second word for the normal order of presentation, and from the onset of the first word for the reversed presentation order. Latencies were excluded from the analysis when 1) a word was not detected within the time- out period (10% of the responses), 2) a wrong word was repeated (1%), or 3) the latency exceeded the overall mean reaction time per condition by plus or minus 3 standard deviations (1%). These missing data and outliers were substituted by the overall mean reaction time per condition.

Reaction times and errors were analyzed using a four-way analysis of variance with the factors homophone (homophone, non homophonous control), class (open class, closed class), and stress (stressed, unstressed) as within-subject variables, and with order (normal, reversed) as a between-subject variable. Analyses were performed both across subjects (F1) and across items (F2). Significant three-way interactions were found between order, homophone, and class ($F1(1,78) = 51.39$, $p < .01$, $MSe = 12682.33$; $F2(1,72) = 10.20$, $p < .01$, $MSe = 15375.58$) and between order, homophone, and stress ($F1(1,78) = 9.98$, $p < .01$, $MSe = 8849.77$; $F2(1,72) = 4.40$, $p < .05$, $MSe = 6078.43$). Therefore, the effects of homophone, class, and stress were studied separately for the normal and the reversed order. Average word spotting latencies for phrases in both orders are shown in Figure 5.1.

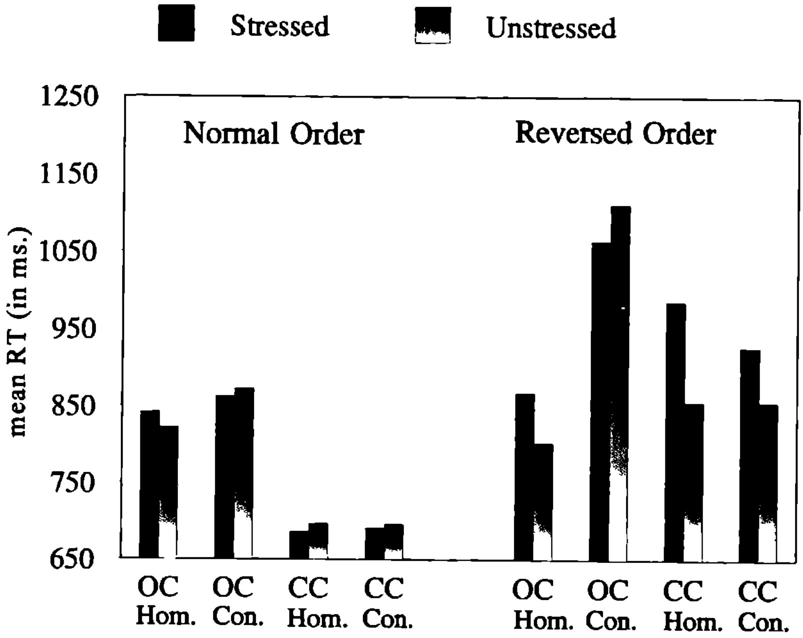

Figure 5.1 *Results of experiment 10. Mean lexical decision latencies for open-class homophones (OC Hom.), closed-class homophones (CC Hom.), open-class control words (OC Con.), and closed-class control words (CC Con.), for both the normal and the reversed order.*

The results for the normal order condition revealed only a significant main effect of class (F1(1,78) = 132.66, $p < .01$, MSe = 15543.35; F2(1,72) = 23.89, $p < .01$, MSe = 20644.33); mean latencies were faster for stressed and unstressed versions of closed-class homophones and their controls, than for the stressed and unstressed versions of open-class homophones and their controls.

For phrases in their reversed order, a main effect of class was again found (F1(1,78) = 99.13, $p < .01$, MSe = 10075.36; F2(1,72) = 11.64, $p < .01$, MSe = 20644.33), but here the effect of class interacted with homophone (F1(1,78) = 133.20, $p < .01$, MSe = 12682.33; F2(1,72) = 25.60, $p < .01$, MSe = 16163.99). Further inspection of the mean latencies obtained in the reversed order showed an effect of class for the control words, in that stressed and unstressed versions of closed-class controls were accessed faster than the stressed and unstressed versions of open-class controls. However, no effect of class was found for the homophones. In fact, both versions of the closed-class homophones and of the open-class homophones showed latencies similar to those of the closed-class control words.

Furthermore, an additional interaction between stress and homophone was found in that unstressed versions of closed-class homophones were recognized faster than stressed versions ($F1(1,78) = 13.40$, $p < .01$, $MSe = 8849.77$; $F2(1,72) = 6.09$, $p < .05$, $MSe = 5971.73$). However, the latter result might be due to the tendency that unstressed words tend to be shorter than stressed words, and short words might be spotted faster than long words. Therefore, the correlation between the word-spotting latencies and the duration of the closed-class homophones was computed. A Pearson correlation analysis showed indeed a significant correlation between stress and duration of the phrases ($r = .4630$, $p < .05$). When the factor duration was included in an analysis of co-variance, the advantage of the unstressed version of the closed-class homophones over the stressed version disappeared.

The overall analyses of the errors showed a significant interaction between order, homophone, and stress ($F1(1,78) = 21.19$, $p < .01$, $MSe = .03$; $F2(1,72) = 5.43$, $p < .05$, $MSe = .03$), and a significant main effect of class ($F1(1,78) = 29.63$, $p < .01$, $MSe = .05$; $F2(1,72) = .38$, $p < .05$, $MSe = .04$). In the normal order, significantly fewer errors were made in the stressed and unstressed versions of the closed-class homophones (0%, 1%) and their controls (2%, 15%) than in the stressed and unstressed open-class homophones (9%, 10%) and the open-class controls (18%, 21%) ($F1(1,78) = 16.83$, $p < .01$, $MSe = .05$; $F2(1,72) = 4.60$, $p < .05$, $MSe = .04$).

The same pattern was found for phrases in the reversed order, in that overall fewer errors were made in stressed and unstressed closed-class homophones (5%, 5%) and their controls (10%, 18%) than in stressed and unstressed open-class homophones (2%, 7%) and open-class controls (17%, 50%) ($F1(1,78) = 12.92$, $p < .01$, $MSe = .05$; $F2(1,74) = 4.15$, $p < .05$, $MSe = .04$). In addition to this main effect of class, in the reversed order the main effects of homophone and stress also reached significance ($F1(1,78) = 90.82$, $p < .01$, $MSe = .03$; $F2(1,74) = 16.60$, $p < .01$, $MSe = .04$ / $F1(1,78) = 33.13$, $p < .01$, $MSe = .03$; $F2(1,74) = 6.56$, $p < .05$, $MSe = .04$). These error-data are consistent with the expectation that fewer errors will be made if a word has a high frequency of occurrence (i.e., is used relatively often).

The pattern of results seems to be quite clear. When open-class/closed-class homophones are presented in a disambiguating context towards either the open- or the closed- class meaning, high-frequency closed-class meanings are retrieved faster than low-frequency open-class meanings (independently of stress). The presence of this frequency effect not only indicates multiple representations for open-class/closed-class homophones (similar to the multiple entries for ambiguous open-class words), it also suggests that frequency is not important at the phonological level; since the two meanings of a homophone share their phonological node, the meanings of a homophone should be retrieved equally fast at this level.

When the homophones were not preceded by a disambiguating context (i.e., in the reversed order), no difference in retrieval time was found. Because the homophones were retrieved as rapidly as the closed-class controls, it seems justified to conclude that without a biasing context, the representation of the homophones' most frequent, closed-class meaning will be accessed. This is exactly the result predicted by so-called threshold models (Morton, 1969, 1970). In these models, representations of words are sensitive to acoustic or visual information belonging to the characteristics of these words. When the feature count exceeds a certain threshold level, word recognition will take place. The present activation of the high-frequency closed-class meaning can thus be explained by the assumption that these words have a lower threshold for activation (i.e., a higher resting activation level) at the meaning level than the low-frequency open-class meaning, and therefore, the closed-class meaning will be accessed faster than the open-class meaning. Furthermore, the relatively few errors made on the open-class homophones in the reversed order - as opposed to the large number of errors made on the open-class non-homophones - also suggests that the closed-class meanings of the homophones were accessed. All homophones in this order are probably treated as closed-class before the second word has even been processed.

Although the sentence contexts used in this experiment clearly directed the listeners towards the open- or closed-class meanings of homophones, it cannot be concluded from the current results that lexical access is context-dependent. As suggested by previous researchers (Balota, 1990; Seidenberg, Waters, Sanders, & Langer, 1984), context can also influence lexical decision latencies at a later, post-access decision stage. In the next priming experiments, the influence of syntactic context on the time-course of lexical access was investigated.

5.3 EXPERIMENT 11: AUDITORY PRIMING

In their study of priming effects with open-class/closed-class homophones, Shillcock and Bard (1993) only presented synonyms of the open-class homophones as target items. After listening to a sentence containing the homophone */wʊd/*, subjects had to make a lexical decision on *timber*. Whereas open-class homophones did prime their associates, no priming was found for closed-class homophones. The exclusion of closed-class associates as targets, however, makes it impossible to decide whether after hearing an open-class prime only open-class associates are primed, or whether closed-class associates are also activated. Furthermore, if closed-class words are processed in an interactive way, priming is predicted for the semantic associates of these words. Because closed-class items have less lexical meaning than open-class words (Taft, 1990; chapter 2 of the present thesis), the strength of association between closed-class items and their associates is expected to be less than between open-class words and their associates. Since the results of experiment 9 (chapter 4) demonstrated only weak priming of the semantic associates of closed-class meanings of embedded homophones, the main purpose of the current experiment is to determine whether closed-class associations can be strong enough to cause reliable priming when used in a priming paradigm.

Subjects were asked to listen to short phrases ending in an open-class/closed-class homophone like *haar*. The syntactic context determined whether the homophone had an open- class meaning ('hair') or a closed-class meaning ('her'). Lexical decisions were made on an associate of the open-class meaning ('wig') or on an associate of the closed-class meaning ('girl'). If association with closed-class items functions similarly to open-class association, priming effects are expected to occur not only for the open-class items but also for words belonging to the closed-class item set.

5.3.1 Method

Participants

Forty-eight students from the subject-pool of the Max-Planck Institute for Psycholinguistics were asked to participate in this experiment. They were randomly assigned to one of four subject groups of twelve subjects each.

Materials

Two sets of twenty-eight experimental items were composed. The first set contained phrases of two to four words which ended in an open-class/closed-class homophone of one to three syllables. Given a specific syntactic context, only the open-class meaning (14 cases) or only the closed-class meaning (14 cases) was possible (e.g., *een broedse hen* 'a broody hen' versus *ze ziet hen* 'she is seeing them'). Phrasal contexts in which one of the words was strongly semantically associated to the meaning of the prime were avoided. Open-class homophones were nouns, adjectives or verbs with a mean word-form frequency of 1295 per 42 million; closed-class homophones were prepositions, numerals, nouns, and adjectives with a frequency of 88155 per 42 million. All homophones served as a prime for associates of the open-class meaning (e.g., *hen - kip* 'chicken') and for associates of the closed-class meaning (e.g., *hen - jij* 'you'). Open-class associates were nouns or adjectives; the closed-class associates were prepositions, pronouns, nouns, and adverbs. The mean word-form frequencies were 2014 and 28746 per 42 million, for the open- and closed-class associates respectively.

A second set of twenty-eight control phrases was constructed. Half of these phrases ended in a non-homophonous open-class prime, the other half ended in a non-homophonous closed-class prime. The non-homophonous primes were as closely matched as possible with the homophonous primes for both word class and word-form frequency (open class 1276 in 42 million, closed class 28746 in 42 million). Targets were semantic associates of both the open-class primes (e.g., *een kleine beker - melk* 'a small mug - milk') and semantic associates of the closed-class primes (e.g., *ik wil beide - samen* 'I want both - together'). Mean word- form frequencies were 4546 per 42 million for the open-class associates and 14722 for the associates of the closed-class items. The experimental phrases are listed in Appendix J.

An additional forty-two filler phrases were constructed, ending either in a non- homophonous open-class prime or in a non-homophonous closed-class prime. These filler phrases were combined with a legal nonword from one to three syllables. Furthermore, twenty-four practice and warm-up phrases - balanced for prime type (12 open-class non- homophonous; 12 closed-class non-homophonous) and for target type (12 words: 6 associates of the prime, 6 unrelated; 12 nonwords) - were constructed.

Procedure

Two lists of items were recorded, one list containing the prime phrases, the other list containing the target words and nonwords in random order. Successively, the items were divided over four item lists in such a way that a phrase was combined with a different target in each list (e.g., *een broedse hen - kip*; *een broedse hen - jij*; *ze ziet hen - jij*; *ze ziet hen - kip*). Each list started with a practice block of twenty phrases, followed by two blocks of twenty-eight items (14 word targets / 14 nonword fillers). The items were pseudo-randomized in such a way that only three word or nonword targets were permitted in succession, and successive targets did not start with the same initial phoneme. The two item blocks each began with an additional two warm-up items. The four item lists were presented to four different groups of subjects.

The individual subjects were seated in a sound-isolated booth, and heard the items over headphones. They were asked to listen to the phrases carefully. After a short pause a word was presented, and the participants had to decide whether this word was a real word or not. If the word did exist in Dutch, they had to press a button marked YES as soon as possible using their dominant hand. If the word was a nonword, a button marked NO had to be pressed. 805 ms. after a response or when a time-out signal was registered, a warning tone was presented for 300 ms. This tone was followed by the next phrase after 300 ms. The interstimulus interval (ISI) between the prime phrase and the target word was 400 ms. In case no response was given, the next trial started 2000 ms. after the offset of the target word.

5.3.2 Results and discussion

Response latencies were measured from the onset of the target items. Responses were excluded from the analysis if the wrong button was pushed (3%) or if the latency exceeded the overall mean reaction time per condition by plus or minus 3 SD (2%). These missing data and outliers were substituted by the overall mean reaction time per condition. Both the reaction times and the error data were analyzed in a three-way analysis of variance with the factors prime class (open / closed), homophone (homophone / non homophonous control) and target associate (open-class associate / closed-class associate).

The reaction time analysis revealed a significant interaction between homophone, prime class and target associate when the data were analyzed over items (F1(1,47) = 2.48, p > .05 ns., MSe = 20862,99; F2(1,51) = 46.37, p < .01, MSe ± 1745,51). Therefore, separate analyses of variance were carried out on the control-data and on the homophone-data. Mean decision latencies for both data sets are presented in Figure 5.2.

In the non-homophonous control condition, a significant interaction was found between prime class and target associate (F(1,47) = 60.02, p < .01, MSe = 4659,60; F2(1,26) = 47.81, p < .01, MSe = 1689,42). Responses to targets preceded by a related open-class prime were faster than responses to these targets when preceded by an unrelated prime. This was also the case for targets following a related closed-class prime versus targets following an unrelated prime.

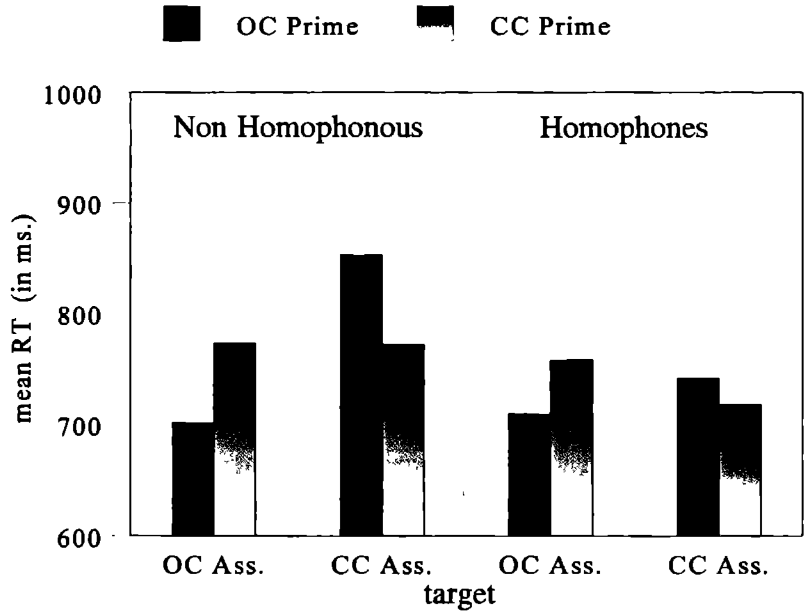

Figure 5.2 *Results of experiment 11. Mean lexical decision latencies on open-class (OC Ass.) and closed-class associates (CC Ass.) preceded by semantically related and unrelated primes for both the non homophonous and the homophonous item groups.*

Both differences were significant in analyses of simple effects (open class: $F1(1,47) = 35.06$, $p < .01$, $MSe = 3260,06$ / $F2(1,26) = 21.25$, $p < .01$, $MSe = 1689,42$; closed class: $F1(1,47) = 43.32$, $p < .01$, $MSe = 3876,16$; $F2(1,26) = 26.62$, $p < .01$, $MSe = 1689,42$).

In the homophone data, the interaction between prime class and target associate again reached significance ($F1(1,47) = 13.81$, $p < .01$, $MSe = 3703,05$; $F2(1,26) = 7.55$, $p < .01$, $MSe = 1799,44$). Decisions on targets that were related to the open-class meaning of the homophone were faster when this target was preceded by the open-class homophone than when it was preceded by the closed-class homophone. When targets were related to the closed-class meaning of the homophone, the decisions were faster for a preceding closed-class homophone compared to a preceding open-class homophone. Statistical analysis, however, showed that whereas the difference for the open-class associates was significant across both subjects and items ($F1(1,47) = 6.15$, $p < .01$, $MSe = 6813,96$; $F2(1,26) = 5.95$, $p < .05$, $MSe = 1799,44$), the difference for the closed-class associates reached significance only in the analysis by subjects ($F1(1,47) = 4.88$, $p < .01$, $MSe = 2719,69$; $F2(1,26) = 2.10$, $p > .05$, $MSe = 1799,44$).

In the error analysis, a significant main effect of prime class and target associate was found ($F1(1,47) = 7.09$, $p < .05$, $MSe = .01$; $F2(1,51) = 6.95$, $p < .01$, $MSe = .00$). Fewer errors were made in targets preceded by a related open-class prime than in targets preceded by an unrelated prime (0% versus 6%). Furthermore, subjects made fewer errors on targets preceded by related closed-class primes when compared to unrelated primes (5% versus 7%). Similar results were found for the homophonous data set. Again, fewer errors were made when targets were semantically related to the prime than when the targets were unrelated to the prime (open-class prime 0% versus 2%; closed-class prime 1% versus 2%).

An important finding of the present study is the demonstration of a closed-class priming effect - not only is it possible to speed up lexical decisions on subsequent targets after an open-class prime, it is also possible to influence decisions using closed-class primes. Apparently, semantic relations between these closed-class items and their associates are strong enough to cause priming. Furthermore, it was shown that for homophones, the associate of the meaning indicated by the syntactic context receives stronger activation than the other possible meaning at 400 ms. after the offset of the prime, irrespective of the frequency of usage of the respective meanings.

5.4 EXPERIMENT 12: CROSS-MODAL PRIMING

In the previous experiment, the prime phrases and target words were presented with an interstimulus interval (ISI) of 400 ms. Such a relatively long interval, however, makes it difficult to determine at which moment in the speech perception process context starts to play a role. To reduce the influence of post-access processes, the targets used in the current experiment were presented both 400 ms. after the offset of the prime phrase and immediately at this offset. Because auditory priming would have pasted the prime phrases and their target words together at an ISI of 0 ms., a cross-modal priming paradigm was used instead. Because of these two alternations (presentation of the target at prime-offset and the cross-modality), the present experiment is also better comparable to Shillcock and Bard's (1993) experiment than the previous intra-modal auditory priming experiment in which the targets were only presented 400 ms. after prime-offset. Two further alternations were made in the current cross-modal priming experiment compared to the previously described auditory priming experiment.

First, whereas cross-class associations between primes and targets were allowed in the previous experiment, open- and closed-class primes were in the present experiment always paired with a target associate belonging to the same vocabulary class. This alternation was made because it is not clear whether word association is related to the way words are stored (in one or in two mental lexicons). A second difference between the two experiments is the addition of a base-line condition. In the previous experiment, the targets in the homophonous condition of the previous experiments were only presented after a related prime (e.g., *kip* 'chicken' was only presented after *broedse hen* 'broody hen' and after *ze ziet hen* 'she is seeing him'). The results therefore indicated the relative level of activation of the contextually appropriate meaning versus the contextually inappropriate meaning. However, the addition of a baseline condition in which homophones are also presented after an unrelated prime word allows determination of the absolute activation levels of both meanings.

5.4.1 Method

Participants

Eight groups of twelve students each were randomly selected from the subject pool of the Max-Planck Institute for Psycholinguistics.

Materials

The set of materials consisted of two subsets of twenty-eight phrases of two to four words. In the first subset, the phrases ended in an open-class/closed-class homophone of one to three syllables. The syntactic context determined whether the homophone either had an open-class or a closed-class meaning (14 cases each). Again, contexts containing a word semantically related to the prime were avoided. The homophones used in this experiment were the same homophones that were used in the previous experiment. These homophones served as primes for targets that were either related to the open-class meaning or to the closed-class meaning. Some of the associates differed from the ones used in the previous experiment; those associates in which many errors were made, and those associates that did not belong to the same class as the prime. The associates of the open-class meaning were nouns and adjectives of one to three syllables with a mean frequency of 958 per 42 million. The closed-class associates were prepositions, pronouns, numerals, and adverbs with a frequency 92115. To provide a baseline, all associates were also presented after an unrelated prime word which was the last word of a short carrier phrase. The unrelated prime words were matched with the original homophonous prime for class (open or closed) and roughly for number of syllables and frequency; the carrier phrases were matched with the original carrier phrases for number of words.

In the second set of materials, all phrases ended with a non-homophonous open- or closed-class control (14 cases each). These non-homophonous control primes were closely matched with the homophonous primes for both word class and frequency (frequency open-class primes 1417 per 42 million; frequency closed-class primes 82799 per 42 million). Open-class primes were paired with semantically related open- class targets, closed-class primes were followed by related closed-class targets. These targets were matched with the targets following the homophonous words for both word class and frequency (frequency open-class targets 942 per 42 million; frequency closed-class targets 24083 per 42 million). In Appendix K, all experimental phrases are listed.

Forty-two additional phrases served as filler items: twenty-one of them ended in a non- homophonous open-class item, the other twenty-one phrases ended in a non-homophonous closed-class item. The filler phrases were followed by a legal-nonword target of one to three syllables. The practice set contained twenty-four phrases, ending either in a non-homophonous open-class word or in a non-homophonous closed-class item. Target items were six semantically unrelated open-class items, six semantically unrelated closed-class items, and twelve nonwords.

Procedure

A list with the prime phrases in random order was read with a natural intonation by a trained female speaker of standard Dutch following the same procedure as described for the previous auditory priming experiment. However, whereas in the auditory priming experiment both prime phrases and target words were presented auditorily, in the current experiment, the targets were shown in the visual modality. They were presented to the participants in 36 point arial font centered on a computer screen. The items were presented in white against a black background color. All items were divided over four lists in such a way that each prime was combined with a different target in each list. In addition, each target was presented after a phrase ending in an unrelated base-line prime (of the same vocabulary class and roughly the same number of phonemes as the original primes). The four lists were presented to four groups of subjects using an ISI of 0 ms., and to four other groups of subjects with an ISI of 400 ms. The first twenty phrases of each list were practice phrases. The experimental and filler phrases were divided over two blocks of twenty-one phrases, each block beginning with two warm-up items. The prime phrases and targets were presented in trials that started with a warning tone of 300 ms. After 300 ms., this tone was followed by the auditorily presented prime phrase. The target words were shown either 0 ms. or 400 ms. after the offset of the prime phrase. The next trial started 805 ms. after each push-button response (for a more detailed description of this part of the procedure, see experiment 2). If no response was given, the next trial started after 2805 ms.

5.4.2 Results and discussion

The response latencies were measured from the onset of the target words. Both wrong responses (ISI = 0 ms. 3%; ISI = 400 ms. 4%) and data exceeding the overall mean reaction time per condition by plus or minus 3 SD (ISI = 0 ms. 1%; ISI = 400 ms. 1%) were replaced by the overall mean reaction time per condition. To determine whether the decisions on target words were facilitated by a related preceding prime, difference scores were computed. A difference score was defined as the reaction time of a specific word preceded by a related prime minus the reaction time to this word preceded by an unrelated prime (the baseline score) calculated over all subjects. In Table 5.2, the original decision latencies and the difference scores are presented for both ISI's. The results of the non- homophonous control set and the homophonous item set will be discussed separately.

Non-homophonous control items

Inspection of the difference scores of the non-homophonous control primes showed a tendency towards priming in all conditions for both ISI's. Statistical analysis using two-tailed t-tests for paired samples showed the 52 ms. difference score of the open-class primes to be significant for an ISI of 0 ms. (e.g., 'cheese' - 'dairy-produce') (t1(47) = -4.04, p < .01; t2(13) = -3.12, p < .01).

Table 5.2 *Original decision latencies in ms. and difference scores relative to the baseline conditions in brackets for both the non-homophonous and the homophonous data set used in Experiment 12*

	ISI = 0 ms.		*ISI = 400 ms.*	
	Controls	*Homophones*	*Controls*	*Homophones*
OC prime / OC target	*533 (52)*	*537 (20)*	*563 (53)*	*562 (0)*
OC prime / CC target	-	*544 (-14)*	-	*542 (8)*
CC prime / CC target	*542 (25)*	*494 (44)*	*540 (42)*	*516 (59)*
CC prime / OC target	-	*561 (7)*	-	*540 (38)*

The smaller difference score of 25 ms. for closed-class primes was marginally significant in the by-subject analysis only (e.g., 'what' - 'how') ($t1(47) = -1.94$, $p = .06$; $t2(13) = -1.27$, $p > .05$ ns.). When the ISI was 400 ms., the difference scores were 53 ms. and 42 ms. for the open- and closed-class associates, respectively. Both effects reached significance when analyzed over subjects only ($t1(47) = -3.36$, $p < .01$; $t2(13) = -1.82$, $p > .05$ ns., and $t1(47) = -2.80$, $p < .01$; $t2(13) = -1.29$, $p > .05$ ns.).

The error-analysis showed 4% errors for targets associated with open-class primes, and 2% errors for closed-class associate targets (ISI is 0 ms.). In the longer ISI of 400 ms., fewer errors were made in the open-class associates (2%), but more errors occurred in the closed-class associates (5%). None of these differences reached statistical significance.

Homophones

For the homophonous item set, almost identical effects were found for the ISI of 0 ms. and the ISI of 400 ms. Open-class homophonous primes ('broody hen') did not show significant priming ($p > .05$) for either their open-class associate ('chicken') nor for the closed- class associate ('you'). The difference scores for the open-class associates were 20 ms. for an ISI of 0 ms., and 0 ms. for an ISI of 400 ms. For the closed-class associates, these scores were -14 ms. and 8 ms., respectively. Closed-class homophones ('to them'), on the other hand, did show clear priming effects for their closed-class associates. The difference scores for these closed-class targets were 44 ms. for an ISI of 0 ms. ($t1(47) = -3.73$, $p < .01$; $t2(13) = -3.03$, $p < .01$), and 59 ms. for an ISI of 400 ms. ($t1(47) = -4.85$, $p < .01$; $t2(13) = -2.70$, $p < .05$). At an ISI of 0 ms., the difference score of 7 ms. For the closed-class homophones with the open-class associates was not significant. At an ISI of 400 ms., however, a tendency towards priming of the open-class associate was found ($t1(47) = -2.38$, $p < .05$; $t2(13) = -2.11$, $p = .06$ ns.).[16]

An indication that these results are not an artefact of the choice of the baseline is provided by an additional analysis on the raw-decision latencies. A three-way analysis of variance was performed with the between-subject

---

[16] *The discrepancy between the results of the present and the previous experiment is not likely to be due to the different associates used in the present experiment since these associates were mostly different in the closed-class homophone condition, in which the results were comparable across experiments.*

factor ISI (0 ms., 400 ms.), and the two within-subject factors prime class (open-class prime, closed-class prime) and target class (open-class target, closed-class target). Because the main effect of ISI was not significant and the interaction between ISI, prime class and target class was only significant across subjects ($F1(1,94) = 5.93$, $p < .05$, $MSe = 3659.33$; $F2(1,52) = 1.76$, $p > .05$ ns., $MSe = 3572.17$), further analyses were carried out over the data of both ISI's combined. It was shown that whereas no significant effect of prime class was found for the open-class targets (i.e., reaction times to 'chicken' were equally fast after 'the hen' and after 'give them'), the effect of prime class was significant when the target was a closed-class item (i.e., reaction times to 'you' were faster after 'give them' than after 'the hen') ($F1(1,95) = 47.07$, $p < .01$, $MSe = 6550.55$; $F2(1,53) = 5.22$, $p < .05$, $MSe = 2155.78$).

The analysis of the errors did not show any significant differences. For the ISI of 0 ms., 2% errors were made when the prime was an open-class homophone, whether it was followed by an open- or a closed-class associate. For closed-class primes, corresponding closed-class associates revealed 1% errors, and open-class associates showed 4% errors. When the ISI was 400 ms., respectively 4% and 2% errors were made when an open-class prime was combined with either an open- or a closed-class associate. Furthermore, closed-class primes followed by a closed-class associate showed 3% errors; closed-class primes combined with an open-class associate revealed 4% errors.

Again, the results seem to indicate a clear pattern. Although Shillcock and Bard's (1993) finding of the absence of priming for an open-class associate by a closed-class homophone was replicated at an ISI of 0 ms. (i.e., no priming for 'would' - 'timber'), a slight tendency towards priming occurred at a longer ISI of 400 ms. Furthermore, the results did not show any significant priming for these associates by open-class homophones ('wood' - 'timber'). In the additional closed-class associate condition, these closed- class associates received significant priming after a closed-class homophone ('would' - 'might') at both ISI's, but no priming was found for closed-associates presented after an open-class homophone ('wood' - 'might'). Overall, the results do not support differential processing for open- versus closed-class items in the sense that the obtained difference between the two classes of words is caused by the difference in class per se (as proposed by Shillcock and Bard). However, the results do show a differential effect of frequency suggesting a large influence of the frequency dominance of the closed-class words and their associates in the access of both open- and closed-class meanings of open-class/closed-class homophones.

5.5 GENERAL DISCUSSION

The aim of the present study was to obtain a better picture of possible processing distinctions between open- and closed-class words with respect to the syntactic context. To investigate whether closed-class words are processed in an interactive way (as predicted by Shillcock and Bard, 1993), homophones with both an open- and a closed-class interpretation were used in different syntactic contexts. Since the two meanings of these homophones are imbalanced in frequency of occurrence, the initial concern was to determine the exact influence of frequency on meaning retrieval. Subsequently, the time-course of the retrieval of both meanings was examined.

5.5.1 Frequency

One account of frequency effects in word recognition has been presented by Levelt (1993). He argued that each lexical item stored in the mental lexicon has its own abstract phonological code or *lexeme* which specifies a word's non-redundant distinctive features. On a syntactic level, each item furthermore has a *lemma* in which syntactic functions such as 'subject of' and 'head of phrase' are represented. Because homophones have one single phonological form but two different meanings, they are likely to be represented by one single lexeme that is connected with two separate lemmas. If frequency is coded on a lexeme level, both meanings of a homophone are expected to be retrieved at a similar rate since their frequency information will be shared. Retrieval of a subordinate meaning will then benefit from the higher frequency of the dominant meaning. However, if frequency is represented on the lemma level (or in the connections between both levels), retrieval speed of either meaning is expected to depend on its own frequency.

The results of the first experiment of the present chapter support the latter possibility. For homophones with both an open- and a closed-class meaning presented in syntactically biasing contexts, high-frequency closed-class meanings were retrieved faster than low-frequency open-class meanings. This result agrees with previous results obtained with homophones having two open-class meanings. Furthermore, dominant closed-class meanings showed similar latencies as their high-frequency control words, and subordinate open-class meanings showed similar latencies as their low-frequency open-class controls. The retrieval time of a subordinate meaning thus does not seem to be influenced by the frequency of its high-frequency twin.

This effect of frequency seems different for perception versus production; experiments by Jescheniak and Levelt (1994) on the role of frequency in speech production indicated representation on a lexeme rather than on a lemma level. For example, when English words were translated into Dutch words which corresponded to the low-frequency meaning of a homophone (having two open-class meanings), the translation latencies appeared to be similar to the latencies of non-homophonous high-frequency control words. Jescheniak and Levelt therefore argued that the subordinate meaning of a homophone inherits the accessing speed from the dominant meaning at the lexeme level.

Frequency might thus be differently represented in perception versus production. There could be multiple representation of words in separate perception and production lexicon (however, see Levelt, 1989, 1993), or coding of frequency on different levels for perception versus production in the same mental lexicon. If frequency is coded at a lexeme level for production and at a lemma level for perception, frequency information starts to play a role at the end of the lexical access procedure in both cases. However, the latter explanation raises some new questions requiring further study. For instance, does a particular word indeed have different frequencies of usage for speech perception versus speech production, and why would it be that for speech production low-frequency meanings of homophones can be processed efficiently by benefiting from the higher frequency of their twin, but this is not the case for speech perception?

An alternative explanation for the advantage of the closed-class words might be that the lexical decision task did not tap into the same processes for the words in the open- and closed-class biased contexts. For instance, if a decision on the closed-class meaning can be based on the syntactic correctness of the phrase, but decisions on the open-class meaning require additional semantic processing (e.g., check that hair in the phrase *short hair* is something that can be short), decisions on closed-class meanings can be made faster than decisions on open-class meanings.

A second finding of the present chapter with respect to the effect of frequency on the retrieval of homophones with both an open- and a closed-class meaning is the absence of a frequency effect between dominant closed-class meanings and subordinate open-class meanings for homophones not biased by a preceding syntactic context. In fact, lexical decisions to both meanings of the homophone turned out to be equally fast as lexical decisions to high-frequency closed-class control words. Because high-frequency words are accessed faster than low-frequency words and lexical decision requires only one meaning of a homophone in order to permit a recognition response, these decisions were probably based on the high-frequency closed-class meanings. This indicates that when a sentence context is absent, meaning retrieval is based on frequency of usage. This explanation is supported by the finding that only few errors were made in the open-class homophones when presented in their reversed order relative to the open-class non-homophones in this position. In the next section, the time-course of the influence of the syntactic context on the retrieval of frequency imbalanced homophones biased by the context towards their open- or closed-class meaning will be discussed.

5.5.2 Syntactic context

Since closed-class words are more easily predictable from the syntactic context than open-class words, Shillcock and Bard (1993) have argued that both meanings of an open-class/closed-class homophone will be accessed when the syntactic context does not indicate that a closed-class word is coming up (*modular processing*). However, they also predicted that only the closed-class meaning will be retrieved when a closed-class word can be anticipated (*directive access*). The results of the present study do not, however, support this possibility. When semantic associates were presented at the offset of a homophone syntactically biased to its open-class meaning, neither associates of the open-class meaning, nor associates of the closed-class meaning were primed. Homophones syntactically biased to their closed-class meaning did prime associates of the closed-class meaning only. Similar results were found for associates presented 400 ms. after the offset of the homophone, with the exception of an additional marginal priming effect for open-class associates in a closed-class context.

These findings can be explained by the unbalanced frequencies of the open-class versus the closed-class meanings together with the assumption that the meaning with the highest frequency (i.e., the closed-class meaning) is always passed on for a check against the context first. Thus when the open-class meaning is biased by the syntactic context, the appropriate open-class meaning will only be checked against the context after the inappropriate closed-class meaning has been checked. By that time, the lexical decision on a following target has already been made. This will prevent activation by open-class meanings of their open-class associates. However, if a closed-class meaning is biased by the syntactic context, fast activation of this meaning will cause priming of closed-class associates. Since in the latter case the open-class meaning will probably be available shortly after, open-class associates might incidentally also receive some priming at a later point in time.

A further important observation was the absence of priming of syntactically biased open-class associates after the relatively long interval of 400 ms. Apparently, the availability of very low-frequency subordinates is substantially delayed compared to both the availability of high-frequency dominant meanings and to the 200 ms. necessary to comprehend either meaning of a frequency-balanced homophone (Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982; Tanenhaus, Leiman, & Seidenberg, 1979). In normal speech processing, however, slower activation of subordinate meanings is not expected to be problematic, since subordinate meanings are obviously used less frequently than dominant meanings, and contexts are usually not only syntactically, but also semantically and pragmatically restrictive. Furthermore, the results of the present auditory priming experiment indicate that eventually the contextually appropriate meaning will be singled out (the raw decision latencies differ by about 150 ms.).[17] Although syntactic context is thus not likely to exercise a differential pre-lexical influence on open- versus closed-class words, this context is important when the individual words of a sentence are integrated into meaningful concepts.

The influence of syntactic context on the processing of open- and closed-class words has also been studied using the *event-related brain potential* method (*ERPs*). In this method, recordings of the EEG are synchronized to the presentation of a stimulus and averaged over a number of trials. Van Petten and Kutas (1991), for example, investigated the influence of both the semantic and the syntactic context on the processing of open- and closed-class words. The results showed an influence of the surrounding syntactic context for closed-class words but not for open-class words. However, the syntactic

---

[17] *The relatively fast decision latencies obtained in the current cross-modal study might also be responsible for the difference with Shillcock and Bard's finding of priming from the open-class meanings of homophones to their associates (the mean latencies are approximately 100 ms. faster than those of Shillcock and Bard).*

constraint on the closed-class words was not found to be greater near the end than near the beginning of a sentence. This suggests that for the processing of closed-class words only the local context is used - perhaps just one or two immediately preceding words. Although the discrepancy between open- and closed-class words with respect to the syntactic context seems to indicate a real distinction between these two vocabulary classes, Van Petten and Kutas argued that this discrepancy should be considered an information-processing effect (reflecting that well-structured sentence usually provide many cues to subsequent closed-class words but only few cues to open-class words). Since the open- and closed-class words further showed very similar context effects, Van Petten and Kutas concluded that their results do not support the idea of different brain processors for the open- versus the closed-class vocabulary.

5.6 CONCLUSION

The results of the present experiments converge on the observation that frequency plays an important role in spoken word recognition; either in the absence of context, or in a syntactically biasing context, high-frequency meanings of a homophone are available before low-frequency meanings. They furthermore indicate that it is unlikely that the syntactic context has a different and specific pre-lexical influence on the processing of open- versus closed-class words - syntactic context seems only important at a later integration stage. This suggests that the metrical segmentation strategy mentioned above, in which closed-class words are looked up in a closed-class lexicon based on their phonological structure (Cutler & Carter, 1987) cannot be assisted by interactive processing of these items with respect to the syntactic context. In addition, if frequency indeed plays an important role in word recognition, the advantage of interactive processing of closed-class words (in that no open-class competitors will be activated) is also reduced. Since open-class words have much lower frequencies than closed-class words, open-class words will receive less activation than closed-class words and therefore cause only little competition.

As described by Norris (1994) for Shortlist, both the observed influence of frequency and of context can easily be implemented in current models of spoken word recognition. In Norris' model, a 'shortlist' of words is activated based on the incoming acoustic information and entered into a competition process. High-frequency meanings can enter this competition process with a higher level of activation than low-frequency meanings. Furthermore, in the competition stage, all candidates will be evaluated against the context. As a result of this evaluation procedure, the activation levels of plausible candidates can be increased, and the activation levels of implausible candidates can be decreased. Implausible candidates will therefore cause less competitive inhibition, and speed up the recognition of plausible ones (see also Norris (1986) for a description of frequency and context effects in visual word recognition).

The present findings thus support a model of spoken word recognition in which both subordinate and dominant meanings of homophones are activated in parallel. However, dominant meanings will enter the competition process with a higher level of activation, and thus with priority to be *checked* against the context first. In the next chapter, the results of the current and the previous chapters will be summarized and discussed with respect to the question of whether the distinction between open- and closed-class words is used in speech segmentation.

GENERAL DISCUSSION AND CONCLUSION

CHAPTER 6

ABSTRACT

The combined results of the experiments presented in the previous chapters motivate the conclusion that the open-class/closed-class distinction does not play a role in the segmentation of continuous speech. Neither did stress prove to be a stable cue to vocabulary class, nor did listeners use the syntactic context to predict upcoming closed-class words. After a discussion on the implications of these results with respect to the Shortlist model of spoken-word recognition (Norris, 1994), it will be argued that the findings are consistent with storage of the two vocabulary classes in a single lexicon, and that they support a sceptical attitude towards the open-class/closed-class distinction in recent studies of language production, language acquisition, and impaired language processing.

6.1 THE RESULTS TIED TOGETHER

Do listeners use the distinction between open- and closed-class words in the segmentation of incoming continuous speech? In the present thesis, I addressed this question both by studying the relation between stress and vocabulary class (are open-class words easier to recognize when they carry stress and closed-class words when they are unstressed?), and by investigating whether closed-class words can be predicted from the syntactic context. As mentioned in the introductory chapter, Dutch listeners will only be able to use the correspondence between stress and vocabulary class if this relationship is stable. However, the present results consistently demonstrated unstable effects of stress on the recognition of both the open- and the closed-class vocabularies. Although listeners tended to recognize stressed open-class words faster than unstressed open-class words and the reversed pattern was observed for closed-class words, this result was consistent neither for words used in a meaningless lexical context (e.g., *tot-ruuf* 'till-ruuf' and *ruuf-tot* in Chapter 3), nor for words in meaningful phrases (e.g., *tot-gauw* 'till soon' in Chapter 4 and Chapter 5). The recognizability of the open- and closed-class words interacted with their position in the phrase and their frequency of usage (stronger effects of stress for words that did not occupy their canonical position in a phrase, and a more pronounced effect of stress for low-frequency words). In addition, the influence of stress on the recognition of these words varied with the context in which they were presented (larger effects of stress for words not presented in a sentence context). The possibility that these findings were actually due to vowel quality rather than to stress was excluded by the observation that the listeners had severe problems in recognizing words with a reduced vowel when these words were not presented in a meaningful context (e.g., *tət-ruuf* in Chapter 3).

These results strongly suggest that stress and vocabulary class are not reliably correlated in Dutch, and Dutch listeners are thus not likely to use this cue in their segmentation of continuous speech. Support for this conclusion was provided by the observation that stress did not prevent closed-class words from being activated. In Chapter 4, the stressed closed-class item *dus* 'so' in the sentence *de vreemde artiest spaarde DUS-ters* 'the weird artist collected dressing-gowns' primed its associate *kortom* 'in short'. The latter result also suggests that in the initial activation stage of possible word candidates syntactic context does not have an influence. That is, embedded closed-class words will prime their associates indicates, even if these words did not fit in the context.[18] This finding - regarding the processing of closed-class words - adds to the growing body of experimental evidence in favor of on-line activation of open-class alternatives (Gow and Gordon, 1995; Shillcock, 1990; Tabossi, Burani, & Scott, 1995; Vroomen & De Gelder, 1995; Zwitserlood, 1989; Zwitserlood & Schriefers, 1995).

That context is more likely to bear its influence at a post-access level rather than at a pre-access or access level was furthermore suggested by the finding that when homophones such as *hen* were syntactically biased to their closed-class meaning, only the associate of this closed-class meaning ('they') was primed, and the associate of the open-class meaning ('chicken') did not receive priming. Although this result at first sight suggested that listeners *are* in fact able to use the syntactic context to predict upcoming closed-class words, the additional observation that the open-class associate was actually primed somewhat later in the perception process excluded this possibility. As extensively discussed in Chapter 5, these results can best be explained by an account in which the syntactic context cannot influence lexical access of closed-class words. That is, both meanings are initially accessed, but with a larger activation for the high-frequency closed-class meaning than for the low-frequency open-class meaning. This explanation is consistent with both the reported modular processing of open-class words with respect to the syntactic context (Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982; Tanenhaus, Leiman & Seidenberg, 1979), and with faster processing of the high-frequency meaning of frequency-imbalanced open-class/open-class homophones in semantically unbiasing lexical contexts (Hogaboam & Perfetti, 1975; Simpson, 1981).

A role of frequency in spoken-word recognition - another major item of the present research program - was also indicated by the finding that lexical decisions on open-class/closed-class homophones which were not preceded by a lexical context (i.e., *hen geef* 'them give' in Chapter 5) appeared to be based on the high-frequency closed-class meaning. Furthermore, when these homophones were syntactically biased towards either their high-frequency closed-class meaning (*geef hen* 'give them') or their low-frequency open-class meaning (*de hen* 'the chicken'), lexical decisions turned out to be faster for the high-frequency closed-class meanings. Other evidence for a role of frequency was presented in Chapter 4. When homophones such as *hen* were used in a

---

[18] *In about one third of the sentences of each condition, the embedded closed-class word itself did not constitute a contextually appropriate continuation of the sentence.*

sentence which syntactically biased the closed-class meaning, semantic associates of the high-frequency closed-class meaning but not of the low-frequency open-class meaning were primed in an early stage of the recognition process. Evidently, high-frequency meanings of a homophone are passed on for a check against the context before low-frequency meanings.

The observed absence of a pre-lexical processing distinction between open- and closed-class words with respect to the influence of both stress and syntactic context agrees with the absence of such a distinction in simple lexical decision and single-word shadowing tasks (Chapter 2). Since the existence of another, so far unknown, cue to vocabulary class in the incoming speech is rather unlikely, it seems therefore justified to conclude that the open-class/closed-class distinction at least does not play a crucial role in the segmentation of running speech. In the next sections, the implications of this conclusion for the SHORTLIST model will be discussed, followed by a brief discussion of its impact on the debate concerning the actual reality of an open-/closed-class distinction.

6.2 IMPLICATIONS FOR SHORTLIST

The SHORTLIST model developed for the recognition of spoken words (Norris, 1994) claims that word access is entirely based on the speech signal. The present observation that the relation between stress and vocabulary class is not used in speech segmentation does not require any adaptation of this model. It should be noticed, however, that the absence of a stable correlation between stress or vowel quality and vocabulary class does not automatically imply that stress or vowel quality are unimportant for the segmentation of Dutch. For instance, as in English, the large majority of Dutch words start with a strong syllable (Baayen & Schreuder, 1994; van Kuijk, 1996; Vroomen & de Gelder, 1995). Therefore, vowel quality or stress might play a similar role in the segmentation of Dutch as it does in the segmentation of English. As described in the introductory chapter, the role of vowel quality in English has been incorporated into SHORTLIST's possible-word constraint by decreasing the activation of words with a strong onset which are misaligned with a strong syllable in the speech signal (Norris, McQueen, Cutler, & Butterfield, in press). In this way, lexical candidates with a strong onset will have a larger chance to win the competition process.

As already discussed at some length in Chapter 5, the post-access influence of the syntactic context on word recognition can quite easily be implemented into SHORTLIST. That is, after the 'shortlist' of the most likely candidates has been accessed, these candidates will be evaluated against the syntactic context. When a word fits into the syntactic context, its activation will be increased; when this word does not fit into the context, its activation will be decreased. Again, an increase in activation enlarges the likelihood that a word will win the competition process.

The present results further have clear implications for the underlying assumption of SHORTLIST concerning frequency, namely that frequency of usage of word candidates is not allowed to influence the level of activation of these candidates. That is, the results of the current thesis clearly demonstrate that words that are used relatively frequently are recognized faster than words that are not used very frequently. The apparent influence of frequency on spoken-word recognition can be implemented into SHORTLIST by allowing high-frequency words to enter the competition process with a higher activation level than low-frequency words. Words with the highest level of activation will then have priority to be checked for their contextual appropriateness.[19]

6.3 THE OPEN-/CLOSED-CLASS DISTINCTION RECONSIDERED

With respect to the open-/closed-class distinction, the current results add to the evidence against differential pre-lexical processing of open-class/closed-class words, and they also severely reduce the likelihood of the existence of a dual lexicon. If neither stress nor syntactic context can provide a stable indication of the vocabulary class of word, then how can a listener decide which lexicon to access? The necessity of separate storage of open- and closed-class words is furthermore diminished by the present observation that frequency of usage plays a role in the recognition of spoken words; if frequency can influence the activation levels of word candidates and thus

---

[19] *Note that this implementation of frequency into SHORTLIST is awkward if, in speech perception, frequency is coded at a lemma level rather than at a lexeme level (a possible explanation for the results of experiment 10 in chapter 5), since SHORTLIST is primarily concerned with access and representation of word forms (lexemes).*

determines the impact of words in the competition process, the relatively low frequency of the open-class words will prevent these words from being strong competitors for the closed-class candidates. In contrast, if frequency were to play no role in spoken-word recognition, competition from the open-class words could indeed be excluded by separate storage and activation of closed-class words.

Although competition processes have not directly been studied in the present thesis, these processes could be used in the future to investigate storage of open- and closed-class words in greater detail. For instance, selective access of a closed-class lexicon will only allow the closed-class vocabulary to be activated. Since the closed-class vocabulary is such a small set of items, the recognition of a closed-class target should then hardly suffer from competition. Consequently, if open- and closed-class words are separately stored, recognition processes will be considerably faster compared to storage of all words in one single mental lexicon (where open-class words would also be able to participate in the recognition process).

Can we thus conclude, almost twenty years after Bradley postulated a computational distinction between open- and closed-class words, that these two vocabulary classes are in fact computationally similar? Though the present results cautiously point towards this conclusion and agree with the proposal of a continuous vocabulary, as recently claimed for language production (Dell, 1990; Kohn & Smith, 1993), impaired language processing (Bates & Wulfeck, 1989), and for language acquisition (Slobin, 1996), there are - unfortunately - still too many issues to be solved before such a strong statement is justified. First, experimental results might have been compromised by the choice of the experimental items, in particular the closed-class words. Since the closed-class vocabulary consists of only a few hundred words, experimenters are severely restricted in finding materials that meet all necessary requirements. In addition, most studies on open-/closed-class processing focus on the processing of monosyllabic words. As indicated in the introductory first chapter, this choice can be justified by the observation that those closed-class words that are most prototypical are monosyllabic. For instance, of a corpus of 367 Dutch closed-class words (based on the inventory of Van Wijk and Kempen; 1980), the monosyllabic words exhibited the highest mean frequency of usage of 2.87 logfreq.).[20] Monosyllabic words are furthermore nearly always produced unstressed. If closed-class words are processed differently from open-class words, this should thus be most obvious for the most prototypical cases.

However, closer inspection of the set of Dutch closed-class words mentioned above, also showed that the largest number of closed-class words consists of more than one syllable: whereas about a quarter of the 367 closed-class words turned out to be monosyllabic (26%), almost twice as many words were disyllabic (41%), and another quarter of the closed-class words contained three syllables (25%). In addition, 25% of all monosyllabic closed-class words could be classified as prepositions.[21] In the past, the classification of especially this group of words has been disputed; in the traditional open-class/closed-class dichotomy, prepositions were taken as closed-class words, but in syntactic theory, these words have been grouped with the nouns, verbs, and adjectives (Tesak & Hummer, 1994).

Both the restricted attention to the most prototypical closed-class cases, and the inclusion of fuzzy sub-sets of closed-class words such as prepositions, might obscure what is really going on in open-/closed-class processing. However, the difficulty in defining *what* prototypical cases are and the existence of groups of words that do not clearly belong to either the open-class or to the closed-class vocabulary might also indicate that we are hunting for a distinction between two classes of words that are in fact not separate classes at all. It might thus be the case that the difference in processing between closed-class pronouns and open-class nouns is not larger than the difference in processing between two groups of open-class words; a difference which can be located at a post-access level.

---

[20] *The frequency and syllable counts are based on the word-form listings of the CELEX lexical database (1990). Only those adverbs were included that were not presented in van Wijk & Kempen's listing of adverbs that can never act as closed-class words. Closed-class words that were not represented in CELEX were left out of both the frequency and the syllable counts. Furthermore, the frequency of the closed-class words with more than one syllable decreased when the number of syllables increased (from 1.69 logfreq for bisyllabic words to 0.15 logfreq for closed-class words consisting of six syllables).*

[21] *Of the remaining monosyllabic closed-class words, 16% were adverbs, 39% were pronouns, 16% were conjunctions, 2% were numerals, and 3% were articles. The complete corpus of closed-class words (ranging from 1 to 6 syllables) consisted of 22% prepositions, 31% adverbs, 25% pronouns, 17% conjunctions, 2% numerals, 2% verbs, and 1% articles.*

A second issue that needs to be solved before definite decisions on open- and closed-class processing are warranted involves those experimental results that disagree with similar pre-lexical processing and single storage of open- and closed-class words. For instance, if open- and closed-class items are processed similarly, then why do these words seem to elicit different activities in the left versus the right hemisphere (Chiarello & Nuding, 1987; Mohr, Pulvermüller & Zaidel, 1994)? And why do the two vocabulary classes show early differences in wave forms in event-related potential measurements (Neville, Mills & Lawson, 1992; Pulvermüller, Lutzenberger & Birbaumer, 1994)?

A major difference between these studies and the present thesis is the use of a visual task in the former ones, and the use of auditory tasks in the latter. However, there does not seem to be an *a priori* reason why an open-/closed-class distinction would be more useful and likely in visual versus auditory processing. First, as pointed out in the introductory chapter, in written text, the individual words are separated by blanks, and an open-/closed-class distinction is thus not necessary to assist in the segmentation procedure. Second, although both word length and syntactic context might be used as indicators of vocabulary class in reading, neither of these cues have been proven to be a reliable indicator of the vocabulary class of a word. Future studies on the open-/closed-class distinction therefore also need to concentrate on possible indicators of vocabulary class in written language to be able to determine whether differences in visual versus auditory processing of open- and closed-class words are related to the availability of modality specific cues to vocabulary class.

Although questions concerning differences and similarities between both subsystems (i.e., reading and listening) of language comprehension should be further investigated, the tendency observed in the open-/closed-class literature to shift focus from visual towards auditory processing seems already a step forwards. Clearly, reading is not what the human language faculty is really about. And above all, we all listen and speak without explicit education before we are taught how to read and write. A listening task as an experimental tool to investigate language processing furthermore does not only allow for studying the language capacity of healthy adults, but also allows for studying language processing of children and language impaired populations such as dyslexics and aphasics (Matthei & Kean, 1979). Finally, effects of word length and word duration are easier to study on-line in listening than in reading tasks since the amount of language input to a subject can be better controlled when the stimuli are auditorily presented.

Although the lack of agreement of the experimental results in language comprehension may thus rule out a definite decision for or against a possible pre-lexical processing distinction between open- and closed-class words, it does provide an indication of the complicated nature of this issue. The continuing debate on open- versus closed-class processing furthermore demonstrates that it is still relevant to get this piece of the puzzle of human language processing in its right place. Perhaps a solution will be found within the next twenty years.

6.4 CONCLUDING REMARKS

In conclusion, the present thesis does not support the possibility that Dutch listeners make use of the open-class/closed-class distinction in the segmentation of continuous speech; the relation between stress and vocabulary class proved unstable, and syntactic context could not be used to predict upcoming closed-class words. Although I fully realize that negative evidence like this can never be as strong as positive evidence, the observed absence of a pre-lexical processing distinction between open- and closed-class words seems to argue for storage of both classes in one single mental lexicon, rather than for storage in separate open- and closed-class lexicons. The finding that the open-class/closed-class distinction does not play a role in the segmentation of Dutch might be good news for Dutch listeners struggling with the segmentation of the Chinese 'closed-class-free' sentence *jinzhanhuazaiyangguangxiashengkai*, and for native Chinese speakers wanting to learn Dutch. At least in this respect, the two languages do not differ.

REFERENCES

Altmann, G., & Carter, D. (1989). Lexical stress and lexical discriminability: Stressed syllables are more informative, but why? *Computer Speech and Language*, **3**, 265-275.

Baayen, R., & Schreuder, R. (1994). Prefix stripping re-revisited. *Journal of Memory and Language*, **33**(3), 357-375.

Balota, D. (1990). The role of meaning in word recognition. In D. A. Balota, G. B. Flores d'Arcais, & K. Rayner (Eds.), *Comprehension processes in reading* (pp. 9-32). Hillsdale, NJ: Erlbaum.

Balota, D., & Chumbley, J. I. (1984). Are lexical decisions a good measure of lexical access? The role of word frequency in the neglected decision stage. *Journal of Experimental Psychology: Human Perception and Performance*, **10**, 340-357.

Balota, D. A., & Chumbley, J. I. (1985). The locus of the word-frequency effect in the pronunciation task: lexical access and/or production? *Journal of Memory and Language*, **24**, 89-106.

Bates, E., & Wulfeck, B. (1989). Crosslinguistic studies of aphasia. In B. MacWhinney and E. Bates (Eds.), *The crosslinguistic study of sentence processing* (pp. 328-371). New York: Cambridge University Press.

Blackwell, A. & Bates, E. (1995). Inducing agrammatic profiles in normals: Evidence for the selective vulnerability of morphology under cognitive resource limitation. *Journal of Cognitive Neuroscience*, 7(2), 228-257.

Bleasdale, F. (1987). Concreteness-dependent associative priming: Separate lexical organization for concrete and abstract words. *Journal of Experimental Psychology: Learning, Memory and Cognition*, **13**, 582-594.

Bock, K. (1989). Closed-class immanence in sentence production. *Cognition*, **31**, 163-186.

Bradley, D. C. (1978). *Computational distinctions of vocabulary type*. Doctoral Dissertation, Cambridge, MA: MIT Press.

Bradley, D. C., & Garrett, M. F. (1983). Hemisphere differences in the recognition of closed and open class words. *Neuropsychologia*, **21**(2), 155-159.

Bradley, D. C., Garrett, M. F., & Zurif, E. B. (1980). Syntactic deficits in Broca's aphasia. In D. Caplan (Ed.), *Biological studies of mental pro-*

cesses. Cambridge, MA: MIT Press.

Bond, Z. S., & Small, L. H. (1983). Voicing, vowel, and stress mispronunciations in continuous speech. *Perception and Psychophysics,* **34**, 470-474.

Brown, R. (1973). *A first language: The early stages*. Cambridge, MA: Harvard University Press.

Celex. Dutch Database (release N31), [Online]. (1990). Available: Nijmegen: Centre for Lexical Information.

Chafetz, J. (1994). The closed-class vocabulary as a closed set. *Applied Psycholinguistics*, **15**, 273-287.

Chiarello, C., & Nuding, S. (1987). Visual field effects for processing content and function words. *Neuropsychologia*, **25**(3), 539-548.

Chumbley, J. I., & Balota, D. A. (1984). A word's meaning affects the decision in lexical decision. *Memory & Cognition*, **12**, 590-606.

Cole, R. A., & Jakimik, J. A. (1978). Understanding speech: How words are heard. In G. Underwood (Ed.), *Strategies of information processing* (pp. 67-116). San Diego, CA: Academic Press.

Cole, R. A., & Jakimik, J. A. (1980). A model of speech perception. In R. A. Cole (Ed.), *Perception and production of fluent speech* (pp. 133-163). Hillsdale, NJ: Erlbaum.

Colé, P., & Segui, J. (1994). Grammatical incongruency and vocabulary type. *Memory & Cognition*, **22**(4), 387-394.

Coltheart, M. (1980). Deep dyslexia: A review of the syndrome. In M. Coltheart, K. Patterson, and J. C. Marshall (Eds.), *Deep dyslexia* (pp. 22-47). London: Routledge & Kegan Paul.

Cutler, A. (1986). Forbear is a homophone: Lexical prosody does not constrain lexical access. *Language and Speech*, **29**(3), 201-220.

Cutler, A. (1993). Phonological cues to open- and closed-class words in the processing of spoken sentences. *Journal of Psycholinguistic Research,* **22**(2), 109-131.

Cutler, A., & Butterfield, S. (1992). Rhythmic cues to speech segmentation: Evidence from juncture misperception. *Journal of Memory and Language,* **31**, 218-236.

Cutler, A., & Carter, D. M. (1987). The predominance of strong initial syllables in the English vocabulary. *Computer Speech and Language,* **2**, 133-142.

Cutler, A., & Clifton, Ch. (1984). The use of prosodic information in word recognition. In H. Bouma & D. G. Bouwhuis (Eds.), *Attention and Performance X. Control of Language Processes* (pp. 183-196). Hillsdale

N.J.: Lawrence Erlbaum Associates.

Cutler, A., Dahan, D., & Donselaar, W. van (1997). Prosody in the recognition of spoken language. A literature review. *Language and Speech*, **40**(2), 141-201.

Cutler, A., & Foss, D. (1977). On the role of sentence stress in sentence processing. *Language and Speech*, **20**, 1-10.

Cutler, A., Mehler, J., Norris, D., & Segui, J. (1986). The syllable's differing role in the segmentation of French and English. *Journal of Memory and Language*, **25**, 385-400.

Cutler, A., Mehler, J., Norris, D. G., & Segui, J. (1992). The monolingual nature of speech segmentation by bilinguals. *Cognitive Psychology*, **24**, 381-410.

Cutler, A., & Norris, D. (1988). The role of strong syllables in segmentation for lexical access. *Journal of Experimental Psychology: Human Perception and Performance*, **14**(1), 113-121.

Cutler, A., & Otake, T. (1994). Mora or phoneme? Further evidence for language-specific listening. *Journal of Memory and Language*, **33**, 824-844.

Dell, G. S. (1990). Effects of frequency and vocabulary type on phonological speech errors. *Language and Cognitive Processes*, **5**(4), 313-349.

Fear, B. D., Cutler, A., & Butterfield, S. (1995). The strong/weak syllable distinction in English. *Journal of the Acoustical Society of America*, **97**(3), 1893-1904.

Field, J. (1995). Retrieving the functor: the processing of weak syllables in lexical segmentation. *Working Papers in English and Applied Linguistics*, **2**, 55-73. Cambridge UK: Research Centre for English and Applied Linguistics.

Flores d'Arcais, G. B. (1981). The acquisition of meaning of the connectives. In W. Deutsch (Ed.), *The child's construction of language*. London: Academic Press.

Forster, K. I. (1976). Accessing the mental lexicon. In R. J. Wales & E. C. T. Walker(Eds.), *New approaches to language mechanisms*. Netherlands: North Holland.

Forster, K. I. (1981). Frequency blocking and lexical access: One mental lexicon or two? *Journal of Verbal Learning and Verbal Behavior*, **20**, 190-203.

Forster, K. I., & Bednall, E. S. (1976). Terminating and exhaustive search in lexical access. *Memory & Cognition*, **4**, 53-61.

Frauenfelder, U. H. (1996). Computational models of spoken word recognition. In T. Dijkstra and K. de Smedt (Eds.), *Computational psycholinguistics*, (pp. 114-138). London: Taylor & Francis Ltd.

Friederici, A. D. (1982). Syntactic and semantic processes in aphasic deficits: The availability of prepositions. *Brain and Language*, **15**, 249-258.

Friederici, A. (1983a). Aphasics' perception of words in sentential context: Some realtime processing evidence. *Neuropsychologia*, **21**, 351-358.

Friederici, A. D. (1983b). Children's sensitivity to function words during sentence comprehension. *Linguistics*, **21**, 717-739.

Friederici, A. (1985). Levels of processing and vocabulary types: Evidence from online comprehension in normals and agrammatics. *Cognition*, **19**, 133-166.

Friederici, A. D. (1988). Autonomy and automaticity: Accessing function words during sentence comprehension. In G. Denes, C. Semenze, & P. Bisiacchi (Eds.), *Perspectives on Cognitive Neuropsychology*, (pp. 115-133). Hillsdale, NJ: Lawrence Erlbaum.

Friederici, A. D. (1993). Development of language relevant processing systems: the emergence of a cognitive module. In B. de Boysson-Bardies, S. de Schonen, P. Jusczyk, P. McNeilage, & J. Morton (Eds.). *Developmental neurocognition: Speech and face processing in the first year of life*, (pp. 451-459). Dordrecht: Kluwer Academic Publishers.

Friederici, A. D., & Schoenle, P. W. (1980). Computational dissociation of two vocabulary types: Evidence from aphasia. *Neuropsychologia*, **18**, 11-20.

Friederici, A. D., Weisenborn, J., & Kail, M. (1991). Pronoun comprehension in aphasia: A comparison of three languages. *Brain and Language*, **41**, 289-310.

Fromkin, V. (1987). The lexicon: Evidence from acquired dyslexia. *Language*, **63**, 1-22.

Garnsey, S. M. (1985). *Function words and content words: Reaction time and evoked potential measures of word recognition*. University of Rochester, Rochester NY.

Garrett, M. (1975). The analysis of sentence production. In G. Bower (Ed.), *The psychology of learning and motivation* (pp. 133-177). New York: Academic Press.

Garrett, M. F. (1978). Word and sentence perception. In R. Held, H. J. Leibowitz and H. L. Teuber (Eds.), *Handbook of sensory physiology. Volume VIII: Perception* (pp. 611-625). Berlin: Springer.

Garrett, M. F. (1980). Levels of processing in sentence production. In B.L.

Butterworth (Ed.), *Language Production, Vol. 1: Speech and Talk* (pp. 177-220). London: Academic Press.

Garrett, M. F. (1982). Production of speech: observations from normal and pathological language use. In A. W. Ellis (Ed.), *Normality and pathology in cognitive functions* (pp. 19-75). London: Academic Press.

Garrett, M. F. (1992). Disorders of lexical selection. *Cognition*, **42**, 143-180.

Gerken, L., & McIntosh, B. (1993). Interplay of function morphemes and prosody in early language. *Developmental Psychology*, **29**, 448-457.

Glanzer, M., & Ehrenreich, S. L. (1979). Structure and search of the internal lexicon. *Journal of Verbal Learning and Verbal Behavior*, **18**, 381-398.

Gleitman, L. R., & Wanner, E. (1982). Language acquisition: the state of the state of the art. In E. Wanner, & L. R. Gleitman (Eds.). *Language acquisition: The state of the art*, (pp. 3-48). Cambridge: Cambridge University Press.

Glucksberg, S., Kreuz, F. J., & Rho, S. H. (1986). Context can constrain lexical access: Implications for models of language comprehension. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **4**, 53-61.

Goldman, S. (1991). *The independence of stress and word class effects in auditory word recognition*. Doctoral Dissertation, Northwestern University, Evanston, Illinois.

Golston, C. (1991). *Both lexicons*. Doctoral Dissertation, University of California, Los Angeles.

Gordon, B. (1983). Lexical access and lexical decision: Mechanisms of frequency sensitivity. *Journal of Verbal Learning and Verbal Behavior*, **22**, 24-44.

Gordon, B. (1985). Subjective frequency and the lexical decision latency function: Implications for mechanisms of lexical access. *Journal of Memory and Language*, **24**, 631-645.

Gordon, B., & Caramazza, A. (1982). Lexical decision for open- and closed-class words: failure to replicate differential frequency sensitivity. *Brain and Language*, **15**, 143-160.

Gordon, B. & Caramazza, A. (1983). Closed- and open-class lexical access in agrammatic and fluent aphasics. *Brain and Language*, **19**, 335-345.

Gordon, B., & Caramazza, A. (1985). Lexical access and frequency sensitivity: Frequency saturation and open/closed class equivalence. *Cognition*, **16**, 99-120.

Gow, D. Jr., & Gordon, P. C. (1995). Lexical and prelexical influences on word segmentation: Evidence from priming. *Journal of Experimental*

Psychology: Human Perception and Performance, **21**(2), 344-359.

Greenberg, S. N. , & Koriat, A. (1991). The missing-letter effect for common function words depends on their linguistic function in the phrase. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **17**(6), 1051-1061.

Greenberg, S. N., Koriat, A., & Shapiro, A. (1992). The effects of syntactic structure on letter detection in adjacent function words. *Memory & Cognition*, **20**(6), 663-670.

Grosjean, F., & Gee, J. P. (1987). Prosodic structure and spoken word recognition. *Cognition*, **25**, 135-155.

Haveman, A. P. (1996). Effects of frequency on the auditory perception of open- versus closed-class words. In H. T. Bunnell, & W. Idsardi (Eds.), *Proceedings ICSLP 96. Fourth International Conference on Spoken Language Processing*, Vol. **1** (pp. 78-81). New Castle, Delaware: Citation Delaware.

Herron, D. T., & Bates, E. A. (1997). Sentential and acoustic factors in the recognition of open- and closed-class words. *Journal of Memory and Language*, **37**(2), 217-239.

Heuven, V. J. van (1985). Perception of stress pattern and word recognition: Recognition of Dutch words with incorrect stress position. *Journal of the Acoustical Society of America*, **78**, S21.

Hogaboam, T. W., & Perfetti, C. A. (1975). Lexical ambiguity and sentence comprehension. Journal of Verbal Learning and Verbal Behavior, 14, 265-274.

Holmes, V. (1979). Accessing ambiguous words during sentence comprehension. *Quarterly Journal of Experimental Psychology*, **44**, 13-35.

Howard, D., & Franklin, S. (1988). *Missing the meaning? A cognitive neuropsychological study of the processing of words by an aphasic patient.* Cambridge, MA: The MIT press.

Jastrembski, J. E. (1981). Multiple meanings, number of related meanings, frequency of occurrence, and the lexicon. *Cognitive Psychology, 13*, 178-305.

Jescheniak, J., & Levelt, W. J. M. (1994). Word frequency effects in speech production: Retrieval of syntactic information and of phonological form. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **20**(4), 824-843.

Jongenburger, W. (1996). *The role of lexical stress during spoken-word processing*. Doctoral Dissertation, University of Leiden. Dordrecht: ICG

Printing.

Jongenburger, W., & Heuven, V. J. van (1995a). The role of lexical stress in the recognition of spoken words: prelexical or postlexical? *Proceedings of the XIIIth International Congress of Phonetic Sciences, Stockholm*, (Vol.4, pp. 368-371).

Kean, M. (1977). The linguistic interpretation of aphasic syndroms: Agrammatism in Broca's aphasia, an example, *Cognition*, **5**, 9-46.

Kean, M. (1979). Agrammatism: A phonological deficit?, *Cognition*, **7**, 69-83.

Klosek, J. (1979). Two unargued linguistic assumptions in Kean's "phonological" interpretation of agrammatism, *Cognition*, **7**, 61-68.

Kohn, S., & Smith, K. (1993). Lexical-phonological processing of functors: evidence from fluent aphasia. *Cortex*, **29**, 53-64.

Kolk, H. (1977). The linguistic interpretation of Broca's aphasia. A reply to M.-L. Kean, *Cognition*, **6**, 249-262.

Kolk, H., H. J. & Blomert, L. (1985). On the Bradley hypothesis concerning agrammatism: The nonword interference effect. *Brain and Language*, **26**, 94-105.

Koriat, A., & Greenberg, S. N. (1993). Prominence of leading functors in function morpheme sequences as evidenced by letter detection. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **19**(1), 34-50.

Koster, M., & Cutler, A. (1997). Segmental and suprasegmental contributions to spoken-word recognition in Dutch. In *ESCA, Proceedings Eurospeech97*, 2167-2170.

Koster, M., & Quené, H. (in preparation). Metrical segmentation in Dutch: vowel quality or lexical stress?

Kutas, M., & Hillyard, S. A. (1983). Event-related brain potentials to grammatical errors and semantic anomalies. *Memory and Cognition*, **11**, 539-550.

Lehiste, I. (1970). *Suprasegmentals*. Cambridge MA: MIT Press.

Levelt, W. J. M. (1989). *Speaking: From intention to articulation*. Cambridge, MA: MIT Press.

Levelt, W. J. M. (1993). The architecture of normal spoken language use. In G. Blanken, J. Dittmann, H. Grimm, J. C. Marshall, & C-W. Wallesch (Eds.), *Linguistic disorders and pathologies*: An international handbook (pp. 1-15). Berlin: Walter de Gruyter.

Lieberman, P. (1963). Some effects of semantic and grammatical context on the production and perception of speech. *Language and Speech,* **6**, 172-187.

Luce, P. A. (1986). *Neighborhoods of words in the mental lexicon.* Research on Speech Perception, Tech. Rep., No. 6. Bloomington, Ind. University, Department of Psychology, Speech Research Laboratory.

Marslen-Wilson, W. (1987). Functional parallelism in spoken word recognition. *Cognition,* **25**, 71-102.

Matthei, E. H., & Kean, M. -L. (1989). Postaccess processes in the open vs. closed class distinction, *Brain and Language*, **36**, 163-180.

McClelland, J., & Elman, J. (1986). The TRACE model of speech perception. *Cognitive Psychology*, 18, 1-86.

McQueen, J. (submitted). Segmentation of continuous speech using phonotactics.

McQueen, J. M. & Cox, E. (1995). The use of phonotactic constraints in the segmentation of Dutch. In *Proceedings of Eurospeech '95*, **3**, 1707-1710, Madrid, Spain.

McQueen, J., Cutler, A., Briscoe, T., & Norris, D. (1995). Models of continuous speech recognition and the contents of the vocabulary. *Language and Cognitive Processes,* **10**(3/4), 309-331.

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

MacWhinney, B. (1989). Competition and Teachability. In M. Rice and R. Schiefelbusch (Eds.), *The teachability of language* (pp. 63-104). Baltimore, Maryland: Paul Brookes Publishing Co.

Mehler, J., Dommergues, J.-Y., Frauenfelder, U. H., & Segui, J. (1981). The syllable's role in speech segmentation. *Journal of Verbal Learning and Verbal Behavior*, **20**, 298-305.

Mehta, G., & Cutler, A. (1988). Detection of target phonemes in spontaneous and read speech. *Language and Speech,* **31**(2), 135-156.

Mohr, B., Pulvermüller, F., & Zaidel, E. (1994). Lexical decision after left, right and bilateral presentation of function words, content words and nonwords: Evidence for interhemispheric interaction. *Neuropsychologia*, **32**(1), 105-124.

Moravcsik, J. E. & Healy, A. F. (1995). Effect of meaning on letter detection. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **25**(1), 82-95.

Morton, J. (1969). Interaction of information in word recognition. *Psycholo-*

gical Review, 76, 165-178.

Morton, J. (1970). A functional model for memory. In D.A. Normal (Ed.), *Models of human memory* (pp. 203-254). New York: Academic Press.

Morton, J. (1979). Word recognition. In J. Morton & J.C. Marshall (Eds.), *Psycholinguistics: 2. Structure and processes* (pp. 107-156).

Neville, H., Nicol, J. L., Barss , A., Forster, K. I., & Garrett, M. F. (1991). Syntactically based sentence processing classes: evidence from event-related brain potentials. *Journal of Cognitive Neuroscience*, **3**, 151-165.

Neville, H., Mills, D. L., & Lawson, D. S. (1992). Fractionating language: different neural subsystems with different sensitive periods. *Cerebral Cortex*, **2**, 244-258.

Newport, E. L., Gleitman, H., & Gleitman, L. R. (1977). Mother I'd rather do it myself: Some effects and non-effects of maternal speech style. In. C. E. Snow and C. A. Ferguson (Eds.), *Talking to children: Language input and acquisition.* Cambridge: Cambridge University Press.

Nooteboom, S. G., & Cohen, A. (1984). *Spreken en verstaan.* Assen: Van Gorcum.

Norris, D. (1986). Word recognition: Context effects without priming. *Cognition, 22*, 93- 136.

Norris, D. (1994). SHORTLIST: A connectionist model of continuous speech recognition. *Cognition*, **52**, 189-234.

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.

Norris, D. G., McQueen, J. M., Cutler, A., & Butterfield, S. (in press). The possible-word constraint in the segmentation of continuous speech. *Cognitive Psychology.*

Oldfield, R. C., & Wingfield, A. (1965). Response latencies in naming objects. *Quarterly Journal of Experimental Psychology, 17*, 273-281.

Onifer, W., & Swinney, D. A. (1981). Accessing lexical ambiguities during sentence comprehension: Effects of frequency of meaning and contextual bias. *Memory and Cognition*, **15**, 225-236.

Otake, T., Hatano, G., Cutler, A., & Mehler, J. (1993). Mora or syllable? Speech segmentation in Japanese. *Journal of Memory and Language*, **32**, 258-278.

Pallier, C., Sebastián-Gallès, N., Felguera, T., Christophe, A., & Mehler, J. (1993). Attentional location within the syllable structure of spoken words. *Journal of Memory and Language*, **32**, 373-389.

Petocz, A., & Oliphant, G. (1988). Closed-class words as first syllables do interfere with lexical decisions for nonwords: implications for theories of agrammatism. *Brain and Language*, **34**, 127-146.

Prather, P., & Swinney, D. (1977). *Some effects of syntactic context upon lexical access*. Paper presented at a meeting of the American Psychological Association, San Francisco, August 26, 1977.

Pulvermüller, F., Lutzenberger, W., & Birbaumer, N. (1995). Electrocortical distinction of vocabulary types. *Electroencephalography and clinical Neurophysiology*, **94**, 357-370.

Radeau, M., & Morais, J. (1990). The uniqueness point effect in the shadow ing of spoken words. *Speech Communication*, **9**, 155-164.

Rubenstein, H., Garfield, L., & Millikan, J. A. (1970). Homographic entries in the internal lexicon. *Journal of Verbal Learning and Verbal Behavior, 10*, 57-62.

Scarborough, D. L., Cortese, C., & Scarborough, H. S. (1977). Frequency and repetition effects in lexical memory. *Journal of Experimental Psychology: Human Perception and Performance*, **3**(1), 1-17.

Schwaneveldt, R. W., Meyer, D. E., & Becker, C. A. (1976). Lexical ambibiguity, semantic context, and visual word recognition. *Journal of Experimental Psychology: Human Perception and Performance*, **2**, 243-256.

Sebastián-Gallés, N., Dupoux, E., Segui, J., Mehler, J. (1992). Contrasting syllable effects in Catalan and Spanish. *Journal of Memory and Language*, **31**, 18-32.

Segui, J., Frauenfelder, U., Lainé, C., & Mehler, J. (1987). The word frequency effect for open- and closed-class items. *Cognitive Neuropsychology*, **4**(1), 33-44.

Segui, J., Mehler, J., Frauenfelder, U., & Morton, J. (1982). The word frequency effect and lexical access. *Neuropsychologia*, **20**, 615-627.

Seidenberg, M. S., Tanenhaus, M. K., Leiman, J., & Bienkowski, M. (1982). Automatic access of the meanings of ambiguous words in context: Some limitations of knowledge-based processing. *Cognitive Psychology, 14*, 489-537.

Seidenberg, M. S., Waters, G. S., Sanders, M., & Langer, P. (1984). Pre- and postlexical loci of contextual effects in word recognition. *Memory & Cognition, 12*, 315-328.

Shapiro, L. & Jensen, L. (1986). Processing open and closed class-headed non-words: Left hemisphere support for separate vocabularies. *Brain and*

Language, **28**, 318-327.

Shillcock, R. (1990). Lexical hypotheses in continuous speech. In G.T.M. Altmann (Ed.), *Cognitive models of speech processing* (24-49). Cambridge MA: MIT Press.

Shillcock, R., & Bard, E. (1993). Modularity and the processing of closed-class words. In R. Shillcock & G. Altmann (Eds.), *Cognitive models of speech processing: The second Sperlonga meeting* (pp. 163-185). Hove, U.K.: Lawrence Erlbaum Associates.

Simpson, G. B. (1981). Meaning dominance and semantic context in the processing of lexical ambiguity. *Journal of Verbal Learning and Verbal Behavior*, **20**, 120-136.

Simpson, G. B. (1984). Lexical ambiguity and its role in models of word recognition. *Psychological Bulletin, 96*, 316-340.

Simpson, G. B. (1994). Context and the processing of ambiguous words. In M. A. Gernsbacher (Ed.), *Handbook of Psycholinguistics* (pp. 359-374). San Diego: Academic Press. Inc.

Slobin, D. I. (1996). The origin of grammaticizable notions: beyond the individual mind. In D. I. Slobin (Ed.), *The crosslinguistic study of language acquisition*, Vol. **5**, Mahwah NJ: Lawrence Erlbaum Associates.

Slowiaczek, L. M. (1990). Effects of lexical stress in auditory word recognition. *Language & Speech*, **33**(1), 47-68.

Solomon, R. L., & Postman, L. (1952). Frequency of usage as a determinant of recognition thresholds for words. *Journal of Experimental Psychology, 43*, 195-201.

Stemberger, J. P. (1984). Structural errors in normal and agrammatic speech. *Cognitive Neuropsychology*, **1**(4), 281-313.

Svartvik, J., & Quirk, R. (1980). *A corpus of English conversation.* Lund: Gleerup.

Swinney, D. A. (1979). Lexical access during sentence comprehension: (Re)-consideration of context effects. *Journal of Verbal Learning and Verbal Behavior*, **18**, 645-659.

Swinney, D. A., Zurif, E. B., & Cutler, A. (1980). Effects of sentential stress and word class upon comprehension in Broca's aphasics. *Brain and Language*, **10**, 132-144.

Tabossi, P. (1988). Accessing lexical ambiguity in different types of sentential contexts. *Journal of Memory and Language, 27*, 324-340.

Tabossi, P., Burani, C., & Scott, D. (1995). Word identification in fluent speech. *Journal of Memory and Language*, 34, 440-467.

Tabossi, P, & Zardon, F. (1993). Processing ambiguous words in context. *Journal of Memory and Language, 32*, 359-372.

Taft, M. (1990). Lexical processing of functionally constraint words. *Journal of Memory and Language, 29*, 245-257.

Tanenhaus, M. K., Dell, G. S., & Carlson, G. (1987). Context effects and lexical processing: A connectionist approach to modularity. In J. L. Garfield (Ed.), *Modularity in knowledge representation and natural language understanding*. Cambridge, MA: MIT Press.

Tanenhaus, M. K., Leiman, J. M., & Seidenberg, M. S. (1979). Evidence for multiple stages in the processing of ambiguous words in syntactic contexts. *Journal of Verbal Learning and Verbal Behavior, 18*, 427-440.

Tesak, J., & Hummer, P. (1994). A note on prepositions in agrammatism. *Brain and Language*, **46**, 463-468.

Valian, V., & Coulson, S. (1988). Anchor points in language learning: The role of marker frequency. *Journal of Memory and Language*, **27**, 71-86.

Van Donselaar, W., Koster, M., & Cutler, A. (in preparation). *Voornaam* is not a homophone: Lexical prosody and lexical access in Dutch.

Van Kuijk, D. (1996). Does lexical stress or metrical stress better predict word boundaries in Dutch? In H. T. Bunnell, & W. Idsardi (Eds.), *Proceedings ICSLP 96. Fourth International Conference on Spoken Language Processing*, Vol. **3** (pp. 1585-1588). New Castle, Delaware: Citation Delaware.

Van Petten, C., & Kutas, M. (1991). Influences of semantic and syntactic context on open- and closed-class words. *Memory & Cognition, 19*, 95-112.

Van Wijk, C., & Kempen, G. (1980). Funktiewoorden. - Een inventarisatie voor het Nederlands. (An Inventory of Dutch Function words). *Review of Applied Linguistics*, **47**, 53-68.

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.

Vroomen, J., Zon, M. van, & de Gelder, B. (1996). Cues to speech segmentation: Evidence from juncture misperception and word spotting. *Memory and Cognition*, **24**(6), 744-755.

Whaley, C. P. (1978). Word-Nonword classification time. *Journal of Verbal Learning and Verbal Behavior*, **17**, 143-154.

Wingfield, A. (1968). Effects of frequency on identification and naming of objects. *American Journal of Psychology, 81*, 226-234.

Zwitserlood, P. (1985). *Activation of word candidates during spoken word-recognition*. Paper presented to Psychonomic Society Meetings, Boston, Mass.

Zwitserlood, P. (1989). The locus of the effects of sentential-semantic context in spoken-word processing. *Cognition*, **32**, 25-64.

Zwitserlood, P., & Schriefers, H. (1995). Effects of sensory information and processing time in spoken-word recognition. *Language and Cognitive Processes*, **10**, 121-136.

APPENDICES

CHAPTER 2: APPENDIX A

Open- and closed-class words used in the Experiments 1, 2, and 3

(Approximate translations are given in brackets)

Open class (high frequency)	**Closed class (low frequency)**	**Open-class (low frequency)**	
bang (afraid)	*der (of the)*	*blut (broke)*	*pips (pale)*
dag (day)	*doch (but, yet)*	*chloor (chlorine)*	*plint (plinth)*
doen (do)	*geen (no, none)*	*iel (thin)*	*schriel (mean)*
fonds (fund)	*gij (you)*	*kaf (chaff)*	*slons (slattern)*
kind (child)	*jou (you)*	*kerks (churchy)*	*sluik (lank)*
koe (cow)	*men (one)*	*kien (keen)*	*smaad (indignity)*
man (man)	*mits (provided that)*	*klif (cliff)*	*spriet (blade)*
mand (basket)	*per (by)*	*kram (staple)*	*tof (topping)*
uur (hour)	*uw (your)*	*lor (rag)*	*urn (urn)*
wijn (wine)	*veel (much)*	*mak (tame)*	*velg (rim)*
wit (white)	*zelf (self)*	*mul (loose)*	*vrek (miser)*
zien (see)	*zulks (this)*	*paaps (popish)*	*wuft (frivolous)*

CHAPTER 2: APPENDIX B

Nonwords used in the Experiments 1 and 3

struim, zwark, wem, bork, kelm, mulk, juuf, birst, laart, wirst, geemt, slif, spreul, kloes, oof, plimp, schriek, wuist, scheem, traal, grauk, briek, krok, slant, lan, eel, ilk, taar, naks, ocht, dif, tie, hin, laar, tun, oots, ket, tat, daap, nit, dil, ip, weur, nief, guin, gem, wunt, ieks

CHAPTER 3: APPENDIX C

List of experimental items used in Experiment 4

(Approximate English translations are given in brackets)

Closed Class (low frequency)	**Open Class (low frequency)**	**Closed Class (high frequency)**	**Open Class (high frequency)**
des-bool (of the)	*dof-bool (dull)*	*geen-deuf (none)*	*tuin-deuf (garden)*
mits-deul (provide)	*muts-deul (bonnet)*	*tot-woeg (till)*	*pop-woeg (doll)*
zulk-fijs (such)	*bink-fijs (bounder)*	*hem-fuul (him)*	*ham-fuul (ham)*
gij-woem (you)	*tij-woem (tide)*	*zich-daam (oneself)*	*vis-daam (fish)*
niks-deut (nothing)	*nimf-deut (nymph)*	*of-deup (or)*	*as-deup (ash)*
per-daaf (by)	*tor-daaf (beetle)*	*met-duis (with)*	*pet-duis (cap)*
ter-deug (at)	*lor-deug (dud)*	*op-fuis (on)*	*aap-fuis (monkey)*
nee-duip (no)	*fee-duip (fairy)*	*die-heuf (that)*	*koe-heuf (cow)*
jij-fuin (you)	*jus-fuin (gravy)*	*ik-fuun (I)*	*oor-fuun (ear)*
ja-huik (yes)	*reu-huik (male dog)*	*te-guif (at)*	*pa-guif (father)*
mee-puuk (with)	*keu-puuk (cue)*	*dat-poeg (that)*	*dak-poeg (roof)*
ten-guik (in)	*bon-guik (ticket)*	*in-peep (in)*	*oom-peep (uncle)*
zelf-peep (self)	*larf-peep (larve)*	*en-gien (and)*	*eeuw-gien (century)*
toe-gies (towards)	*pui-gies (front)*	*van-keep (from)*	*pan-keep (pot)*
hun-fijp (their)	*rum-fijp (rum)*	*het-fijm (the)*	*dun-fijm (thin)*

CHAPTER 3: APPENDIX D

List of experimental items used in Experiment 5

(Approximate English translations are given in brackets)

Closed Class (low frequency)	**Open Class (low frequency)**	**Closed Class (low frequency)**	**Open Class (high frequency)**
bool-des (of the)	*bool-dof (dull)*	*deuf-geen (none)*	*deuf-tuin (garden)*
deul-mits (provide)	*deul-muts (bonnet)*	*woeg-tot (till)*	*woeg-pop (doll)*
weug-zulk (such)	*weug-bink (bounder)*	*fuul-hem (him)*	*fuul-ham (ham)*
woem-gij (you)	*woem-tij (tide)*	*daam-zich (oneself)*	*daam-vis (fish)*
deut-niks (nothing)	*deut-nimf (nymph)*	*weun-of (or)*	*weun-as (ash)*
daaf-per (by)	*daaf-tor(beetle)*	*geul-met (with)*	*geul-pet (cap)*
wuun-ter (at)	*wuun-lor (dud)*	*juil-op (on)*	*juil-aap (monkey)*
wuim-nee (no)	*wuim-fee (fairy)*	*heuf-die (that)*	*heuf-koe (cow)*
fuin-jij (you)	*fuin-jus (gravy)*	*soej-ik (I)*	*soej-oor (ear)*
puun-ja (yes)	*puun-reu (male dog)*	*guif-te (at)*	*guif-pa (father)*
puul-mee (with)	*puul-keu (cue)*	*poeg-dat (that)*	*poeg-dak (roof)*
guik-ten (in)	*guik-bon (ticket)*	*goej-in (in)*	*goej-oom (uncle)*
jeen-zelf (self)	*jeen-larf (larve)*	*gien-en (and)*	*gien-eeuw (century)*
giel-toe (towards)	*giel-pui (front)*	*kuim-van (from)*	*kuim-pan (pot)*
jeel-hun (their)	*jeel-rum (rum)*	*fijm-het (the)*	*fijm-dun (thin)*

CHAPTER 3: APPENDIX E

List of experimental items used in Experiment 6

(Approximate English translations are given in brackets)

Closed Class (lexicalized schwa)	**Open Class (lexicalized schwa)**	**Closed Class (full vowel)**	**Open Class (full vowel)**
joef-'r (her)	*roef-dun (thin)*	*moof-doch (but)*	*koof-dom (stupid)*
kaaf-'m (him)	*taaf-puk (tiny tot)*	*gief-per (by)*	*rief-pen (pen)*
deul-ge (you)	*meul-pul (vase)*	*rool-ter (at)*	*tool-pech (bad luck)*
huul-z'n (his)	*wuul-rum (rum)*	*jeut-nee (no)*	*seut-leem (loam)*
goel-'t (the)	*soel-juf (miss)*	*juim-ten (at)*	*nuim-web (web)*
weul-me (me)	*jeul-rups (caterpillar)*	*puul-zelf (self)*	*huul-zerk (stone)*
fool-we (we)	*wool-rug (back)*	*teur-geen (none)*	*jeur-leeg (empty)*
weur-je (you)	*reur-mug (mosquito)*	*heur-zich (oneself)*	*neur-wig (wedge)*
heum-ze (they)	*feum-uk (tiny tot)*	*peug-of (or)*	*laug-os (ox)*
soer-te (at)	*goer-muf (stuffy)*	*kuig-met (with)*	*wuig-lef (swank)*
jeel-de (the)	*reel-juk (yoke)*	*jeup-van (from)*	*meup-vak (compartment)*

CHAPTER 4: APPENDIX F

List of experimental phrases used in Experiment 7

(Approximate English translations are given in brackets)

OC = Open Class, CC = Closed Class

HF = high frequency, MF = medium frequency, LF = low frequency

OC- = nonsense syllable to be combined with open-class words (e.g., *angst-deul*)

CC- = nonsense syllable to be combined with open-class words (e.g., *we-peef*)

OC / HF	**OC / MF**	**OC / LF**	**CC / HF**	**CC / LF**	**OC- / CC-**
angst (fear)	*zand (sand)*	*inkt (ink)*	*we (we)*	*me (me)*	*-deul / -peef*
bed (bed)	*dak (roof)*	*pek (pitch)*	*tot (till)*	*ten (at)*	*-woem / -ruuf*
deur (door)	*geur (smell)*	*koor (choir)*	*hem (him)*	*men (they)*	*-fuin / -baaf*
feit (fact)	*huid (skin)*	*kuit (spawn)*	*wat (what)*	*dit (this)*	*-puuk / -beeg*
geest (ghost)	*vuist (fist)*	*toorn (wrath)*	*zich (oneself)*	*doch (but)*	*-duip / -feup*
groep (group)	*stoep (pavement)*	*sloep (boat)*	*of (or)*	*dus (so)*	*-huik / -keep*
grond (soil)	*front (front)*	*klont (lump)*	*door (through)*	*per (by)*	*-peep / -tief*
hand (hand)	*tand (tooth)*	*lont (fuse)*	*om (around)*	*jou (you)*	*-guik / -soer*
hond (dog)	*bord (plate)*	*lint (ribbon)*	*je (you)*	*ge (you)*	*-gies/ -raal*
hoofd (head)	*fruit (fruit)*	*schuit (boat)*	*aan (at)*	*der (from)*	*-poek / -tiek*
huis (house)	*muis (mouse)*	*leus (slogan)*	*voor (before)*	*ter (at)*	*-bool / -wuik*
juist (exactly)	*woest (wild)*	*kwiek (sprightly)*	*ze (she)*	*wie (who)*	*-daap / -poek*
kerk (church)	*park (park)*	*berk (birch)*	*met (with)*	*zulk (such)*	*-fijs / -boof*
lang (tall)	*dik (fat)*	*tam (tame)*	*die (that)*	*ja (yes)*	*-fijp / -tuif*
man (man)	*pan (pot)*	*den (fir)*	*op (on)*	*zelf (self)*	*-woeg / -kieg*
nacht (night)	*jeugd (youth)*	*vacht (fur)*	*hij (he)*	*jij (you)*	*-peep / -deuf*
nooit (never)	*thans (at present)*	*schier (almost)*	*ik (I)*	*niks (nothing)*	*-daaf / -heuk*
stad (city)	*blad (leaf)*	*krat (crate)*	*te (on)*	*nee (no)*	*-fuul / -joek*
ver (far)	*ruw (rough)*	*dor (dry)*	*dat (that)*	*na (after)*	*-jien / -liem*
vol (full)	*kil (chilly)*	*tof (great)*	*in (in)*	*u (you)*	*-duis / -fijm*

vriend (friend)	*straat (street)*	*kreeft (lobster)*	*een (a)*	*geen (none)*	*-heuf / -koof*
vrouw (woman)	*sneeuw (snow)*	*klauw (claw)*	*en (and)*	*gij (you)*	*-deut / -meuf*
woord (word)	*poort (gate)*	*taart (cake)*	*van (from)*	*hun (their)*	*-fuis / -meul*
zaak (case)	*taak (task)*	*peuk (stub)*	*het (the)*	*mits (if)*	*-daam / -keem*
zwaar (heavy)	*braaf (decent)*	*stoer (sturdy)*	*de (the)*	*joh (-)*	*-deup / -muuk*

CHAPTER 4: APPENDIX G

List of experimental phrases used in Experiment 8

(Approximate English translations are given in brackets)

HF = high frequency / LF = low frequency

HF closed-class + HF open-class

de hond (the dog), het boek (the book), een man (the man), dat kind (that child), ik sliep (I slept), hij praat (he talks), die vis (that fish), zij roept (she calls), zijn hand (his hand), haar stoel (her chair), wat geld (some money), mijn slot (my lock)

HF closed-class + LF open-class

de hint (the cue), het juk (the yoke), een map (a folder), dat kalf (that calf), ik snoof (I sniffed), hij preekt (he preaches), die wol (that wool), zij roert (she stirs), zijn helm (his helmet), haar spuit (her sprayer), wat gips (some gyps), mijn spul (my stuff)

LF closed-class + HF open-class

geen hond (no dog), dit boek (this book), hun man (their man), ons kind (our child), wie sliep (who slept), jij praat (you sleep), meer vis (more fish), gij roept (you call), uw hand (your hand), jouw stoel (your chair), zulk geld (that kind of money), elk slot (every lock)

LF closed-class + LF open-class

geen hint (no cue), dit juk (this yoke), hun map (their folder), ons kalf (our calf), wie snoof (who sniffed), jij preekt (you preaches), meer wol (more wool), gij roert (you stir), uw helm (your helmet), jouw spuit (your sprayer), zulk gips (some gyps), elk spul (all stuff)

HF preposition + HF open-class

van goud (of gold), in ernst (in earnest), te voet (on foot), met rust (leave alone), aan boord (on board), op schoot (on somebody's lap), naar bed (to bed), door schuld (through somebody's fault), bij dag (by day), tot gauw (see you soon)

HF preposition + LF closed-class

uit haat (from hatred), na Maart (after March), ten top (to extremeness), naast school (next to the school), ter been (be a (good/bad) walker), langs huis (pass by your house), per trein (by train), sinds nu (from now on), plus vijf (plus five), ad vier (at point four)

CHAPTER 4: APPENDIX H

List of experimental words used in Experiment 9

(Approximate English translations are given in brackets; associates given after dash)

Homophones (stressed)

ALbums (albums), al (universe) - universum (universe), al (every) - ook (also) / BIJbels (Bibles), bij (bee) - wesp (wasp), bij (with) - langs (along) / HAARlemmers (residents of Haarlem), haar (hair) - pruik (wig), haar (her) - ze (she) / HENdels (grips), hen (hen) - kip (chicken), hen (them) - jij (you) / MIJNschachten (mine-shafts), mijn (mine) - ontploffing (explosion), mijn (mine) - hem (his) / MEERvouden (plurals), meer (lake) - water (water), meer (more) - weinig (few) / NAARlingen (wretched fellows), naar (bad) - ziek (ill), naar (to) - ginds (over there) / PLUSpunten (advantages), plus (plus) - teken (sign), plus (and) - vele (many) / RONDreizen (tours), rond (round) - vierkant (square), rond (about) - circa (about) / WAARheden (truth), waar (merchandise) - handel (trade), waar (were) - hier (here) / WIJzers (hands), wei (meadow) - gras (grass), wij (we) - jullie (your) / ZIJramen (side windows), zij (flank) - heup (hip), zij (she) - hun (their)

Non-homophonous (stressed) / Closed class

DOCHters (daughters), doch (but) - echter (however) / DUSters (dressing-gowns), dus (so) - kortom (in short) / METworsten (sausages), met (with) - zonder (without) / OFfers (sacrifices), of (or) - als (if) / TOENdra's (tundras), toen (then) - destijds (at the time) / ZELFmoorden (suicides), zelf (oneself) - ik (I) / ERkers (bay windows), er (there) - ginds (over there) / NIETSnutten (good-for-nothings), niets (nothing) -alles (everything) / UITspraken (decisions), uit (out) - achter (behind) / ZOden (sods), zo (so) - wanneer (when) / Unies (unions), u (you) - gij (you) / AANdelen (shares), aan (on) - tegen (against)

Non-homophonous (stressed) / Open class

HAMsters (hamsters), ham (ham) - spek (bacon) / KAFtans (caftans), kaf (chaff) - graan (corn) / BANjo's (banjo's), ban (excommunication) - vloek (curse) / BALsems (balms), bal (ball) - spel (game) / KEIzers (emperors), kei (boulder) - steen (stone) / KAPsters (hairdressers), kap (cap) - muts (bonnet) / EScorts (escorts), es (ash) - boom (tree) / BAKvissen (adolescents), bak (tray) - doos (box) / PESTkoppen (bully's), pest (plague) - ziekte (illness) / JUKbeenderen (cheek-bones), juk (yoke) - zwaar (heavy) / TIJdingen (news), tij (tide) - eb (ebb) / BLOKnoots (writing-block), blok (block) - vierkant (square)

Non-homophonous (unstressed) / Closed-class

hoeRA'S (hurrah's), hoe (how) - waarom (why) / danSEURS (dancer), dan (then) - nu (now) / geDROCHten (monsters), ge (you) - je (you) / meLOEnen (melons), me (me) - zich (oneself) / naTUren (natures), na (after) - voor (before) / inSEKten (insects), in (in) - tussen (in between) / perCELen (site), per (by) - thans (now) / diEten (diets), die (that) - welke (which) / enZYmen (enzymes), en (and) - maar (but) / desPOten (despots), des (of the) - ondanks (even though) / teGOEden (balances), te (at) - daar (there) / vanDAlen (vandals), van (from) - der (from)

Non-homophonous (unstressed) / Open-class

vaarWELS (farewells), vaar (sail) - boot (boat) / arTIESten (artists), ar (sleigh) - slee (sleigh) / reuZINnen (female giants), reu (male dog) - hond (dog) / karTONnen (cardboard boxes), kar (cart) - wiel (wheel) / lakTAten (lactoses), lak (sealing-wax) - verf (paint) / dikTAten (notes), dik (fat) - groot (big) / briIJANten (brilliants), bril (glasses) - glas (glass) / koePONS (materials), koe (cow) - stier (bull) / horMOnen (hormones), hor (wire gauze) - vlieg (fly) / porTAlen (porches), por (stab) - stomp (punch) / bankROEten (bankruptcy), bank (sofa) - stoel (chair) / mosKEEen (mosques), mos (moss) - groen (green)

CHAPTER 5: APPENDIX I

List of experimental phrases used in Experiment 10

(Approximate English translations are given in brackets)

Homophones: Open class / Closed class	**Controls: Open class / Closed class**
kort haar (short hair) / voor haar (for her)	*wit bier (white beer)/ naast hem (next to him)*
zijn hen (his chicken) / bij hen (with them)	*geen hor (no screen) / dat hier (this here)*
veel hei (lots of heather) / doet hij (does he)	*die bui (that shower) / toen wat (then what)*
klein meer (small lake) / iets meer (bit more)	*groot zeil (large sail) / toch daar (still there)*
vier mei (May fourth) / geef mij (give me)	*heel end (long way) / van wie (from whom)*
de mijn (the mine) / aan mijn (to my)	*oud wijf (old woman) / en ook (and also)*
ik men (I drive) / zegt men (they say)	*Piet won (Piet won) / niet jij (not you)*
drie ons (three ounces) / roep ons (call us)	*met thee (with tea) / breng hun (bring them)*
uw wei (your meadow) / zelfs wij (even we)	*hoog tij (high tide) / eet u (are you eating)*
een zij (a side) / denkt zij (she thinks)	*jouw kei (your boulder) / wel zo (like this)*

CHAPTER 5: APPENDIX J

List of experimental phrases used in Experiment 11

(Approximate English translations are given in brackets)

Open-class Homophones

een groot buiten - villa (a large country-house - villa); zulke enige - prachtige (such a lovely thing - magnificent); knal groen haar - pruik (bright green hair - wig); een broedse hen - kip (a broody hen - chicken); de stille hei - paars (the silent moors - purple); een klein meer - water (a small lake - water); de maand mei - lente (the month of May - spring); ik *men - teugel (I drive - bridle); een oude mijn - steenkool (an old mine - coal); een halve ons - gewicht (half an ounce - weight); helemaal rond - cirkel (completely round - circle); de dure waar - handel (the expensive merchandise - trade); in de wei- gras (in the meadow - grass); je linker zij- heup (your left side - hip)*

Closed-class Homophones

ik kan er buiten - zonder (I don't need it - without); slechts enige - sommige (just some - a few); vraag het haar - meisje (ask her - girl); ze ziet hen - jij (she is seeing them - you); of slaapt hij - man (or is he sleeping - man); ze heeft meer - aantal (she has more - number); kom bij mij - hem (come to me - him); dat zegt men - persoon (that's what they say - person); dat is mijn - bezit (that is mine - property); geef het ons - hun (give it to us - theirs); de tafel rond - omheen (around the table - on all sides of); weet je waar - plek (you know were - place); dat zeggen wij - jullie (that's what we are saying - you); dat weet zij - vrouw (she knows that - woman)

Open-class Controls

een kleine beker - melk (a small cup - milk); uitermate gelukkig - blij (extremely happy - pleased); om zijn hals - nek (around his neck - neck); een grote haan - kam (a big cock - crest); een bange haas - konijn (a scared hare - rabbit); in de map - blaadjes (in the folder - sheets); een scherp mes - lepel (a sharp knife - spoon); ze morst - knoeit (she is spilling - making a mess); een grijze muis - kaas (a grey mouse - cheese); een domme oen - kluns (a stupid dud - noodle); toch niet slecht - goed (after all not that bad - good); in de waan - idee (be under the delusion - idea); een groot wiel - spaak (a large wheel - spoke); een witte zwaan - gans (a white swan - goose)

Closed-class Controls

ik wil beide - samen (I want both - together); niet allemaal - menigeen (not all of them - many a man); eet eens wat - beetje (just eat something - little); genoeg voor elk - ieder (enough for everybody - anybody); toch maar die - welke (just those - which); nog het meest - weinig (most - few); alleen maar dit - specifiek (only this - specific); dat denkt u - gij (that's what you think - thou); ze wast zich - eigen (she is washing herself - own); ik ruik iets - onbepaald (I smell something - indefinite); niet er naast - boven (not next to it - over); geef *eens hier - daar (just give it - there); het kost niets - veel (it doesn't cost much - a lot); totaal geen - alles (entirely nothing - everything)*

CHAPTER 5: APPENDIX K

List of experimental phrases used in Experiment 12

(Approximate English translations are given in brackets)

Open-class Homophones

een groot buiten - villa (a large country-house - villa); zulke enige - prachtige (such a lovely thing - magnificent); knal groen haar - pruik (bright green hair - wig); een broedse hen - kip (a broody hen - chicken); de stille hei - paars (the silent moors - purple); een klein meer - bootje (a small lake - small boat); de maand mei - lente (the month of May - spring); ik men - teugel (I drive - bridle); een oude mijn - springstof (an old mine - explosive); een halve ons - gewicht (half an ounce - weight); helemaal rond - cirkel (completely round - circle); de dure waar - handel (the expensive merchandise - trade); in de wei- gras (in the meadow - grass); je linker zij- heup (your left side - hip)

Closed-class Homophones

je kunt er buiten - zonder (you don't need it - without); slechts enige - sommige (just some - a few); zeg het haar - ze (tell her - she); opa zag hen - allemaal (granddad saw them - all of them); dat deed hij - zijn (that's what he was doing - his); je hebt er meer - weinig (you have more - few); kom bij mij - jou (come to me - yours); dat zegt men - iedereen (that's what they say - everybody); dat is mijn - uw (that is mine - yours); geef het ons - we (give it us - we); de tafel rond - om (around the table - round); weet je waar - hier (you know where - here); dat riepen wij - jullie (that's what we were shouting - you); dat weet zij - hun (she knows that - theirs)

Open-class Controls

een kleine bever - knaagdier (a small beaver - rodent); deze volgende - huidige (the next - current); een plakje kaas - zuivel (a slice of cheese - diary); een kleurige rif - koraal (a colorful reef - coral); de ronde kei - rots (the round boulder - rock); een gescheurde pees

- beenderen (a ruptured tendon - bones); de wilde zee - strand (the wild sea - beach); ik buk - krom (I'm bending - crooked); een grote pauk - trom (a large kettledrum - drum); een oude urn - graf (an old urn - grave); fluweel zacht - ruw (velvety soft - rough); de mooie kieuw - vis (the nice gill - fish); een flinke bui - regen (a heavy shower - rain); een grijze pij - monnik (a grey habit - monk)

Closed-class Controls

ik bedoel dat ene - beide (I mean that one - both); geef het elkaar - allebei (give it each other - both); de jongen wast zich - hem (the boy is washing himself - him); nog het meest - weinig (still the most - few); toch maar die - welke (still that one - which one); dat denk jij - ge (that's what you think - thou); ik ruik iets - veel (I smell something - a lot); dat weet u - gij (that's what you know - thou); eet eens wat - hoe (just eat something - how); genoeg voor elk - ieder (enough for everybody - anybody); alleen maar dit - zulk (just this - such); niet er naast - boven (not next to it - over); het kost niets - alles (it doesn't cost anything - everything); ik was me zelf (I'm washing myself - self)

SAMENVATTING

Stel dat je luistert naar een zin die gesproken wordt in een taal die je niet kent, zoals bijvoorbeeld naar *jinzhanhuazaiyangguangxiashengkai.* Omdat je geen individuele woorden kunt onderscheiden, is het niet mogelijk aan deze zin een betekenis toe te kennen. Wanneer je de taal eenmaal beheerst kan het opdelen of segmenteren van deze Chinese zin in woorden triviaal lijken (de vijf woorden *jinzhanhua zai yangguang xia shengkai* betekenen *de goudsbloemen gedijen in het zonlicht*). Binnen de psycholinguistiek is echter nog niet geheel duidelijk hoe dit segmentatieproces precies in zijn werk gaat. In deze dissertatie wordt onderzocht welke aanwijzingen Nederlandse luisteraars gebruiken bij de segmentatie van Nederlandse spraak, met name of het verschil tussen zogenaamde open- en gesloten klasse woorden hierbij een rol speelt.

Open-klasse woorden worden traditioneel gedefinieerd als woorden die een duidelijke betekenis hebben, zoals zelfstandige en bijvoeglijke naamwoorden. Deze klasse woorden wordt 'open' genoemd omdat er relatief makkelijk woorden aan toegevoegd kunnen worden (nieuwe woorden in een taal zijn bijvoorbeeld vaak bijvoeglijke naamwoorden). De gesloten-klasse bevat woorden die over het algemeen grammaticale relaties tussen de open-klasse woorden aangeven, zoals bijvoorbeeld lidwoorden en persoonlijke voornaamwoorden. Deze klasse wordt zelden uitgebreid met nieuwe woorden. Andere verschillen tussen open- en gesloten-klasse woorden zijn de frequentie waarmee deze woorden worden gebruikt (de individuele gesloten-klasse woorden worden frequenter gebruikt dan de individuele open-klasse woorden) en hun klemtoon patroon (open-klasse woorden krijgen vaak klemtoon, gesloten-klasse woorden worden vaak onbeklemtoond uitgesproken). Ook verschillen beide klassen in hun voorspelbaarheid uit de zinscontext:

gesloten-klasse woorden zijn beter te voorspellen dan open-klasse woorden. Op grond van deze verschillen is voorgesteld dat de open- en gesloten-klasse woorden in verschillende delen van ons mentale woordenboek of 'lexicon' zijn opgeslagen - de zogenaamde 'dual lexicon' hypothese. Hoewel gescheiden opslag het taalverwerkingsproces zou kunnen versnellen is een voorwaarde hiervoor dat een luisteraar binnenkomende spraak kan classificeren in open- en gesloten-klasse woorden, waarna deze woorden in het betreffende lexicon opzocht kunnen worden. Open- en gesloten-klasse woorden verschillen dan op een pre-lexicaal niveau, dat wil zeggen in het stadium voordat ze in het lexicon worden geactiveerd. Een dergelijk pre-lexicaal verschil tussen open- en gesloten-klasse woorden is in het verleden meermalen aangetoond (bijvoorbeeld door Bradley, 1978). Over het algemeen werd in deze onderzoeken echter geen of onvoldoende rekening gehouden met de eerder genoemde intrinsieke verschillen tussen beide soorten woorden.

In hoofdstuk 2 wordt ingegaan op de mogelijkheid dat eerder gevonden pre-lexicale verschillen tussen open- en gesloten-klasse woorden worden veroorzaakt door het grote verschil in frequentie. Voor een drietal experimenten werden daarom open- en gesloten-klasse woorden van een gelijke frequentie geselecteerd, zodat een mogelijke invloed van frequentie op de resultaten uitgesloten werd. De woorden werden gemengd met nonsens woorden en aan luisteraars aangeboden door een koptelefoon. Deze luisteraars bepaalden van ieder woord of het al dan niet een bestaand woord is (de 'lexical decision' taak). De resultaten lieten zien dat luisteraars sneller beslissingen namen over open-klasse dan over gesloten-klasse woorden. Omdat de beslissingen over deze gesloten-klasse woorden even traag waren als over de nonsens woorden werd echter geconcludeerd dat het gevonden verschil tussen open- en gesloten-klasse woorden waarschijnlijk niet te wijten is aan een zuiver pre-lexicaal onderscheid, maar eerder aan het verschil in betekenis (lexical decision is makkelijker wanneer een woord een duidelijke betekenis heeft).

De mogelijkheid dat luisteraars spraak classificeren in open- en gesloten-klasse woorden op grond van het klemtoonpatroon is het onderwerp van de volgende twee hoofdstukken. In de experimenten beschreven in hoofdstuk 3 werden éénlettergrepige nonsens woorden gecombineerd met zowel open- en gesloten-klasse woorden (bijvoorbeeld *rum-fijp* en *hun-fijp*) als met andere nonsens woorden (bijvoorbeeld *jun-fijp* en *wum-fijp*). Het klemtoon patroon van de combinaties werd gevarieerd: de eerste lettergreep was beklemtoond en de tweede onbeklemtoond, of de eerste lettergreep was onbeklemtoond en de tweede beklemtoond. Luisteraars kregen de taak om zo snel mogelijk op een knop in te drukken wanneer ze een bestaand woord hoorden (het 'word-spotting' paradigma). Wanneer de samenhang tussen woordklasse en klemtoon wordt gebruikt bij het segmenteren van spraak, zullen open-klasse woorden sneller herkend worden wanneer ze beklemtoond zijn en gesloten-klasse woorden wanneer ze geen klemtoon dragen. In eerste instantie leken de resultaten dit te bevestigen: open-klasse woorden werden iets sneller herkend wanneer ze beklemtoond waren en gesloten-klasse wanneer ze onbeklemtoond waren. Dit resultaat bleek echter alleen te gelden voor woorden met een bepaalde gebruiksfrequentie en tevens bleek het effect te veranderen wanneer de volgorde van de woorden werd omgedraaid (zoals *fijp-rum* en *fijp-hun*). Gezien de te grote variabiliteit van de resultaten lijkt het dus niet waarschijnlijk dat luisteraars klemtoon gebruiken om spraak te classificeren in open- en gesloten-klasse woorden.

Om uit te sluiten dat deze bevindingen werden veroorzaakt door de onnatuurlijke nonsens context waarin de woorden werden aangeboden, werden in hoofdstuk 4 beklemtoonde en onbeklemtoonde open- en gesloten-klasse woorden gebruikt in een betekenisvolle context. Een deel van de luisteraars maakte een lexicale decisie over het eerste woord (bijvoorbeeld *de-hond* versus *ru-hond*), een ander deel maakte een beslissing over het tweede woord (*de-hond* versus *de-gont*). De resultaten waren wederom variabel en werden daarom opgevat als een aanwijzing dat ook in een betekenisvolle context luisteraars beklemtoonde woorden niet automatisch classificeren als 'open' en onbeklemtoonde woorden als 'gesloten'.

Deze conclusie werd bevestigd door de resultaten van een 'cross-modal priming' experiment. In een dergelijk paradigma wordt uitgegaan van de veronderstelling dat wanneer een woord in het lexicon geactiveerd wordt, andere woorden die met dit woord geassocieerd zijn in meer of mindere mate ook geactiveerd zullen worden. Een luisteraar zal bijvoorbeeld dus sneller een 'lexical decision' kunnen maken over het woord *riem* wanneer dit woord wordt voorafgegaan door het woord *hond* (er vindt 'priming' plaats) dan wanneer er vooraf een ongerelateerd woord wordt aangeboden. In het huidige experiment werden auditief zinnen aangeboden die eindigden met een woord dat een woord met meerdere betekenis betekenissen - een homofoon - bevatte. Bijvoorbeeld, het woord hendels bevat de beklemtoonde homofoon hen die als zelfstandig naamwoord een open-klasse betekenis heeft en als persoonlijk voornaamwoord een gesloten-klasse betekenis. Wanneer luisteraars beklemtoonde woorden als open-klasse classificeren, zou de gesloten-klasse betekenis van hen niet geactiveerd moeten worden. De resultaten lieten echter zien dat lexicale decisies over associaties van de gesloten-klasse betekenis (jullie) wél enigszins geprimed worden; beklemtoonde homofonen krijgen dus niet automatisch een open-klasse betekenis.

Hoewel luisteraars inkomende spraak dus niet op basis van klemtoon lijken te classificeren in open- en gesloten-klasse woorden, sluit dit niet uit dat luisteraars hiervoor een andere cue gebruiken. Hoofdstuk 5 onderzoekt Shillcock en Bard's (1993) hypothese dat de grammaticale (syntactische) context gebruikt wordt om gesloten-klasse woorden te voorspellen. Deze woorden worden vervolgens opgezocht in een gesloten-klasse lexicon. Vindt er geen voorspelling plaats, dan wordt een woord opgezocht in een open-klasse lexicon. Om deze hypothese te toetsen werd wederom het cross-modal priming paradigma gebruikt. Hierbij werden auditief frasen aangeboden, die eindigden met een homofoon die door de syntactische context of een relatief laagfrequente open-klasse of een relatief hoogfrequente gesloten-klasse betekenis kreeg (*een broedse hen* versus *ze ziet hen*). Deze frasen werden direct gevolgd door een visueel aangeboden associatie van één van deze betekenissen (*kip* en *jullie*). Uit de resultaten bleek inderdaad priming op te treden van het woord gerelateerd aan de gesloten-klasse betekenis van de homofoon wanneer deze homofoon door de context een gesloten-klasse betekenis had (*ze ziet hen - jullie*). Echter, wanneer de geassocieerde woorden niet onmiddelijk na de homofoon werden aangeboden maar enkele miliseconden later, bleek tevens de associatie van de open-klasse betekenis (*kip*) zwak geprimed te worden. Deze resultaten laten zien dat de gesloten-klasse, hoogfrequente betekenis eerst beschikbaar komt. Wanneer deze betekenis niet in de context past wordt alsnog de laagfrequente open-klasse betekenis geactiveerd. De context kan derhalve niet bepalen welke woorden geactiveerd worden, en wordt dus niet gebruikt om gesloten-klasse woorden te voorspellen.

Uit de resultaten kan geconcludeeerd worden dat zowel klemtoon als syntactische context niet door luisteraars gebruikt worden om in spraak open- en gesloten-klasse woorden te classificeren. Het onderscheid tussen beide woordklassen lijkt dus geen rol te spelen in de segmentatie van het Nederlands. De resulaten zijn tevens inconsistent met de dual lexicon hypothese waarbij open- en gesloten-klasse woorden gescheiden zijn opgeslagen. De huidige bevindingen zijn van belang voor recente modellen van spraakherkenning (zoals bijvoorbeeld Shortlist; Norris, 1994). Ze suggereren dat frequentie in deze modellen een belangrijke rol zou moeten spelen en dat de syntactische context pas in het spel komt wanneer de meest waarschijnlijke woordkandidaten al geactiveerd zijn.

CURRICULUM VITAE

Alette Haveman studied Modern Linguistics (graduated in 1991) and Experimental Phonetics (graduated in 1992) at the *Rijksuniversiteit Utrecht,* the Netherlands. After completing her studies, she spend one year at the Aphasia Research Center in Boston, USA, working on syntactic self-corrections by aphasic patients. Upon her return to the Netherlands, she got a one-year research appointment at the Max-Planck-Institute for Psycholinguistics in Nijmegen to work on the production of plural morphology. A stipend from the Max-Planck-Gesellschaft in 1994 successively enabled her to carry out her dissertation research at the same institute, from which the results are described in the current thesis. After finishing her thesis, she worked at NYFER - Nijenrode Forum for Economic studies. In early 1998, she will work as a postdoctoral fellow at the *Centre de Recherche en Neurosciences Cognitives / Centre National de la Recherche Scientific* in Marseille, France.

MPI SERIES IN PSYCHOLINGUISTICS

1. The electrophysiology of speaking. Investigations on the time course of semantic, syntactic, and phonological processing
   Miranda van Turennout

2. The role of the syllable in speech production. Evidence from lexical statistics, metalinguistics, masked priming, and electromagnetic midsagittal articulography
   Niels O. Schiller

3. Lexical access in the production of ellipsis and pronouns
   Bernadette M. Schmitt

4. The open-/closed-class distinction in spoken-word recognition
   Alette Haveman

ISBN 90-76203-04-0