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# Formant field characteristics of low vowels in Standard British English

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Prohlašuji, že jsem diplomovou práci vypracovala samostatně s využitím uvedených pramenů a literatury.

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# 1. Introduction

Standard British English vowels have always drawn ample attention among phoneticians. It is certainly due to the fact that Standard British English served as a referential variety not only for educational purposes. However, few of the studies analysed data drawn from natural connected speech. Mostly artificial conditions created for measuring the acoustic properties of vowel formant frequencies resulted in vowels relatively neatly separated, whereas studies of connected speech usually reveal considerable overlaps between the regions of vowels in the vowel space. Earlier studies have reported on the effects of different immediate environment on vowels, yet these also derive from controlled speech recorded in laboratory conditions. Data collected in this manner are further used to describe vowel changes over certain time periods and they also serve in research of vowel perception.

In comparison to that, the aim of the present study was to analyse the formant field characteristics of Standard British English vowels in a representative sample of connected speech. The study is confined only to the low vowel region of Standard British English mainly because of the extent of analysis that would have to be conducted if all the vowels were included. Besides that, the region of the English low vowels has a special attraction to it. There have been many reports on shifts of some of the low vowels in various directions and mutual effects of the vowels in the low region of the English vowel space, some of them predicting a merger or 'death' of some of them. Nevertheless, the reports by various authors are rather inconsistent.

This study aimed to describe some acoustic characteristics of low vowels of a widely recognized English variety as it is spoken by its most genuine representatives, i.e., the BBC radio announcers. The results produced by an analysis of such sample were expected to provide objective data which could reveal the behaviour of the English vowels in the low region. The analysis focused on three main aspects: the mean values, the position and variability of the English low vowels in the low vowel space, the mean values, position and variability of the English low vowels in individual speakers and the behaviour of low vowels in different immediate contexts.

## 2. General trends in vowel system inventories

More than one third of the 317 languages of the UPSID database, namely 109 primary systems (no secondary articulation), are based on five vowel phonemes. Six-vowel and seven-vowel languages follow making up 60 and 44 primary vowel systems, respectively (Schwartz, 1997). With regard to the degree of exploitation of the possible positions in the vowel space, it has been revealed that the most favoured one on the backness scale is the front area, while on the high-low axis the preferred position is the mid range followed by high position. The low position is employed to the smallest extent (Schwartz, 1997) of all - thus the low back and high mid positions containing both rounded and unrounded sounds appear to be the least occupied.

In order to facilitate investigations of vowel systems vowels are traditionally divided into peripheral and non-peripheral (or interior) according to their position in the vowel space. The attribute peripheral in Schwartz's paper is ascribed to front unrounded /i ɪ e 'e' ɛ æ/, back rounded /u ʊ o'o'ɔ ɒ̞/ and additionally low /ɐ a̟ a ɑ ɒ/ vowels (vowel symbols enclosed in ' ' were used by Schwartz as well as Maddieson (Schwartz, 1997) in the grid of the 37 vowel symbols of UPSID as a "cover symbol" for mid vowels whose quality was only described as "mid" by the sources consulted); the term interior subsumes the remaining sounds. Schwartz (ibid.) considers two important characteristics of the peripheral structure: symmetry (equal number of front and back vowels in the peripheral structure with one low sound) and holes (a peripheral system "has a hole" if one of the extreme vowels as well as its "equivalent" is missing, e.g., if the system lacks both /i/ and /ɪ/). Schwartz's classification of the UPSID database languages proves strong tendency towards symmetry in vowel systems provided that symmetry is loosely defined in the sense that any front peripheral vowel does not necessarily have its back peripheral counterpart with exactly the same degree of height. In other words, a system is not strictly symmetrical unless all front vowels have their corresponding back counterparts, nevertheless, a given system may be considered symmetrical when one or more of the back peripheral counterparts slightly deviate in height. Apart from this fact well known from previous works (Maddieson (in Schwartz, 1997), Crothers, 1978), Schwartz's classification confirms that when there is asymmetry, it is more likely to be left (i.e., front) than right (i.e., back). Symmetrical systems may be bottom, up or unmarked. The label "bottom" is assigned to systems which have more than one low vowel; in case there is no low sound in the peripheral structure, Schwartz attributes it the mark "up". The "classic" case, i.e., unmarked, is a system with an odd number of peripheral vowels with one low sound. Out of the 317 languages only 11 are "bottom" and 1 is "up".

The high non-peripheral vowels are quite 'nicely balanced', however, probability of occurrence of front rounded and back unrounded (i.e., interior vowels) decreases from high to low, with clear exception of schwa, which is the preferred non-peripheral vowel. Hence lower-mid /œ/ and /ʌ/ are rather marginal. The number of occurrence of /ʌ/ amounts to 4 % in the Crothers' Stanford Phonology Archive (SPA) languages and only 0,01 % in the languages of the UPSID database (Henton, 1990). Schwartz (1997) reports four languages with /ʌ/ in a primary system: three together with /ɔ/ and one alone.

Although there seems to be considerable symmetry in the distribution of vowels across the vowel space, Schwartz (1997) points out that there is a strong bias towards "left" interior (i.e., front rounded) vowels - there are two times fewer back unrounded than front rounded vowels at the interior of primary systems. '*This is not a simple replication of the trend towards "left" peripheral systems, because altogether there are only 6 % more front unrounded vowels than back rounded ones in primary systems*', states Schwartz (ibid.).

## 2.1 Distribution of vowels within the vowel space

Another significant issue of the universal tendencies in world languages is the spread of vowels in the vowel space. According to the dispersion theory (DT) vowels may be sufficiently, rather than maximally dispersed through the vowel system: "the distinctive sounds of a language tend to be positioned in phonetic space so as to maximize perceptual contrast" (Fletcher and Butcher, 2003); however, articulatory economy counterbalances the perceptual demands for a contrast. For example, in Australian indigenous languages, including Arrernte, Warlpiri, and Burarra which have two, three, and five contrastive vowels, respectively, it was found that the acoustic vowel spaces of these languages tend to be "compact" compared to languages with large vowel inventories such as English or Swedish, thus illustrating the principle of sufficient dispersion, as opposed to maximum dispersion. Vowel spaces are less dispersed in non-laboratory versus laboratory speech (Fletcher and Butcher, 2003).

In some languages the distance between individual levels of openness may differ. For example, for the female speakers in Cantonese the distance between the mid vowels and the high vowels in the F1/F2 plane is larger than the distance between the mid vowels and the low vowel [a], though it is similar for the male speakers (Zee, 2003).

Recent studies of English (Henton, 1983; Henton, 1990) and Czech (Hedbávná, 2002) vowel systems showed, that their speakers frequently exercise the principle of sufficient dispersion to such degree that it can, particularly in Czech, border on comprehensibility. Some phoneticians debate the outcome of the gradual reduction of the distance between /ʌ/ and /æ/ in RP or the significant overlapping of /ə/ and /ʌ/ in the West Coast American variety of English. However, these examples are not mere isolated shifts within the systems: Henton (1983) compared formant frequencies of English vowels as measured by Wells in 1962 with values measured twenty years later to reveal a "dramatic contraction" of the whole vowel system. The direction upwards prevails, leading to reduction of the distance between the vowels along the height scale, especially in the low and central regions. The development in terms of contraction of the Czech vowel inventory appears to be very similar, the result of which are significant overlaps and flattening of the traditional triangular distribution of the Czech phonemes. The leading principle, then, seems to be neither sufficiently, nor maximally, but competitively dispersed phonemes in the vowel space.

## 2.2 Low vowels across languages

The range between the open-mid and open lines of the IPA vowel chart comprises 12 vowel sounds. As the *Handbook of IPA* (1999) notes, the symbols in the chart have status only as reference points and therefore it is often difficult to select the most appropriate symbol for a particular language. It is especially so in the case of the mid central vowels [ə ɘ ɜ ɞ]; the symbols [ə] and [ɐ] are used to illustrate vowels in the mid central and lower central regions; the symbol [ʌ] can stand for a back as well as a central low vowel; [a] often represents an open central vowel, but it is generally used to refer to low vowels ranging between the front and central region. As can be seen, the borders of the individual symbols are not clearly cut and may therefore refer to sounds from a fairly wide range.

**Table 2.2.1** The open-mid to open area of vowel space in languages listed in the *Handbook of the IPA* (1999) (unmarked type) and *University of Victoria Phonetic Database* (1994) (marked in bold face). Neither allophones nor dialect variations are included in the table. The classification into the six groups is approximate, respecting the position of the symbols in the source material. For the purposes of our work, we transformed some of the IPA symbols used by their authors into IPA-based British English notation, i.e., the vowels in the open-mid to open vowel region of the languages described by both the source databases that were qualitatively close to the four British English low vowels, namely /æ, ʌ, ɑː, ɒ/, were related to them with the respective notation. They are recorded in the four middle columns, which are of our main interest. Since the English low vowel area cannot encompass the sound variability of the world languages, the vowels different in quality from the RP English sounds had to be captured by their positioning in the table and with the aid of the IPA diacritics. The number of vowels does not include diphthongs. (Abbreviations: f=front, b=back, o=open, omid=open-mid, i=half way between open and open-mid tongue height)

| | Low vowels and their position in the vowel area | | | | | |
|---|---|---|---|---|---|---|
| **Language (No. of vowels)** | **f_omid** | **f_i** | **central** | **b_open** | **b_i** | **b_omid** |
| **Ahousaht (Nootka) (7)** | | æ̝ː | | ɑ̟ː | | |
| Amharic (6) | | | a | | | |
| **Arabic (Egyptian) (6)** | | | a̝, a̝ː | | | |
| Arabic (3) | | | a̝ | | | |
| **Armenian (6)** | | | a | | | |
| **Bulgarian (6)**<br>(Bulgarian (8)) | (ɛ̞) | | (ʌ, a) | ɑ | | (ɔ̞) |
| Catalan (10) | ɛ̞ | | a | | | ɔ̞ |
| **Chinese (Cantonese) (11)**<br>(Chinese (11)) | | | aː<br>(ʌ, a̝) | | | |
| **Chinese (Modern standard) (9)** | | | a | | | |
| Croatian (11) | | | a | | | |
| Czech (10) | | | a̝, a̝ː | | | |
| **Ditidaht** (6) | | | aː | | | |
| Dutch (13) | | | aː | ɑ̠ | | |
| English (Californian) (11) | ɛ̞ | æ | ʌ | ɑ | | |
| **English (Canadian) (11)** | ɛ̞ | æ̝̈ | ʌ̝ | | ɒ | |
| **Estonian (9)** | | æ̝ | | ɑ | | |
| **Ewe (14)** | | | a, ã | | | ɔ̞, ɔ̞̃ |
| **Finish (16)** | | æ, æː | | ɑ, ɑː | | |
| French (14) | | | a | | | ɔ̞ |
| **Gaelic (Scots) (25)** | ɛ̞, ɛ̞ˑ, ɛ̞̃ː | | a̝, a̝ˑ, ã̝ː | | | ɔ̞, ɔ̞ˑ, ɔ̞̃ː |
| Galician (7) | ɛ̞ | | a | | | ɔ̞ |
| **Garífuna (12)** | | | a, aː | | | |
| **Georgian (5)** | | | a | | | |
| German (16) | ɛ̞ː, œ | | a, aː | | | ɔ̞ |
| **Gugu Yalanji (3)** | | | a | | | |
| Hausa (10) | | | aː | | | |
| Hebrew (5) | | | a | | | |
| Hindi 11(+13nasal counterparts) | ɛ̞ | æ | | ɑ̟ | | ɔ̞ |
| **Hungarian (14)**<br>(Hungarian (14)) | (ɛ̞) | | aː<br>(aː) | ɑ̟<br>(ɑ̞) | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Igbo (8) | | æ̝ | | | | |
| **Inarisaami (Laapish) (13)** | | | a̝, a̝ː | ɑ̟, ɑ̟ː | | |
| **Inuktitut (3)** | | | a | | | |
| Irish (11) | | æ̝ | ʌ̝, a | | | ɔ̞ |
| **Japanese (5)**<br>(Japanese (5)) | | | a<br>(a̝) | | | |
| **Kaantju** (6) | | | a, aː | | | |
| **Kazakh (9)** | ɛ̞ | æ̝ | | ɑ | | |
| Kirghiz (16) | ɛ̞, ɛ̞ː | | | ɑ, ɑː | | |
| **Korean (16)**<br>(Korean (18)) | ɛ̞̈, ɛ̞̈ː<br>(ɛ̞ː) | | a, aː<br>(ʌ̝ˉ, a̝, aː) | | | |
| **Miriam (6)** | | | a | | | |
| **Nyangumarta (3)** | | | a | | | |
| Persian (6) | | æ̽ | | | ɒ̜ | |
| Portuguese (14) | ɛ̞ | | a | | | ɔ̞ |
| **Runyoro (10)** | | | a, aː | | | |
| **Russian (5)** | ɛ̞ | | a̝ | | | |
| **Rutooro (10)** | | | a, aː | | | |
| Sindhi (10) | ɛ̞ | | ə, a | | | |
| **Sinhala (14)** | | | a̝, a̝ː | ɑ̟, ɑ̟ː | | |
| **Skagit (4)** | | | a | | | |
| Slovene | | | a | | | |
| **Spokane-Kalispel-Flathead (5)** | | | a | | | |
| **Swedish (17)**<br>(Swedish (17)) | ɛ̞ː | | a | ɑː | | |
| Taba (5) | | | a̝ | | | ɔ̞ |
| **Tadjik (6)** | | | a̝ | | | |
| **Tatar (9)** | | æ̞ | | ɑ̝ | | |
| Thai (9) | | | a | | | ɔ̞ |
| **Thai (Bangkok) (18)** | ɛ̞̈, ɛ̞̈ː | | a, aː | | | |
| Tuhang Besi (5) | ɛ̞ | | a | | | |
| Turkish (12) | | | a | | | |
| **Turkish (Ankara) (16)** | | | a, aː | | | |
| **Ukrainian (6)** | ɛ̞ | | a | | | |
| **Umpila (6)** | | | a, aː | | | |
| **Uzbek (5)** | | | a̝ | | | ɔ̞ |
| **Xhosa (5)** | | | a | | | |
| **Yoruba (11)** | | | a | | | |
| *Compare:* | | | | | | |
| RP English (12) | | æ | ʌ | ɑː | ɒ | |

Because of the multifarious designation of some of the IPA symbols and in order to show efficiently the relations between the English low vowels and low vowels in other languages, we designed a chart listing low vowels (see Table 2.2.1 above) possessed by languages recorded in the *Handbook of IPA* (1999) and the *University of Victoria Phonetic Database* (1994), in which we transformed most of the IPA symbols used in the databases into IPA-based RP English notation. This means that the vowels in the open-mid to open vowel region of the languages described by both the source databases that were qualitatively close to the four British English low vowels, namely to /æ, ʌ, ɑː, ɒ/, were related to (i.e., noted by) the RP English vowels as described by Roach (2000) with their respective notation. Doing that the symbol ʌ in our chart stands for an open-mid central vowel. The low central vowel, which could be transcribed as [æ̞−] in terms of the English notation, is treated differently in our chart because of its quality as well as its high frequency among languages: it was assumed that the low central vowel will be best characterised by the symbol a.

The table is divided into six columns: front open-mid, front intermediate (half way between open and open-mid tongue height), central, back open, back intermediate and back open-mid. The four middle columns correspond to the four RP vowels in the low vowel space, i.e., /æ, ʌ, ɑː, ɒ/. The columns in the margins were designed to include the phonemes /ɛ/ and /ɔ/, which are not low vowels in RP English, but have such quality in other languages.

Since the sounds in the English low vowel area cannot encompass the sound variability, the slight differences in quality between the RP English sounds and the low vowels in other languages had to be captured with the aid of IPA diacritics. Neither allophones nor dialect variations are included in the table. The classification into the six groups is approximate, respecting the position of the symbols in the IPA-based English notation chart (Roach, 2000) and in the IPA chart (in case of /a/).

The relation between RP English notation and the IPA symbols can be expressed in the following way:

**Table 2.2.2** The approximate correspondence between RP and the IPA chart symbols

| RP | IPA |
|---|---|
| ɛ | ɛ̞ |
| æ | æ̟ |
| ʌ | ɐ |
| ɑ | ɑ̠ |
| ɒ | ɒ̝ |
| ɔ | ɔ̞ |

It should be kept in mind that the size proportions of the RP and IPA vowel charts do not agree. Hence all our classifications and transformations concerning the source databases as well as Table 2.2.1 are only simplifications.

Some of the languages are listed twice due to two different data sources and may often differ in the number of phonemes as well as location of the phonemes in the diagram of the vowel space. In order to simplify the table somewhat languages that appeared twice and were not specified as particular varieties of the language were allotted only one line (these are: Bulgarian, Hungarian, Japanese, Korean and Swedish), where the *University of Victoria Phonetic Database* (1994) was taken as the primary source (since it is more extensive), whereas languages where at least one of the varieties was specified were recorded separately (Arabic, English, Thai and Turkish). Chinese occurs three times, but only two instances, each from a different database, are treated as varieties in our table. As a result of these simplifications there are 64 different languages and their varieties.

There is a universal which states that with a few exceptions all vowel systems have the basic three sounds /i a u/ (Crothers, 1978). The relation among them could be expressed by the following formula: a>i>u. /u/ is placed last since it is most prone to some kind of anomaly; /a/ on the other hand is the most frequent and stable. Indeed, all languages in the *Handbook of IPA* (1999) as well as the *University of Victoria Phonetic Database* (1994) have at least one low *a*-sound (see Table 2.2.1 above). Our table also confirms what has been stated above, namely that the low back area comes out as the least exploited. The most numerous in this area is mid-open /ɔ̞/, which is much lower than the English /ɔ/, and closer to the cardinal vowel no. 6 [ɔ]. This sound is followed by open /ɑ/, be it long or short.

Ten of the 64 different vowel systems (e.g., Estonian, Persian, Kazakh) do not contain any sound within the central area despite the fact that this position is otherwise inhabited to the largest extent in our classification (72 sounds compared to 35 for the front and 34 for the back space). This might also be the result of our classification of the front-back region into only three categories: sounds situated half way between the front and central division lines had to be allocated to one class only.

The symbol ʌ appears only once to denote what should be a mid-open back vowel in Korean (although in our chart it is grouped among the central vowels mainly with respect to the designation of the symbol in RP English); in comparison to RP English the Korean /ʌ/ is raised and retracted: [ʌ̝−]. Five times the symbol ʌ is used to represent an open-mid central vowel out of which two instances pertain to variants of English (the only English variants recorded here: Canadian /ʌ/, which is noted as slightly higher than RP /ʌ/, and Californian AmE /ʌ/). The remaining three belong to Chinese, Bulgarian and Irish (this one again having a slightly raised quality). This number would reduce to only three instances of /ʌ/ if we disregarded the variants of Bulgarian, Chinese and Korean (marked by the brackets) - languages which appear in each of the databases.

The open-mid back vowel /ɒ/ groups among the rarest low-vowel-area sounds in the languages listed by the *Handbook of IPA* and the *University of Victoria Phonetic Database*, occurring only in Canadian English and Persian (where it is unrounded).

So far we have been concerned with the rare vowel sounds in languages. However, our table contains 68 instances of the central vowel /a/ and its 'varieties' (if we do not count the six bracketed /a/s which belong to the "double" languages), which makes it the most favoured vowel in languages in the low vowel space. On the other hand, the symbol ɑ occurs only 17 times (both long and short) if we disregard one of the sources for Hungarian. Looking at the front area, the preference for mid-open (i.e., raised) vowels in the front area is evident. ɛ-sounds in our chart, which are lower compared to RP English /ɛ/, by far outnumber the front æ-sound (labelled æ), which occupies a range of positions in the front area. The quality of the front æ-sound is usually more raised than the RP English /æ/. As has been stated, the back open /ɑ/ belongs among much rarer vowels than the central /a/ or the front /æ/ in languages. Relative to the RP English /ɑː/ it is characterised by advanced position in exactly seven instances (one of them bracketed, i.e., belonging to the secondary source of Hungarian), in the remaining cases it is fairly comparable to the RP /ɑː/ - only twice it has a retracted quality.

To summarize, in terms of RP English, the low vowel space of the 64 languages and their varieties can be divided into six categories out of which the open-mid front and open-mid back regions occupied by ɛ- and ɔ-sounds respectively are not directly the subject of our study since they fall qualitatively within the higher region of the vowel space in RP English. In the region occupied by the four qualitatively distinct low vowels in RP English, an overwhelming majority of the languages recorded by the *Handbook of IPA* (1999) and the *University of Victoria Phonetic Database* (1994) contain an open central vowel /a/. In contrast to that, less than a fifth of the languages employ the front vowel /æ/ and only a slightly higher number of the languages have the open back /ɑː/. The back open-mid /ɒ/ occurs in just about 1.2 % of the languages in Table 2.2.1. There is no language in Table 2.2.1 which would have four vowels distinguished by quality from each other in the region delimited by the four RP English vowels. Only the two varieties of English, Irish and the secondary (bracketed) variety of Korean approach this number with three vowels each. Finnish, Inarisaami and Sinhala have each two pairs of low vowels that differ in length; nine is the number of languages that work with two low vowels of different qualities (the total taken from both sources is twelve languages); the rest have either one low sound or two which differ merely in duration.

### 2.3 RP low vowels in the mirror of universals

On the scale showing the text frequency of occurrence of colloquial RP vowels, as presented by Gimson (1991, adopted from D. B. Fry, The Frequency of Occurrence of Speech Sounds in Southern English, *Archives Néerlandaises de Phonétique Experimentale*, XX (1947), pp. 103-6), /ʌ/ occupies the fifth position with 1.75 % (total all vowels: 39.21 %). It is followed by /æ/ with 1.45 % and /ɒ/ making up 1.37 % of all English sounds. /ɑː/ is the rarest of the low vowels occurring in less than one per cent - precisely 0.79 %. The only monophthong that is less exploited in English than the open back vowel is /ɜː/. From the frequency rates of the English low vowels we can see that they are not the 'mainstream' sounds of English, being nearly ten times less frequent than the most common /ə/. However, Cruttenden (1994) claims that "whatever the relative frequency of actual occurrences of the items contained in the phoneme inventory, the full system (20 vocal sounds) must be regarded as complex compared with the systems of many other languages". English with its 12 monophthongs belongs among approximately 6 per cent of the UPSID languages whose systems comprise this particular number of vocalic sounds.

If we were to apply Schwartz's (1997) terminology, we could say that RP English (as described in Roach, 1991) has no "large" holes. It can be classified as a symmetrical "bottom" language containing two low peripheral vowels /æ/ and /ɑ/ which is a rare phenomenon among languages (see above). Moreover, it is rather exceptional in the high concentration of vowels in the low (open-mid to open) position since it equals in number the more close areas, which all comprise four sounds, despite the fact that the low position is the most disfavoured one. Another important feature of RP English as well as several other varieties of English is the presence of the non-peripheral vowel /ʌ/ which is considered to be one of the rarest sounds in language vowel systems. In the previous section we saw that besides /ʌ/ it is also the back open /ɒ/ that is sparsely distributed among languages in favour of mid-open /ɔ/ or unrounded /ɑ/ in the back position.

To summarize, RP English seems to embody 'the exception that proves the rule' in that it in many respects behaves in contradiction to the universal tendencies in vowel systems. This leads us to an observation that English as a global language from the sociolinguistic point of view is a marginal type from the point of view of a linguist-typologist.

## 3. Description of RP English low vowels

The four monophthongal sounds /æ, ʌ, ɑː, ɒ/ are the four lowest (open-mid to open) sounds in the RP English vowel inventory, which is traditionally claimed to comprise six short /ɪ, e, æ, ʌ, ɒ, ʊ/ and five long vowels /iː, ɜː, ɑː, ɔː, uː/. Despite its importance in the English vowel system, /ə/ or schwa is often treated separately because it differs from the rest of the vowels in many respects. Its formant value is comparable to that of /ɜː/, which in comparison to /ə/ is much more stable in different phonological environments. Therefore many authors, when describing the relations between the two vowels, prefer /ɜː/ as the referential sound (see further Henton, 1990).

## /æ/

In the vowel chart of IPA the symbol æ stands for an unrounded front vowel half way between the open-mid and open limit lines. Volín (2002) acknowledges the appropriateness of the design of this symbol which is an obvious merger of 'a' and 'e', since it indicates the quality of the represented vowel, namely the intermediate position in the low vowel region as well as its length in comparison to the rest of English short vowels. In terms of cardinal values, the quality of /æ/ is nearer to *C* [ɛ] than to *C* [a]. The formant frequencies of /æ/ are as follows:

| | F1 | F2 | F3 |
|---|---|---|---|
| /æ/ | 800 | 1760 | 2500 |

(Gimson, 1991)

According to *Gimson's Pronunciation of English* (Cruttenden, 1994) /æ/ is pronounced with

> the mouth slightly more open than for /e/; the front of the tongue is raised to a position midway between open and open-mid, with the side rims making a very slight contact with the back upper molars; the lips are neutrally open. In the south of England /æ/ is often produced with considerable constriction in the pharynx, the tongue itself having rather more tension than is the case for /e/.

Earlier literature, such as Vachek and Firbas (1959), describe /æ/ as a low front vowel a little raised. Jones (1955) allows much greater variability to this vowel when he identifies /æ/ as intermediate between half-open and open front; for some speakers it may be "between ɛ and æ, for some between æ and cardinal a". Bauer (1985) took up the venture to track the changes /æ/ underwent in the 20th century and we may conclude from her paper that /æ/ at the time between 1949 and 1966 was being realized as a closer vowel in comparison to earlier times; Bauer's measurements provided F1 values of /æ/ (F1=651.9 Hz) produced by men that were in fact the lowest of all the compared literature in her paper, most of which was of later date than Bauer's recordings. Gimson's formant values (above) dating back to 1980, which are also provided by Bauer (1985), classify /æ/ as much lower, although undoubtedly due to the female contribution to the average values. Despite the discussion on the lowering of /æ/ Bauer encountered with in literature at that time available, she (Bauer, 1985) points out the retraction of /æ/ as a more significant change. This change is in compliance with Henton's (1983) observation of /æ/'s movement backwards and only slightly up towards the centre of the vowel space in comparison to Wells's values (in Henton, 1983). In contrast to these observations, Hawkins (2005) confirmed the increase in the frequency of F1, i.e., a lowering tendency pointed out earlier by Gimson.

Cruttenden (1994) seems to solve the discrepancy between the data by distinguishing two other varieties of /æ/ in addition to the RP form, which may point to further development in the quality of /æ/. Refined RP, also referred to as 'conservative', has a closer variety of /æ/ almost at the level of *C*[ɛ] which may also be diphthongized to [ɛᵊ]. On the other hand, many younger speakers (term which is not closely specified by Cruttenden) of RP use a more open realization of this vowel around *C*[a].

Although it was difficult for Gimson (1991) to believe that two vowels of relatively high frequency of occurrence (/æ/ - 1.45 %; /ʌ/ - 1.75 %) should merge, he admitted the possible confusion of /æ/ and /ʌ/ in the low region. However, recent development seems to be that the lowering of /æ/ in some speakers results in a retreat of /ʌ/ towards the central region to avoid such merger (Cruttenden, 1994).

As has been stated above, the vowel /æ/, traditionally considered as a short vowel, is now generally longer in RP than the other short vowels. Such lengthening is particularly apparent before voiced consonants, e.g., in *cab, bag, badge*. Moreover, Cruttenden (1994) notes that some RP speakers in the south of England seem to have a contrast between /æ/ and /æː/ as in words *jam* (to eat) /dʒæm/ and *jam* (of traffic) /dʒæːm /.

/ʌ/

In the IPA vowel chart the sound /ʌ/ occupies an open-mid back position and stands as the unrounded counterpart to /ɔ/. However, the RP English /ʌ/ has a slightly different quality: in terms of the Cardinal values it can be characterised as a centralised, raised [a], with formant frequencies:

| | ***F1*** | ***F2*** | ***F3*** |
|---|---|---|---|
| /ʌ/ | 760 | 1320 | 2500 |

(Gimson, 1991)

*Gimson's Pronunciation of English* (Cruttenden, 1994) describes the short RP /ʌ/ as:

> articulated with a considerable separation of the jaws and with the lips neutrally open; the centre of the tongue (or part slightly in advance of centre) is raised just above the fully open position, no contact being made between the tongue and the upper molars. The quality is that of a centralized and slightly raised *C*[a] = [ä].

It seems then that for a vowel of such timbre the IPA symbol ɐ would be more appropriate (and some dialectologists use it, e.g., Trudgill, 1984). Further support for this can be found also in Roach's practical course (2000) according to which /ʌ/ is 'a central vowel, and [the diagram shows that] it is more open than the open-mid tongue height'. Also Ladefoged (1982), who describes [ʌ] as one of the secondary cardinal vowels, reports that the RP vowel used in words "cut" or "bud" is 'usually more open than [ʌ], perhaps about half-way between open and half-open, and very much further forward', which would reflect in higher values of both F1 and F2. If we compare his 'reasonable average' frequencies of [ʌ] for a male voice, F1 = 600 Hz and F2 = 1170, with the values given by Gimson (1991), the female part in the latter's values becomes apparent, having formant frequencies markedly higher. Unfortunately, Ladefoged does not give further references concerning the origin of his data, so that it cannot serve as another link in the overview of the development of this vowel's quality.

Refined RP has a variety of /ʌ/ which is more of a back vowel, marginally raised. Cockney has a vowel further forward and more open, approaching *C*[a].

A significant contribution to the mapping of the changes in /ʌ/ is quite a recent analysis carried out by Henton (1990). One of her main aims was to investigate the forms of the present day /ʌ/ according to speaker sex and regional differences. The study reports the quality of /ʌ/ as it appears in three varieties of English: RP, Northern Modified English and West Coast American English (for the latter two see section 9 on English varieties below).

The study provides two-dimensional F1-F2 diagrams showing the distribution of eleven English vowels for male and female speakers separately. From the diagram reflecting twenty male RP speakers it can be seen that the 2-SD ellipse of /ʌ/ overlaps to the largest extent with that of /ɑː/ and to a lesser extent with that of /ɜː/. There is only a small space common to /ʌ/ and /æ/. In comparison to the /ʌ/ as produced by women the male /ʌ/ occupies a considerably smaller area in the vowel space. For the female speakers the ellipse of /ʌ/ overlaps much more with all the three neighbouring vowels, of which /ɜ/ is in the first place, sharing more than half of its space with /ʌ/. Generally, it can be said that /ʌ/ is most similar to /ɑː/ for male speakers, but much more similar to /ɜː/ for female speakers. It is particularly in F1 that /ʌ/ resembles the other vowels. The small differentiation in the F1 mean values of /ʌ/ (658 and 757 Hz for male and female speakers respectively) and /ɑː/ (648 and 774 Hz) points at a very similar degree of openness. (Henton gives all formant values in Bark. The values were converted into Hz using the equation $f = 1960 /[26.81 / (z+0.53)-1]$). This information agrees with Gimson's account of the two vowels, according to which they are produced with 'the centre of the tongue (or part slightly in advance of centre) raised just above the fully open position' and 'part of the tongue between the centre and back in the fully open position', respectively. But as Henton says 'more interesting is the degree of similarity in the mean F1 and F2 values for the females /ʌ/ and /ɜ/ vowels: 0.76 Bark (= 99 Hz) and 0.61 (= 87 Hz) difference respectively'. These figures show a radical approximation of /ʌ/ to the other vowels, while the vowel space between those vowels is shrinking. The similarity between the figures for /ʌ/ and /ɑ/ is not surprising if we consider the historical development of /ʌ/ (see section 8 below). It has been pointed out earlier that literature ascribes fronting and raising tendencies to /ʌ/. Henton's values for the vowel, in context with /ɜ/, of the female speakers indicate the movement towards a higher position. Henton summarizes these observations by the following words: 'for these speakers of RP, the vowel /ʌ/ is no longer a half-open back vowel, ... It has become raised and centralized'. Further she points at the differences stemming from speaker sex; it was found that female speakers produced more variable and even more centralised tokens of /ʌ/.

According to Henton (1990) the vowel /ʌ/ appears to be the fastest changing vowel in the whole English vowel system. Some authors (Gimson, 1989 and Bauer, 1979, both in Henton, 1990) admit that /ʌ/ is a vowel that has seen most changes in the twentieth century. Both Jones (1909, in Henton, 1990) and Ward (in Henton, 1990) described /ʌ/ as a back vowel in British English, although, as Henton (1990) says, listeners familiar with Jones' original recordings of the vowel would mark it as closer to ə or ɛ. Also the acoustic analysis of Jones'data carried out in 1989 revealed a noticeably fronter character of /ʌ/ with the approximate values of F1= 540 Hz and F2= 1210 Hz. The trend towards centralisation became even more obvious, as more than forty years after the 1909 research even Jones' /ʌ/ appeared to have moved towards the centre of the vowel space somewhat (Henton, 1990). In his Pronunciation of English (1966) /ʌ/ gained the status of a half-open, central, unrounded vowel. He recorded the variation of /ʌ/ within the speakers of Southern English, who 'may use a more advanced and less ə-like vowel than mine' (1964). With respect to this Bauer (1985) admits that it is

> likely that the change taking place with /ʌ/, described in the handbooks as change taking place in the middle of this century, was actually well established, perhaps even virtually complete, by the time it was noted in print, in 1956, by Jones.

Bauer goes even further in her paper stating that her data show little or no evidence of the change from centralized back vowel to central-to-front vowel and little evidence of /ʌ/ having been, during the 20$^{th}$ century, a half-open back vowel. Regardless of these findings and earlier observations Vachek and Firbas (1959) depended fully on Jones' earlier description of /ʌ/ and took backness as its primary feature. It becomes apparent from their instructions that should help students to reach an 'accurate or almost accurate pronunciation': one can reach /ʌ/ from open [ɔ] through delabialization.

Acoustic studies of later date have brought yet further evidence for constant change in the vowel /ʌ/. Henton (1982) compared the monophthongal sounds spoken by eleven male speakers as measured by Wells (1962) and she found out that /ʌ/ underwent considerable changes. The differences amounted to -77 Hz for F1 and -36 Hz for F2, where the change in F1 should be considered as sufficient to effect a perceptible change in the vowel quality. Wells (1982) remarked on the fronting of /ʌ/ in RP, but Henton (1990), as has already been stated, did not confirm this tendency and ascribed the decreasing distance between /ʌ/ and /æ/ to the backing of the fronter more open vowel, a movement observed already in Henton (1982). Gimson (1991) also mentions further progress into the front region. At the same time he points at the presence of /æ/ and remarks that if the lengthening of the front open vowel becomes general, /ʌ/ may fulfil the function of front open short vowel in opposition to both /æ/ and /ɑː/. There have appeared some analyses attempting to prove and explain the forward movement of /ʌ/ (Bauer, 1985 and Martinet, 1990, both in Henton), but they did not reach any satisfactory conclusion. In fact, Bauer (1985) concluded that no change is currently taking place within RP to /ʌ/, although there is considerable variation in the realization of this phoneme. Henton (1990) evaluated one of Martinet's reasons for the change as more acceptable. According to Martinet (in Henton, 1990) the changes are caused by the 'isolation of /ʌ/ in phonological space and its consequent aptness to engage in erratic movements'.

### /ɑː/

The symbol ɑː denotes the sound that is open back as opposed to /a/ and unrounded as opposed to /ɒ/. Cruttenden describes /ɑː/ as a normally long vowel

> articulated with a considerable separation of the jaws and the lips neutrally open; a part of the tongue between the centre and back is in the fully open position, no contact being made between the rims of the tongue and the upper molars. The quality is somewhat nearer to *C* [ɑ] than to *C* [a].

The respective formant frequencies taken from Gimson (1991) are

| | ***F1*** | ***F2*** | ***F3*** |
|---|---|---|---|
| /ɑː/ | 740 | 1180 | 2640 |

In 1945 Gimson (Bauer, 1985) commented that /ʌ/ and /ɑː/ are 'very close to each other qualitatively, and might be seen as a long and a short version of the same phonematic unit'. If we compare the position of the two vowels (taken average values, not depicting areas of dispersion) in the vowel space as it is devised by Wells (1962), these two vowels are indeed qualitatively the most similar sounds in the low region, /ʌ/ being slightly lower. Twenty years later in Henton (1983) both /ʌ/ and /ɑː/ were raised to approximately the same height, the distance between them reduced even more. Nevertheless, the mean formant values of /ɑː/ show that it saw the smallest changes of all the low vowels between 1962 and 1982. Also Bauer (1985) did not observe any changes for /ɑː/ currently under way, although there was considerable variation in the realization of /ɑː/. Similarly, Hawkins (2005) observed large individual differences, mainly due to F1. The development of this sound did not seem to take any diverse direction during the following decade, either. Henton's experiment (1990) more or less confirms that the ellipses depicting the distribution of /ʌ/ and /ɑː/ for male speakers have the largest overlap in comparison with the other adjacent vowels, the distinction being reached only by different second formant values. For female speakers the overlaps of /ɑː/ with /ʌ/ and /ɒ/ are comparable in size, although /ɒ/ differs from the rest by lower F1 values, i.e., it is higher.

A variety of /ɑː/ retracted near to the quality of *C*[ɑ] is typical of Refined RP. In some words a pronunciation with /ɑː/ rather than /æ/ is typical of this variety of RP, e.g., in *gymnastics* and *Atlantic* (Cruttenden, 1994).

### /ɒ/

The English /ɒ/ differs from short back open vowels occurring in other languages. Usually, it is more open and backer than in other vowel systems. The vowel's symbol ɒ rightly evokes its quality being somewhere between [o] and [ɑ]. In terms of cardinal vowels the quality of /ɒ/ corresponds to that of an open lip-rounded *C*[ɑ], i.e., secondary *C*[ɒ]. Cruttenden's (1994) account of the vowel's articulation is as follows:

> This short vowel is articulated with wide open jaws and slight, open lip-rounding; the back of the tongue is in the fully open position, no contact being made between the tongue and the upper molars.

Such articulatory setting is liable to produce a sound with formant values:

| | ***F1*** | ***F2*** | ***F3*** |
|---|---|---|---|
| /ɒ/ | 560 | 920 | 2560 |

More than half a century ago /ɒ/ was described by Jones as a fully low back vowel rounded (Vachek and Firbas, 1959), although the diagram depicts /ɒ/ half way between *C*[ɒ] and *C*[ɑ]. In his *Pronunciation of English* (1955) Jones reported a more raised position than fully low of the vowel. As one of the participants of the "dramatic contraction" (reported on by Henton (1983)), /ɒ/ shifted upwards and slightly back acquiring the position once occupied by /ɔː/. Hawkins (2005) reported no changes in the quality of /ɒ/. We can hardly elicit any facts from comparison of the results Henton arrived at in her 1983 and 1990 papers, since the latter does not give formant values for all the vowels we are interested in in the present paper. We can only learn from the diagrams that /ɒ/ as produced by female speakers is characterised by greater variation as well as a more centralised position than /ɒ/ pronounced by male speakers.

Generally, within RP the realizations of /ɒ/ vary the least of all the low vowels. In Cockney and Refined RP /ɔː/ is sometimes preferred to /ɒ/ in words such as *off, cloth*. (For more on variation of low vowels see section 9).

### 3.1 Terminology

For the purposes of this paper I adopted the following terminology:

| | full | short |
|---|---|---|
| /æ/ | front, not quite as open as cardinal vowel no. 4, short, lips neutrally open | front open-mid |
| /ʌ/ | central, more open than the open-mid tongue height short, lips neutrally open | central open-mid |
| /ɑː/ | not fully back, open, long, lips neutrally open | back open |
| /ɒ/ | not fully back, between open-mid and open tongue height short, open lip-rounding | back open-mid |

## 4. Formant values of the English low vowels as presented in previous studies

In Table 4.1 we assembled a number of the formant measurements of the low vowels by various phoneticians, giving evidence from periods throughout the 20th century.

The oldest source in our table comes from Peterson & Barney (1952) and has been quoted several times later (e.g., in Kent & Read 1992). It gives average formant values for vowels of male speakers of American English (note that American English does not contain the phoneme /ɒ/ and therefore this column remains blank).

The second oldest data set presented in our table was measured by Bauer. She chose 37 recordings of students and staff members who came to the Department of Phonetics, University of Edinburgh, between the years 1949 and 1966 (Bauer, 1985). Each speaker made a recording of 'The Story of Arthur the Rat'. Only recordings of the participants who were auditorily evaluated as RP speakers were analysed. Bauer did not analyse the open-mid back vowel.

Wells' sample from 1962 derives from 25 male speakers who were judged at the time to be a fairly homogeneous group of RP speakers, with one exception whom Wells remarks upon. The participants of the experiment read a list of sentences in the form "The word is ___", where the variable contained a hVd sequence.

Approximately twenty years later, Henton (1983) followed the same procedure to obtain data that would be maximally comparable with Wells' from 1962. The comparison based on these two samples reveals that the formant values obtained by Henton are all notably lower, i.e., in her experiment the vowels were realised as retracted and higher than those measured by Wells.

Four years before Henton's paper (1983) was issued, Fry (1979, adopted from Henton (1983)) presented the average formant values without sex distinction. Together with Gimson's data (1980), who also calculated the average values from both male and female speakers' realizations, his values belong to the highest. Unfortunately, at the time of writing this paper, we had no more details concerning the collection of either Fry's or Gimson's data.

In her 1990 study, Henton assembled a spoken corpus including instances of monophthong vowels in word-list hVd contexts as she did in 1983 after Wells (1962), however, she does not present the average values of the front open-mid and back open-mid vowels.

Another more recent study in our table, the one carried out by Deterding (1997), is of particularl interest to our study because it analysed monologues of five BBC presenters broadcast during the 1980s. The data came from the same source as ours, the manner of presentation (connected speech) corresponds with that used in our study and all speakers are said to have Standard Southern British accent. The conclusions drawn from the comparison of our and Deterding's results should therefore be unaffected by the method of data collection and any discrepancies found between the two sets should be attributable to the time lapse between the two studies or the method of analysis. Deterding noted the difficulty with measuring the first formant of /æ/ and /ʌ/, also tokens that occurred after the approximants /j , w, r/ or before /l/ were avoided in his analysis, 'as they would have severe coarticulatory effects on the locations of the first three formants'. In the same study Deterding demonstrates how manner of presentation can affect vowel quality by providing us with values of the vowel formants measured in citation forms in his 1990 study. The comparison of the two studies of Deterding's showed that the male vowels were significantly less peripheral in the measurements of the tokens extracted from connected speech than in measurements of the vowels in citation words.

**Table 4.1** The results of previous acoustic studies of English vowels. Each data set was collected under different criteria, which should be kept in mind when drawing conclusions from their comparisons. The table presents the studies in order of the approximate date of origin of the analysed material. The information on the speaker sex, English variety and naturalness of presentation of the source data is given where it was available. All measurements are given in Hertz.

| Studies | Formant number | /æ/ | /ʌ/ | /ɑ:/ | /ɒ/ |
|---|---|---|---|---|---|
| Peterson & Barney (1952, in Kent & Read 1992 ) (Hz), male speakers of American English | 1 | 660 | 640 | 730 | |
| | 2 | 1700 | 1200 | 1100 | |
| | 3 | 2400 | 2400 | 2450 | -- |
| Bauer (1985, data from between 1949 and 1966) (Hz), male RP speakers | 1 | 652 | 658 | 669 | |
| | 2 | 1647 | 1365 | 1070 | |
| | 3 | -- | -- | -- | -- |
| **Wells** (1962, in Henton 1983) (Hz), male RP speakers | 1 | 748 | 722 | 677 | 599 |
| | 2 | 1746 | 1236 | 1083 | 891 |
| | 3 | 2460 | 2537 | 2540 | 2605 |
| Fry (1979, in Henton 1983) (Hz), male and female speakers | 1 | 750 | 720 | 680 | 600 |
| | 2 | 1750 | 1240 | 1100 | 900 |
| | 3 | -- | -- | -- | -- |
| Gimson (1980, 1991) (Hz), male and female RP speakers | 1 | 800 | 760 | 740 | 560 |
| | 2 | 1760 | 1320 | 1180 | 920 |
| | 3 | 2500 | 2500 | 2640 | 2560 |
| **Deterding** (1997) (Hz), BBC male speakers, connected speech from 1980s | 1 | 690 | 644 | 646 | 558 |
| | 2 | 1550 | 1259 | 1155 | 1047 |
| | 3 | 2463 | 2551 | 2499 | 2487 |
| Deterding (1997) (Hz) citation forms from his 1990 study | 1 | 732 | 695 | 687 | 593 |
| | 2 | 1527 | 1224 | 1077 | 866 |
| | 3 | -- | -- | -- | -- |
| **Henton** (1983) (Hz), male RP speakers | 1 | 713 | 645 | 636 | 551 |
| | 2 | 1615 | 1200 | 1050 | 860 |
| | 3 | 2491 | 2519 | 2540 | 2530 |
| Henton (1990) (Hz), male RP speakers | 1 | | 658 | 648 | |
| | 2 | | 1194 | 1037 | |
| | 3 | -- | -- | -- | -- |
| **Hawkins** (2005) (Hz), male speakers of RP, citation forms, measured in 2001 | 1 | 737 | 640 | 629 | 505 |
| | 2 | 1576 | 1199 | 1057 | 860 |
| | 3 | -- | -- | -- | -- |

The latest data were adopted from Hawkins (2005). In 2001 Hawkins carried out an analysis of RP vowel sounds produced by male speakers of four different age groups: 65+, 50-55, 35-40 and 20-25. As many of the authors quoted above Hawkins followed the analysed citation forms of words with hVd context. Unlike Wells (1962), she tried to avoid hypercorrection or unnaturalness in the subjects' presentation of the citation forms by inserting filler words into the list of experimental words. For each category there were five speakers, for each vowel Hawkins obtained eighty items. The values presented in Table 4.1 are only approximate, i.e., they were calculated from the means of the first two formant frequencies for each age group. It is worth noticing the close similarity between Henton's (1983) and Hawkins' (2005) data, which were obtained applying the same method of analysis, i.e., citation forms were read with vowels in hVd context. It seems that in the course of the twenty years that passed between the two studies, the front open-mid vowel became slightly lower and backer, the back open-mid vowel moved higher in the vowel space, however, /ʌ/ and /ɑː/ did not undergo any changes at all.

To summarize, the referential data presented in Table 4.1 include, on the one hand, measurements that are mutually comparable, such as Wells' (1962), Henton's (1983) and Hawkins' (2005), but often data for which we lack important information concerning method of analysis and therefore drawing any conclusions from their comparison with other results should be done with caution. The measurements that fuse both male and female values have been added primarily to make the picture complete. With regard to the data source and the method of analysis the most relevant results for our study are presented by Deterding (1997).

## 5. Major trends in the English low vowel space

Despite the high susceptibility of vowels to phonetic changes in comparison with consonantal sounds, Trudgill (1984) claims that no phonetic changes on the way towards phonemic merger observed already by Daniel Jones have actually materialized. The levelling of /aiə, auə/ to either [aːə] or /aː/ (=/ɑː/) (a development attested in RP for well over a century) appears to be related to idiosyncratic variations of style (ibid.). Apart from the wider lexical distribution of /ɑː/ no other changes were registered.

In the meantime, the lengthening of /æ/ before /b, d, g, dʒ, m, n/, regarded by Jones and by Ward (1945, in Trudgill 1984) as a recent development, has become established. Cruttenden (1994) as well as Gimson (in editions that preceded the version revised by Cruttenden) take the lowering movement of /æ/ for granted.

The lowering of the front open-mid vowel seems obviously more common amongst young speakers, 'possibly to avoid the comic effect made by the older RP from nearer to front half-open often with strong pharyngealization' (Trudgill, 1984). Hawkins (2005) confirms that, not only impressionistically, the trends observed by Gimson and Wells appear to be continuing still, especially younger speakers' RP has a more open /æ/. The changes Hawkins (ibid.) observed affect the relationship between /æ/ and /ɑː/, with F1 higher for the former than the latter in all but the oldest speakers (65+). The shift of /æ/ is considered to have an effect on /ʌ/, which, Cruttenden (1994) believes, is 'pushed' to the central region to avoid a merger with /æ/. However, already in the 1980s two studies (Henton, 1983, and Bauer, 1985) pointed at a noticeable retraction of /æ/ rather than lowering tendencies in the front open-mid vowel, which Bauer did not see discussed in the literature of that time:

> With respect to /æ/, there is now some recognition in the recent literature that it is more open than the standard descriptions would lead one to believe. In this study it appeared that the opening was of relatively minor importance, but that there is significant retraction of /æ/.
>
> (Bauer, 1985)

In her discussion, Bauer (1985) recalls Henton suggesting that the retraction (and according to her also raising) of /æ/ is part of a general pattern of F2 and F1 lowering, which leads to the raising of /ʌ/ and (to a lesser extent) /ɑː/. If we compare this with what has been stated above, it seems that two different authors revealed two different developments of the front open-mid vowel and ascribed the same effect to it on /ʌ/. Nevertheless, these observations are impeached by Bauer (1985) who found no evidence of the shifts of /ʌ/ and /ɑː/ in her data, thus not confirming any influence of /æ/ on the two backer vowels.

The concerns associated with the possible merger of /ʌ/ and /æ/ might have had serious justification in the observed fronting movement of /ʌ/ towards the front open-mid vowel. Both Gimson (1991) and Wells (1982) reported on this tendency. However, Henton (1983) did not confirm this; instead, she believes that it is /æ/ that is moving backwards, closer to the central open-mid vowel. All in all, in both 1983 and 1990's papers Henton showed the raising of /ʌ/ heading for the central area, *pace* to Bauer (1985), who denied any change currently taking place within RP to this vowel. Taking into consideration the findings by Henton (1990) in contemporary British English, namely /ʌ/ showing the shift towards the mid central vowel, it seems that the development of this sound is much in direction of /ə/.

The debate on the possible confusion of /æ/ and /ʌ/ has not been the only 'big issue' in the low vowel space. Also the qualitative distance between /ʌ/ and /ɑː/ has led to conclusions that these two phonemes might one day be differentiated only by their length (Gimson, 1945, in Bauer, 1985). Although such development has not been observed, for male speakers the two vowels do share larger proportion of space than any other two low vowels (see Henton, 1990).

Since /ɔː/ is becoming firmly established with a higher tongue position and closer lip-rounding than was usual fifty years ago, /ɒ/ has become a regular vowel in words where orthographic *o* occurs before the voiceless fricatives e.g., *off, cloth, loss* where /ɔː/ had been an admissible variant. Also words such as *salt* or *fault* pronounced with /ɔː/ are often realized with /ɒ/ by younger speakers (Trudgill & Hannah, 1982). Apart from the changes in the lexical distribution of /ɒ/, this vowel does not seem to cause much excitement among phoneticians. In her study, Hawkins (2005) found no changes for /ɒ/. It is undisputedly due to its isolated position in the back region, largely dispreferred by languages and therefore not likely to compete with other vowels for space.

According to Hawkins (2005), current developments in RP appear to include a tendency for peripheral monophthongs to shift in an anticlockwise direction around the vowel quadrilateral, although not all monophthongs are shifting (e.g., /ɑː/). On the other hand, Henton's papers suggest that the system of English low vowels has taken direction towards centralisation resulting in a smaller dispersion across the vowel space.

Compared to female speakers, who realize the low vowels as considerably fronter, with greater variation and overlaps, the male speakers' low vowels appear to be much more distinct.

### 6. Phonotactic possibilities of English low vowels

Nearly all English vocalic sounds, including the low vowels, occur initially; /æ, ʌ, ɒ/ do not occur finally. In unaccented syllables /ʌ/ is often replaced by /ə/, primarily in function words (i.e., conjunctions, prepositions, etc.), where the weak form counts as one of standard realizations and is listed in the lexicon. /ɑː/ constitutes a monosyllabic word *are*; as a long vowel it does not precede final /ŋ/.

In a word initial CV- cluster /æ/ can be preceded by any English consonant that appears initially. The other three low vowels are slightly restricted in their distribution.

Like /ʌ/, /ɒ/ does not occur after /z/ and /ʒ/. In addition to that, there is no English word beginning in a */ðɒ-/ sequence. The open back vowel does not occur after /ð/, /z/ and /w/.

Out of the 41 CCV- initial cluster combinations (Gimson, 1991), /æ/ does not follow /dw-/ or any of the 14 /Cj-/ clusters (the latter combination is only followed by /uː/ and /ʊə/ or occasionally /ʊ/). /ʌ/ is even more restricted in its phonotactics: it does not combine with /sf-/ or any /Cw-/ clusters apart from /sw-/. /ɒ/ has an almost identical distribution to /æ/ except that it does not further combine with /θw-/ and /sf-/. With regard to CCV- combinations, the vowel /ɑː/ approaches /ʌ/ in the high number of the clusters with which it does not combine (the number being 21). Out of the six /Cw-/ clusters, /ɑː/ occurs after /sw-/ and /kw-/. As opposed to /æ, ʌ, ɒ/ it is never preceded by /ʃr-/ and /θr-/. Like /ʌ, ɒ/ it does not occur after /sf-/.

/æ/ and /ʌ/ have identical distribution after CCC clusters: they both occur after /spl-, spr-, str-, skr-/. These four clusters together with /skw-/ combine with /ɒ/. In contrast to that, /ɑː/ only occurs with /str-/ (Gimson, 1991).

In the word final –VC cluster the low vowels do not occur before 2 to 3 consonants; none of them appears before /ð/.

The low vowels belong to vowels which combine with more than half of the 59 –CC clusters. Furthermore, /ʌ/ groups among the vowels that show the highest rate of combination with –CC.

CCC clusters follow predominantly short vowels, among them /æ, ʌ, ɒ/. /ʌ/ is one of the five vowels which combine with a cluster that no other vowel does, for /ʌ/ it is /-ldʒd/.

## 7. The written form of English low vowels

In contrast to the constant development of vowel quality, the English spelling stabilised during the eighteenth century. The written form of words does not reflect their pronunciation and the vowels have more possible spellings varying considerably in frequencies.

The open-mid front vowel appears in two written forms: the lexical frequency of spellings of /æ/ with <a> is 99 % (*hand, lamp, macho, marry*), the remaining 1 % are accounted for by <ai> (*plaid, plait*) and isolated spellings such as in words *timbre* [tæmbə], *reveille* [rɪˈvæli].

For the open-mid central vowel spellings in <u> (*cut, drug, dull, sun*) have a lexical frequency of 91 %, those in <o> (*son, come, among, one, done, month*) follow with 7 % and those in <ou> (*country, southern, couple, enough*) represent /ʌ/ at 2 %. (The text frequencies, because of the high frequency of some words in <o> are somewhat different at 63 %, 27 % and 8 %, respectively). The frequencies of spellings in <oo> (*blood, flood*) and <oe> (*does*) are so negligible that they need not be expressed in percentages (Cruttenden, 1994). Nosek (1979) presents the words *blood* and *flood* as the only representatives of <oo> spellings. Many earlier *u* spellings changed to *o* after 1250, if <m, n, u, v, w> were contiguous, e.g., *son* (OE sunne, sunu), *come* (cuman), *wonder* (wundor), *monk* (munuc), *honey* (hunig), *love* (lufu). Interestingly, some words such as *country* (OF cuntree) and *southern* (OE sūth) deviated in their pronunciation from the regular development. Unlike e.g., ME hous (in OE spelled hūs), which underwent changes ū>əu>au in the course of four centuries, the words *country, southern* were pronounced differently under the Norman influence and resulted in present day /ʌ/.

Similarly to /ʌ/ the open back vowel is characterized by a variety of spelling forms. The lexical frequency of /ɑː/ as <ar> (*part, car, march, charge*) is 60 % (the text frequency being the same) and that of <a> without <r> (*Bach, pass, after, bath, tomato*) 32 % (text frequency 34 %). Many of the simple <a> spellings involve a following voiceless fricative where the /ɑː/ was originally short (and remains as /æ/ in General American and in Northern English). Very often /ɑː/ is marked as <a> before nasals /m, n/ or the liquid /l/ preceding another consonant within the same morpheme: *grant, dance, half, calm, palm*. Other spellings, called 'irregular' by Nosek (1991), are much less common. Among these belong <ear> (*heart, hearth*), <er> (*clerk, Derby, sergeant*) and <au> (*aunt, laugh*).

/ɒ/ spelled as <o> has a lexical frequency of 95 % (*dock, bonk, dog, holiday*). Spellings in <a> appear in 4 % (*was, what, swan, want*). (The text frequencies are 92 %

and 6 %, respectively). The 'irregular' spellings are <au> as in *because, cauliflower, Austria* and <ou, ow> in words *cough, trough, Gloucester, knowledge.*

As has been stated above (see section 3), for the English low vowels the IPA transcription traditionally uses the symbols æ, ʌ, ɑ: and ɒ. SAMPA, the computer readable transcription, transcribes these English vowels with the symbols {, V, A and Q, respectively.

**8. A brief outline of the historical development of the English low vowel sounds**

Only as late as in the last two centuries have people been able to record sound which would serve as evidence of changes in vowel quality. The characteristics of vowels of times before technical advance enabled their preservation are only partly determinable due to written records. An important basis for the reconstruction of English in its earlier periods is the pronunciation of Latin in the Middle Ages. Vowel symbols were used in the earliest writing with the values that these symbols had in the Latin alphabet as acquired by the English from the Irish missionaries. Therefore the following description of the vowel system of the earliest English periods is merely approximate. It is restricted mainly to the vowel area which is the subject of this research paper.

During the past nine centuries, English has undergone more dramatic changes (including many phonological changes) than any other major European language in the same period. The OE vowel system consisted of 14 monophthongs (a set of seven short vowels [æ e i a o u y] with their long counterparts) and six diphthongs ([ea eo ie] plus the same number of long ones). Out of the vowel sounds, four, namely [æ, æ:, a, a:], fell within the lowest area of the vowel space. Quirk & Wrenn (1993) compare the difference in pronunciation between [a:] in OE *hām* 'farmstead' and [a] as in *hamm* 'pasture' to the difference between French *lâche* and *pâte.* <æ> as in OE *þæt* represents a sound corresponding to Modern English [æ] when short and roughly the vowel sound of ModE *mare* when long.

In general, the OE long vowels have changed more than the OE short vowels. Except for [a:, æ:] the long vowel sounds remained more or less unchanged in Middle English (ME) (Pyles & Algeo, 1982). [a:] in OE written <a> was rounded to [ɔ:] (except in the Northern dialect where it persisted until the end of 13th century when it became [eː]); [æː] became ME [ɛː]. This, Pyles-Algeo states, was really the only particularly noteworthy change in quality. Also the short vowels of OE stressed syllables that remained short were unchanged in most ME speech, but for two vowels. Among them [æ] which fell together with short [a] in central dialects and came to be written like it in the half of the 13th century: OE *glæd* > ME *glad* (in Southwest Midland and in Kentish it developed into [e] written <e>). Short as well as long diphthongs underwent the process of monophthongization: [ea]>[æ] (shortly after 1000) consequently >[a]; [ēa]>[æː]>[eː]. Besides these spontaneous changes Vachek (1960) identified several combinatory changes on the way from OE to ME which also had some impact on sounds in the mid-open to open area. OE short [a] changed into Middle English [aː] in stressed open syllables, as in *name* (short vowels in such positions were lengthened in ME by the middle of the 13th century). Long vowels and diphthongs were shortened before all non-lengthening consonant groups, thus *læ:dde>lædde* 'led'. In the 14th and 15th centuries e+tautosyllabic r gave rise to a+r: OE *steorre* >ME *sterre* > *star* 'star'.

All the changes during the ME period resulted in reshaping of the system of vowels from square to triangle diagram containing three mid-open to open long vowels: open [ɛː, ɔː] and [aː], and their short somewhat raised counterparts. The long subsystem of classical ME possessed four degrees of openness of its 7 vowels, while its corresponding short system had only three comprising 5 sounds (Vachek, 1960).

By the early Modern English period, all the long vowels had shifted within the complex change known as the Great Vowel Shift. ME [ɛː, ɔː] were raised in their articulation giving [e] and [o], respectively and so getting beyond the scope of our interest. Similarly [aː] as in *name*, which comes from OE short [a] in open syllables, was fronted, subsequently going through the stages [æː], [ɛː], [e] towards a close-mid area and present day diphthong [eɪ]. Towards the end of the ME period, following the Great Vowel Shift, a close-mid centralized back [ʊ] started to change in its quality. It became lowered and unrounded, (the unrounded stage appears to have been reached by or during the seventeenth century in the London region), going through an intermediate stage with the quality between /ə/ and /ʊ/, resembling /o/. This sound, which was assigned the symbol ʌ, acquired its contemporary qualities only as late as at the end of the eighteenth century. In some cases this process did not take place, so in words where we would expect /ʌ/, e.g., in words *put, pull, bull, wolf, etc.*, the pronunciation remained /ʊ/ (Henton, 1990). There was a partly rounded variant of short [ɔ], i.e., [ɒ], which is the most widespread British pronunciation of words such as *god, stop*, etc. The sound that saw the most obvious changes was the ME [a] which developed into [æ] (Pyles & Algeo, 1982).

In order to arrive at the full repertoire of the present day English mid-open to open vowels, we must mention Vachek's combinatory changes of ME vowels in Early ModE. One of these was the lengthening of [æ] and [ɔ] followed by the voiceless fricatives [f, θ, s] resulting in [æ:], [ɔ:] which in ModE appear as [ɑ:] (as in *ask*) and [ɔ:], the latter one usually shortened (as in *often*).

As a result of these changes the present day ModE system contains the four low vowels [æ], [ʌ], [ɑ:] and [ɒ].

The following table based on Gimson (1991) summarizes the major sources of the present-day English low vowels:

| PresE | Derived from |
|---|---|
| /æ/ | OE [ɑ] (*man, cat*);<br>OE [æ] (sad, back, apple): OE [ɛ:ə] (*shadow, shank*);<br>shortened OE [ɑ:] (*hallow*) or OE [ɑ:] (*ladder, mad*);<br>Scandinavian [ɑ] (*flat, anger*);<br>regularly from OF [a] (*lamp, manner, passage*) and occasionally from OF [au] (*salmon, savage*)<br>Most earlier sequences of the type [wa-] retained /æ/ in some cases, especially when a velar consonant follows (*wag, wax, twang* X *watch, quality, water*). |
| /ʌ/ | OE [ʊ] (*sun, love, nut, ugly*);<br>shortened OE [u:] (*us, husband, utter, enough*);<br>OE [y] (*blush, much, such*); OF [u] (*cousin, touch, dozen, colour*);<br>OF [u] or [o] before a nasal consonant (*number, sum, front, uncle*);<br>OF [y] (*just, judge, public, study*).<br>Some PresE /ʌ/ forms have developed from a ME [o:] (*flood, blood, done, month, glove, mother*). The words *one* and *none* underwent an irregular development, otherwise they would come out as /əun, nəun/ as in *alone* instead of the present day /wʌn, nʌn/. This form derives from a shortened, raised ME vowel, preceded in the case of *one* by [w], originally considered a vulgarism. The vowel of *none* results from an analogy with that of *one*. |

| | |
|---|---|
| /ɑː/ | through loss of post-vocalic /r/ in the eighteenth century, short [a] or [æ] > /ɑː/ (*charm, march*); the short [a] or [æ] may derive from ME [ɛ] (*far, star*) or earlier French [ɛ] (*clerk, farm, sergeant*);<br>lengthening of [a] or [æ] due to the following fricative (*staff, pass, father, path, bath*);<br>reduction of OF [ã] > ME [ɑu] > [ɒː] > /ɑː/ (*aunt, branch, command*);<br>reduction of ME [ɑu] and late ME loss of [ɫ] > /ɑː/ (*half, calf, palm*);<br>approximation of foreign values in more recent borrowings mainly from French and Italian (*charade, moustache, memoir*);<br>new /ɑː/ is appearing in PresE resulting from levelling of sequences [aʊə] and [aɪə] (*our, hour, tower, fire*); |
| /ɒ/ | OE [ɔ] (*dog, cock, song*) and OF [ɔ] (*offer, lodge, jolly*); shortened OE [oː] (*blossom, soft*) (occasionally);<br>rounding of ME short [a] preceded by [w], during the seventeenth century it established as /ɒ/ (*what, watch, was, want*);<br>shortening of ME [ɔː] in words such as *gone, shone*;<br>monophthongization and shortening of ME forms in words such as *knowledge, sausage;*<br>/ɒ/ followed by a nasal consonant occasionally represents [ɑ̃] in recent French borrowings (*restaurant, fiance*) |

### 9. Low vowels in the varieties of Standard English

The outline of the following sections is primarily based on Trudgill and Hannah (1982), i.e., we adopted their division of the varieties of English as well as terminology. If not noted otherwise, the data were taken over from this reference book.

Trudgill and Hannah (1982) distinguish two main standard varieties of English. One of them is traditionally referred to as 'British English' spoken, with minor differences, in England, Wales, Scotland, Northern Ireland, The Republic of Ireland, Australia, New Zealand and South Africa. However, as far as pronunciation is concerned, Standard British is claimed to be 'RP' (spoken by only about 3 – 5 % of the population in England, but considered prestigious in the whole of the British Isles) and therefore it means something much more restrictive. To avoid terminological confusion, Trudgill and Hannah (1982) refer to the combination of British Standard English grammar and vocabulary with the RP pronunciation as English English (EngEng). The other form of Standard English is referred to as North American English

(NAmEng), meaning English as it is written and spoken by educated speakers in the United States of America and Canada.

Nevertheless, in many other parts of Asia and Africa we are more likely to come into contact with Australian English (AusEng), New Zealand English (NZEng), or South African English (SAfEng) than with EngEng or NAmEng (ibid.).

Taking as a source the gradual spread of English over the world Trudgill compares altogether nine varieties according to the countries or other territories where English is spoken. He distinguishes the 'English' type of English containing EngEng, Welsh English (WEng), AusEng, NZEng and SAfEng, and the 'American' type including Canadian English (CanEng) and US English (USEng). Scottish and Irish English are treated separately. Although we follow Trudgill and Hannah's framework, it must be noted that the division into 'English' and 'American' type of varieties seems anachronistic, since for a long time all the varieties they describe have been developing independently to form their characteristic phonemic systems and their typology is purely historical.

In terms of this distinction Trudgill depicted the crucial differences in pronunciation of low vowels in a diagram which reveals that:

1. /ɑː/ rather than /æ/ is used in *path* in The Republic of Ireland, England, Wales, South Africa, Australia and New Zealand
2. in South Africa, Australia and New Zealand speakers use closer vowels for /æ/ and /ɛ/, also monophthongization of /ai/ and /ɑu/ has been recorded in these areas
3. speakers in Australia and New Zealand pronounce /ɑː/ as front [aː] in *part*
4. there is absence of contrast of /ɒ/ and /ɔː/ as in *cot* and *caught* in Canada, Northern Ireland and Scotland
5. in Canada, USA, Northern Ireland and Scotland /æ/ rather than /ɑː/ in *can't* is used
6. USA and Canada see the absence of contrast of /ɒ/ and /ɑː/ as in *bother* and *father*
7. /ɒ/ in *pot* is realized as unrounded in the USA, Canada and The Republic of Ireland

Most of the following subsections deal with the main differences between the individual accents as delimited by Trudgill and Hannah (1982) in greater detail.

## 9.1 'English' types of English (RP, Near-RP and non-RP accents)

### 9.1.1 The term RP

It becomes obvious from literature that in all English-speaking countries there is a close connection between social class and language: "Speech stratification correlates with social stratification." (Wells, 1982). In all parts of England there can be found a range of accents from Received Pronunciation (RP), which is at the top of the social scale, through regional accents down to a broad local accent, linguistically the most distant from RP. We shall focus here on the most prominent accent, which RP undoubtedly still is, although it is not fully void of certain geographical specifications.

The awareness of the role of accents in the British society has a long tradition. The term 'RP' itself was originally coined to designate an accent spoken by certain social group. However, not always did phoneticians agree on its basis, which could be either regional or social or a mixture of the two. The term has been in use for nearly a century and since its launch it has been used to refer to several accents of English according to what was considered to be the standard at each particular time. In the 1st edition of *English Pronouncing Dictionary* (1917) Daniel Jones attempted to represent the pronunciation '*that was most usually heard in the families of Southern English persons whose menfolk have been educated at the great public boarding-schools*', hence 'public school pronunciation' (PSP). By 1926 Jones abandoned the term PSP in favour of 'received pronunciation' (RP), the definition remaining unchanged. In Jones's time RP was considered to be 'accentless'. To this extent it was likely to be the most widely understood form of speech and the accent that the BBC had been seeking to avoid any criticism of its announcers' pronunciation (Trudgill, 1984).

In Palmer's dictionary published in 1926 his author rejected part of Jones's definition and stated that '*it is not one of the regional pronunciations at all, but a special sort of class dialect that is independent of locality*', and further he redefined the speaker of RP as anyone who is the least influenced by regional dialects. By saying this he only paraphrased Henry Sweet (1908, in Trudgill (1984)) who wrote on behalf of Standard English (not yet RP) eighteen years earlier that:

> Standard English ... is now a class dialect more than a local dialect: it is the language of the educated all over Great Britain ... The best speakers of Standard English are those whose pronunciation, and language generally, least betray their locality...

In 1977 referring to Jones's understanding of RP Gimson noted that '*such definition of RP is hardly tenable today*' admitting that this label was applicable to a wider sample of contemporary speakers (EPD, 1977). Not many years later, in 1982 Wells defined RP as something that

> anyone living in the United Kingdom hears constantly from radio and television announcers and newsreaders and from many other public figures. Everyone in Britain has a mental image of RP, even though they may not refer to it by that name and even though the image may not be very accurate. Many English people are also regularly exposed to RP in personal face-to-face contact. For a small minority, it is their own speech.

The 15th edition of EPD (1991) abandoned British English RP as archaic and changed for the standard called BBC English which immediately leads us to the origin of its data - '*the pronunciation of those newsreaders on BBC radio and television who speak with an English accent*' (16th ed., 2003). The same practice is applied in the domain of AmE; the variety is referred to as "network English". The reason for the choice of these pronunciation models is claimed to be the fact that almost all speakers of English watch TV, therefore the "TV accents" are very understandable. They are also easy to learn since the British and American national broadcasting are widely available nowadays.

Besides RP, there are significant variety labels "General British" and "General American" used by J.W. Lewis (1972): '*each characterises the fluent, spontaneous, everyday usage of those educated speakers whose speech is of the most generally accepted kind and least restricted in terms of geographical region or social grouping*'. The term "General British" would include Wells' mainstream RP (what is left after exclusion of adoptive and U-RP), adoptive RP (that variety of RP spoken by adults who did not speak RP as children), and to a considerable extent Near-RP (accents which are not exactly RP though not very different from it), while excluding U-RP (upper-crust RP) (Wells, 1982).

Although lexicography ceased using the term RP over a decade ago, among compilers (e.g., Roach, Cruttenden) of reference books on phonetics (as well as other phoneticians) the label is still widely used. No matter when in the past centuries the label was used, it has always referred to an evolving system with the same phonological basis of the south-eastern region of England, although nowadays non-localizable within England. Regardless of whether it is referred to as RP or BBC, this accent bears a significant referential value which explains why it often becomes object of research including the present study.

### 9.1.2 Near-RP and non-RP accents

Quite understandably, RP is the first accent treated by Trudgill, but since a whole chapter is devoted to its description, we will proceed with what Trudgill refers to as near-RP accents with a rather vague definition: "*accents which are not exactly RP though not very different from it*" (Wells, 1982).

Northern near-RP accent speakers are likely to differ from RP in their use of /æ/ rather than /ɑː/

i. in words where orthographic *a* is followed by the voiceless fricatives /f/, /θ/ or /s/ as in *laugh, path, grass*;

ii. in words where orthographic *a* is followed by the nasal clusters /nt/, /ns/, /nʃ/, /nd/, /mp/: *plant, dance, branch, demand, sample* (Trudgill, 1982). Also the use of /ɒ/ rather than /ʌ/ in *one, once* applies in the midlands and north of England. In much midlands, northern and Welsh near-RP there is absence of opposition between /ʌ/ and /ə/ (Wells, 1982).

Wells (1982) came up with more diversified RP. U-RP (i.e., upper-crust RP) speakers have an opening-diphthong realization [ɛæ] of /æ/ in *trap*. Both the /ʌ/ of *strut* and the /ɑː/ of *balm* are back. In old-fashioned U-RP or old-fashioned RP generally *cloth* words are pronounced with /ɔː/ rather than with the usual /ɒ/. Adoptive RP (adopted by adults who did not speak RP as children) merges imperceptibly into mainstream RP, which corresponds to Gimson's general RP.

The vowel system of London English is almost isomorphic with that of RP, only the vowels of *trap* and *lot* may be somewhat less open. The most striking difference occurs in the vowel quality of *strut*, which in London is a front vowel ranging from a fronted [ɐ̟] to a quality like that of cardinal 4, [a]. /ɑː/ has a fully back variant, qualitatively equivalent to cardinal 5 (Wells, 1982).

The south of England can be divided into three basic areas: home counties, East Anglia and the west country. The home counties are dominated linguistically by London, and their urban speech has strong affiliations to that of London. The East Anglian accent is like that of London, and like RP, in having a firm opposition between *strut* and *foot* (/ʌ/ vs. /ʊ/) and in having undergone *bath* broadening ([baːθ]). In

Norfolk, unlike in the rest of East Anglia, the *lot* vowel has an unrounded variant, ranging from [a] to [a̠].

In the west of the southern region of England, short vowels are traditionally lengthened, so that one can have pronunciations of the type [tɒˑp] *top.* The distinction of length particularly among front/central open vowels tends to be missing in some areas. In most rural western speech and not exceptionally in urban speech the *trap* vowel is qualitatively [a] rather than [æ]. Since in some areas *bath* vowel can be realized as [a], the phonemic distinction between /a/ and /æ/ sometimes disappears (Wells, 1982).

Wells (1982) did not follow the traditional dialectologists' concept of the north (north of a line from the Lune to the Humber) and instead calls everything from the Severn - Wash line northwards up to the Scottish border 'the (linguistic) north'. This geographical area comprises the midlands, the middle north and the far north.

The two most important characteristics setting northern local accents apart from the southern ones are:

i. the absence of the *foot-strut* split, i.e., the lack of a phonemic opposition between the vowels of *foot* and *strut*;
ii. the absence of *bath* broadening, i.e., the use in *bath* words of the vowel of *trap*.

The first differentiation is due to the failure of the Middle English [ʊ] to split into two phonemes in this region. As a result a five-term system was preserved as opposed to other English six-short-vowel systems. The system comprises /ɪ, ɛ, a, ɒ, ʊ/ of *kit, dress, trap, lot* and *foot-strut*, respectively. This fact gives rise to a sociolinguistic variation between a local five-term system and the national, overtly more prestigious, six-term system. It appears that the further north one goes the higher up the social scale is the crossover between the two systems located. In the West Midlands conurbatin, it is probably true to say that all speakers do to some extent have a *foot* vs. *strut* opposition. In other areas such as further north, though, particularly lower social classes do not make any difference between *foot* and *strut*.

A relatively recent description of the northern English [ʌ] in the sociolinguistic context is provided by Henton (1990). She refers to the accent she describes as Northern Modified (MN), basically covering the same northern England region as it was delimited by Wells (1982). The research showed that the role of /ʌ/ in MN is not to distinguish the meaning, but that it has become a social marker. As has been stated above, whether /ʌ/ is or is not used is a question of social prestige, but also geographical latitude (Wells, 1982). Obviously the five-short-vowel system is local and less prestigious than the six-vowel-system.

It must be noted that the speakers analysed by Henton were not typical representatives of northern accent. They had all grown up in Leeds, but later moved for educational or professional reasons. They had all lived away from Leeds for at least three years and were exposed to southern varieties of British English, hence the term *Northern Modified.* Wells (1982) described the vowel in words like *strut* produced by MN speakers as intermediate stages, perceptually unidentifiable neither with /ʌ/ nor with /ʊ/:

> One is the use of qualities for the STRUT vowel which are distinct from the [ʊ] of FOOT but nevertheless perceptually different from any realization of RP [ʌ]; the other is the hypercorrect avoidance of [ʊ] in FOOT words...
>
> Such intermediate qualities for the STRUT vowel include a vocoid somewhat opener than [ʊ], namely a mid back [ʊ], the unrounded equivalent, [ɤ]: and a half-open vocoid, unrounded or slightly rounded, similar to cardinal [ʌ] (and therefore somewhat different from RP [ʌ], which is usually central rather than back). They also include a mid or half-close [ə], central and unrounded.
>
> The last-mentioned possibility, stressed [ə] in STRUT, seems to be particularly characteristic of northern near-RP, with pronunciations such as *cup* [kəp], *brother* [brəðə].

Particularly in the Midlands, the *strut* set is usually more or less successfully distinguished from the *foot* set in relatively formal or relatively higher-class local accents by the use of [ə].

Henton concentrated on the intermediate stages that were approximations to RP /ʌ/. There were three hypotheses at the beginning of the research which were founded on the data known until then:

- adoption of the six-short-vowel system by speakers with higher rank on the social 'scale'
- great inter-speaker variability in the realization of the target phoneme
- greater tendency in female speakers to produce /ʌ/ qualitatively closer to the RP form (if we take into account the accommodation theory)

All the three hypotheses were later confirmed. There appeared speakers who adopted the sixth vowel and used it systematically. All the intermediate stages reported by

Wells also occurred. The diagrams in Henton's paper demonstrate a great variability of /ʌ/ particularly in F1. The coefficient of variation of Bark values of MN male and female speakers' F1 amount to 17.53 and 19.59 respectively, compared to RP values of 7.57 for male and 8.79 for female speakers. Female speakers' vowels occupy a larger area than those produced by male speakers. The F1 values are comparable to those of RP speakers, i.e., they are the closest to /ɜ/. However, the mean values of the second formant indicate that the MN realizations are backer than the RP speakers' vowels. It becomes clear from Henton's experiment that male MN speakers are more conservative, because they retain in their speech a vowel quality nearer to their original /ʊ/. Female speakers tend to approach the southern /ʌ/ in their pronunciation and thus are more 'progressive'. Henton notes that these differences are also auditorily apparent, ranging in height from /ʊ/ to /ʌ/. According to her, nine vowels out of the twenty produced by MN female speakers had perceptually the quality of /ʌ/, whereas only four MN male vowels were perceived in the same way. Sometimes the southern quality of /ʌ/ is in such favour of female speakers that lexemes containing /ʊ/ become the soil for hypercorrection. The author summarizes that the above-mentioned proportions "suggest a tendency towards a stronger, more conscious retention of original accentual features by MN males, and greater susceptibility to linguistic accommodational pressures by MN females". Therefore in addition to geographical latitude and socio-economic status which are crucial in describing the tendencies in northern accents, as pointed out by Wells, it is necessary to take into account also the differences in speech according to speaker sex. Only the three-dimensional distinction can describe all the tendencies of /ʌ/ which appear in MN besides Wells' /ʌ/ and /ə/.

In the north of England the words belonging to the standard lexical set *bath* are very generally pronounced with the same short open vowel as *trap*, namely /a/ (= RP /æ/).

We have seen that northern accents typically have five rather than six vowels in the short vowel system. Except in West Midlands, all tend to be opener than in RP. In particular, [a] is a fully open vowel somewhere between front and central [a ~ a̠ ]. The *lot* vowel is also perceptibly opener than mainstream RP /ɒ/; it is also less rounded. The *cloth* words have a short /ɒ/ throughout the north (unlike in some accents of RP).

The vowel of *palm* and *start* varies from a front [aː] to a back [ɑː], while the front variety may coincide with the realization of the vowel in *trap* words, which differs only in length, as [pak] vs. [paːk]. The backer type is like RP /ɑː/ or backer.

Wells (1982) further points out that the northern accents exhibit a difference of vowel incidence as compared with RP or other accents. For example *one* is pronounced [wɒn] in parts of the north, rather than the expected [wʊn] (RP [wʌn]).

Northern speech tends to retain strong vowels in certain environments where RP and other accents show weakening. Notable among these are Latin prefixes such as *ad-*, *con-*, etc. when pretonic (Wells, 1982).

The last 'English' English accent in Britain to be treated here is Welsh English. The major phonological difference between WEng and RP is the tendency towards /æ/ rather than /ɑː/ in *last* or *dance* (Trudgill, 1982). In many places in Wales, the quality of /aː/ in this set of words (with RP /ɑː/) is socially sensitive, with a front [aː] being stigmatised as compared with a central to back RP-style [ɑ̟ː].

According to Wells (1982) the principal distinction from the RP vowel system is the *strut*-schwa merger. In *strut* words the vowel used is typically mid, unrounded, and central or somewhat back of central, [ə ~ ʌ̞̈]. It does not contrast with /ə/ in unstressed syllables, so that *a large untidy room* and *a large and tidy room* tend to be homophonous.

In all parts of Wales there seems to be a tendency for the pairs /a, aː/, /ɒ, ɔː/ to differ principally in length, rather than in quality, so that much the same vowel quality can be heard in pairs of words such as *hat-heart*, *shot-short* (Wells, 1982). Unstressed orthographic <a> tends to be [a] rather than [ə], e.g., *sofa* [soːfa]. Unstressed orthographic <o> tends to be [ɒ] rather than [ə], e.g., *condemn* [kɒnˈdɛm].

Australian English (AusEng) corresponds with RP in having /ɑː/ before voiceless consonants, but like non-RP north-of-England accents it often has /æ/ in *dance, sample, plant, branch*, etc., even though the pronunciation of these words occurs also with /ɑː/. There is some regional variation (it is said that /ɑː/ is particularly common in South Australia) as well as variation from word to word. RP smoothing of /auə/ > /ɑː/ does not occur.

Apart from the phonological differences between RP and 'broad' AusEng, which are sparse (Wells, 1982) (as opposed to 'mild' AusEng spoken by users of the language that are socially higher), Trudgill (1982) recorded considerable phonetic differences. *Australia, auction, salt*, which may have /ɒ/ or /ɔː/ in RP, have only the former sound in AusEng. In some areas, /ɔː/ may be heard in *off, often* more frequently than in RP. AusEng front vowels tend to be closer than in RP: /æ/ pronounced as [ɛ̝]. Similarly, /ɒ/ is realized as closer [ɔ̝]. The pronunciation of /ɑː/ vowel corresponds with a very front [aː] in comparison to most other varieties of English.

On behalf of /ʌ - ɑː/ distinction Bernhard (in Yallop and Clark, 1990) stated that the difference between the long vowel of *calm* (RP /ɑː/) and the short vowel of *come* (RP /ʌ/) in AusEng is entirely a matter of duration. However, Yallop and Clark (1990) provide a figure depicting /ʌ/ as much closer than /ɑː/. Ingram and Park (1997) confirm Bernhard's view of the development in the relation of /ʌ/ and its adjacent vowels in AusEng, by seeing significant vowel quality differences for all but one of the tense-lax pairs /ɑː - ʌ/ (*card-cud*), where the phonetic contrast is (again – compare Bernhard in Yallop and Clark, 1990) almost solely one of length.

According to Bauer (in Henton, 1990) Australian and New Zealand English (NZEng) varieties are more advanced in their vowel system changes than RP is. Wells (1982) reported fronting of AusEng /ʌ/ towards the cardinal 4 area as "a drag-chain consequence of the movement of /æ/ up and away from cardinal 4". The movement of /ʌ/ from being an unrounded back vowel to a front vowel, which was observed in AusEng before Cockney and RP, is viewed by Bauer (in Henton, 1990) as a trigger to the changes in the quality of vowels in the front region and in Australian English vowel system as a whole. She ascribes the move to the difficulty to make perceptual distinctions in the back area of the vowel chart and to "unnaturalness of unrounded back vowels". The third motivation that might have caused the shift was the isolatin of /ʌ/ in the back region. In contrast to that, when /ʌ/ is placed in the fronter position, the vowel pattern is considerably neater. Henton labeled all the three Bauer's reasons as rather "provocative".

Phonologically and phonetically NZEng accents are very similar to AusEng. In fact, New Zealand accent is so similar to an Australian one that it is difficult for outsiders to tell them apart. Yet, in NZEng words such as *dance, sample, grant,* etc. normally have /ɑː/ rather than /æ/. The open-mid front vowel /æ/ tends to be even closer than in AusEng. *Old, toll, sold,* etc. may have /ɒ/ rather than /ou/. For many speakers these sounds are neutralized before /l/. In broad New Zealand English /ʌ/ is "very definitely a front vowel" (Bauer in Henton, 1990). Regarding New Zealand English, Wells (1982) does not record any dramatical changes in /ʌ/, but he places it in the central region of the vowel chart.

Trudgill and Hannah (1982) describe South African English (SAfEng) phonology as identical to that of many south-east England varieties, but its phonetics is perhaps closest to that of NZEng. Like RP and NZEng (but unlike AusEng), SAfEng can be readily recognized by /ɑː/ in *dance* distinctively backer and sometimes weakly rounded [ɒː] unlike in RP. From Trudgill's table of SAfEng vowel sounds it becomes clear that /æ/ and /ɒ/ are closer than in RP; also Wells (1982) confirms this. Wells (1982) notes that both /ʌ/ and /ɑː/ are central to back in SAfEng (as against central to front in AusEng).

## 9.2 'American' types of English

There is more regional variation in NAmE pronunciation than in AusNZEng and SAfEng, but there is no universally accepted totally regionless standard pronunciation as in EngEng. Trudgill (1982) describes primarily the NAmEng accent of an educated central-eastern variety, but later discusses several regional differences concentrating on varieties of educated speech. Remarkably, the only phonological differences between the RP and the NAm systems reported on by Trudgill are those that follow from the rhotic character of the NAmEng (/iə/ and /ɛə/ present only in RP) and the differences in no other than the mid-open to open vowel area.

So what are the main differences? The three RP vowels /ɒ/, /æ/ and /ɑː/ correspond to only two vowels in NAmEng - /ɑ/ and /æ/. However, due to phonetic difference between RP /ɒ/ and United States English (USEng) /ɑ/ and the differences in vowel distribution in many sets of words, the relation between the two systems becomes much more complicated (Trudgill and Hannah, 1982):

i. In many words spelled with *a,* the correspondence is straightforward: *cat* RP /æ/ = NAmEng /æ/. Similarly, in words spelled with <o>, the correspondence is also reliable: *pot* RP /ɒ/ = NAmEng /ɑ/.

However, there are more problematic cases such as:

ii. Many words felt to be 'foreign' have /ɑ/ in NAmEng, but an /æ/ in RP as in *Milan*, probably due to the closer quality of NAmEng /æ/. This tendency is not general though, as reverse correspondence is found in some words (e.g., *khaki*).

iii. 'Foreign' words (e.g., *Bogota*) spelled with *o* and realized by an RP speaker as /ɒ/ tend to have an /ou/ in NAmEng.

iv. NAmEng does not have the RP distinction /ɒ/ - /ɑː/ *bomb – balm*, it has /ɑ/ for both sets of words, although in certain regions the *a* spelling can be differentiated from words with *o* by a longer vowel /ɑː/. Because of the lack of this distinction NAmEng being a rhotic accent differentiates words such as *cod* and *card* only by means of the /r/.

v. The distribution of words over the RP /ɒ/ and /ɔː/: NAmEng /ɑ/ and /ɔ/ differs from their distribution in words *cot* and *caught*. In some cases RP /ɒ/ corresponds to NAm /ɑ/ (*cot*), and RP /ɔː/ to NAm /ɔ/ (*caught*). But it is also the case that RP /ɒ/ corresponds to NAm /ɔ/ in words having an *o* before *ng* or before one of the voiceless fricatives (*loss*). Sometimes it applies also to *o* before *g* as in *dog, fog.*

vi. In words such as *path, laugh, grass*, where RP has /ɑː/ before voiceless fricatives, NAmEng has /æ/. This applies also to RP /ɑː/ before /nt/, /ns/, /nʃ/, /nd/, /mp/. NAmEng also has /æ/ in *half, banana, can't* (Trudgill and Hannah, 1982).

Trudgill and Hannah (1982) do not describe the American counterpart of the RP open-mid central vowel. For this purpose we resorted to Wells' description of General American (also referred to as 'Network English') accent. Here /ʌ/ is characterized as a centralized back vowel; the fronted qualities which are found in some parts of the south of England being unknown in North America (Wells, 1982).

Volín (2004) carried out a survey on the differences between RP and GenAm. We adopted his table (here Table 9.2.1) which illustrates the lexical frequency of the differences between RP and GenAm vowels. The table gives us the number of occurrences of the particular difference type in every thousand words that were analyzed. The bottom line presents the percentage of each specific type within the vowel differences. In his paper Volín distinguishes seven types of vowel differences. Although dipthongs are not a concern of the present study, it deserves mentioning for its significant share in the vowel differences between RP and GenAm, which amounts to 39.1 per cent of the whole vowel difference sample. Out of the remaining six types three, namely /ɒ → ɒː/, /ɒ → ɔː/ and /ɔː→ ɒː/, are not mentioned by Trudgill and Hannah (1982), which is supposedly due to different data sources.

**Table 9.2.1** Frequency of the differences between RP and GenAm vowel realization. The line **x:1000** tells us how many differences of the particular type there are in every one thousand words. The last line gives the percentages of each of the types in the sample of vowel differences.

| Type | əu → ou | ɒ → ɑː | ɒ → ɒː | ɒ → ɔː | ɔː → ɒː | ɑː → æ | æ → ɑː |
|---|---|---|---|---|---|---|---|
| x : 1000 | 91 | 85 | 8 | 4 | 22 | 7 | 6 |
| % | 39.1 | 36.5 | 3.4 | 1.7 | 9.4 | 7.3 | 2.6 |

The /ɒ → ɑː/ type is the most frequent difference accounting for 36.5 per cent of the different vowel realization, e.g., *logical* RP /lɒdʒɪkl/ vs. GenAm /lɑːdʒɪkl/. The type when RP /ɒ/ is pronounced as /ɒː/ in GenAm was not recorded by Trudgill and Hannah (1982). According to Volín, this type is not very common and its occurrence is rather arbitrary: e.g., *chop* is pronounced /tʃɑːp/, but *hop* is realized as /hɒːp/. The latter may as well be pronounced with /ɑː/, only the /ɒː/ realization is more usual. This type has a 3.4 per cent share in the vowel differences. There is yet another difference which stems from the absence of  in the GenAm phonemic system. It is the realization of RP /ɒ/ as /ɔː/ if it is followed by /r/, such as in the word *forest*: RP /fɒrɪst/, but /foːrəst/ in GenAm. This type accounts for 1.7 of all the vowel differences. Note that Trudgill and Hannah reported that <o> followed by <ng>, a voiceless fricative or sometimes even <g> is pronounced as [ɔ] in NamEng rather than as RP [ɒ]. The remaining two categories deal with the different distribution of /ɑː/ and /æ/ in the two variants. In 7.3 per cent of cases RP open back /ɑː/ is usually produced as open-mid front /æ/ before nasal and fricative consonants in GenAm: *example* /ɪg'zɑːmpl/ in RP vs. /ɪg'zæmpl/ in GenAm, *past* RP /pɑːst/ vs. GenAm /pæst/ (see more examples above). As Trudgill & Hannah and Volín remarked, the last category of differences /æ → ɑː/ occurs exclusively in words of foreign origin; it presents only 2.6 per cent of the vowel differences.

### 9.2.1 Variation within North American English

Many NAmEng accents demonstrate a merger of /e/, /eɪ/, /æ/ before /r/; also /ɜː/ and /ʌ/ are not distinguished in the same position. Thus *furry* and *hurry* rhyme. In fact, descriptions of American English /ʌ/, some of them published as early as thirty years ago, record the disappearance of /ʌ/ before /r/ and its subsequent replacement by the central /ɜː/. Finding support in her experiment, Henton (1990) admitted further spreading of the coalescence of /ʌ/ with /ɜː/ (particularly in West Coast American English =WCA) also in other positions. A comparison of the results of Henton's analysis (1990) shows that the tendencies concerning the process of centralisation of /ʌ/ in British and American English for male and female speakers are quite opposite, with female BrE speakers being more 'progressive' than the male speakers. For the WCA male speakers' /ʌ/ is slightly fronter than for their RP counterparts. For the WCA females /ʌ/ is less advanced than for the RP females. WCA speakers were generally closer in the quality of the two vowels than the British English speakers. Recalling the descriptions by various American authors, Henton (ibid.) summarizes the results in the following words: "In both varieties [RP and WCA], /ʌ/ vowels are raised from an open position, with the WCA vowel being the closer.... from trends observed here ... it appears that the two varieties are not as divergent with respect to the acoustic values of [ʌ] as the literature portrays them to be".

It has been pointed out earlier that speakers of NAmEng pronounce *horrible* like *cot* with /ɑ/. Nevertheless, away from the East coast of the USA and in Canada these words are realized with /ɔ/. Alternatively, as for example in large areas of Illinois, both the set of *port, pore* and the set of *horrible* have /ou/.

In large areas of the USA (particularly the North and West) and in most of Canada, the distinction between /ɑ/ and /ɔ/ is absent or is currently being lost, the vowel in pairs such as *cot/caught* is around [ɑ].

The accent spoken in Boston and adjoining areas resembles RP in that it has a relatively rounded /ɒ/ in, e.g., *pot* and an unrounded vowel /a/ as in *part*, but also in *path, dance* and *last*.

There is considerable variation in NAmEng in the pronunciation of the vowel /æ/. Trudgill and Hannah (1982) reported a strong tendency for this vowel to become much closer in northern cities such as Chicago, Detroit, Cleveland, Buffalo, Rochester and New York. Thus, *bad* may range from [bæˑd] through [bɛˑd] to [beəd] and [bɪəd]. This change is accompanied by a corresponding fronting of the vowel /ɑ/ of *hot*, which may range from [hɑt] through [hat] even to [hæ̞t].

A distinctively southern feature of USEng is the tendency to monophthongize /aɪ/, e.g., *high* [haˑ].

A feature restricted to Canadian English which is known as 'Canadian raising' involves the occurrence of very different allophones of /aɪ/ and /ɑu/ depending on whether or not there is a following voiceless consonant.

### 9.3 Scottish and Irish English

First of all, Scottish Standard English (Scottish Standard English is a form of standard English spoken by educated Scottish people which is grammatically and lexically not very different from that used elsewhere, although realized with a very obviously Scottish accent) vowel system makes use of fewer sounds than RP due to the rhotic character of the Scottish accent (/ɪe/, /ɛə/, /ʊə/ and /ɜː/ do not occur). Vowel duration tends to vary sharply according to the phonetic environment: vowels are long in morpheme-final position, or after /v, ð, z, r/ except for vowels /ɪ/ and /ʌ/, which are always short.

The RP distinction between /æ/ and /ɑː/ does not exist in most ScotEng varieties; /a/ is used for the vowel of *bad, bard, calm*, although some middle-class speakers do distinguish between the individual sounds, probably as a result of the influence of RP.

There is no RP-type distinction between /ɒ/ and /ɔː/ for many speakers (Wells, 1982), thus making no difference between words *cot-caught*; /ɔ/ is used for both. /ʌ/ is described as a central vowel in the *strut* set. In some Scottish accents ʌ may be used to symbolize the pronunciation of the vowel of *kit* words or it may appear in an unstressed final vowel as in the word *comma*.

The English that was originally spoken in and around Dublin was introduced for the most part from the west and west Midlands of England and still shows signs of this today. This variety of English has spread over most of the Irish Republic. On the other hand, the English of the north of Ireland has its roots in Scotland. Trudgill uses the labels NIrEng and SIrEng to refer to English of the Scottish and west England origins, respectively.

In comparison with ScotEng NIrEng /ɒ/ and /ɔː/ may contrast, but only before /p, t, k/, thus *awful* and *offal* are homophonous. In SIrEng words such as *path* may often have /æ/ rather than /ɑː/. Some words which have /ɒ/ in RP may have /ɔː/ in SIrEng. There is a rounded [ɔ̝] for /ʌ/ (Trudgill, 1982).

Wells (1982) gives a more detailed description than Trudgill (1982) but for our purposes it shall suffice to outline only his general characteristic of Irish English.
In compliance with Trudgill (1982) Wells states that a typical Irish accent of English has all the four RP low vowels /æ/, /ʌ/, /ɑː/ and /ɒ/ in *trap, strut, calm* and *lot* respectively. The RP /ɑː/ has a somewhat fronter Irish counterpart /aː/ (as in Trudgill (1982)). /æ/ is commonly around cardinal [a], though educated Dubliners use [æ]. The quality of Irish English /ʌ/ is strikingly different from other English accents. It is typically a mid centralized back somewhat rounded vowel which might best be symbolized [ɵ̠] or [ɔ̈] (compare Trudgill above). Unrounded back and central qualities, of the type [ɤ, ɘ], are also encountered, as well as a quality indistinguishable from conservative RP [ʌ]. However, the extent to which the opposition between [ʌ] and [ʊ] is maintained, i.e., what is their lexical incidence, is debatable and varies in different accents of Irish English. The same complication can be found with the front vowel [æ],

which may alternate with [ɛ] in words such as *drank, catch* and *carry*. The lexical incidence of the vowels /æ - aː/ corresponds generally to standard accents in that *trap* words have /æ/ and *palm* words have /aː/, nevertheless, their incidence may also vary considerably. The open-mid back vowel is usually unrounded, of the type [ɑ, ɑː], often advanced [ɑ̟]. There is the same problem with /ɒ - ɔː/ as with the pair /æ - aː/, i.e., the lexical incidence differs from RP, e.g., in Dublin *was* or *doll* is heard with /ɔː/ (RP /ɒ/).

### 10. Variability of formant frequency values

In the previous section (section 9) we concentrated on the regional variation of English low vowel realization, including aspects of vowel quality as well as quantity. Apart from geographical distinction, there are numerous other factors underlying the variability of production as well as acoustic and perceptual characteristics of vowels. We can distinguish the factors of variation in terms of one individual or more individuals. Respectively, we can talk about within-speaker and between-speaker sources of variation (after Rosner & Pickering 1994). In the following subsections we shall restrict ourselves mainly to the determinants of changes in vowel quality.

#### 10.1 Sources of between-speaker variation

Apart from the geographically determined variation among collectives of users of a language, there are other noticeable differences between the acoustic images of vowels among speakers of a certain language stemming from speaker identity, i.e., speaker's sex and age. Both of the latter factors entail differences in the anatomical properties of speakers' vocal tracts resulting in varying acoustic properties of their speech.

The length of vocal folds determines the fundamental frequency and partially influences the vowel spectrum. As fundamental frequency grows, there is an increase in the interval between harmonics of the laryngeal source spectrum. At some harmonic spacings it can become more difficult to discern the location of formants in the spectrum. Infants have the shortest vocal folds and vocal tract, which results in highest fundamental frequency and formant frequencies. The average F0 value measured for the mid-central vowel produced by an infant is 400 Hz, i.e., approximately three times as high as for men; the first three formant frequencies are about double the frequencies as for an adult male at 1000, 3000 and 5000 Hz (Kent & Read 1992). There is a gradual decrease in F0 as well as formant centre frequencies as the vocal tract lengthens with age. Also the variability of formant frequency for a given vowel produced by a given subject becomes lower beyond the age of three (Rosner & Pickering 1994).

Apart from the anatomical considerations phoneticians have observed specific habits characteristic of women's speech. Goldstein (1980) and Labov (1972) (both in Rosner & Pickering 1994) claimed that women tend to produce vowels which occupy a wider vowel space than men. However, Pickering (1986) found out that the dispersion of female vowels varies among languages (in Rosner & Pickering 1994). Henton's paper (1990) also illustrates different speaker-sex behaviour. In her study, RP female speakers produced more variable and even more centralized tokens of /ʌ/ than RP speakers of the opposite sex. Apart from RP, Henton studied other two varieties in her paper (1990): MN (Northern Modified) and WCA (West Coast American), and also in these two the sex distinction of /ʌ/ became apparent. Moreover, it has been found out that women score significantly closer to the prestige norm than men (Wells, 1982). Although MN short vowel system has only five members, i.e., it does not contain /ʌ/, Henton showed that particularly female MN speakers tend to approach the southern English /ʌ/ instead of the phoneme /ʊ/, which has the role of the open-mid central vowel in the northern varieties of English. There were even instances of hypercorrection in the women's realizations of words such as *hood*, which was pronounced with /ʌ/ or /ə/, although it has the same phoneme /ʊ/ in both varieties.

### 10.2 Sources of within-speaker variation

These include consonantal environment, stress, speaking style or register, momentary speaker characteristics such as speaking rate, F0, presence or absence of whispering and even inherent variation within one speaker when environment and rate are preserved (Rosner and Pickering 1994).

Perception tests carried out by Kallail and Emanuel (1971, in Rosner and Pickering 1994) revealed that **whispered** American English vowels tended to be identified correctly at about 65 per cent rate as opposed to 80 per cent rate of successful identification of their vocalised counterparts. The authors of the experiment assumed it could be due to less experience with whispered speech, in which the centre frequencies of formants are significantly higher than centre frequencies of vocalised vowels. Whispering appeared to have greater effect on F1, both absolutely and relatively, the smallest effect was measured for F3. This discrepancy between the effect of whispering on F1 and the two higher formants is probably due to the strong dependence of F2 and F3 on the front-cavity resonance (F1 is more susceptible to changes in the laryngeal cavity). The low vowels in the Kallail and Emanuel (ibid.) study were affected the least, even though they are supposed to show some affiliation of F2 to the back cavity and their F2 differences between whispered and vocalised pronunciation should therefore be quite large.

It has been found that vowels have their own 'intrinsic **F0**'. Peterson and Barney's (1952, in Rosner and Pickering 1994) data showed that lower F0 values tend to accompany higher F1 values across different vowels.

The acoustic properties of all sound elements vary depending on whether the speaker is engaged in **casual or formal speech**. Spectrographic comparison of clear and conversational speech reveal a tendency to avoid modified or reduced forms of vowel segments in clear pronunciation (Kent & Read 1992). The less formal the speech, the smaller the acoustic contrast between vowels can be expected (Rosner & Pickering 1994).

Lindblom's study (1963, in Rosner and Pickering 1994) gave evidence that rapid **speech rate** does not allow the articulators to assume a configuration for production of a certain vowel as when producing the vowel in isolation. This phenomenon is referred to as *target undershoot*. For both F1 and F2, the directions of the deviations from target values indicated that at fast rates articulators fall short of their target positions. Lindblom argued that undershoot arises from changes in the relative timing of articulatory events as speech rate increases, which causes the formant frequencies move towards those for schwa (the mid vowel). This effect was both vowel-dependent and context-dependent. However, several later studies (quoted by Rosner and Pickering ibid.) do not confirm Lindblom's original findings too strongly: The extent of formant frequency changes varies with speaker and speaker's language. In many instances, the formant frequencies showed to be insensitive to change of speaking rate. Moreover, formant frequency changes, when they do occur, do not necessarily take the form of centralisation as Lindblom proposed. Finally, as in coarticulation (see further below), the effects of changes in speech rate are on average more prominent for F2 than for F1.

Relative to the speaking rate is vowel **duration**. As vowel duration decreases, the steady-state region of the vowel shrinks and the area occupied by the transients expands.

Varied results were found also for the effects of **stress**. Rosner and Pickering (1994) conclude that the formant frequency changes caused by phonetic vowel reduction are relatively minor and vary in magnitude between different speakers.

The last phonetic parameter we are going to look at in more detail in this section is **coarticulation**, which is crucial to our study. Since speech sounds occur in continuous strings, articulators must accommodate large variations in their settings from one sound to the next. Rosner and Pickering (1994) point out that there has been a commonly held theory among phoneticians (e.g., Joos) that vowels in context undergo a process referred to as vowel reduction. According to this so called "reduction hypothesis" vowel formants move closer together, shifting from a more peripheral distribution towards a more centralised one. However, Rosner and Pickering (1986, in Rosner and Pickering 1994), disproved this hypothesis by calculations of values of neutralized vowels based on a vocal-tract model and their comparison with the observed values. Rather than from articulatory neutralization does the vowel formant variation result from assimilation to their immediate context (this conclusion is in compliance with Lindblom's observations on Swedish made in 1963, in Rosner and Pickering 1994). In terms of production, the three main articulatory gestures (location of the constriction, constriction size, size of the mouth aperture) together with the momentary vocal tract length (as a function of larynx lowering and lip protrusion) characteristic of a vowel in null environment (produced isolated) interact with the gestures for the surrounding consonants. However, only incidentally does this interaction produce /ə/.

In her 1962 study, Borovičková found that Czech vowels vary greatly with various contexts as well as their syllable position. Nevertheless, she doesn't draw any general conclusions for different environments from her data, which she admits are too limited for such task. According to Borovičková a Maláč (1967) it is mainly F2 that is influenced by the place of articulation of the neighbouring consonants. Jašová (2001) analysed only the effects of plosives on the Czech vowels. She discovered that F2 of vowels is influenced most by labials (it is lower than the average) and palatals (F2 significantly higher than the average). Velar and alveolar stops change the F2 to a lesser extent.

In 1963 Stevens and House carried out an analysis of American vowels produced in different consonantal environments (except for rhotic, nasal and approximant context). The individual vowels were set in pseudowords of the form /hə'CVC/. Rosner and Pickering (1994) converted the formant values into ERB (formant auditory unit). Their graph reveals that different consonantal environments affect E(F1) and E(F2) for the various vowels somewhat differently, nevertheless, the trends are similar for all environments. In the region of low vowels the study produced the following results: consonants with different place of constriction cause a dramatic fall in E(F1) for /ʌ/, whilst E(F1) of /ɑ/ barely changes. For /æ/ the downward effect on E(F1) of the surrounding consonants differing in place of articulation seems to be small, the velar environment triggering the lowest average value. /æ/ gained lower E(F2) values for all the three contexts, labial having the most noticeable influence. In /ʌ/, velar environment had no effect on E(F2), whilst postdental context generated higher and labial lower values. All those contexts seemed to have an upward effect on E(F2) of /ɑ/ (in the following order from smallest to highest: labial, velar and postdental). Nonetheless, Rosner and Pickering reported that these changes are rather unimpressive and very likely unnoticeable by listeners.

Consonants with different manner of articulation had almost no effect on E(F2) of /ʌ/. Voiced and plosive environment shift /ʌ/ closest to the central region. /æ/ gains a slightly higher and backer position in all the four contexts, yet the shifts caused by voiced and fricative consonants are greater. /ɑ/ retains its E(F1) on the same level throughout the four environments, the E(F2) values increased compared to the value in the null environment.

In their 1966 study on the influence of fricatives, affricates and stops on adjacent vowels, Stevens, House and Paul (Rosner and Pickering, 1994) report that deviations in F2 from null values (measured in null environment: average of /hə'hVd/ or /#V#/ productions by their speakers) were larger for high than for low vowels. The deviations were negative for front and positive for back vowels. Stop consonants caused F2 deviations that ranged from –100 to +100 Hz, with fricatives the range went from –280 to almost +400 Hz. Consonantal environment tended to increase bandwidths of the first three formants, but usually caused minor changes to centre F3 frequency.

Rosner and Pickering (1994) compared several other studies to derive the following: the location of constriction of vowels is sensitive to different consonantal environments, particularly for the high back vowels, i.e., the low vowels are less influenced by their consonantal context than some of the other vowels. Besides that, lax vowels coarticulate more readily with the surrounding context than do tense vowels. The centre frequency of F2 (the author probably meant the average frequency of the formant region) is generally more susceptible to coarticulatory changes, particularly to shifts in constriction location, than the centre frequency of F1.

One group of sounds has so far been neglected in our overview of coarticulatory effects in vowels. It is a group of sonorants, the most significant among them being nasal consonants. Nasalized vowels are characterised by a resonance component in the area of around 250 Hz, which is lower than F1 of an oral vowel realized in the same way. Besides that, the usual F1 frequency is damped by antiresonance, F2 or F3 frequencies are moved higher (Palková, 1997). Another source (Stevens 1985, in Rosner and Pickering 1994, p. 179) provides a graph clearly showing that the first formant of nasalised vowels is higher rather than lower than F1 of the corresponding oral vowel. The same influence was observed by Hála (1941, p. 242) in the Czech /aː/, which reached higher F1 and lower F2 values in nasalised context than it did in oral context. No matter which direction F1 under the influence of a nasal takes, the resulting nasalised vowel spectrum does differ from the spectrum of its purely oral counterpart.

### 10.3 Summary

In summary, we can study vowel formant frequency variation in individual speakers or in groups of individuals. Several factors have been observed which affect vowels' spectra to various extent. All the factors taken into consideration in the previous sections are, as a rule, speaker, language and speaking context dependent, so it is impossible, in some cases, to state the general principles of variation (e.g., the effects of speech rate and stress).

Speech register, speech rate, duration and stress often play important part in reduction of vowel contrast. Certain factors tend to trigger more notable changes in one formant than in the other of the first two. Namely, whispered vowels have F1 more affected than F2 (or F3). On the other hand, speech rate and coarticulation seem to cause greater variation in F2. Further, we could see that vowels are more resistant to context differing in manner of articulation than in place of articulation. Deviations in F2 from null values tend to be negative for front and positive for back vowels. Fricatives seem to affect F2 of vowels more than twice as much as stops. Each vowel is influenced differently by the same environment. Low vowels become affected less than some other vowels, particularly high-back vowels.

## 11. The present study

The theoretical part of the study provided a general background for our investigation. First of all, it defined the position of Standard British English among a representative group of world languages with regard to vowel system universals. Further, it gave a description of the English low vowels and outlined major trends in the development of the Standard British English low-vowel region as recorded in previous research. These two sections gave rise to the terminology used throughout this study. Besides phonotactic possibilities and a brief outline of historical development of the English low vowels, the first part also deals with the issue of vowel variation, specifically regional, between-speaker and within-speaker variation.

The material for the present analysis was adopted from approximately three-minute recordings of news read by twenty male BBC announcers. The investigated parameters in each vowel item included the first three formant frequencies and their bandwidths, fundamental frequency and duration. These parameters were used to investigate the low vowels from three different perspectives:

i. low vowels generally
ii. low vowels in individual speakers
iii. low vowels differing in place and manner of articulation of their immediate context.

The first part of the analysis yielded the mean values, the regions the low vowels occupy in the vowel space, and data on variability along with distribution of each of the four low vowels. The results were subsequently compared with those from previous studies. Concerning the individual speakers analysis, the aim was to discover how the individual speakers' low vowels differ and whether there are any traceable patterns of behaviour among the four low vowels within the speakers' low-vowel regions. Finally, the investigation of low vowels differing in their immediate context was carried out to reveal whether and how different contexts affect the low vowel formant frequencies in connected speech.

## 12. Material and method

### 12.1 Selection of items

For the research twenty male professional BBC news announcers from the Institute of Phonetics' BBC Corpus (created at Charles University in Prague) were selected. Since they are all experienced speakers it is quite reasonable to assume that they avoid negligent pronunciation in their speech and present the texts in a natural way. To support this assumption it can be said that in the past BBC English (one of a number of British accents also referred to as British Received Pronunciation) served as a "model pronunciation" (especially for teachers of English) and to a certain degree it has kept its status until the present day (cf. section 9.1.1 above).

Approximately three minutes long recordings of world news presented by each of the speakers were made between years 2000 and 2002. These audio recordings were transcribed in phonemic transcription, i.e., the text was transcribed in accord with the pronunciation given in the lexicon, which is considered as the standard. The type of transcription used does not note phonetic subtleties and deviations from the standard such as different degree of openness, etc., but it reflects allophonic changes - where weak form is accepted as standard and is realised so, it is transcribed as reduced. The transcribed texts as well as the recordings of these texts are available in Appendix.

All items in our list of the English low vowels were chosen according to the transcription. In case a doubt arose concerning a transcription symbol used for a particular sound (transcriber's mistake might have appeared) the case was reexamined and if necessary the word in question was shifted into the correct group of items.

### 12.1.1 Selection of items for measurements and descriptive statistics

On the whole, the transcribed texts yielded 2223 items that became the subject of our analysis. (The figure would be even higher if words that were not articulated clearly or happened to be only partially pronounced or were classified as infrequent acronyms were included.) Tables 12.1.1.1 below give the numbers of all items of each of the phonemes in question provided by the twenty transcribed texts. Not all of these items appeared to suit our survey in many respects. In order to obtain the appropriate items we set up five criteria that had to be fulfilled: the vowel in an appropriate item was not allowed to be a result of levelling, it had to be stressed and accented; furthermore, it had to be a lexical, fully established English word providing complete and relevant data (see below for the definitions). In compliance with these we excluded items which

1. were result of monophthongization of the phonetic sequence [aʊə] > [ɑː] as in *our, hour*
2. were function words
3. were non-English
4. were unstressed/unaccented
5. had incomplete (or irrelevant) data of measurement

The criteria were always applied in a fixed order, as a result of which each item occupies only one category corresponding to the first unfulfilled condition, which is reflected in the overview tables (Tables 12.1.1.1).

There were altogether 16 tokens which did not satisfy condition no. 1. Cases of monophthongization were identified in two words, *hour* and *our*, both from the open back vowel list. Although the latter might be a proper contributor to the formant statistics since its monophthongized form is recognized as an optional RP realization, the varying degree of the transition to a monophthong could give rise to unreliable results.

Function words created the largest group of all the excluded items (380 out of 836 items) followed by non-English words (n = 324). Among these we counted words, names (including second names) and abbreviations which are considered as non-established among speakers of English. Interestingly, the number of non-English words transcribed as either the open-mid front or the open back vowel exceeded one third of excluded items in each of these groups.

Only words carrying stress and accent at the same time could enter into the appropriate items domain. 158 words emerged which did not fulfil this criterion.
If an item was not removed from the list on the grounds that it possessed any of the features from 1 to 4, it underwent measuring. Completeness (that is all the investigated parameters of the individual items had to acquire some value) involving also consideration of relevance of data (that is intuitively judged reasonability of formant measurement, i.e., if a measured formant frequency was considered as either exceedingly high or low, it was a sound candidate for exclusion) was the last component of the selection stage. The accomplishment of the measurement depended largely on the vowel quality and the software used for this purpose. The rates of items excluded on the basis of incompleteness indicate that the open back vowel (30 items incomplete) posed the greatest difficulties in this respect.

**Tables 12.1.1.1** General statistics for individual speakers capturing the results of the appropriate items selection process

**Front open-mid**

| Speaker | Appropriate items | Word-initial | ʔ- | V- | Excluded items | Function words | Non-English | Unstressed/ Unaccented | Incomplete items |
|---|---|---|---|---|---|---|---|---|---|
| AS | 21 | 6 | 1 | 0 | 14 | 4 | 8 | 2 | 0 |
| CC | 31 | 4 | 2 | 0 | 34 | 11 | 18 | 2 | 3 |
| DJ | 17 | 4 | 2 | 0 | 8 | 2 | 5 | 0 | 1 |
| DL | 13 | 1 | 1 | 0 | 7 | 3 | 4 | 0 | 0 |
| DR | 18 | 0 | 0 | 0 | 12 | 7 | 3 | 2 | 0 |
| ED | 32 | 9 | 6 | 0 | 18 | 1 | 11 | 5 | 1 |
| FL | 23 | 4 | 3 | 1 | 14 | 5 | 6 | 2 | 1 |
| GF | 33 | 0 | 0 | 4 | 13 | 8 | 3 | 2 | 0 |
| JI | 27 | 3 | 2 | 0 | 16 | 7 | 5 | 4 | 0 |
| JL | 26 | 7 | 4 | 0 | 19 | 9 | 4 | 3 | 3 |
| JS | 14 | 2 | 0 | 0 | 13 | 4 | 8 | 1 | 0 |
| JSh | 18 | 2 | 0 | 1 | 22 | 18 | 1 | 3 | 0 |
| MP | 19 | 3 | 3 | 0 | 25 | 10 | 9 | 6 | 0 |
| NK | 16 | 2 | 1 | 0 | 16 | 4 | 10 | 2 | 0 |
| PJ | 26 | 4 | 4 | 0 | 18 | 5 | 5 | 6 | 2 |
| RC | 23 | 4 | 4 | 0 | 19 | 4 | 10 | 1 | 4 |
| RH | 27 | 4 | 2 | 1 | 12 | 4 | 6 | 2 | 0 |
| RL | 11 | 2 | 1 | 0 | 19 | 9 | 3 | 4 | 3 |
| RM | 21 | 3 | 2 | 0 | 15 | 6 | 6 | 3 | 0 |
| SM | 19 | 3 | 1 | 0 | 26 | 9 | 12 | 5 | 0 |
| Total | 435 | 67 | 39 | 7 | 340 | 130 | 137 | 55 | 18 |

**Central open-mid**

| Speaker | Appropriate items | Word-initial | ʔ- | V- | Excluded items | Function word | Non-English | Unstressed/ Unaccented | Incomplete items |
|---|---|---|---|---|---|---|---|---|---|
| AS | 10 | 0 | 0 | 0 | 9 | 5 | 2 | 2 | 0 |
| CC | 15 | 0 | 0 | 0 | 8 | 2 | 0 | 4 | 2 |
| DJ | 14 | 0 | 0 | 0 | 3 | 3 | 0 | 0 | 0 |
| DL | 22 | 2 | 1 | 0 | 5 | 3 | 0 | 2 | 0 |
| DR | 21 | 1 | 0 | 0 | 7 | 5 | 0 | 1 | 1 |
| ED | 17 | 0 | 0 | 0 | 8 | 5 | 1 | 2 | 0 |
| FL | 26 | 1 | 1 | 0 | 10 | 0 | 1 | 7 | 2 |
| GF | 22 | 3 | 2 | 1 | 3 | 2 | 0 | 0 | 1 |
| JI | 14 | 3 | 3 | 0 | 4 | 1 | 0 | 3 | 0 |
| JL | 19 | 1 | 1 | 0 | 8 | 3 | 0 | 5 | 0 |
| JS | 13 | 1 | 1 | 0 | 5 | 1 | 3 | 1 | 0 |
| JSh | 17 | 3 | 1 | 1 | 5 | 2 | 1 | 2 | 0 |
| MP | 19 | 3 | 1 | 0 | 4 | 1 | 0 | 3 | 0 |
| NK | 23 | 0 | 0 | 0 | 12 | 5 | 3 | 4 | 0 |
| PJ | 22 | 1 | 1 | 0 | 7 | 4 | 0 | 2 | 1 |
| RC | 7 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 1 |
| RH | 12 | 0 | 0 | 0 | 3 | 1 | 2 | 0 | 0 |
| RL | 19 | 2 | 2 | 0 | 3 | 2 | 0 | 1 | 0 |
| RM | 18 | 1 | 1 | 0 | 2 | 0 | 0 | 2 | 0 |
| SM | 20 | 0 | 0 | 0 | 15 | 4 | 7 | 4 | 0 |
| Total | 350 | 22 | 15 | 2 | 123 | 49 | 20 | 46 | 8 |

**Back open**

| Speaker | Appropriate items | Word-initial | ʔ- | V- | Excluded items | Function word | Non-English | Unstressed/ Unaccented | Incomplete items | Mono-phthon-gised |
|---|---|---|---|---|---|---|---|---|---|---|
| AS | 18 | 2 | 1 | 1 | 22 | 4 | 14 | 2 | 0 | 2 |
| CC | 13 | 2 | 1 | 0 | 12 | 5 | 6 | 1 | 0 | 0 |
| DJ | 13 | 3 | 2 | 1 | 5 | 1 | 3 | 0 | 0 | 1 |
| DL | 11 | 3 | 2 | 0 | 6 | 2 | 4 | 0 | 0 | 0 |
| DR | 17 | 1 | 0 | 0 | 10 | 0 | 7 | 3 | 0 | 0 |
| ED | 16 | 0 | 0 | 0 | 12 | 3 | 7 | 1 | 0 | 1 |
| FL | 21 | 3 | 1 | 1 | 7 | 0 | 4 | 2 | 0 | 1 |
| GF | 8 | 3 | 1 | 0 | 9 | 3 | 3 | 2 | 0 | 1 |
| JI | 16 | 0 | 0 | 0 | 12 | 3 | 7 | 2 | 0 | 0 |
| JL | 16 | 1 | 1 | 0 | 5 | 1 | 1 | 2 | 0 | 1 |
| JS | 11 | 1 | 1 | 0 | 10 | 4 | 5 | 1 | 0 | 0 |
| JSh | 14 | 1 | 0 | 1 | 8 | 1 | 4 | 3 | 0 | 0 |
| MP | 20 | 2 | 0 | 2 | 6 | 1 | 3 | 1 | 1 | 0 |
| NK | 22 | 5 | 4 | 0 | 14 | 2 | 9 | 2 | 0 | 1 |
| PJ | 11 | 4 | 4 | 0 | 12 | 2 | 7 | 2 | 0 | 1 |
| RC | 6 | 1 | 0 | 0 | 6 | 1 | 2 | 0 | 1 | 2 |
| RH | 18 | 2 | 1 | 0 | 8 | 2 | 4 | 0 | 0 | 2 |
| RL | 17 | 1 | 0 | 0 | 8 | 1 | 5 | 0 | 0 | 2 |
| RM | 9 | 1 | 1 | 0 | 15 | 1 | 12 | 1 | 0 | 1 |
| SM | 14 | 0 | 0 | 0 | 6 | 0 | 4 | 2 | 0 | 0 |
| Total | 291 | 36 | 20 | 6 | 193 | 37 | 111 | 27 | 2 | 16 |

**Back open-mid**

| Speaker | Appropriate items | Word-initial | ʔ- | V- | Excluded items | Function word | Non-English | Unstressed/ Unaccented | Incomplete items |
|---|---|---|---|---|---|---|---|---|---|
| AS | 20 | 1 | 0 | 1 | 8 | 8 | 0 | 0 | 0 |
| CC | 14 | 1 | 0 | 0 | 12 | 7 | 2 | 0 | 3 |
| DJ | 21 | 1 | 0 | 1 | 15 | 8 | 1 | 3 | 3 |
| DL | 18 | 1 | 1 | 0 | 11 | 5 | 5 | 1 | 0 |
| DR | 25 | 3 | 0 | 2 | 21 | 15 | 2 | 2 | 2 |
| ED | 11 | 1 | 0 | 0 | 8 | 6 | 2 | 0 | 0 |
| FL | 13 | 1 | 0 | 1 | 12 | 8 | 0 | 2 | 2 |
| GF | 15 | 2 | 1 | 1 | 18 | 10 | 2 | 2 | 4 |
| JI | 13 | 1 | 1 | 0 | 12 | 8 | 2 | 2 | 0 |
| JL | 13 | 1 | 0 | 1 | 10 | 6 | 0 | 3 | 1 |
| JS | 14 | 0 | 0 | 0 | 12 | 7 | 4 | 1 | 0 |
| JSh | 13 | 1 | 0 | 0 | 17 | 12 | 1 | 3 | 1 |
| MP | 20 | 0 | 0 | 0 | 17 | 8 | 7 | 2 | 0 |
| NK | 10 | 2 | 1 | 1 | 14 | 8 | 5 | 1 | 0 |
| PJ | 14 | 0 | 0 | 0 | 24 | 12 | 2 | 2 | 8 |
| RC | 11 | 1 | 0 | 0 | 15 | 7 | 4 | 1 | 3 |
| RH | 22 | 5 | 2 | 0 | 14 | 7 | 4 | 1 | 2 |
| RL | 14 | 3 | 0 | 1 | 15 | 8 | 6 | 1 | 0 |
| RM | 13 | 0 | 0 | 0 | 16 | 9 | 4 | 2 | 1 |
| SM | 17 | 1 | 0 | 0 | 9 | 5 | 3 | 1 | 0 |
| Total | 311 | 26 | 6 | 9 | 280 | 164 | 56 | 30 | 30 |

After carrying out the five-step selection we obtained a list of 435 appropriate items of /æ/, 350 of /ʌ/, 291 of /ɑː/ and 311 of /ɒ/.

### 12.2 The number of items provided by individual speakers

The number of appropriate items of the open-mid front vowel ranges between 11 in the text by speaker labelled RL and 33 by speaker GF. The mean is 21.75 items per speaker.

Speaker RC presents us with the smallest group of the open-mid central vowel containing only 7 items, whereas speaker FL has 26 items. The mean is 17.5.

The list of back open vowel items appropriate for measuring contains between 6 (speaker RC) and 22 (speaker NK) items with the lowest mean value 14.55 items per speaker.

The smallest number of the open-mid back vowel is 10 in the repertoire of speaker NK. In contrast to that, speaker DR occupies the first place with 25 items. This time the average number of items equals 15.55.

### 12.3 Method of analysis

Each item was edited and saved separately (to hear them refer to Appendix). The formant values were measured from three central steady-state periods (although exceptionally an off-centre value had to be taken) using Praat software (version 4.0.26, Paul Boersma and David Weenink, Summer Institute of Linguistics) with a default setting. If either F0 or F1 did not appear, the maximum formant setting was altered within the range of 4000 – 5500 Hz. However, it should be noted that with the formant settings ranging between 4000 – 4400 Hz F1 and F3 appeared significantly lower - especially in the case of the back open-mid vowel. In eighteen, eight, sixteen and thirty cases of the front open-mid, central open-mid, back open and back open-mid vowel, respectively, manipulation with the parameter did not help produce any reasonable data and those items had to be eliminated as incomplete (items selection criterion no. 5). Two back open vowels allowed for their formant values to be read visually.

The formant frequencies of 77 sounds had to be taken from one or two periods only owing to improper display of the formants. The number of items measured in this way varies with the vowel quality: front open-mid v. = 3, central open-mid v. = 26, back open v. = 15 and back open-mid v. = 33. These numbers indicate that the open-mid central and the open-mid back vowels posed the biggest problems with measuring.

Vowel duration was also measured, but since we will be concerned mainly with the formant structure of the four vowels in various contexts, these data as well as the bandwidths and F0 will not be worked with and can serve as a starting point to further research.

### 12.3.1 Classification of items

There are four groups of items corresponding to the number of low vowels in English, which are subdivided into groups according to the individual speakers (IndiS). Each speaker was allotted one table consisting of a column specifying the position of the item in the text (BG = breath group) for quick identification, information concerning lexical stress and accent, the context of the vowel item, duration, F0 frequency and values of the first three formants along with their bandwidths. The environment of each measured vowel is captured in fourteen columns and the parameters are filled in on binary basis.

The first three columns provided for the sounds initially positioned, labelled as 'word-initial'. The next step was to investigate whether such sound appeared after a pause (marked 'after p') or a glottal stop (marked 'ʔ-'). In the end, it appeared unnecessary to set up the 'after p' category since not one item fitted in. All word-initial items were preceded either by a glottal stop or a vowel or a consonant sound. (For example, the item 'Alex' in the context of *with Alex Sabin* (BG = AS 01-01-01) is realized with the preposition *with* as 'one word'. It contains an open-mid front vowel in an initial position and is therefore marked 'word-i' = 1, 'ʔ-' = 0, 'V-' = 0.) Altogether, our sample includes 151 items (the open-mid front vowel winning the largest share of 67 such words) beginning with the measured sound. Nearly half of them (exactly 80) are preceded by a glottal stop.

If a measured sound immediately followed a vowel, regardless of the position it occurred in, it was recorded by a '1' in the 'V-' column. As for the remaining ten columns, five parametres were devised for each adjacent sound (preceding and following): obstruent voiceless and sonorant - noting the manner of articulation (obstruent voiced sounds were marked by zeros in both obstruent voiceless and sonorant category, i.e., it does not have its own column), and labial, coronal and velar marking the place of articulation. The category of obstruent stands for speech sounds where the passage of the air from the lungs is obstructed in some way. Sonorants include sounds with a relatively free passage of air (vowels, approximants and nasals).

Glottal stop was treated as a voiceless obstruent, since there would not be enough material to give objective results if the items containing this sound were listed so as to form separate groups. The parameter labial subsumes sounds labelled as labial and labiodental in the IPA table of consonants, the category of coronals contains sounds pronounced between the dental and palatal areas (including dental and palatal), the rest fall within the group of velars. Only the sound /w/ received two marks – labial and velar – at the same time. All the tables which resulted from the analyses described in sections 12.3 and 12.3.1 are available in Appendix.

### 12.3.2 Description of the context groups

Apart from the division of all items into groups according to individual speakers, the groups of the four sounds, labelled as has been outlined in the previous section, were further clustered into groups according to place and manner of articulation. This process resulted in nine groups according to manner of articulation (gr. 1–9) for each sound listed in Table 12.3.2.1 (a).

**Tables 12.3.2.1 (a)** The nine groups according to manner of articulation as they appear in our sample. (Abbreviations: o vcd = voiced obstruent , o vls = voiceless obstruent, son = sonorant, V = vowel sound). **12.3.2.1 (b)** The eleven groups according to place of articulation as they appear in our sample. (Abbreviations: lab = labial, cor = coronal, vel = velar, V = vowel sound).

| **a.** Gr. No. | Type |
|---|---|
| 1 | o vcd-V-o vcd |
| 2 | o vcd-V-o vls |
| 3 | o vcd-V-son |
| 4 | o vls-V-o vcd |
| 5 | o vls-V-o vls |
| 6 | o vls-V-son |
| 7 | son-V-o vcd |
| 8 | son-V-o vls |
| 9 | son-V-son |

| **b.** Gr. No. | Type |
|---|---|
| I | lab-V-lab |
| II | lab-V-cor |
| III | lab-V-vel |
| IV | cor-V-lab |
| V | cor-V-cor |
| VI | cor-V-vel |
| VII | vel-V-lab |
| VIII | vel-V-cor |
| IX | vel-V-vel |
| X | lab+vel-V-cor |
| XI | cor-V-lab+vel |

The environment groups according to place of articulation are different for each vowel: except for the open-mid central vowel they all possess the first nine groups, the open-mid front vowel being restricted only to those. Also the open-mid central vowel has 9 classes, but it is due to the lab+vel-V-cor group (gr. X), which replaces the vel-V-vel environment (gr. IX). The open-mid back vowel presents a merger of both, i.e., it splits into 10 groups: the 9 'standard' groups plus lab+vel-V-cor. Finally, in one case the back open sound occurs between a coronal and a labio-velar sound. It is a rarity in the form of the country name *Malawi*. The list of the context combinations based on place of articulation that appeared in our sample is given in Table 12.3.2.1 (b) above.

Tables 12.3.2.2 below show the numerical distribution of each vowel across the groups defined by both place and manner of articulation. Hence we know, for example, that there are only 10 front open-mid vowels in the fully labial environment (gr. I): 6 of them are preceded by a voiced obstruent, 4 of them belong to gr. 4 (o vls-V-son), but none occurs immediately after a sonorant sound. As a rule, those groups which were pointed out as insufficiently represented gather items from less than five of the nine possible groups according to manner of articulation.

**Tables 12.3.2.2** The number of items of each low vowel in a given context

| **Front open-mid** | lab- -lab | lab- -cor | lab- -vel | cor- -lab | cor- -cor | cor- -vel | vel- -lab | vel- -cor | vel- -vel | total |
|---|---|---|---|---|---|---|---|---|---|---|
| o vcd- -o vcd | **3** | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 5 |
| o vcd- -o vls | 2 | 4 | **6** | 2 | 0 | 3 | 0 | 1 | 0 | 18 |
| o vcd- -son | 1 | 19 | 16 | 4 | 10 | 1 | 0 | **21** | 0 | 72 |
| o vls- -o vcd | 0 | 0 | 0 | 1 | 0 | 0 | 6 | **9** | 0 | 16 |
| o vls- -o vls | 0 | 11 | 7 | 2 | 6 | 17 | **34** | 7 | 8 | 92 |
| o vls- -son | 4 | **43** | 0 | 0 | 16 | 2 | 6 | 38 | 0 | 109 |
| son- -o vcd | 0 | 0 | 0 | **4** | 4 | 0 | 0 | 0 | 0 | 8 |
| son- -o vls | 0 | 7 | 2 | 11 | **25** | 11 | 0 | 0 | 0 | 56 |
| son- -son | 0 | 10 | 0 | 6 | **35** | 4 | 0 | 4 | 0 | 59 |
| total | 10 | 95 | 31 | 30 | 96 | 38 | 46 | 81 | 8 | 435 |

| **Central open-mid** | lab- -lab | lab- -cor | lab- -vel | cor- -lab | cor- -cor | cor- -vel | vel- -lab | vel- -cor | lab+vel- -cor | total |
|---|---|---|---|---|---|---|---|---|---|---|
| o vcd- -o vcd | 0 | 1 | 0 | 3 | 3 | 1 | 57 | 0 | | 65 |
| o vcd- -o vls | 1 | 1 | 0 | 0 | 11 | 4 | 0 | 0 | | 17 |
| o vcd- -son | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 7 | | 11 |
| o vls- -o vcd | 7 | 0 | 0 | 2 | 7 | 0 | 6 | 12 | | 34 |
| o vls- -o vls | 0 | 0 | 0 | 4 | 5 | 0 | 2 | 6 | | 17 |
| o vls- -son | 0 | 5 | 0 | 8 | 4 | 0 | 9 | 51 | | 77 |
| son- -o vcd | 0 | 1 | 3 | 0 | 9 | 7 | 0 | 0 | | 20 |
| son- -o vls | 0 | 4 | 0 | 7 | 4 | 11 | 2 | 0 | | 28 |
| son- -son | 0 | 21 | 0 | 10 | 24 | 1 | 0 | 0 | 25 | 81 |
| total | 8 | 33 | 3 | 34 | 71 | 24 | 76 | 76 | 25 | 350 |

| **Back open** | lab- -lab | lab- -cor | lab- -vel | cor- -lab | cor- -cor | cor- -vel | vel- -lab | vel- -cor | vel- -vel | cor- -lab+vel | total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| o vcd- -o vcd | 13 | 5 | 2 | 0 | 0 | 0 | 0 | 5 | 0 | | 25 |
| o vcd- -o vls | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | | 2 |
| o vcd- -son | 0 | 5 | 0 | 0 | 3 | 0 | 0 | 1 | 0 | | 9 |
| o vls- -o vcd | 1 | 3 | 0 | 0 | 14 | 2 | 2 | 12 | 1 | | 35 |
| o vls- -o vls | 0 | 41 | 29 | 3 | 4 | 0 | 5 | 4 | 2 | | 88 |
| o vls- -son | 2 | 15 | 0 | 2 | 30 | 0 | 8 | 1 | 0 | | 58 |
| son- -o vcd | 0 | 1 | 0 | 5 | 7 | 0 | 0 | 1 | 0 | 0 | 14 |
| son- -o vls | 0 | 2 | 10 | 1 | 16 | 2 | 0 | 0 | 0 | 0 | 31 |
| son- -son | 0 | 6 | 0 | 4 | 18 | 0 | 0 | 0 | 0 | 1 | 29 |
| total | 16 | 78 | 41 | 15 | 93 | 4 | 15 | 25 | 3 | 1 | 291 |

| **Back open-mid** | lab- -lab | lab- -cor | lab- -vel | cor- -lab | cor- -cor | cor- -vel | vel- -lab | vel- -cor | vel- -vel | lab+vel- -cor | total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| o vcd- -o vcd | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | | 2 |
| o vcd- -o vls | 0 | 2 | 0 | 2 | 0 | 6 | 0 | 0 | 0 | | 10 |
| o vcd- -son | 5 | 3 | 0 | 0 | 25 | 0 | 0 | 1 | 0 | | 34 |
| o vls- -o vcd | 1 | 2 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | | 5 |
| o vls- -o vls | 6 | 2 | 2 | 6 | 5 | 3 | 5 | 2 | 1 | | 32 |
| o vls- -son | 0 | 48 | 0 | 0 | 10 | 0 | 8 | 37 | 6 | | 109 |
| son- -o vcd | 0 | 2 | 0 | 12 | 3 | 0 | 0 | 0 | 0 | 1 | 18 |
| son- -o vls | 0 | 0 | 2 | 16 | 14 | 7 | 2 | 0 | 0 | 17 | 58 |
| son- -son | 0 | 5 | 0 | 14 | 7 | 10 | 0 | 0 | 0 | 7 | 43 |
| total | 12 | 65 | 4 | 52 | 64 | 26 | 16 | 40 | 7 | 25 | 311 |

### 12.3.2.1 Context groups according to manner of articulation

Tables 12.3.2.1.1-4 give the specifications of the vowel environment realizations, where each of the four vowels has nine tables corresponding to the number of groups according to manner of articulation (see Table 12.3.2.1a above).

/æ/

Table 12.3.2.1.1 shows that gr. 6 (o vls-V-son) comprises more than a third of the whole sample, exactly 109 items, of the open-mid front vowel. Thirty-five is the number of /æ/s between /p/ and /l/, the most frequent context of this vowel. It is followed by twenty-one and eighteen items of /æ/ in the contexts /g/-/n/ (gr. 3) and /l/-/n/ (gr. 9), respectively. It is worth noticing that all these three groups, which amount to 240 items, have a sonorant in the left context. The open-mid front vowel appears in the environment of two voiceless obstruents in 92 cases - most often between /k/-/p/ (n=17). Groups 1 and 7 are fairly poorly represented, the first comprising only 5 and the latter 8 items. The items classed in gr. 5 and gr. 6 equally boast 20 different environment realizations.

**Tables 12.3.2.1.1** The specifications of the environment realizations of the front open-mid vowel /æ/

| Gr. 1 o vcd-/æ/-o vcd | |
|---|---|
| b-b | 3 |
| b-d | 1 |
| g-ð | 1 |
| total | 5 |

| Gr. 2 o vcd-/æ/-o vls | |
|---|---|
| b-k | 5 |
| b-s | 1 |
| b-t | 2 |
| b-tʃ | 1 |
| d-k | 2 |
| dʒ-k | 1 |
| dʒ-p | 2 |
| g-s | 1 |
| v-f | 2 |
| v-k | 1 |
| total | 18 |

| Gr. 3 o vcd-/æ/-son | |
|---|---|
| b-n | 13 |
| b-ŋ | 15 |
| b-r | 2 |
| ð-l | 1 |
| d-l | 1 |
| d-m | 1 |
| d-n | 7 |
| g-n | 21 |
| v-l | 3 |
| v-m | 1 |
| v-n | 1 |
| v-ŋ | 1 |
| z-m | 3 |
| z-ŋ | 1 |
| z-n | 1 |
| total | 72 |

| Gr. 4 o vls-/æ/-o vcd | |
|---|---|
| h-d | 4 |
| h-z | 2 |
| k-b | 4 |
| k-v | 2 |
| t-b | 1 |
| ʔ-d | 3 |
| total | 16 |

| Gr. 5 o vls-/æ/-o vls | |
|---|---|
| f-k | 4 |
| f-ʃ | 1 |
| h-p | 3 |
| k-p | 17 |
| k-s | 3 |
| k-ʃ | 2 |
| k-tʃ | 1 |
| p-k | 3 |
| p-s | 6 |
| p-t | 4 |
| s-t | 3 |
| s-s | 2 |
| s-k | 1 |
| θ-f | 1 |
| t-f | 1 |
| t-t | 1 |
| t-k | 16 |
| ʔ-f | 14 |
| ʔ-θ | 1 |
| ʔ-k | 8 |
| total | 92 |

| Gr. 6 o vls-/æ/-son | |
|---|---|
| f-m | 4 |
| h-n | 4 |
| h-r | 1 |
| k-m | 6 |
| k-n | 11 |
| k-r | 11 |
| p-l | 35 |
| p-n | 7 |
| p-r | 2 |
| s-l | 1 |
| s-n | 2 |
| s-ŋ | 1 |
| t-l | 5 |
| t-n | 6 |
| tʃ-l | 1 |
| tʃ-n | 1 |
| ʔ-l | 2 |
| ʔ-n | 5 |
| ʔ-r | 4 |
| total | 109 |

| Gr. 7 son-/æ/-o vcd | |
|---|---|
| i:-d | 1 |
| n-d | 1 |
| r-d | 1 |
| r-dʒ | 1 |
| r-v | 4 |
| total | 8 |

| Gr. 8 son-/æ/-o vls | |
|---|---|
| i-k | 3 |
| l-k | 1 |
| l-p | 5 |
| l-s | 1 |
| l-ʃ | 3 |
| m-k | 2 |
| m-s | 3 |
| m-t | 4 |
| n-f | 2 |
| n-k | 3 |
| n-ʃ | 16 |
| r-f | 4 |
| r-k | 4 |
| r-ʃ | 1 |
| r-t | 4 |
| total | 56 |

| Gr. 9 son-/æ/-son | |
|---|---|
| l-m | 3 |
| l-n | 18 |
| l-r | 1 |
| l-ŋ | 2 |
| m-n | 10 |
| n-m | 3 |
| n-l | 2 |
| n-n | 5 |
| n-r | 2 |
| r-l | 2 |
| r-n | 5 |
| r-ŋ | 2 |
| ʊ-n | 4 |
| total | 59 |

/ʌ/

The distribution of the open-mid central vowel resembles that of the open-mid front vowel with respect to the largest number of items found in the immediate vicinity of a sonorant sound (n=217). Exactly 81 instances of /ʌ/ occurred in a fully sonorant context. Out of these 24 were between /w/-/n/ mainly due to the word *one*, twenty times the open-mid central vowel was surrounded by /l/-/n/ as in *London* and the same number of /ʌ/s was preceded by /m/ and followed by /n/ as in words *month* or *money*. Similarly to the open-mid front vowel, gr. 6 (o vls-V-son) reaches a fairly high number, exactly 77 items. This group is followed by 65 items of /ʌ/ between two voiced obstruent sounds which can be best exemplified by the word *government*. The number of items from gr. 3 (o vcd-V-son), the most poorly represented group, comprises as few as 11 items. (For more details see Tables 12.3.2.1.2.).

**Tables 12.3.2.1.2** The specifications of the environment realizations of the open-mid central vowel /ʌ/

| Gr 1. o vcd- /ʌ/-o vcd | |
|---|---|
| b-dʒ | 1 |
| d-b | 3 |
| d-g | 1 |
| dʒ-dʒ | 3 |
| g-v | 57 |
| total | 65 |

| Gr 2. o vcd-/ʌ/-o vls | |
|---|---|
| b-s | 1 |
| d-s | 2 |
| d-k | 4 |
| dʒ-s | 9 |
| v-p | 1 |
| total | 17 |

| Gr 3. o vcd-/ʌ/-son | |
|---|---|
| d-n | 2 |
| g-l | 1 |
| g-n | 6 |
| z-l | 2 |
| total | 11 |

| Gr 4. o vls-/ʌ/-o vcd | |
|---|---|
| h-d | 1 |
| k-v | 6 |
| p-b | 7 |
| s-b | 2 |
| s-ð | 7 |
| ʔ-ð | 11 |
| total | 34 |

| Gr 5. o vls-/ʌ/-o vls | |
|---|---|
| k-s | 5 |
| k-t | 1 |
| s-f | 1 |
| s-s | 3 |
| s-tʃ | 2 |
| t-f | 3 |
| ʔ-p | 2 |
| total | 17 |

| Gr 6. o vls-/ʌ/-son | |
|---|---|
| f-n | 3 |
| h-n | 11 |
| k-l | 2 |
| k-m | 9 |
| k-n | 28 |
| k-r | 8 |
| p-n | 2 |
| θ-m | 1 |
| s-m | 7 |
| s-l | 2 |
| s-n | 1 |
| t-n | 1 |
| ʔ-n | 2 |
| total | 77 |

| Gr 7. son-/ʌ/-o vcd | |
|---|---|
| l-d | 1 |
| m-d | 1 |
| m-g | 3 |
| n-ð | 8 |
| r-g | 7 |
| total | 20 |

| Gr 8. son-/ʌ/-o vls | |
|---|---|
| iː-p | 1 |
| m-s | 2 |
| m-tʃ | 2 |
| ŋ-p | 1 |
| n-f | 1 |
| n-p | 1 |
| r-k | 11 |
| r-p | 4 |
| r-ʃ | 3 |
| r-s | 1 |
| uː-p | 1 |
| total | 28 |

| Gr 9. son-/ʌ/-son | |
|---|---|
| j-ŋ | 1 |
| l-n | 20 |
| m-l | 1 |
| m-n | 20 |
| n-m | 5 |
| n-n | 1 |
| r-m | 5 |
| r-n | 3 |
| w-n | 24 |
| w-r | 1 |
| total | 81 |

### /ɑː/

Tables 12.3.2.1.3 clearly indicate that /ɑː/ is the most abundant in the environment of two voiceless obstruents making up 88 items of the 291 cases. Over one third were found in /p/-/t/ context of words such as *part*, about an equal number of /ɑː/ were identified in the name *Pakistan* or *Pakistani* – in the /p/-/k/ environment. Gr. 6 is once again the second largest containing 58 items. Groups 1, 4, 8 and 9 are very close to each other in the amount of /ɑː/s which ranges between 25 and 35. Only two words on our list (*gas* and *ask* in the string *he'd asked*) contain the open back vowel preceded by a voiced obstruent and followed by a voiceless obstruent (gr. 2).

**Tables 12.3.2.1.3** The specifications of the environment realizations of the open back vowel /ɑː/

| Gr. 1 o vcd-/ɑː/-o vcd | |
|---|---|
| b-b | 13 |
| b-d | 2 |
| b-z | 1 |
| b-g | 2 |
| g-d | 5 |
| v-dʒ | 2 |
| total | 25 |

| Gr. 2 o vcd-/ɑː/-o vls | |
|---|---|
| d-s | 1 |
| g-s | 1 |
| total | 2 |

| Gr. 3 o vcd-/ɑː/-son | |
|---|---|
| b-n | 3 |
| d-n | 3 |
| g-n | 1 |
| v-n | 2 |
| total | 9 |

| Gr. 4 o vls-/ɑː/-o vcd | |
|---|---|
| f-b | 1 |
| f-ð | 2 |
| h-b | 1 |
| h-d | 2 |
| k-b | 1 |
| k-g | 1 |
| k-z | 2 |
| p-d | 1 |
| t-g | 2 |
| tʃ-dʒ | 14 |
| ʔ-dʒ | 8 |
| total | 35 |

| Gr. 5 o vls-/ɑː/-o vls | |
|---|---|
| h-f | 4 |
| f-ʔ | 1 |
| k-t | 1 |
| k-ʔ | 1 |
| p-k | 28 |
| p-ʃ | 1 |
| p-s | 9 |
| p-t | 31 |
| t-f | 3 |
| t-θ | 1 |
| t-t | 3 |
| ʔ-θ | 1 |
| ʔ-s | 3 |
| ʔ-k | 1 |
| total | 88 |

| Gr. 6 o vls-/ɑː/-son | |
|---|---|
| f-m | 2 |
| k-l | 1 |
| k-m | 1 |
| p-l | 15 |
| ʃ-m | 1 |
| s-m | 1 |
| s-r | 1 |
| tʃ-l | 2 |
| tʃ-n | 1 |
| t-n | 26 |
| ʔ-m | 7 |
| total | 58 |

| Gr. 7 son-/ɑː/-o vcd | |
|---|---|
| iː-dʒ | 3 |
| l-dʒ | 3 |
| l-v | 5 |
| m-d | 1 |
| ŋ-dʒ | 2 |
| total | 14 |

| Gr. 8 son-/ɑː/-o vls | |
|---|---|
| iː-f | 1 |
| iː-k | 1 |
| l-s | 16 |
| m-k | 10 |
| m-tʃ | 2 |
| r-k | 1 |
| total | 31 |

| Gr. 9 son-/ɑː/-son | |
|---|---|
| iː-m | 1 |
| l-m | 1 |
| l-n | 1 |
| l-w | 1 |
| m-l | 1 |
| m-n | 5 |
| n-m | 2 |
| r-l | 1 |
| r-n | 16 |
| total | 29 |

/ɒ/

The number of /ɒ/s does not exceed two in the first environment group. Also groups 2 (n=10) and 4 (n=5) are so small in number that they are inclined to yield insignificant data in later analyses. On the other hand, the results of analyses carried out on gr. 6, which includes 109 items, can be generalised. Most frequently, i.e., in 22 words, the open-mid back vowel appears between /p/ and /n/; another 21 items of /ɒ/ can be found in words such as *conference* or *economy*. Also the numbers of items in groups 8 (son-V-o vls) and 9 (son-V-son) are not insignificant: they have 58 and 43 instances of /ɒ/, respectively. (For details see Tables 12.3.2.1.4).

**Tables 12.3.2.1.4** The specifications of the environment realizations of the open-mid back vowel /ɒ/

| Gr. 1 o vcd-/ɒ/-o vcd | |
|---|---|
| b-dʒ | 1 |
| dʒ-b | 1 |
| total | 2 |

| Gr. 2 o vcd-/ɒ/-o vls | |
|---|---|
| b-s | 2 |
| d-k | 6 |
| z-f | 2 |
| total | 10 |

| Gr. 3 o vcd-/ɒ/-son | |
|---|---|
| b-m | 5 |
| b-n | 1 |
| d-l | 8 |
| d-n | 3 |
| dʒ-n | 10 |
| dʒ-r | 2 |
| g-n | 1 |
| v-l | 2 |
| z-l | 2 |
| total | 34 |

| Gr. 4 o vls-/ɒ/-o vcd | |
|---|---|
| p-v | 1 |
| p-z | 2 |
| s-v | 1 |
| ʔ-b | 1 |
| total | 5 |

| Gr. 5 o vls-/ɒ/-o vls | |
|---|---|
| f-k | 2 |
| h-s | 1 |
| k-f | 1 |
| k-t | 1 |
| p-p | 6 |
| p-s | 2 |
| ʃ-p | 2 |
| ʃ-t | 5 |
| s-f | 1 |
| t-k | 3 |
| t-p | 3 |
| ʔ-p | 1 |
| ʔ-f | 3 |
| ʔ-k | 1 |
| total | 32 |

| Gr. 6 o vls-/ɒ/-son | |
|---|---|
| f-l | 10 |
| f-r | 6 |
| k-m | 8 |
| k-ŋ | 6 |
| k-n | 21 |
| k-r | 15 |
| p-l | 11 |
| p-n | 22 |
| θ-r | 9 |
| t-r | 1 |
| total | 109 |

| Gr. 7 son-/ɒ/-o vcd | |
|---|---|
| l-b | 1 |
| m-d | 2 |
| r-b | 9 |
| r-dʒ | 3 |
| r-v | 2 |
| w-d | 1 |
| total | 18 |

| Gr. 8 son-/ɒ/-o vls | |
|---|---|
| ɪ-f | 1 |
| ɪ-t | 1 |
| iː-p | 7 |
| l-k | 3 |
| l-p | 1 |
| l-s | 2 |
| l-t | 3 |
| m-k | 2 |
| ŋ-p | 1 |
| n-f | 2 |
| n-k | 1 |
| n-p | 2 |
| r-k | 3 |
| r-p | 3 |
| r-s | 8 |
| ʊ-p | 1 |
| w-ʃ | 17 |
| total | 58 |

| Gr. 9 son-/ɒ/-son | |
|---|---|
| l-m | 6 |
| l-ŋ | 6 |
| m-n | 4 |
| m-r | 1 |
| n-l | 2 |
| n-m | 6 |
| n-n | 2 |
| n-r | 1 |
| ɪ-l | 2 |
| r-m | 2 |
| r-ŋ | 4 |
| w-n | 7 |
| total | 43 |

#### 12.3.2.2 Context groups according to place of articulation

Examining the realization of the preceding sound, we discover that for the front open-mid and back open-mid vowels a coronal sound is the most frequently occurring, the number reaching 164 for /æ/ and 142 for /ɒ/. The open-mid central vowel most often follows a velar sound - in exactly 152 cases. The majority of items, namely, 135 instances of the back open vowel are preceded by a labial sound. The number of /ɑː/s decreases with backer position of the preceding sound. The minor group no. X includes the fewest items of the central open-mid as well as the back open-mid vowel, in either case amounting to 25.

The right-hand context is dominated by the coronal sound, which by far outnumbers the remaining sounds in all the vowel repertoires: open-mid front: n=276, open-mid central: n=205, open back: n=196 and open-mid back: n=193 items with a coronal sound on the right. Tables 12.3.2.2.1-4 below provide the specifications of the context realizations of the four low vowels with respect to the place of articulation (each set of tables relates to one of the low vowels).

/æ/

The preferred position of the front open-mid vowel is between two coronal sounds (n=99) closely followed by lab-V-cor (gr. II, n=95) and vel-V-cor context (gr. VIII, n=82). Gr. XI presents the most scarcely occupied group.

**Tables 12.3.2.2.1** The specifications of the environment realizations of the front open-mid vowel /æ/ with regard to place of articulation.

| Gr. I lab-/æ/-lab | |
|---|---|
| b-b | 3 |
| f-m | 4 |
| v-f | 2 |
| v-m | 1 |
| total | 10 |

| Gr. II lab-/æ/-cor | |
|---|---|
| b-d | 1 |
| b-n | 13 |
| b-r | 2 |
| b-s | 1 |
| b-t | 2 |
| b-tʃ | 1 |
| f-ʃ | 1 |
| m-n | 10 |
| m-s | 3 |
| m-t | 4 |
| p-l | 34 |
| p-n | 7 |
| p-r | 2 |
| p-s | 6 |
| p-t | 4 |
| v-l | 3 |
| v-n | 1 |
| total | 95 |

| Gr. III lab-/æ/-vel | |
|---|---|
| b-k | 5 |
| b-ŋ | 15 |
| f-k | 4 |
| m-k | 2 |
| p-k | 3 |
| v-k | 1 |
| v-ŋ | 1 |
| total | 31 |

| Gr. IV cor-/æ/-lab | |
|---|---|
| d-m | 1 |
| dʒ-p | 2 |
| l-m | 3 |
| l-p | 5 |
| n-f | 2 |
| n-m | 3 |
| r-f | 4 |
| r-v | 4 |
| t-b | 1 |
| t-f | 1 |
| z-m | 3 |
| θ-f | 1 |
| total | 30 |

| Gr. V cor-/æ/-cor | |
|---|---|
| d-l | 1 |
| d-n | 7 |
| l-n | 18 |
| l-r | 1 |
| l-s | 1 |
| l-ʃ | 3 |
| n-d | 1 |
| n-l | 2 |
| n-n | 5 |
| n-r | 2 |
| n-ʃ | 16 |
| r-d | 1 |
| r-dʒ | 1 |
| r-l | 2 |
| r-n | 5 |
| r-t | 4 |
| r-ʃ | 1 |
| s-l | 1 |
| s-n | 2 |
| s-s | 2 |
| s-t | 3 |
| t-l | 5 |
| t-n | 6 |
| t-t | 1 |
| tʃ-l | 1 |
| tʃ-n | 1 |
| z-n | 1 |
| ð-l | 1 |
| ɨ-d | 1 |
| total | 96 |

| Gr. VI cor-/æ/-vel | |
|---|---|
| d-k | 2 |
| dʒ-k | 1 |
| i-k | 3 |
| l-k | 1 |
| l-ŋ | 2 |
| n-k | 3 |
| r-k | 4 |
| r-ŋ | 2 |
| s-k | 1 |
| s-ŋ | 1 |
| t-k | 16 |
| t-ŋ | 1 |
| z-ŋ | 1 |
| total | 38 |

| Gr. VII vel-/æ/-lab | |
|---|---|
| h-p | 3 |
| k-b | 4 |
| k-m | 6 |
| k-p | 17 |
| k-v | 2 |
| ʔ-f | 14 |
| total | 46 |

| Gr. VIII vel-/æ/-cor | |
|---|---|
| g-n | 21 |
| g-s | 1 |
| ɑ-ð | 1 |
| h-d | 4 |
| h-n | 4 |
| h-r | 1 |
| h-z | 2 |
| k-n | 11 |
| k-r | 10 |
| k-r | 1 |
| k-s | 3 |
| k-tʃ | 1 |
| k-ʃ | 2 |
| ʔ-d | 3 |
| ʔ-l | 2 |
| ʔ-n | 5 |
| ʔ-r | 4 |
| ʔ-θ | 1 |
| ʊ-n | 4 |
| total | 81 |

| Gr. X vel-/æ/-vel | |
|---|---|
| ʔ-k | 8 |
| total | 8 |

/ʌ/

The largest share of the central open-mid vowel list falls within gr. VII (vel-V-lab) and VIII (vel-V-cor), both groups comprising 76 items. The cor-V-cor environment is almost as copious as the previous groups (n=71). On the other hand, only 3 instances of /ʌ/ fitted in the lab-V-vel group.

**Tables 12.3.2.2.2** The specifications of the context realization of the central open-mid vowel with regard to place of articulation

| Gr. I lab-/ʌ/-lab | |
|---|---|
| p-b | 7 |
| v-p | 1 |
| total | 8 |

| Gr. II lab-/ʌ/-cor | |
|---|---|
| b-dʒ | 1 |
| b-s | 1 |
| f-n | 3 |
| m-d | 1 |
| m-l | 1 |
| m-n | 20 |
| m-s | 2 |
| m-tʃ | 2 |
| p-n | 2 |
| total | 33 |

| Gr. III lab-/ʌ/-vel | |
|---|---|
| m-g | 3 |
| total | 3 |

| Gr. IV cor-/ʌ/-lab | |
|---|---|
| d-b | 3 |
| i:-p | 1 |
| n-f | 1 |
| n-m | 5 |
| n-p | 1 |
| r-m | 5 |
| r-p | 4 |
| s-b | 2 |
| s-f | 1 |
| s-m | 7 |
| t-f | 3 |
| θ-m | 1 |
| total | 34 |

| Gr. V cov-/ʌ/-cor | |
|---|---|
| d-n | 2 |
| d-s | 2 |
| dʒ-dʒ | 3 |
| dʒ-s | 9 |
| l-d | 1 |
| l-n | 20 |
| n-n | 1 |
| n-ð | 8 |
| r-n | 3 |
| r-s | 1 |
| r-ʃ | 3 |
| s-n | 1 |
| s-s | 3 |
| s-tʃ | 2 |
| s-ð | 7 |
| s-l | 2 |
| t-n | 1 |
| z-l | 2 |
| total | 71 |

| Gr. VI cor-/ʌ/-vel | |
|---|---|
| d-g | 1 |
| d-k | 4 |
| j-ŋ | 1 |
| r-g | 7 |
| r-k | 11 |
| total | 24 |

| Gr. VII vel-/ʌ/-lab | |
|---|---|
| g-v | 57 |
| k-m | 9 |
| k-v | 6 |
| uː-p | 1 |
| ʔ-p | 2 |
| ŋ-p | 1 |
| total | 76 |

| Gr. VIII vel-/ʌ/-cor | |
|---|---|
| g-l | 1 |
| g-n | 6 |
| h-d | 1 |
| h-n | 11 |
| k-l | 2 |
| k-n | 28 |
| k-r | 8 |
| k-s | 5 |
| k-t | 1 |
| ʔ-n | 2 |
| ʔ-ð | 11 |
| total | 76 |

| Gr. X lab+vel-/ʌ/-cor | |
|---|---|
| w-n | 24 |
| w-r | 1 |
| total | 25 |

/ɑː/

The cor-V-lab+vel group contains one symbolic /ɑː/; just a few more occur in gr. VI (n=3) and IX (n=4). Lab-V-cor (gr. II, n=77) and cor-V-cor (gr. V, n=94) environments are the two most occupied.

**Tables 12.3.2.2.3** The specifications of the context realization of the back open vowel with regard to place of articulation.

| Gr. I lab-/ɑː/-lab | |
|---|---|
| b-b | 13 |
| f-b | 1 |
| f-m | 2 |
| total | 16 |

| Gr. II lab-/ɑː/-cor | |
|---|---|
| b-d | 2 |
| b-n | 3 |
| b-z | 1 |
| f-ð | 2 |
| m-d | 1 |
| m-l | 1 |
| m-n | 5 |
| m-tʃ | 2 |
| p-d | 1 |
| p-l | 15 |
| p-s | 9 |
| p-t | 31 |
| p-ʃ | 1 |
| v-dʒ | 2 |
| v-n | 2 |
| total | 78 |

| Gr. III lab-/ɑː/-vel | |
|---|---|
| b-g | 2 |
| f-ʔ | 1 |
| p-k | 28 |
| m-k | 10 |
| total | 41 |

| Gr. IV cor-/ɑː/-lab | |
|---|---|
| iː-f | 1 |
| iː-m | 1 |
| l-m | 1 |
| l-v | 5 |
| n-m | 2 |
| s-m | 1 |
| t-f | 3 |
| ʃ-m | 1 |
| total | 15 |

| Gr. V cor-/ɑː/-cor | |
|---|---|
| d-n | 3 |
| d-s | 1 |
| iː-dʒ | 3 |
| l-dʒ | 3 |
| l-n | 1 |
| l-s | 16 |
| n-dʒ | 1 |
| r-l | 1 |
| r-n | 16 |
| s-r | 1 |
| t-n | 26 |
| t-t | 3 |
| tʃ-dʒ | 14 |
| tʃ-l | 2 |
| tʃ-n | 1 |
| t-θ | 1 |
| total | 93 |

| Gr. VI cor-/ɑː/-vel | |
|---|---|
| iː-k | 1 |
| r-k | 1 |
| t-g | 2 |
| total | 4 |

| Gr. VII vel-/ɑː/-lab | |
|---|---|
| h-b | 1 |
| h-f | 4 |
| k-b | 1 |
| k-m | 1 |
| ʔ-m | 7 |
| total | 14 |

| Gr. VIII vel-/ɑː/-cor | |
|---|---|
| g-d | 5 |
| g-n | 1 |
| g-s | 1 |
| h-d | 2 |
| k-l | 1 |
| k-z | 2 |
| ʔ-dʒ | 8 |
| ʔ-s | 3 |
| ʔ-θ | 1 |
| ŋ-dʒ | 1 |
| total | 25 |

| Gr. IX vel-/ɑː/-vel | |
|---|---|
| k-g | 1 |
| k-ʔ | 1 |
| ʔ-k | 1 |
| total | 3 |

| Gr. XI cor-/ɑː/-lab+ve | |
|---|---|
| l-w | 1 |
| total | 1 |

/ɒ/

The back open-mid vowel is more equally distributed among the groups: the highest number that a separate group of the vowel reaches is 64. As in the previous case it is gr. II (lab-V-cor) and V (cor-V-cor). There is a shortage of items in groups III (n=4) and IX (n=7).

**Tables 12.3.2.2.4** The specifications of the context realization of the back open-mid vowel with regard to place of articulation.

| Gr. I lab-/ɒ/-lab | |
|---|---|
| b-m | 5 |
| p-p | 6 |
| p-v | 1 |
| total | 13 |

| Gr. II lab-/ɒ/-cor | |
|---|---|
| b-dʒ | 1 |
| b-n | 1 |
| b-s | 2 |
| f-l | 9 |
| f-r | 6 |
| m-d | 2 |
| m-n | 4 |
| m-r | 1 |
| p-l | 11 |
| p-n | 22 |
| p-s | 2 |
| p-z | 2 |
| v-l | 2 |
| total | 65 |

| Gr. III lab-/ɒ/-vel | |
|---|---|
| f-k | 2 |
| m-k | 2 |
| total | 4 |

| Gr. IV cor-/ɒ/-lab | |
|---|---|
| dʒ-b | 1 |
| iː-p | 7 |
| l-b | 1 |
| l-m | 6 |
| l-p | 1 |
| n-f | 2 |
| n-m | 6 |
| n-p | 2 |
| r-b | 9 |
| r-m | 2 |
| r-p | 3 |
| r-v | 2 |
| s-f | 1 |
| s-v | 1 |
| t-p | 3 |
| z-f | 2 |
| ɪ-f | 1 |
| ʃ-p | 2 |
| total | 52 |

| Gr. V cor-/ɒ/-cor | |
|---|---|
| d-l | 8 |
| d-n | 3 |
| dʒ-n | 10 |
| dʒ-r | 2 |
| l-s | 2 |
| l-t | 3 |
| n-l | 2 |
| n-n | 2 |
| n-r | 1 |
| r-dʒ | 3 |
| r-s | 8 |
| t-r | 1 |
| z-l | 2 |
| ɪ-l | 2 |
| ɪ-t | 1 |
| ʃ-t | 5 |
| θ-r | 9 |
| total | 64 |

| Gr. VI cor-/ɒ/-vel | |
|---|---|
| d-k | 6 |
| l-k | 3 |
| l-ŋ | 6 |
| n-k | 1 |
| r-k | 3 |
| r-ŋ | 4 |
| t-k | 3 |
| total | 26 |

| Gr. VII vel-/ɒ/-lab | |
|---|---|
| k-f | 1 |
| k-m | 8 |
| ʔ-b | 1 |
| ʔ-f | 3 |
| ʔ-p | 1 |
| ŋ-p | 1 |
| ʊ-p | 1 |
| total | 16 |

| Gr. VIII vel-/ɒ/-cor | |
|---|---|
| g-n | 1 |
| h-s | 1 |
| k-n | 22 |
| k-r | 15 |
| k-t | 1 |
| total | 37 |

| Gr. IX vel-/ɒ/-vel | |
|---|---|
| k-ŋ | 6 |
| ʔ-k | 1 |
| total | 7 |

| Gr. X lab+vel-/ɒ/-cor | |
|---|---|
| w-d | 1 |
| w-n | 7 |
| w-ʃ | 17 |
| total | 25 |

# 13. Results

## 13.1 The average formant values of the English low vowels

This section presents the results of the average formant values of the English low vowels as they were realised by the 20 male BBC speakers. Table 13.1.1 below presents the basic statistical characteristics of the four vowels: mean (average) value, standard deviation, maximum and minimum value measured, skew, kurtosis and the coefficient of variation. Besides the first three formants it contains information on duration, fundamental frequency and the first three formant bandwidths (all formant values in Hertz).

It becomes obvious from the mean figures that the vowels are characterised by relative proximity. The difference between the most open vowel (/æ/) and the closest vowel (/ɒ/) does not exceed 128 Hz in the high-low dimension; the two "middle" vowels, /ʌ/ and /ɑː/, are realised with the same degree of openness, with the average F1 = 583 Hz for the open-mid central vowel and F1=582 Hz for the open back vowel.

While the low vowels except for /ɒ/ are marked by an almost indistinguishable degree of openness, the average values of the second formant indicate greater distances between the individual vowels and hence their clearer separation. From this we may conclude that the distinction of the low vowels is largely secured by their second formants.

As far as the third formant is concerned, /ɒ/ has the lowest value of all, the rest being fairly similar.

The average values of the low vowels are plotted on a F1-F2 graph in Figure 13.1.1, where they are marked by simple geometrical shapes (triangle = open-mid front v., square = open-mid central v., circle = open back v., diamond = open-mid back v.). More importantly, Figure 13.1.1 shows the average values inside ellipses of the respective vowels drawn to one standard deviation. It reveals considerable overlaps between all the four vowel categories. Apparently, the ellipses for /ʌ/ and /ɑː/overlap to the largest extent, which is in accordance with Henton's (1990) and previously also Gimson's (1945 in Bauer, 1985) finding; however, the overlap of /ɑː/ and /ɒ/ is comparable in its size.

**Table 13.1.1** The basic statistical characteristics of the four vowels: mean (average) value, standard deviation, maximum and minimum value measured, skew, kurtosis and the coefficient of variation. Besides the first three formants it contains information on duration, fundamental frequency and the first three formant bandwidths (all the formant values are in Hertz).

| /æ/ | duration | F0 | F1 | F2 | F3 | bandwidth F1 | bandwidth F2 | bandwidth F3 |
|---|---|---|---|---|---|---|---|---|
| mean | 92,9 | 128,2 | 630,0 | 1480,8 | 2448,1 | 622,3 | 173,2 | 438,4 |
| SD | 32,9 | 25,1 | 129,9 | 113,8 | 177,8 | 311,1 | 110,9 | 328,5 |
| max | 249,7 | 220,0 | 994,0 | 1840,0 | 2929,0 | 1885,7 | 755,5 | 4758,0 |
| min | 32,6 | 77,2 | 248,0 | 1046,0 | 2021,0 | 68,0 | 34,6 | 70,8 |
| skew | 1,5 | 0,6 | -0,1 | -0,2 | 0,0 | 0,9 | 2,1 | 6,3 |
| kurt | 3,3 | 0,5 | -0,3 | 0,6 | -0,3 | 0,8 | 5,3 | 71,2 |
| $C_{var}$ | 35,4 | 19,9 | 20,6 | 7,7 | 7,3 | 49,9 | 64 | 74,9 |

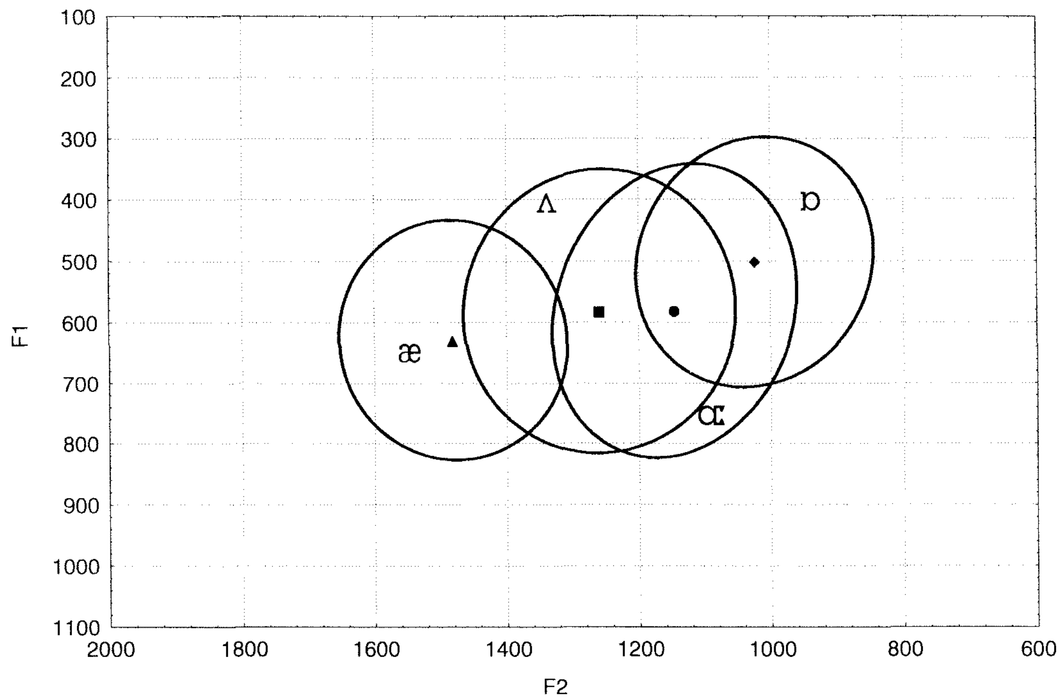
| /ʌ/ | duration | F0 | F1 | F2 | F3 | bandwidth F1 | bandwidth F2 | bandwidth F3 |
|---|---|---|---|---|---|---|---|---|
| mean | 77,8 | 128,1 | 583,2 | 1258,8 | 2413,5 | 732,7 | 175,2 | 454,5 |
| SD | 20,2 | 27,3 | 153,3 | 135,6 | 205,5 | 373,8 | 122,9 | 345,3 |
| max | 143,6 | 232,0 | 983,0 | 1805,0 | 2977,0 | 2372,7 | 1332,0 | 2777,0 |
| min | 24,5 | 79,1 | 204,0 | 885,0 | 1705,0 | 78,6 | 40,1 | 70,3 |
| skew | 0,4 | 0,9 | 0,0 | 0,8 | -0,2 | 0,7 | 4,3 | 2,7 |
| kurt | 0,3 | 1,2 | -0,4 | 1,2 | 0,1 | 0,7 | 30,8 | 10,9 |
| $C_{var}$ | 26 | 21,3 | 26,3 | 10,8 | 8,5 | 51 | 70,1 | 76 |

| /ɑː/ | duration | F0 | F1 | F2 | F3 | bandwidth F1 | bandwidth F2 | bandwidth F3 |
|---|---|---|---|---|---|---|---|---|
| mean | 116,6 | 124,1 | 582,4 | 1145,6 | 2425,3 | 801,0 | 158,9 | 418,0 |
| SD | 37,2 | 27,1 | 158,6 | 121,7 | 252,1 | 399,5 | 152,9 | 238,1 |
| max | 265,1 | 215,3 | 993,0 | 1648,0 | 2963,0 | 2351,2 | 1467,6 | 1782,3 |
| min | 36,3 | 72,1 | 207,0 | 928,0 | 1773,0 | 38,9 | 35,8 | 5,0 |
| skew | 0,6 | 0,6 | -0,1 | 1,3 | -0,4 | 0,8 | 4,6 | 1,7 |
| kurt | 1,0 | 0,2 | -0,6 | 1,8 | -0,6 | 0,9 | 27,6 | 5,6 |
| $C_{var}$ | 31,9 | 21,8 | 27,2 | 10,6 | 10,3 | 49,9 | 96,2 | 57,0 |

| /ɒ/ | duration | F0 | F1 | F2 | F3 | bandwidth F1 | bandwidth F2 | bandwidth F3 |
|---|---|---|---|---|---|---|---|---|
| mean | 73,2 | 131,2 | 501,7 | 1024,3 | 2261,6 | 760,4 | 213,5 | 430,8 |
| SD | 21,2 | 26,3 | 134,5 | 118,2 | 239,1 | 387,4 | 208,0 | 272,5 |
| max | 157,4 | 244,6 | 898,0 | 1488,0 | 2922,0 | 2175,6 | 1749,6 | 2184,6 |
| min | 29,7 | 78,5 | 175,0 | 730,0 | 1499,0 | 61,5 | 30,6 | 69,9 |
| skew | 0,7 | 0,6 | 0,0 | 0,8 | -0,4 | 0,9 | 3,2 | 2,1 |
| kurt | 0,9 | 0,6 | -0,5 | 1,3 | 0,1 | 1,1 | 14,2 | 7,4 |
| $C_{var}$ | 29,0 | 20,0 | 26,8 | 11,5 | 10,6 | 50,9 | 97,4 | 63,3 |

So far, our findings have been similar to Henton's (1990). Nevertheless, in Henton's study (ibid.) no three ellipses (drawn to two standard deviations! as opposed to our ellipses drawn to one SD) overlap, whereas our Figure 13.1.1 below shows an extensive overlap between /ʌ/, /ɑː/and /ɒ/. Despite its large overlap with /ʌ/, the open-mid front vowel /æ/ appears to be the most isolated and thus the most distinct vowel of the four.

**Figure 13.1.1** Positions of the English low vowels on the F1-F2 diagram. The ellipses are drawn to one standard deviation. The geometrical shapes show the position of the average values of the low vowels (triangle = open-mid front v., square = open-mid central v., circle = open back v., diamond = open-mid back v.). The graph is calibrated in Hertz.




In order to see whether dispersion of the four low vowels would lower if we focused on the first two formant ratios rather than comparing their absolute values (supposing that the ratios and differences between formants are almost equal for all speakers of a certain language variety, we can thus bypass the variability produced by individual idiosyncracies), we designed formant transformations of three types: F2-F1, F1/F2 and F2/F1 (plotted on axis x), all against F2 (axis y) (see Appendix). However, our experiment yielded results comparable to Figure 13.1.1 above. Following this experiment we tried calculating F2:F0 correlation for the four vowels of two randomly selected speakers. Should a correlation be found, the value of the F2:F0 ratio would then be plotted onto a two-dimensional graph against F1 values. However, although some correlation did indeed appear ($r>0.2$), it was for different vowels in the two speakers (see Appendix). Such inconsistency and the coefficient $p$ for correlation by far exceeding the figure 0.01 in the eight examined items (pointing to insignificance of $r$) leads us to the conclusion that the variability of our sample is its inherent feature. It seems therefore that in connected speech the low vowels, particularly those with the greatest overlaps, lose some of their distinctive value demonstrated by minimal pairs, and intelligibility is largely secured by broader context. Nonetheless, we must take into consideration the vowel inventories of individual speakers, who may produce the four vowels with lesser overlaps in their speech.

As we can see in section 13.2 below, none of the speakers clearly separates /ʌ/ and /ɑː/, although perceptually, due to /ɑː/'s significantly longer duration (about 23 ms longer than the second longest vowel /æ/ with its average duration of 92.9 ms) these vowels are likely to reach higher identification rate than their acoustic spectra suggest. Seven of the 20 speakers realise their open-mid front vowel as completely or almost fully isolated from the rest. /ɒ/ overlaps with the fronter vowel(s) in the speech of all speakers, yet in three speakers it shares less than half of its territory with any other vowel (usually /ɑː/). On the whole, the degrees of overlaps between the four vowels in individual speakers vary, but the overall tendencies remain the same.

### 13.1.1 Comparison of our results with previous studies

We have already pointed out some similarities between our study and the results of Henton's (1990), notably the marked overlapping of the low vowels. Table 13.1.1.1 below (which is an adaptation of Table 4.1 from section 4 above and differs from it only in that it contains also values obtained in our study) shows that in the present analysis we have measured the lowest values of F1 for all the low vowels in comparison with the other studies. Furthermore, in our study the average /æ/ is realised with the lowest F2 and /ɒ/ with the second highest F2. In other words, the English low vowels as we measured them were pronounced with the smallest degree of mouth opening, the open-mid front vowel seems to be realised as more retracted than it had been before and the back open-mid vowel seems to be moving further front in the vowel space. However, the data for RP male speakers in our Table 13.1.1.1 (see page 80) show neither the fairly radical retraction of /æ/ nor the fronting of /ɒ/ to be results of regular unidirectional tendencies. For instance, Henton's (1983) F2 value of /æ/ presents a slight peak in the chronological row of F2 values of the front open-mid vowel; Henton's average F2 value of /ɒ/ presents a dip between Deterding's and our values. We can see that F2 of /ʌ/ in our study belongs to the higher values in this category. Nevertheless, the difference between the lowest and highest measured values of F2 in male RP /ʌ/ in Table 13.1.1.1 is not as significant as in /æ/, the rise in the value also is not chronological (Henton's values point to a more retracted quality of /ʌ/ than Deterding's or our values do). A similar pattern can be observed in the case of /ɑː/: it appears to have undergone less marked quality changes than the other three low vowels; in both her studies Henton measured /ɑː/ to be backer than ours or Deterding's (in connected speech). Apart from the development of F1 of /ɑː/ and /ɒ/, where a steady downward movement can be traced over the time span, the other F1 and F2 values of the low vowels fluctuate. Being aware of the impact of method of analysis on the results, we consider it unlikely that such irregularity in values, as we observed it in our Table 13.1.1.1, should reflect an actual change in quality of the low vowels over a period of time.

Unfortunately, there is only the 1997 study of Deterding's that matches our method of analysis in many respects (see section 4 above) and therefore qualifies for comparison with our results. It is probably due to this fact that Deterding's results most resemble our values. Mainly, there is a striking similarity between the two sets of the F2 values. For /ʌ/ the F2 averages equal, for /ɑː/ they differ by 11 Hz and, finally, Deterding's F2 for /ɒ/ is just 23 Hz higher. Only the difference of 69 Hz between our /æ/ and that of Deterding's on the front-back axis points to a greater qualitative and thus perceivable distinction of them.

The F1 values of the low vowels presented by Deterding (1997) are approximately 60 Hz higher than our values. A question arises whether this may be ascribed to the fact that Deterding avoided to include items where there was j, l, r or w in the immediate context (which can have undesired effects on the first three formant values), or to an actual shift in pronunciation over the time that passed between the two studies. This might become clearer in the coming sections that will address the influence of adjacent environment on the vowel formants.

To summarize, our F1values of the low vowels are the lowest that have been recorded by the authors quoted in the present study. The front open-mid vowel seems to have acquired a more retracted quality, the remaining, backer vowels yielded higher F2 values than all but Deterding's (1997) results, which indicates a frontward movement of these vowels. On the whole, it can be said that the low vowels pronounced by the 20 male RP speakers have a more centralised quality than the reference data.

**Table 13.1.1.1** Results of previous acoustic studies of English vowels and our results for comparison. Each data set was collected under different criteria, which should be kept in mind when drawing conclusions from their comparisons. The table presents the studies in order of the approximate date of origin of the analysed material. The information on the speaker sex, English variety and naturalness of presentation of the source data is given where it was available. The non-shaded parts feature data for male RP speakers. All measurements are given in Hertz.

| Studies | Formant number | /æ/ | /ʌ/ | /ɑː/ | /ɒ/ |
|---|---|---|---|---|---|
| Peterson & Barney (1952, in Kent & Read, ? ) (Hz), male speakers of American English | 1 | 660 | 640 | 730 | |
| | 2 | 1700 | 1200 | 1100 | |
| | 3 | 2400 | 2400 | 2450 | -- |
| Bauer (1985, data from between 1949 and 1966) (Hz), male RP speakers | 1 | 652 | 658 | 669 | |
| | 2 | 1647 | 1365 | 1070 | |
| | 3 | -- | -- | -- | -- |
| Wells (1962, in Henton, 1983) (Hz), male RP speakers | 1 | 748 | 722 | 677 | 599 |
| | 2 | 1746 | 1236 | 1083 | 891 |
| | 3 | 2460 | 2537 | 2540 | 2605 |
| Fry (1979, in Henton, 1983) (Hz), male and female speakers | 1 | 750 | 720 | 680 | 600 |
| | 2 | 1750 | 1240 | 1100 | 900 |
| | 3 | -- | -- | -- | -- |
| Gimson (1980, 1991) (Hz), male and female RP speakers | 1 | 800 | 760 | 740 | 560 |
| | 2 | 1760 | 1320 | 1180 | 920 |
| | 3 | 2500 | 2500 | 2640 | 2560 |
| Deterding (1997) (Hz), BBC male speakers, connected speech from 1980s | 1 | 690 | 644 | 646 | 558 |
| | 2 | 1550 | 1259 | 1155 | 1047 |
| | 3 | 2463 | 2551 | 2499 | 2487 |
| Deterding (1997) (Hz) citation forms from 1990 study | 1 | 732 | 695 | 687 | 593 |
| | 2 | 1527 | 1224 | 1077 | 866 |
| | 3 | -- | -- | -- | -- |
| Henton (1983) (Hz), male RP speakers | 1 | 713 | 645 | 636 | 551 |
| | 2 | 1615 | 1200 | 1050 | 860 |
| | 3 | 2491 | 2519 | 2540 | 2530 |
| Henton (1990) (Hz), male RP speakers | 1 | | 658 | 648 | |
| | 2 | | 1194 | 1037 | |
| | 3 | -- | -- | -- | -- |
| Hawkins (2005) (Hz), male speakers of RP, citation forms, measured in 2001 | 1 | 737 | 640 | 629 | 505 |
| | 2 | 1576 | 1199 | 1057 | 860 |
| | 3 | -- | -- | -- | -- |
| **Syslová** (2006) (Hz) BBC male speakers, recordings made between 2000 and 2002 | 1 | 630 | 583 | 582 | 501 |
| | 2 | 1481 | 1259 | 1146 | 1024 |
| | 3 | 2448 | 2414 | 2425 | 2262 |

### 13.1.2 Do our results tally with the general trends?

In chapter 5 above we outlined the major trends in the qualitative changes of the RP low vowels as they were recorded throughout the 20$^{th}$ century. Among others, /æ/ was stated to be undergoing the processes of lowering and retraction. Our results, which we confronted with the most up-to-date study of Deterding's (1997), do not confirm the downward movement pointed out by Cruttenden (1994); on the contrary, they indicate a development in the upward direction (observed by Henton 1990 and Bauer 1983). Further, our results point to the shifting of /æ/ to a backer region. The central open-mid vowel was described by Henton (1990) as rising, other authors (Gimson 1991 and Wells 1982) observed the fronting of /ʌ/. The comparison of our data with the previous studies of male RP speech does not go against these statements.

Although the low vowels seem to be gravitating towards a more central region, the fears that /æ/ and /ʌ/ might merge appear to be less justifiable than the concerns about the potential fusion of /ʌ/ and /ɑː/. Firstly, /ʌ/ and /ɑː/ resemble each other in their quality more than any other two low vowels, and secondly, /æ/ has a tendency to retain its position as the most isolated of the four.

/ɑː/ and /ɒ/ have enjoyed minor interest among phoneticians. However, from what we know about the qualitative proximity of the two vowels, we may assume that in order to preserve its position closest to /ʌ/, the vowel /ɑː/ is also undergoing a frontward movement (although it goes against Hawkins' (2005) belief that the change in the RP vowel system has taken an anticlockwise direction). /ɒ/ does not seem to be undergoing any changes (Hawkins 2005). There are hardly any other comments by the quoted phoneticians apart from the changes in the lexical distribution of /ɒ/, the investigation of which reaches beyond the scope of this paper.

### 13.1.3 Variability and distribution of the low vowel formant values

In order to see how variable the English low vowels are we calculated the standard deviation (SD) values of their first three formants from the mean values. Figure 13.1.3.1(a) represents the SD values of the first three formants, showing the degree to which scores vary from the mean. It is obvious that the open-mid front vowel gives the most satisfactory results with respect to all three formants. The open-back vowel comes out as the second most stable, but only in the region of F1 and F2. There is only a 5 Hz difference between the measures of dispersion of F1 in the open-mid central and the open-back vowels. As well as in F1, the open-back vowel reaches the highest SD in F3, which ranks the vowel among the more variable in the low vowel space.

how the formant values are spread out between the lowest and highest measured values. We shall give a description of each vowel separately in the following subsections.

### 13.1.4 Distribution of the low vowel formant values

/æ/

As the figures of $C_{var}$ and SD may suggest, the range between the minimum and maximum value is considerably high for all the three formants of the four vowels (see Table 13.1.3.1 in the previous section for more details). The maximum F1 value of the 435 items of /æ/ is 994 Hz, which is 746 Hz higher than the lowest one. The mean value calculated for /æ/ is 630 Hz, i.e., slightly over the middle of the range. Although the distribution of /æ/'s F1 values is shown to be negatively skewed (skew=-0.1), the median value points in the opposite direction, which designates that one of these indicators is inaccurate. Nevertheless, both the figures indicate a very balanced distribution of the values in relation to the mean. The number of F1 values farther from the mean is somewhat higher than in normal distribution (kurt=-0.3).

The values of /æ/'s F2 range between 1046 and 1840 Hz. The mean value is only about 1 Hz higher than the median and as for F1, skew (=-0.2) indicates the opposite tendency. Thus we may conclude that the second formant values are evenly spread on both sides from the mean. However, in contrast to F1, a greater amount of the F2 values is closer to the mean as against the normal distribution (kurt=0.6).

Even the values of F3 tend to remain normally distributed. Only the kurtosis figure (=-0.3) indicates that there are more scores lying farther from the mean than in the normal distribution.

On the whole, the values of all three formants of /æ/ can be said to have almost normal distribution. (A distribution is considered 'normal' if about 68 % of scores fall within the range of +/- 1SD from the mean.)

/ʌ/

For F1 and F3 of /ʌ/ we made a similar observation as for the front open-mid vowel with regard to the almost negligible deviation of the mean values from the median. However, the skewness figure confirms this finding only in case of F3 (skew=-0.2). More scores of F1 seem to occur farther from the mean (than in normal distribution), while the F3 items appear to be within 'normal distribution'. The values of F1 range between 204 and 983 Hz, F3 values occur between 1705 and 2997 Hz.

By comparison, F2 of /ʌ/ behaves somewhat differently. As both skewness and median figures reveal, items which are lower than the mean (=1259 Hz) prevail (skew=0.8). At the same time more scores are closer to the mean than in a normal distribution (kurt=1.2). The F2 values range between 885 and 1805 Hz.

/ɑː/

There is a negligible difference between the mean (=582 Hz) and median (=594 Hz) values of F1 measured for /ɑː/, which implies that there is approximately the same amount of scores above and below the mean. More items lie farther from the mean than in a normal distribution. The range of the open-back vowel's F1 is delimited by 207 and 993 Hz.

The differences between the mean and median values for F2 and F3 are more significant than for /ʌ/ and /æ/. More F2 scores are lower than the mean (skew=1.3); as in /ʌ/ more items occur closer to the mean in comparison to a normal distribution. F2 values measured for /ɑː/ reach from 928 to 1648 Hz.

The range of F3 lies between 1773 and 2963 Hz. More than a half of its items have higher values than the mean (=2425 Hz) and more values appear farther from the mean (than in a normal distribution).

/ɒ/

The maximum and minimum F1 values of /ɒ/, 898 and 175 Hz respectively, are the lowest by comparison with the other vowels. The F1 scores spread out evenly in both directions from the mean (skew=0.0), nevertheless, more items occupy the tails of the distribution curve (kurt=-0.5) than in a normal distribution.

Similarly to the F2 of /ʌ/ and /ɑː/, the second formant values of the open-mid back vowel slightly deviate from the normal distribution. Over half of the scores are lower than the mean; values closer to the mean (=1024 Hz) outnumber the remaining ones. The range of F2 scores stretches from 730 to 1488 Hz.

For F3 the minimum value measured is 1499 Hz, the maximum value reached 2922 Hz. The skewness figure (=-0.4) for F3 points to a slightly higher number of scores above the mean. In terms of peakedness, the distribution of F3 appears to be normal (kurt=0.1).

### 13.1.5 Percentage of scores within the range of mean +/- 1 SD

Table 13.1.5.1 below allows comparison of the number of items whose first, second, or third formant value occurs within the range of mean +/- one standard deviation. Out of the first three formants it is F2, which most frequently occurs within the set region; it is surpassed only by F3 of the open-mid back vowel by 1.6 %. On the other hand, F1 in all vowels has the smallest share of values within the given range. On the whole, a minimum of 61.8 % (the portion of F1 values of the open-mid front vowel, surprisingly the least variable in terms of F1) of the values of each formant of the four vowels did not exceed the boundaries of one standard deviation from the mean. Interestingly, the open-mid front vowel, which has been described as the least variable, is represented by the smallest share of F1 and F2 items from within the mean +/- 1 SD range. This entails that more scores do not fall far beyond this limit (in order to keep the SD value as low as it is).

**Table 13.1.5.1** Number of items with a formant value within the interval: mean +/- 1 standard deviation (SD) and this number converted into percentages. The last line indicates the number and percentage of items with all three formants within the range of mean +/- 1 SD.

| | open-mid front (n=435) | | open-mid central (n=350) | | open-back (n=291) | | open-mid back (n=311) | |
|---|---|---|---|---|---|---|---|---|
| | No. within mean +/- 1 SD | % | No. within mean +/- 1 SD | % | No. within mean +/- 1 SD | % | No. within mean +/- 1 SD | % |
| F1 | 269 | 61,8 | 229 | 65,4 | 191 | 65,6 | 198 | 63,7 |
| F2 | 299 | 68,7 | 262 | 74,8 | 220 | 75,6 | 217 | 69,8 |
| F3 | 296 | 68,0 | 240 | 68,6 | 192 | 65,9 | 223 | 71,7 |
| F1, 2, 3 | 151 | 34,7 | 123 | 35,1 | 100 | 34,4 | 102 | 32,8 |

The last line of Table 13.1.5.1 indicates the number and percentage of items with all three formants within the range of mean +/- 1 SD. It can be seen that for the low vowels there are between 32.8 (/ɒ/) and 35.1 % (/ʌ/) of items whose all three formants fall within the delimited range. This observation points to the fact that only about a third of each measured sound form the 'ideal' vowels (on the assumption that the average values we have measured are considered to be ideal).

### 13.1.6 Summary

Our analysis revealed that /æ/ is the most stable of the low vowels, reaching the lowest $C_{var}$ values for all first three formants. /ʌ/, /ɑː/ and /ɒ/ yielded comparable results with regard to F1 and F3, $C_{var}$ of /ʌ/'s F2 is visibly lower compared to the two backer sounds. The least stable formant of the three is F1 producing $C_{var}$ values almost three times as high as F2 or F3.

Distribution of all formants of the four vowels has been found to be mostly normal, at least in terms of their skewness and peakedness. The indicators of distribution (skew and kurtosis) exceeded or approached value +1 only for F2 of all but the open-mid front vowel. In all these instances it indicated that, firstly, most of the scores are closer to the mean and, secondly, there are more scores below the mean than in the normal distribution. The remaining skew and kurtosis figures do not point to any significant deviations from normal distribution of the analysed samples.

Between 61.8 and 75.6 % of the scores of each of the vowel formants lie within the range of mean+/- 1 SD, while 68 % is considered to be characteristic of normal distribution. However, only approximately a third of all items of each vowel have all three formants within this range.

### 13.2 The English low vowels in individual speakers

Now that we have presented the general nature of the male English low vowels, we are curious to see how the individual speakers contributed to the overall results. We will examine the measured acoustic parameters to find out which of the speakers

i. tend to push/pull the average value of the vowel in a certain direction (frontwards/backwards/upwards/downwards)

ii. exhibit a well-defined realization of the low vowel (i.e., it occupies a smaller vowel-space area than at least two of the remaining vowels)

iii. pronounce the vowel as distinct from the other vowels (i.e., there is only a subtle overlap with the other vowels)

The individual speakers' ellipses drawn to one standard deviation referred to in the following text can be seen in Figures 13.2.1 (further below), the average values of all the speakers' low vowels are available in Table13.2.1 below. To see the statistics calculated for the low vowels in individual speakers refer to Appendix.

**Table 13.2.1** The average formant values of the low vowels in individual speakers in Hz.

| | front open-mid | | | central open-mid | | | back open | | | back open-mid | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F1 | F2 | F3 | F1 | F2 | F3 | F1 | F2 | F3 | F1 | F2 | F3 |
| **AS** | 652 | 1508 | 2500 | 676 | 1324 | 2464 | 678 | 1235 | 2421 | 575 | 1051 | 2320 |
| **CC** | 619 | 1528 | 2574 | 498 | 1305 | 2522 | 459 | 1179 | 2217 | 344 | 954 | 2088 |
| **DJ** | 737 | 1328 | 2440 | 589 | 1250 | 2481 | 615 | 1115 | 2347 | 545 | 972 | 2153 |
| **DL** | 322 | 577 | 1065 *) | 692 | 1237 | 2624 | 679 | 1136 | 2654 | 553 | 1009 | 2421 |
| **DR** | 593 | 1438 | 2401 | 434 | 1234 | 2272 | 409 | 1137 | 2362 | 391 | 1021 | 2080 |
| **ED** | 761 | 1434 | 2316 | 654 | 1268 | 2422 | 720 | 1122 | 2580 | 523 | 1031 | 2315 |
| **FL** | 602 | 1526 | 2430 | 669 | 1229 | 2335 | 531 | 1040 | 2164 | 478 | 1035 | 2218 |
| **GF** | 618 | 1478 | 2362 | 674 | 1247 | 2418 | 719 | 1079 | 2628 | 647 | 988 | 2207 |
| **JI** | 721 | 1515 | 2407 | 636 | 1250 | 2297 | 548 | 1097 | 2279 | 512 | 1010 | 2252 |
| **JL** | 610 | 1431 | 2641 | 486 | 1355 | 2554 | 540 | 1234 | 2695 | 454 | 1092 | 2320 |
| **JS** | 520 | 1479 | 2288 | 471 | 1255 | 2295 | 422 | 1123 | 2346 | 413 | 1115 | 2210 |
| **JSh** | 628 | 1432 | 2496 | 477 | 1260 | 2376 | 495 | 1078 | 2407 | 457 | 999 | 2179 |
| **MP** | 528 | 1616 | 2400 | 551 | 1284 | 2423 | 574 | 1186 | 2321 | 546 | 1019 | 2236 |
| **NK** | 724 | 1469 | 2452 | 711 | 1202 | 2437 | 742 | 1198 | 2536 | 641 | 1038 | 2442 |
| **PJ** | 651 | 1535 | 2439 | 545 | 1329 | 2368 | 610 | 1157 | 2520 | 476 | 995 | 2180 |
| **RC** | 515 | 1450 | 2518 | 422 | 1284 | 2466 | 456 | 1136 | 2429 | 381 | 1090 | 2315 |
| **RH** | 590 | 1470 | 2455 | 604 | 1171 | 2458 | 558 | 1102 | 2399 | 513 | 957 | 2290 |
| **RL** | 614 | 1526 | 2400 | 626 | 1196 | 2392 | 631 | 1182 | 2408 | 595 | 1067 | 2425 |
| **RM** | 562 | 1457 | 2432 | 541 | 1245 | 2347 | 525 | 1144 | 2486 | 443 | 1018 | 2312 |
| **SM** | 556 | 1513 | 2353 | 547 | 1288 | 2373 | 627 | 1177 | 2550 | 539 | 1099 | 2419 |

*) 770/1461/2674

### /æ/

The average values of the open-mid front vowel show it to be the lowest and frontest vowel of the four. However, this is not true for a considerable number of the individual speakers as the scatter ellipses in Figures 13.2.1 reveal. In some cases (e.g., in speakers AS, GF, NK, MP, PJ), the ellipse of /æ/ (drawn to one SD) in the vowel space occupies a higher region than the ellipse of /ʌ/, i.e., it is realised with a smaller degree of openness than /ʌ/. Although some items of /æ/ in such cases may be realised as more open than those of /ʌ/, on average higher values prevail. If we compare the average values of /æ/ and /ʌ/ of all the speakers, we can see that for five of them (FL, GF, MP, RH and RL) /ʌ/ has a more open quality than /æ/. For some, the two average values are very similar or so with a perceptible difference.

Speakers DR, JS, MP, RC, RH and RM clearly contribute to a more close character of /æ/ with their average values of F1 below 600 Hz. As opposed to that, speakers DJ, DL, ED, JI, NK tend to pull this vowel down the vowel space with average F1 values over 700 Hz. The most obvious 'frontward puller' is speaker MP with average F2=1616 Hz (compare with the average F2 of all speakers being 1481 Hz). Other speakers realise the average /æ/ with at least 80 Hz less.

We noted an observation in section 13.1, that /æ/ comes out as the most distinct and isolated vowel of the English low vowels. The graphs presenting the vowels in individual speakers show that this does not always have to be the case. This is often due to a rather back character of /æ/ or a fronter character of the backer vowels, which results in considerable overlaps (e.g., CC, DJ, JL, PJ, RM). On the other hand, the scatter ellipses of /æ/ of speakers FL, ED, JI, MP, NK, RC and RL preserve a relatively independent position.

As we saw in the previous section, /æ/ is the vowel with the lowest variability of the first three formants. Nevertheless, speakers DL, FL, RC and SM are less consistent in their pronunciation of /æ/ than in some or all of the other vowels.

### /ʌ/

The open-mid central vowel has been described as being the most similar to /ɑː/ with regard to F1 and F2. We further saw that it also shares a considerable area of the vowel space with /æ/ and /ɒ/. Since /ʌ/ is a central vowel, the chances of its occupying a discrete position decrease. Due to this fact, the high variability of its formant values or the high variability of the neighbouring vowels, /ʌ/ overlaps with the adjacent vowels in the vast majority of speakers. It is only speaker JI whose /ʌ/ can be described as relatively distinct.

Figures 13.2.1 reveal that /ʌ/ in speakers DR, RC and RL, and in some others not being far from this state, is subsumed completely by another vowel. In speakers RC and RL this may be ascribed to the fact that their /ʌ/s vary the least of all the measured subjects. The case of RC draws particular attention as his values of /ʌ/ are so consistent that they form an ellipse of uncommonly small proportions in comparison to the other speakers' /ʌ/s as well as to the neighbouring vowels. On the other hand, JSh pronounces /ʌ/ with such inconsistency in comparison with his realization of the other vowels that his /ɒ/, despite being relatively well-defined, is subsumed wholly within the region of /ʌ/.

Since /ɑː/ is the main competitor of /ʌ/, we examined their mutual position in the individual speakers. As far as the degree of openness of /ʌ/ in relation to the backer

/ɑː/ is concerned, on average, there is a tendency among speakers CC, DL, DR, FL, JI, JS and RH to realise /ʌ/ with greater mouth opening than /ɑː/, i.e., /ʌ/ is lower than /ɑː/. The average F2 values in individual speakers show that speakers NK and RL realise /ʌ/ and /ɑː/ with an almost identical degree of backness.

We were further curious to see how the individual speakers contributed to the overall quality of /ʌ/. The chief 'upward-pulling force' is represented by speaker CC, though with high variability of /ʌ/, DR, whose vowels are generally oriented towards the close back region of the vowel space, JS, who similarly pulls up all the vowels' averages, JSh and RM both realising /ʌ/ with the most noticeable variability of the open-mid central vowel of all speakers, RC reaching the lowest values of F1 for /ʌ/, and finally, speakers JL, MP and PJ. The remainder of the speakers can be labelled as 'downward pullers' with the average first formant value of /ʌ/ above 583 Hz (the average for all speakers'/ʌ/). The most prominent among these are speakers AS, DL, ED, FL, GF, JI and NK, who pronounce /ʌ/ as low as the average /æ/ or lower (F1 $\geq$ 630 Hz). However, the comparison of /ʌ/ and /æ/ within each of these speakers' inventories independently shows that /ʌ/ is actually lower than /æ/ only in speakers AS, GF and FL.

The /ʌ/s of AS, CC, ED, JL, MP, PJ, RC and SM have a more front quality than what was stated as being the average in terms of backness/frontness. Although we might expect a large overlap of /æ/ and /ʌ/ in such cases, /æ/ has a tendency to occupy an even more front region, thus gaining independence. Nevertheless, there are speakers (JL, DJ, JSh, PJ and RM) who clearly defy this trend and we find considerable overlaps between the two vowels regardless of the degree of frontness of /ʌ/.

### /ɑː/

Above, in section 13.1, we pointed out that /ɑː/ almost completely coincides with /ʌ/ in the range and location of F1 in the vowel space. However, neither F2 can positively distinguish the two vowels: altogether, they share about two thirds of their ellipses. The fact that the area occupied by /ɑː/ is heavily loaded in the speech of the

BBC newsreaders, is further supported by the fact that over fifty per cent of the area delimited by /ɒ/ stretches into that of /ɑː/. The proportions between the overlaps of /ɑː/ with the adjacent vowels differ slightly, yet a similar pattern can be traced in all the speakers examined individually, which entails that none of them reserves a distinct area to /ɑː/.

For all but six speakers the average values of F2 range between 1100 and 1200 Hz. Only speakers AS and JL realise their /ɑː/ with the average frequency over 1200 Hz, both having very good chances of being identified as having central rather than back quality. On the other hand, the average F2 values in speakers FL, JI and JSh reach less than 1100 Hz. The speakers FL, GF, JI and JSh further play an important part in lowering the /ɑː/'s average F1, i.e., in pushing the vowel upwards to occupy a vowel area more characteristic for /ɒ/. Beside those, also speakers CC, DR, JS and RC tend to pull the vowel higher. It is mainly speakers ED, GF, NK, AS and DL who are accountable for raising the F1 average of /ɑː/, thus lowering it in the vowel space.

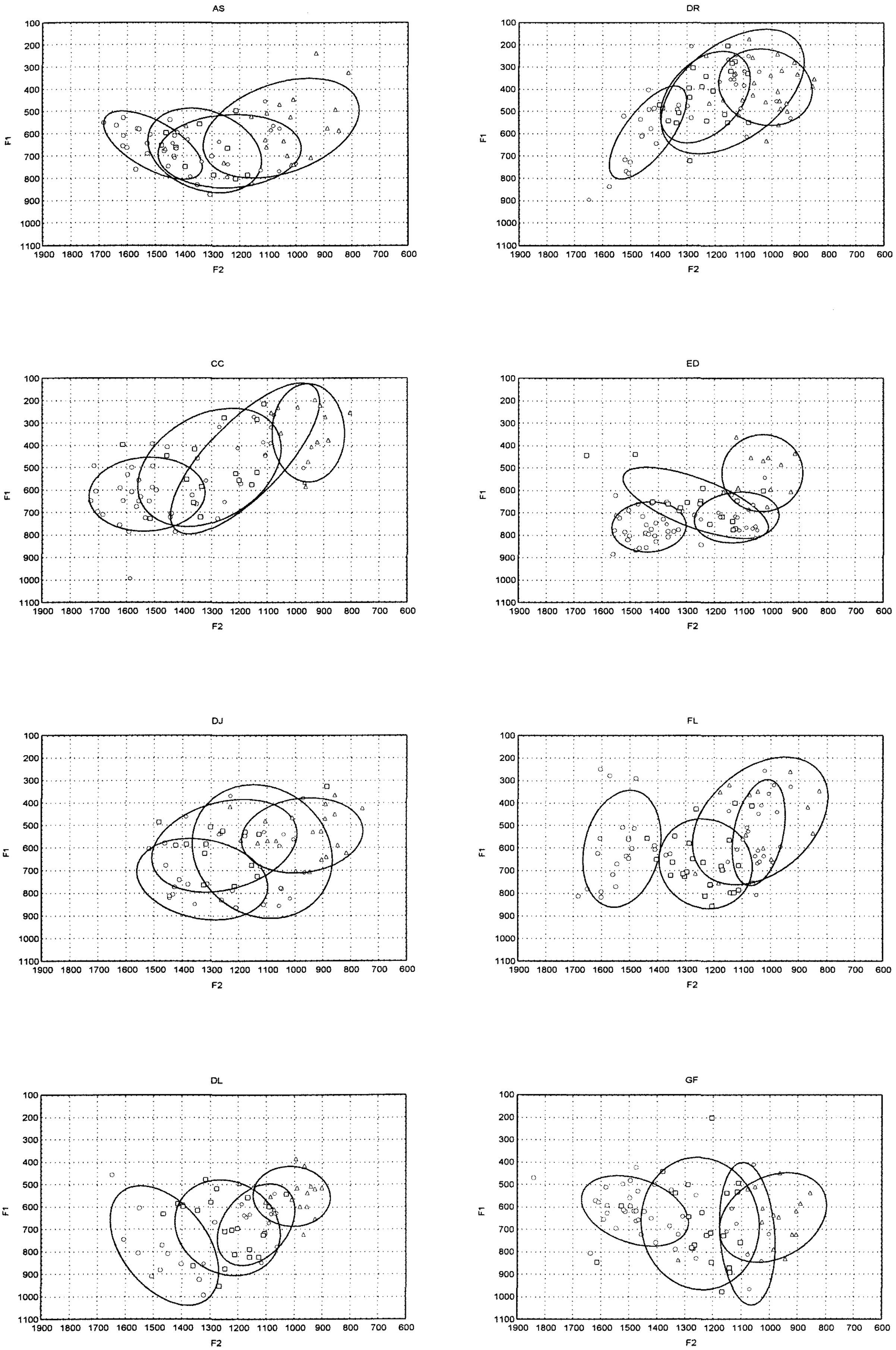
Since /ɑː/ is defined as an open vowel as opposed to /æ/, /ʌ/ and /ɒ/, which are defined as open-mid vowels, we were interested in the number of speakers who realise /ɑː/ with a higher degree of openness than the other low vowels. Judging from the average values, there are only five such speakers: GF, MP, NK, RL and SM. AS's mean F1 of /ɑː/ differs from his mean F1 of /ʌ/ only by 2 Hz, which is too low a figure to be interpreted as a significant difference.

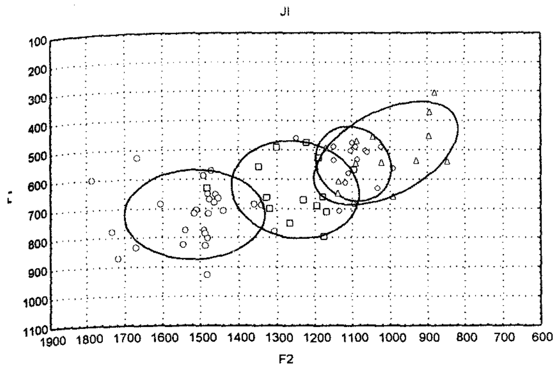
/ɑː/ is a relatively well-defined vowel for speakers DL, ED, FL, JI, JS, JSh, SM. As the ellipses suggest, in speakers JI, JS, JSh and SM /ɑː/ presents the most stable vowel of the four.

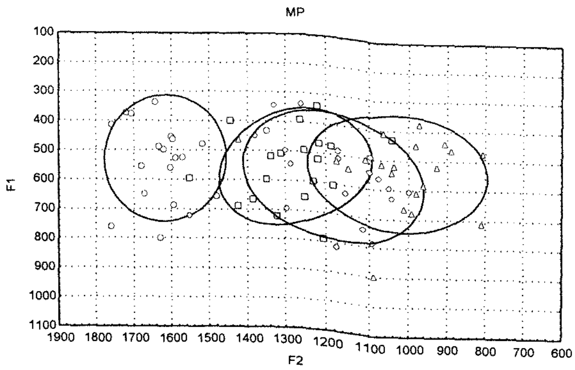
### /ɒ/

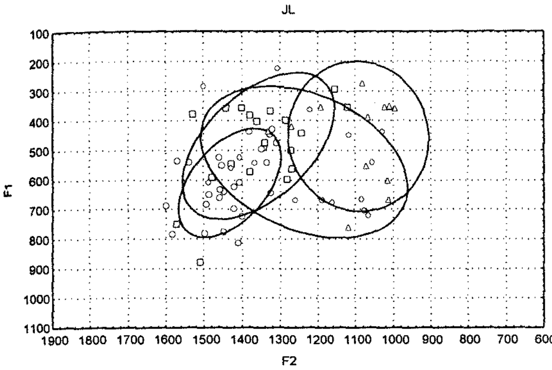
/ɒ/ is the highest as well as backest of the four low vowels. It occupies a smaller area of the vowel space than /ɑː/ and /ʌ/, but it is not as distinct as /æ/ in general. As has been stated earlier, this vowel, despite being a peripheral vowel in terms of position in the vowel space, overlaps considerably with its fronter neighbours.

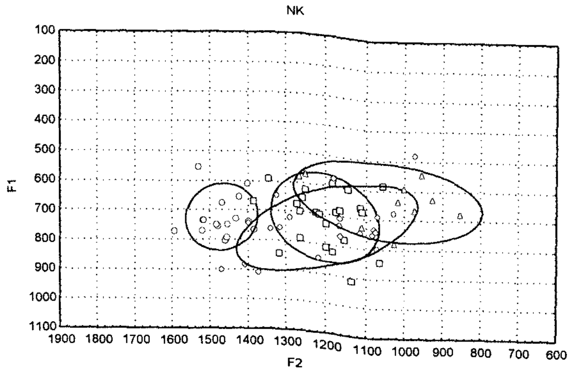
**Figures 13.2.1** Positions of the English low vowels in individual speakers on the F1-F2 diagram. The ellipses are drawn to one standard deviation. The geometrical shapes show the position of the individual values of the low vowels (triangle = open-mid front v., square = open-mid central v., circle = open back v., diamond = open-mid back v.). The graph is calibrated in Hertz.

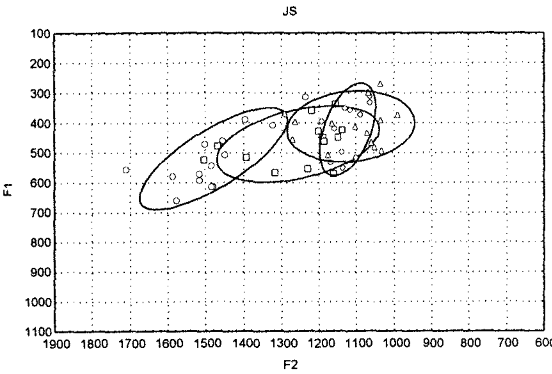


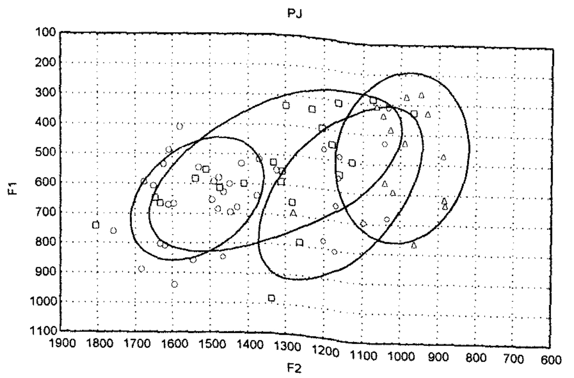

JI
F1
F2

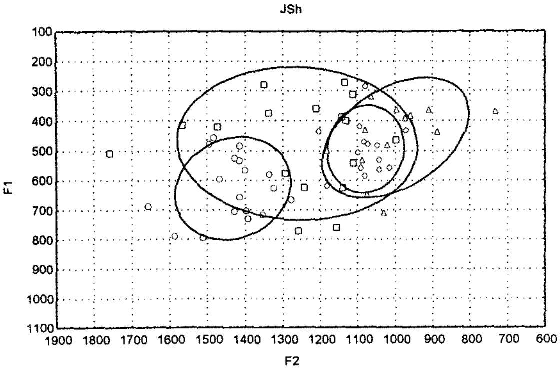

MP
F1
F2

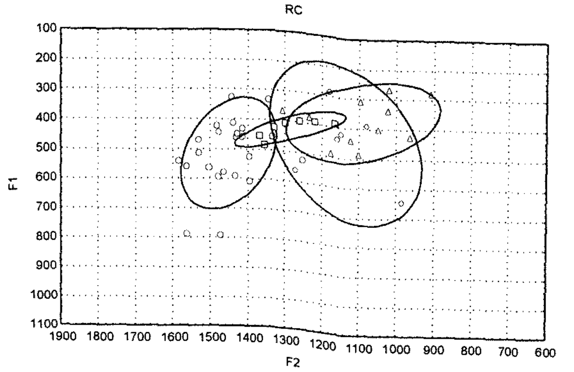

JL
F1
F2

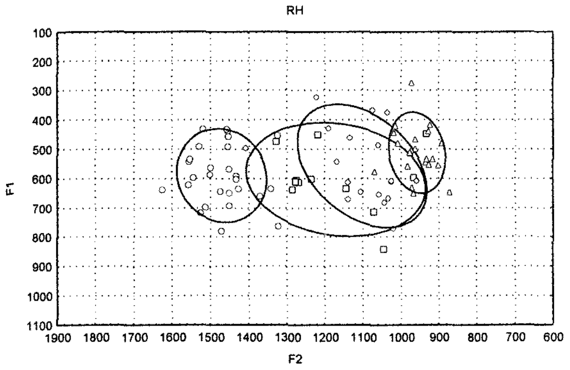

NK
F1
F2


JS
F1
F2


PJ
F1
F2


JSh
F1
F2


RC
F1
F2


RH
F1
F2
100
200
300
400
500
600
700
800
900
1000
1100
1900
1800
1700
1600
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1300
1200
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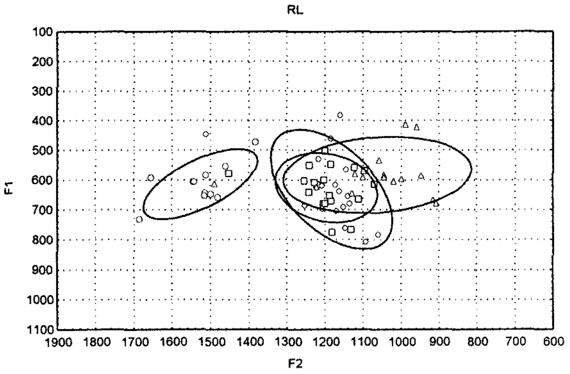
1000
900
800
700
600


RL
F1
F2
100
200
300
400
500
600
700
800
900
1000
1100
1900
1800
1700
1600
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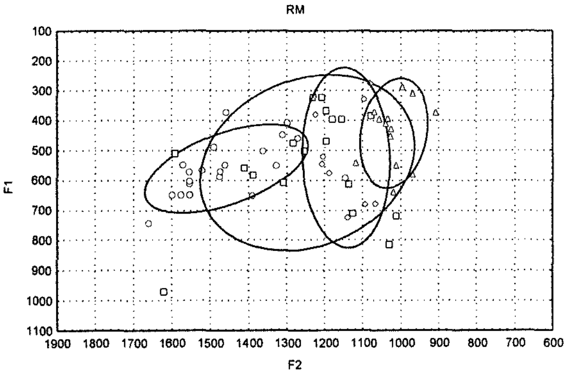
1000
900
800
700
600


RM
F1
F2
100
200
300
400
500
600
700
800
900
1000
1100
1900
1800
1700
1600
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1300
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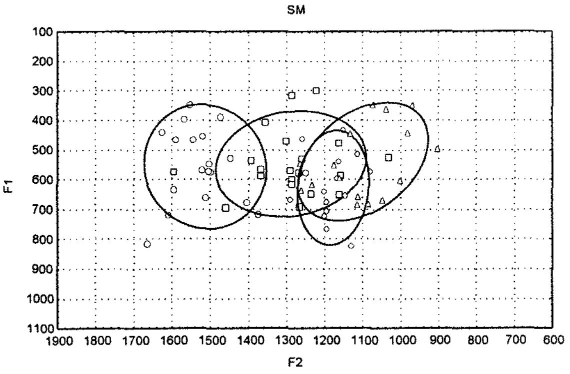
1000
900
800
700
600


SM
F1
F2
100
200
300
400
500
600
700
800
900
1000
1100
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600

We found out that all speakers except for FL and JS realise /ɒ/ as backer than the other vowels. The average F2 of /ɒ/ for speaker FL closely corresponds to the average F2 of his /ɑː/, only his /ɒ/ lies somewhat higher. Speaker JS, on the other hand, can be said to realise these two vowels as practically identical. This is due to his unusually front quality of /ɒ/ whose average F2 amounts to1114 Hz, while the average F2 of /ɑː/ for all speakers is 1146 Hz. Also the positions of the two vowels in the speech of JS in terms of openness blur (there is only a 10 Hz difference).

Another example of non-standard behaviour with regard to the overall character of the low vowels can be seen in speakers GF and MP whose /æ/s have a more close quality than their /ɒ/s. In all the other speakers /ɒ/ retains the status of the highest of the low vowels, although often only by a margin ahead of /ʌ/ (e.g., in speaker SM the average F1(/ɒ/)=438 Hz, whereas the average F1(/ʌ/)=446 Hz).

The major upward-pulling force is represented by speakers CC, DR, RC and JS, the former three exhibiting average values of /ɒ/ below 400 Hz while the average for all speakers amounts to 502 Hz. Incidentally, all these speakers are characterised by notably high vowel-area position of most of their low vowels. From the opposite pole, associating the representatives of the lowest-positioned /ɒ/, the following must be mentioned: AS, RL, NK and GF with average F1 575, 595, 641 and 647 Hz, respectively.

We have noted above that speaker JS tends to realise /ɒ/ with uncommonly front quality. Apart from him also speakers JL and SM have high F2 average values for /ɒ/ (reaching just over or nearly 1100 Hz). Compared to that, speakers CC, DJ and RH most prominently show a backward tendency with regard to the quality of /ɒ/, their average F2 values being 954, 972 and 958 Hz, respectively.

Some of the speakers have a well-defined /ɒ/, e.g., DL, ED, JS, NK, RL, RH. However, none of the 20 subjects devotes a fully distinct area to the open-mid back vowel, although we can notice clearer separation from the remaining vowels in speakers AS, DL, ED and RH.

In summary, approximately a third of the speakers have /æ/ fully or nearly separate without overlaps with the backer vowels. In contrast to that, /ʌ/ never occupies its own area, without competing with the adjacent vowels. Neither does /ɑː/, which overlaps with /ʌ/ by at least half of its ellipse in all but two speakers, in the remaining cases it shares most of its space with the back /ɒ/.

These results may lead us to think that /ʌ/ and /ɑː/ represent the most vulnerable of the four sounds in terms of perception. However, since /ɑː/ belongs to vowels with long duration, and has been proved to be such in our sample reaching average duration value of 116 ms (as opposed to /æ/:dur=92.9 ms, /ʌ/:dur=77.8 ms and /ɒ/:dur=73.2 ms), its identification by a listener is apt to be largely secured. Nevertheless, another identification problem might arise with respect to the qualitative proximity of /ʌ/ and /ɒ/, noticeable for example in speakers RL, JS or JSh.

### 13.2.1 Statistically significant differences between the individual speakers

In the previous section we were focussing on the relations among the low vowels within each speaker's vowel space. We examined what part each of them played in the overall results, how distinct and well-defined the individual speakers' low vowels are in relation to others and to the overall mean formant values of the vowels. We derived these characteristics from the speakers' mean formant values in combination with the scatter-ellipses showing the distribution of the measured vowels on a two-dimensional (F1-F2) graph (Figure 13.2.1 above). In the previous section we compared the variability of the individual speakers' formants with the aid of the coefficient of variation to find the most and the least stable representatives of each vowel, as well as the speakers whose all four low vowels vary to the smallest and largest extent. Broadly speaking, we were looking for differences and similarities between the individual speakers, yet not knowing which of the findings can be generalised.

By comparison, this section aims to present the **statistically significant** differences between the individual speakers' vowel formants (as a measure of vowel quality). First of all, we stated the null hypothesis that there is no difference between our subjects' first two vowel formants. In order to either confirm or reject the hypothesis, we carried out t-tests for independent samples where each variable contained the data for one group, i.e., one speaker. If $p$ (or $p$-level, an indicator of statistic significance, which is reported with a t-test) reaches value lower than 0.05, the difference between two given mean values is said to be statistically significant, i.e., it can be generalised (the lower the *p*-level, the more significant the observed difference). The same analysis was conducted for both F1 and F2. All the measured *p* values are available in Appendix.

Two speakers' vowels were regarded to be different when both F1 and F2 of the vowels in question were found to be significantly different. Tables 13.2.1.1 below present the 20 speakers' means of F1 and F2 for each vowel and a list of speakers that each subject appeared to be significantly different from.

The tables reveal that out of 180 theoretically possible differences there are 43 of them between the 20 instances of /æ/. Speakers DJ, MP, ED and RC are significantly different from 14, 11, 7 and 7 other speakers, respectively. DJ's /æ/ won the first rank by its mean F1 exceeding 700 Hz and by having the lowest mean F2 (1328 Hz) of all the speakers. The /æ/s which were identified as different from the one of DJ's have all markedly higher and fronter quality. The frontest one among those is the /æ/ of MP's, which, at the same time, belongs to the highest in the vowel space. All /æ/s that significantly differ from that of ED's have a higher and fronter position, the /æ/s different from the RC's one are lower and fronter. The remaining speakers' /æ/ differs from the others in less than 6 cases.

In comparison to /æ/, the 20 speakers' /ʌ/s differ much less from one another, specifically in 18 cases. JL, whose /ʌ/ differs from 7 of the speakers' /ʌ/ is characterised by considerably fronter (F2=1355 Hz) and higher (F1=486 Hz) quality. On the other hand, speakers NK and RL, who significantly differ from 6 and 5 of the speakers, respectively, belong to those whose /ʌ/ is much backer and lower. There are fewer than two significant differences between the other speakers' /ʌ/s.

Between the 20 /ɑː/s there were found 27 differences. Both FL's and JSh's /ɑː/s, which differ from the other speakers in the largest number of cases (8 and 6), tend to acquire a relatively high and back quality in comparison with the other speakers' /ɑː/s. As opposed to that, the mean /ɑː/ of speaker AS occupies the frontest and lowest position, which distinguishes it significantly from 5 other speakers' /ɑː/s.

**Tables 13.2.1.1** Significant differences between individual speakers' vowel formants

| | front open-mid | | | central open-mid | | |
|---|---|---|---|---|---|---|
| **Speaker** | F1 | F2 | Significantly different from | F1 | F2 | Significantly different from |
| **AS** | 652 | 1508 | DJ, ED, MP, RC | 676 | 1324 | DR |
| **CC** | 619 | 1528 | DJ, ED, MP, RC | 498 | 1305 | NK, RL |
| **DJ** | 737 | 1328 | AS, CC, DR, FL, GF, JL, JS, JSH, MP, PJ, RC, RH, RL, RM | 589 | 1250 | |
| **DL** | 771 | 1462 | MP | 692 | 1237 | JL |
| **DR** | 593 | 1438 | DJ, JI | 434 | 1234 | AS |
| **ED** | 761 | 1434 | AS, CC, FL, MP, PJ, RL, SM | 654 | 1268 | |
| **FL** | 602 | 1526 | DJ, ED, NK, RC | 669 | 1229 | JL, NK |
| **GF** | 618 | 1478 | DJ, MP | 674 | 1247 | JL |
| **JI** | 721 | 1515 | DL, JL, JSH, MP, RC | 636 | 1250 | JL |
| **JL** | 610 | 1431 | DJ, JI, MP | 486 | 1355 | DL, FL, GF, JI, NK, RH, RL |
| **JS** | 520 | 1479 | DJ | 471 | 1255 | |
| **JSh** | 628 | 1432 | DJ, JI, MP | 477 | 1260 | |
| **MP** | 528 | 1616 | AS, CC, DJ, DL, ED, GF, JI. JL. JSH. NK. PJ | 551 | 1284 | NK, RL |
| **NK** | 724 | 1469 | FL, MP, PJ, RL | 711 | 1202 | CC, JL, MP, PJ, RC, SM |
| **PJ** | 651 | 1535 | DJ, ED, MP, NK, RC, RL | 545 | 1329 | PJ, NK |
| **RC** | 515 | 1450 | AS, CC, DJ, FL, JI, PJ, RL | 422 | 1284 | NK, RL |
| **RH** | 590 | 1470 | DJ | 604 | 1171 | JL |
| **RL** | 614 | 1526 | DJ, ED, NK, RC | 626 | 1196 | CC, JL, MP, RC, SM |
| **RM** | 562 | 1457 | DJ, PJ | 541 | 1245 | |
| **SM** | 556 | 1513 | ED | 547 | 1288 | NK, RL |

| | open back | | | open-mid back | | |
|---|---|---|---|---|---|---|
| **Speaker** | F1 | F2 | Significantly different from | F1 | F2 | Significantly different from |
| **AS** | 678 | 1235 | FL, JI, JS, JSH, RH | 575 | 1051 | |
| **CC** | 459 | 1179 | | 344 | 954 | ED, JL, NK, RL, RM, SM |
| **DJ** | 615 | 1115 | | 545 | 972 | JL, JS, RC |
| **DL** | 679 | 1136 | FL, JSH | 553 | 1009 | JL, JS, RC |
| **DR** | 409 | 1137 | FL | 391 | 1021 | RH, SM |
| **ED** | 720 | 1122 | FL, JL | 523 | 1031 | CC, JS |
| **FL** | 531 | 1040 | AS, DL, DR, ED, JS, NK, RL | 478 | 1035 | |
| **GF** | 719 | 1079 | JL, MP, RM | 647 | 988 | JL, JS, RC, SM |
| **JI** | 548 | 1097 | AS, NK, RL, SM | 512 | 1010 | JS |
| **JL** | 540 | 1234 | ED,GF, JS | 454 | 1092 | CC, DJ, DL, GF |
| **JS** | 422 | 1123 | AS, FL, JL, SM | 413 | 1115 | DJ, DL, ED, GF, JI, MP, RH |
| **JSh** | 495 | 1078 | AS, DL, NK, PJ, RL, SM | 457 | 999 | |
| **MP** | 574 | 1186 | GF | 546 | 1019 | JS |
| **NK** | 742 | 1198 | FL, JI, JSH, RH | 641 | 1038 | CC, RH |
| **PJ** | 610 | 1157 | JSH | 476 | 995 | |
| **RC** | 456 | 1136 | | 381 | 1090 | DJ, DL, GF, RH |
| **RH** | 558 | 1102 | AS, NK | 513 | 957 | DR, JS, NK, RC, RL, RM |
| **RL** | 631 | 1182 | FL, JI, JSH | 595 | 1067 | CC, RH |
| **RM** | 525 | 1144 | GF | 443 | 1018 | CC, RH, SM |
| **SM** | 627 | 1177 | FL, JI, JS, JSH | 539 | 1099 | CC, DR, GF, RM |

Finally, also /ɒ/ showed to be different in 27 out of the 180 comparisons conducted. Speakers CC, JS and RH differ most frequently, in 6, 7 and 6 cases, respectively. CC's /ɒ/ is distinguished by its high and back quality, JS occupies higher and fronter area compared to the other speakers' /ɒ/, RH belongs to the lowest and backest of our /ɒ/s.

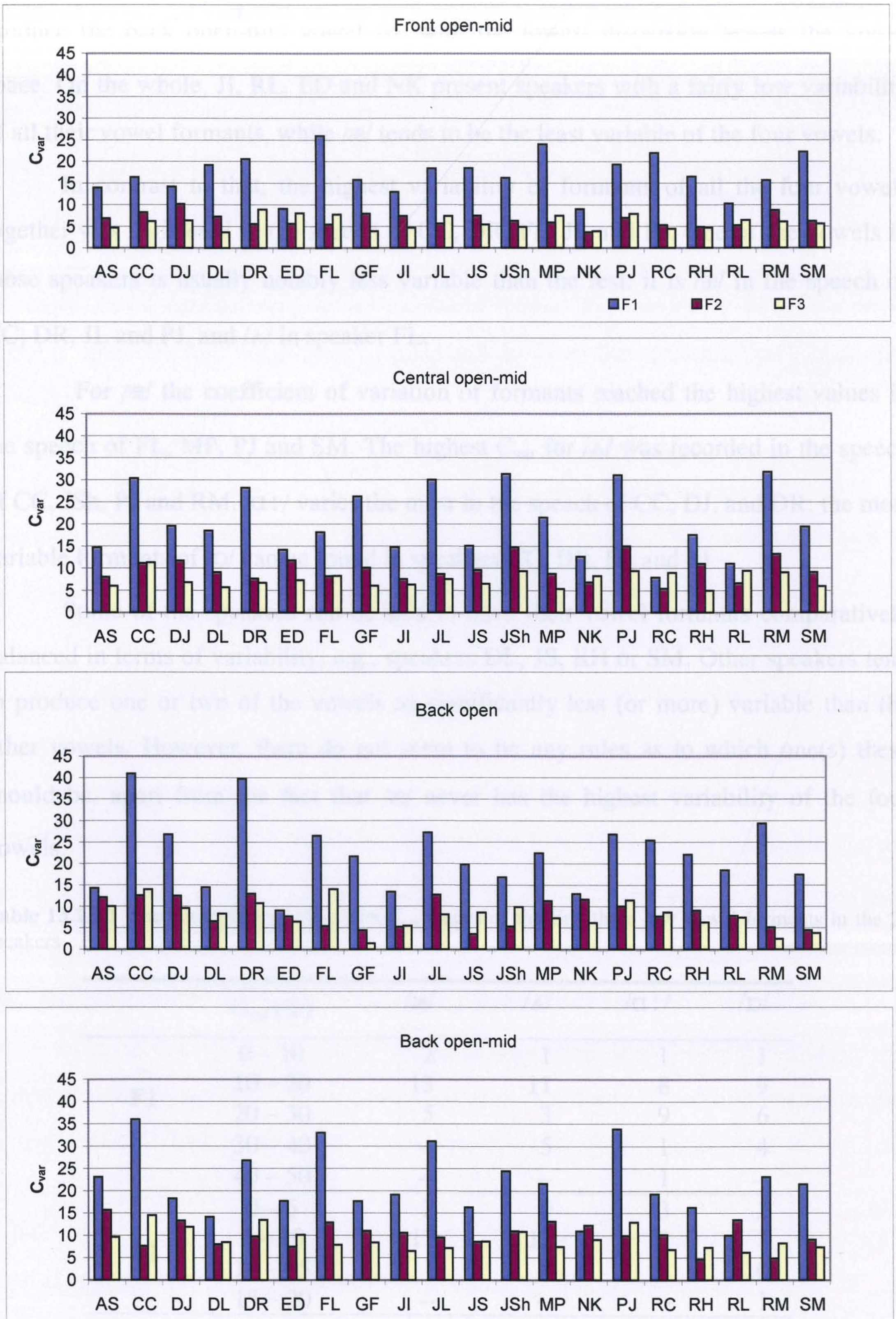
To summarize, our analysis rejected the null hypothesis, because it revealed numerous significant differences in the quality of the low vowels between the individual speakers. Out of the 180 theoretically possible differences between each of the 20 speakers' low vowels, there are 43 significant differences between the twenty sets of /æ/, 18 between the groups of /ʌ/ and 27 between the speakers' realizations of /ɑː/ and /ɒ/. Interestingly, there are the most differences between the individual speakers' groups of a vowel, which has the lowest coefficient of variation of all three formants, i.e., it is the most stable.

### 13.2.2 Variability of formant values in individual speakers

In order to compare the variability of formants as they were realized by the twenty speakers, we plotted bar graphs of the coefficient of variation ($C_{var}$) (Figures 13.2.2.1 below). Each of them illustrates the range of dispersion for each of the low vowels separately. In order to find the speakers with the least and the most variable realization of their vowels we considered all the three formants' figures of the coefficient of variation together.

The comparison revealed that /æ/ is the most stable when produced by speakers ED, NK and RL. /ʌ/ is characterised by a relatively low dispersion in speakers AS, NK, RL and RC. As we have pointed out earlier, RC deserves particular attention in this context, because, for one thing, the $C_{var}$ of all three formants of his central open-mid vowel reaches unusually low values and, secondly, it is distinctively more stable in comparison with the surrounding low vowels of RC's. However, it is particularly the two-dimensional representation of RC's central open-mid vowels (see Figure 13.2.1 in section 13.2) that raises doubts about the validity of the graph input data. Nevertheless, these have proved to be correct.

**Figures 13.2.2.1** The coefficient of variation ($C_{var}$) of the first three low-vowel formants in individual speakers



/ɑː/ varies the least in the speech of JI, ED and SM. Speakers DL, RH and RL produce the back open-mid vowel /ɒ/ with the lowest dispersion across the vowel space. On the whole, JI, RL, ED and NK present speakers with a fairly low variability of all their vowel formants, while /æ/ tends to be the least variable of the four vowels.

In contrast to that, the highest variability of formants of all the four vowels together was registered in the speech of CC, DR, FL, JL and PJ. One of the vowels in those speakers is usually notably less variable than the rest: it is /æ/ in the speech of CC, DR, JL and PJ, and /ʌ/ in speaker FL.

For /æ/ the coefficient of variation of formants reached the highest values in the speech of FL, MP, PJ and SM. The highest $C_{var}$ for /ʌ/ was recorded in the speech of CC, JSh, PJ and RM. /ɑː/ varies the most in the speech of CC, DJ, and DR; the most variable formants of /ɒ/ can be found in speakers CC, DR, FL and PJ.

Some of the speakers can be said to have their vowel formants comparatively balanced in terms of variability, e.g., speakers DL, JS, RH or SM. Other speakers tend to produce one or two of the vowels as significantly less (or more) variable than the other vowels. However, there do not seem to be any rules as to which one(s) these should be, apart from the fact that /æ/ never has the highest variability of the four vowels.

**Table 13.2.2.1** The occupation of the given $C_{var}$ ranges of the first three low vowel formants in the 20 speakers

| | $C_{var}$ (%) | /æ/ | /ʌ/ | /ɑː/ | /ɒ/ |
|---|---|---|---|---|---|
| **F1** | 0 – 10 | 2 | 1 | 1 | 1 |
| | 10 – 20 | 13 | 11 | 8 | 9 |
| | 20 – 30 | 5 | 3 | 9 | 6 |
| | 30 – 40 | -- | 5 | 1 | 4 |
| | 40 – 50 | -- | -- | 1 | -- |
| **F2** | 0 – 5 | 2 | 0 | 3 | 2 |
| | 5 – 10 | 17 | 12 | 9 | 7 |
| | 10 – 15 | 1 | 8 | 8 | 10 |
| | 15 – 20 | -- | -- | -- | 1 |
| **F3** | 0 – 5 | 8 | 1 | 3 | -- |
| | 5 – 10 | 12 | 18 | 12 | 14 |
| | 10 – 15 | -- | 1 | 5 | 6 |

Table 13.2.2.1 above illustrates how the 20 speakers occupy the $C_{var}$ ranges that we stated for the first three formants of the low vowels. It becomes apparent that 75 % of the speakers produce the F1 of the front open-mid vowel with $C_{var}$ below 20 %. The same variability range for /ʌ/ is occupied by 60 % of speakers. Only 50 % of the speakers realise the first formant of /ɑː/ and 45 % of the speakers pronounce /ɒ/ characterised by F1within the range of 0 and 20 %.

95 % of speakers realise their front open-mid vowel with $C_{var}$ for F2 below 10 %, while the remaining vowels are produced within this variability range by 60 % (central open-mid and back open vowels) and 45 % of the speakers (back open-mid vowel).

All the speakers' F3 $C_{var}$ values measured for the front open-mid vowel fall within the range of 0 and 10 %. The central open-mid vowel follows with 95 % of speakers. Only 75 % of speakers pronounce /ɑː/ with the $C_{var}$ of F3 between 0 and 10 %. Even fewer, 70 % of speakers realise /ɒ/ within this variability range.

In summary, most speakers' F1 variability of the low vowels appears between the levels of 10 and 30 %; /ʌ/, /ɒ/ and /ɑː/ exceed the F1 variability level of 30 % in 5, 4 and 2 speakers, respectively. For F2, the majority of $C_{var}$ values in the individual speakers is concentrated between 5 and 15 %. There is only one instance of a low vowel, this being AS's /ɒ/, with variability over 15 %. All the low vowels but /ʌ/ are produced by some speakers with $C_{var}$ below 5 %. F3 of the low vowels is realised with the variability of up to 15 %. $C_{var}$ of the F3 of /æ/ never exceeds 10 %. Most speakers' /ɑː/ and all speakers' /ɒ/ are produced with F3 variability between 5 and 15 %.

Among the twenty speakers we have identified those with the highest and lowest formant variability. Further, we have seen that the levels of formant variability in the speakers' four vowels differ considerably. Therefore it is difficult to state any tendencies. Rather, it can be said that there occurred a number of speakers with similar variability of the four vowels' formants and a group of speakers with one, two or three vowels varying more (or less) than the remaining vowels.

### 13.3 Formant field characteristics with regard to vowel context

For our study the formant values were taken from the steady-state part of the vowel excluding transitions in order to measure the vowel formant when it is the least affected by the immediate environment. Assuming that the effect of the immediate context is minimised, we formulated a null hypothesis saying that neither the manner nor the place of articulation will affect the formant values of the low vowels. In other words, our attempt is to find if any differences can be found between the mean values of the vowel context groups. Other two questions to be answered are the following: Are our findings consistent with the previous findings (with reference to the theoretical part of this study)? Are any of the differences statistically significant?

Apart from the results presented in the following sections there are more detailed descriptive statistics for the low vowels in different contexts available in Appendix.

### 13.3.1 Formant values of low vowels in contexts differing in manner of articulation

The aim of this partial analysis is to discover the systematic differences among the nine groups defined by three context parameters: sonorant, voiced obstruent and voiceless obstruent (see section12.3.2). Table 13.3.1.1 below presents the mean values of the first three formants of the low vowels in the nine different environments.

The comparison of the mean F1 and F2 frequency values of the individual vowels revealed that the context groups differ in tens or hundreds (not more than two) of Hertz, e.g., group 1 as opposed to groups 2, 3, 5 as well as some other groups for the front open-mid vowel. If we examine the mean F1 and F2 values of the nine groups of the four vowels, we realise that /ɒ/ is produced with the highest range of all the vowels (i.e., there is the greatest difference between the lowest and highest F1 and F2 mean values of the nine context groups), /ʌ/ has the lowest range for F2 (160 Hz) and /ɑː/ reaches the smallest difference between its highest and lowest mean group values of F1 (68 Hz). However, if we disregard the values of the groups comprising less than five items, which have appeared to yield either F1 or F2 or both at one of the extreme ends of the range, then the most notable differences are found for the central open-mid vowel (approximately 100 and 160 Hz difference between the lowest and highest means of F1 and F2, respectively). On the other hand, the lowest contrast is found for both F1 and F2 of the back open vowel (68 and 84 Hz, respectively). To a certain extent, these range figures suggest that /ɑː/ tends to be the least liable to changes in the given contexts (T-tests carried out for the 9 groups of /ɑː/ did not find any differences between them. – for more detail see further below).

**Table 13.3.1.1** The mean formant values of low vowels in groups differing in manner of articulation of the given vowel's context. The grey shading marks values calculated from five or fewer items. The red type highlights the highest, the blue type the lowest values for a given vowel.

| | /æ/ | | | /ʌ/ | | | /ɑː/ | | | /ɒ/ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Context group | F1 | F2 | F3 | F1 | F2 | F3 | F1 | F2 | F3 | F1 | F2 | F3 |
| o vcd-V-o vcd | 725 | 1308 | 2395 | 612 | 1347 | 2400 | 605 | 1098 | 2360 | 363 | 847 | 1966 |
| o vcd-V-o vls | 642 | 1484 | 2406 | 596 | 1315 | 2444 | 603 | 1285 | 2445 | 517 | 1098 | 2342 |
| o vcd-V-son | 618 | 1516 | 2440 | 570 | 1334 | 2418 | 626 | 1151 | 2488 | 473 | 1102 | 2292 |
| o vls-V-o vcd | 682 | 1468 | 2481 | 617 | 1252 | 2448 | 584 | 1158 | 2461 | 539 | 962 | 2272 |
| o vls-V-o vls | 656 | 1516 | 2438 | 588 | 1217 | 2366 | 573 | 1131 | 2404 | 465 | 1000 | 2226 |
| o vls-V-son | 599 | 1457 | 2423 | 575 | 1272 | 2418 | 584 | 1182 | 2438 | 505 | 1009 | 2214 |
| son-V-o vcd | 699 | 1378 | 2358 | 514 | 1221 | 2392 | 582 | 1149 | 2372 | 500 | 1030 | 2317 |
| son-V-o vls | 633 | 1482 | 2476 | 579 | 1244 | 2348 | 594 | 1136 | 2416 | 533 | 1024 | 2309 |
| son-V-son | 623 | 1457 | 2515 | 571 | 1180 | 2437 | 558 | 1140 | 2495 | 502 | 1017 | 2288 |

The next subject of our interest was the actual quality of the low vowels in the various contexts differing in manner of articulation. We know from previous studies (Stevens and House - see section 10.2 earlier in this study) that different vowels respond to various environments differently. We have also seen a graph depicting the GenAmE vowels (ibid.) realised in voiced and voiceless environments. Judging from this graph, the F2 frequency of the low vowels (except for /ɒ/, which is replaced by /ɑ/ in GenAmE) tends to reach comparable or slightly higher values in a voiced context than in a voiceless one. For F1, the tendency seems to be the opposite, i.e., F1 frequency is higher in a voiceless environment than in a voiced one. For /æ/ and /ʌ/ the difference in F1 is more pronounced than the difference in F2 in these two contexts. /ɑ/ appeared to undergo the smallest changes in both formants. Since the tendencies were similar for all these three vowels as well as for /ʊ/, we expect /ɒ/ to be affected in the same direction, if not extent of the influence. However, we must note that these differences, particularly when expressed in ERB, were described as unimpressive in terms of perception.

In our analysis, we concentrated, first of all, on the symmetrical contexts (e.g., the preceding as well as the following sound was a voiceless obstruent) where the coarticulation effect is expected to be more noticeable than in a mixed context. We compared the formant values of the vowels produced in a fully voiced environment with those realised in a fully voiceless context. However, Stevens and House's findings were not confirmed, our results are compatible with their measurements only in case of F2 in /ʌ/ (F2 is higher in a voiced context, i.e., between two voiced obstruents than in a voiceless one, i.e., between two voiceless obstruents) and F1 in /ɒ/ (F1 is lower in between two voiceless obstruents than between two voiced ones). In other words, the very opposite seems to be the overriding tendency. For /æ/, /ʌ/ and /ɑː/ the mean F1 frequency was lower in a fully voiceless context than in a fully voiced environment. The mean F2 frequency was found to be lower in a voiced context for /æ/, /ɑː/ and /ɒ/. Yet again, it must be pointed out that the fully voiced environment suffers from lack of underlying data and therefore our results cannot be generalised (there are only 5 items of /æ/ and 2 items of /ɒ/ in this context).

Not even the exclusively sonorant context differentiates itself consistently from the other groups with symmetrical environment. In comparison with the rest of the symmetrical context groups, F1 of the vowels between two sonorants has the lowest mean value in /æ/, /ʌ/ and /ɑː/, but it has the highest mean value in /ɒ/ out of the three symmetrical contexts. F2 behaves for each vowel differently in relation to the vowels' values in a fully voiced and fully voiceless context. It reaches the highest values of the three in vowels /ɑː/ and /ɒ/, but the lowest value in /ʌ/. F2 of the front open-mid vowel surrounded by two sonorant sounds has a higher value than when the vowel is realised between two voiced obstruents, but lower than when pronounced between two voiceless obstruents.

On the whole, the mean formant values of the context groups of the individual vowels resemble each other to the extent that we decided to submit them to *t*-tests to find out if any of the groups differ statistically significantly. We used the same procedure as when we wanted to find the differences between the individual speakers (see section 13.2.1 above). Also here, we regard two groups to be significantly different if the difference is found between both F1 and F2 frequency. All the *p* values are to be found in the Appendix.

The analysis revealed no statistically significant differences between the nine groups of /ɑː/, but it found one difference for each of the remaining vowels. /æ/ pronounced between two voiceless obstruents is significantly different from /æ/ realised between a voiceless obstruent and a sonorant sound (in this order). In the context of two voiceless obstruents (group 5) the vowel gains a lower and fronter quality than in the o vls-V-son (group 6) context. Groups 1 (o vcd-V-o vcd) and 6 (o vls-V-son) and groups 1 (o vcd-V-o vcd) and 3 (o vcd-V-son) almost come out as significantly different - in both cases $p$(F1) slightly exceeds the critical value of 0,05.

/ʌ/ pronounced in an o vcd-V-o vcd context is significantly different from /ʌ/ pronounced in a son-V-o vcd context. Between two voiced obstruents /ʌ/ reaches the highest F2 and the second highest F1 of the nine groups, which differentiates it from /ʌ/ with the lowest F1 and second lowest F2 when pronounced between a sonorant and a voiced obstruent.

Finally, /ɒ/ was found to have a different quality in groups 3 (o vcd-V-son) and 8 (son-V-o vls). Group 3 is characterised by the second lowest mean F1 and the highest F2, as opposed to group 8, whose mean F1 is the second highest of the nine groups and the mean F2 frequency reaches exactly the average of all items of /ɒ/ in our sample (1024 Hz).

In summary, the mean values, particularly the difference between the highest and lowest measured mean formant frequencies, for the context groups of each vowel point to differences in quality between them, although inconsistent across the four vowels. The differences that were expected to be the most pronounced, i.e., the differences between groups defined by symmetrical context, go against the findings from a previous study. The null hypothesis assuming the absence of differences between the context groups was rejected, although we have seen that there are very few significant differences between the groups of vowels in contexts differing in manner of articulation. What underlies these differences is the 'distance' of the values in the vowel space (note that the vowel formants in these groups are frequently the highest or lowest values recorded among the groups). Surprisingly, the statistically significant differences do not occur between the groups with a symmetrical environment. Finally, a given vowel in a given context would have to differ from at least a half of the nine groups in order to be marked as distinct from the rest. Thus, we may conclude that the immediate environment differing in manner of articulation has a negligible effect on the formant frequencies of the low vowels.

### 13.3.2 Formant values of low vowels in contexts differing in place of articulation

Taking into consideration the method of formant measurement employed in this study, we would not expect any notable effect of different place of articulation of the immediate vowel environment on the low vowel formant frequencies.

However, as Table13.3.2.1 shows, the range of the mean values (the difference between the highest and lowest of the group values within each vowel) of the formants the individual vowel groups is higher than the range calculated from the mean values f groups which were result of the differences in manner of articulation (see previous ection). Therefore we may assume more significant differences between the groups of given vowel.

**able 13.3.2.1** The mean formant values of low vowels in groups differing in place of articulation of the ven vowel's context. The grey shading marks values calculated from five or fewer items. The red type ghlights the highest, the blue type the lowest values for a given vowel.

| | /æ/ | | | /ʌ/ | | | /ɑː/ | | | /ɒ/ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Context groups | F1 | F2 | F3 | F1 | F2 | F3 | F1 | F2 | F3 | F1 | F2 | F3 |
| lab-V-lab | 690 | 1336 | 2476 | 490 | 1104 | 2374 | 574 | 1076 | 2354 | 451 | 970 | 2129 |
| lab-V-cor | 639 | 1424 | 2448 | 572 | 1171 | 2485 | 594 | 1107 | 2418 | 498 | 976 | 2243 |
| lab-V-vel | 627 | 1480 | 2391 | 445 | 1154 | 2415 | 579 | 1146 | 2294 | 484 | 967 | 2248 |
| cor-V-lab | 646 | 1428 | 2461 | 584 | 1256 | 2430 | 587 | 1179 | 2502 | 506 | 1054 | 2313 |
| cor-V-cor | 618 | 1472 | 2483 | 609 | 1264 | 2423 | 561 | 1198 | 2472 | 512 | 1089 | 2323 |
| cor-V-vel | 633 | 1538 | 2423 | 525 | 1245 | 2286 | 700 | 1118 | 2529 | 544 | 1050 | 2292 |
| vel-V-lab | 667 | 1525 | 2436 | 608 | 1326 | 2390 | 558 | 1056 | 2404 | 508 | 953 | 2298 |
| vel-V-cor | 589 | 1534 | 2438 | 582 | 1301 | 2435 | 607 | 1168 | 2492 | 520 | 1045 | 2171 |
| vel-V-vel | 740 | 1590 | 2451 | | | | 681 | 1056 | 2338 | 329 | 1006 | 1960 |
| lab+vel -cor | | | | 556 | 1106 | 2409 | | | | 478 | 951 | 2279 |
| cor- -lab+vel | | | | | | | 809 | 1049 | 2621 | | | |

Stevens and House (see section 10.2) studied the influence of immediate context iffering in place of articulation on GenAmE vowels. Their graph depicting the mean alues reveals that each of the low vowels behaves differently in a given environment. )nly F1 of /æ/ and /ʌ/ becomes higher from fully velar to coronal to labial nvironment; F2 of /ɑ/ and /ʌ/ rises from fully labial to velar to coronal context. The ırgest differences were measured for /ʌ/, however, all the shifts were described as egligible from a listener's point of view.

Our data only partly agree with the findings of the earlier study. /æ/ and /ɑː/ ave identically been found to have a higher F1 in the direction from coronal to labial ɔ velar context, but only /ɑ/ (similar to /ɑː/) had these characteristics in Stevens and Iouse's study. /ʌ/'s F1 rises with backer environment, although we lack data on the elar environment for this vowel. The three different contexts have a reverse effect on he F1 of /ɒ/, i.e., it reaches the lowest values when between two velars and the highest alues when realised between two coronals. There are agreements also between the owels' F2, namely for /æ/ and /ʌ/. F2 of /æ/ rises from labial to coronal to velar ontext, /ʌ/ has a higher F2 in a coronal context than in a labial one. The referential data for /ɒ/ for the reasons mentioned earlier were not available. In our study, the labial environment produced the lowest F2 values of /ɒ/, the coronal context yielded the highest figures.

Unlike F1, F2 of the low vowels appears to be a parameter showing a systematic response to environment differing in place of articulation. If we focus on the F2 columns of Table 13.3.2.1 above, we can see that the influence of different place of environment we pointed out for the symmetrical contexts are observable for all the environments beginning in the same type of sound, e.g., if we take the contexts where a labial sound precedes /æ/ as a higher level group, they tend to have an altogether lower value than the contexts beginning with a coronal, etc. In each of those three-member groups we can further see the influence of the right-hand context: a labial context causes the lowest value of the three, the velar context pushes the value up. A similar, although not such a perfect pattern can be observed for /ʌ/. Due to the consistency of its figures we might assume that the missing data for the fully velar environment would be characterised by the highest F2 of the context groups. The pattern we described to fit /ɒ/ (a labial environment yielding the lowest, a coronal environment the highest values) also works partially at a deeper level (looking at the right-hand context). Also F2 of /ɑː/ in our sample responds in harmony with the described pattern (a velar context producing the lowest, the coronal context the highest values), although only at the higher level, i.e., the level of three-member groups.

The lab+vel-V-cor groups of both /ʌ/ and /ɒ/, abundantly represented, produce the F1 and F2 frequencies comparable to the lowest values of the other groups of the respective vowels.

Even for the groups differing in place of articulation, where the ranges of the groups' values outsized those found for the groups differing in manner of articulation and where patterns of a regular F2 behaviour were traced, we decided to carry out *t*-tests (the procedure is described in section 13.2 above) in order to ascertain only the statistically significant differences between the context groups and, in fact, to verify the differences found between the groups of vowels in the symmetrical environments.

A detailed examination of the *p* values revealed that /æ/ is the most susceptible to changes in quality due to its immediate environment of all the low vowels. Here are the groups of /æ/ that differ significantly:

/æ/: p<0,05 for F1 and F2:

vel- -cor X lab- -lab
vel- -cor X lab- -cor
vel- -vel X lab- -cor
vel- -vel X lab- -vel
vel- -vel X cor- -cor

Out of the possible differences between the symmetrical context groups only one was confirmed, namely between vel-V-vel and cor-V-cor groups.

/ʌ/ has significantly higher F1 and F2 frequencies, i.e., it is fronter and lower, than three other groups when preceded by a velar and followed by a labial.

/ʌ/: p<0,05 for F1 and F2:

vel- -lab X lab- -lab
vel- -lab X lab- -vel
vel- -lab X cor- -vel

The *t*-tests reinforced only one significant difference for /ɒ/. Probably it is due to a fairly low number of items (7), six of them followed by [ŋ], that F1 of group X reached such a low mean value (329 Hz) which distinguished it from the /ɒ/ in a fully coronal environment.

/ɒ/: p<0,05 for F1 and F2:

vel- -vel X cor- -cor

No significant differences between the context groups of /ɑː/ were recorded.

To summarize, the aim of this section was to outline some of the important characteristics of the first two formants in the low vowel region with regard to their changes caused by the immediate environment differing in place of articulation. Certain patterns of behavior of the F2 frequency described in earlier studies have been confirmed, however, very few F1 characteristics in the low vowels of an earlier date were supported by our data.

Nonetheless, the absolute differences between the individual groups' mean values of formants, which we used to trace the above-mentioned patterns, rarely have a statistically significant value. The *t*-tests mostly revealed significant differences between groups with mixed, rather than symmetrical context. A group significantly differed from a maximum of three other groups, which leaves it more similar than different in relation to the other context groups.

### 13.3.3 Additional observations

It has been noted earlier (in section 10.2) that F2 is generally more susceptible to coarticulatory changes, particularly to shifts in constriction location. Our analysis confirms this finding. *T*-tests showed more significant changes between the different context groups for F2 than for F1, or more precisely, the effects on F1 did not appear to be significant in such a high number of cases. At the same time, we found more significant changes among the groups of vowels differing in place of articulation than in manner of articulation.

The fact that our analysis did not abound in significant differences among the context groups is certainly partly attributable to the source of our data, this being connected speech, as opposed to the method of analysis used in most of the previous studies (as well as those we used for comparison in this section). As has become evident from the comparison of the overall mean formant values of the low vowels with the results of other studies, the vowel quality differences become more notable when the data are taken from a controlled, disconnected speech.

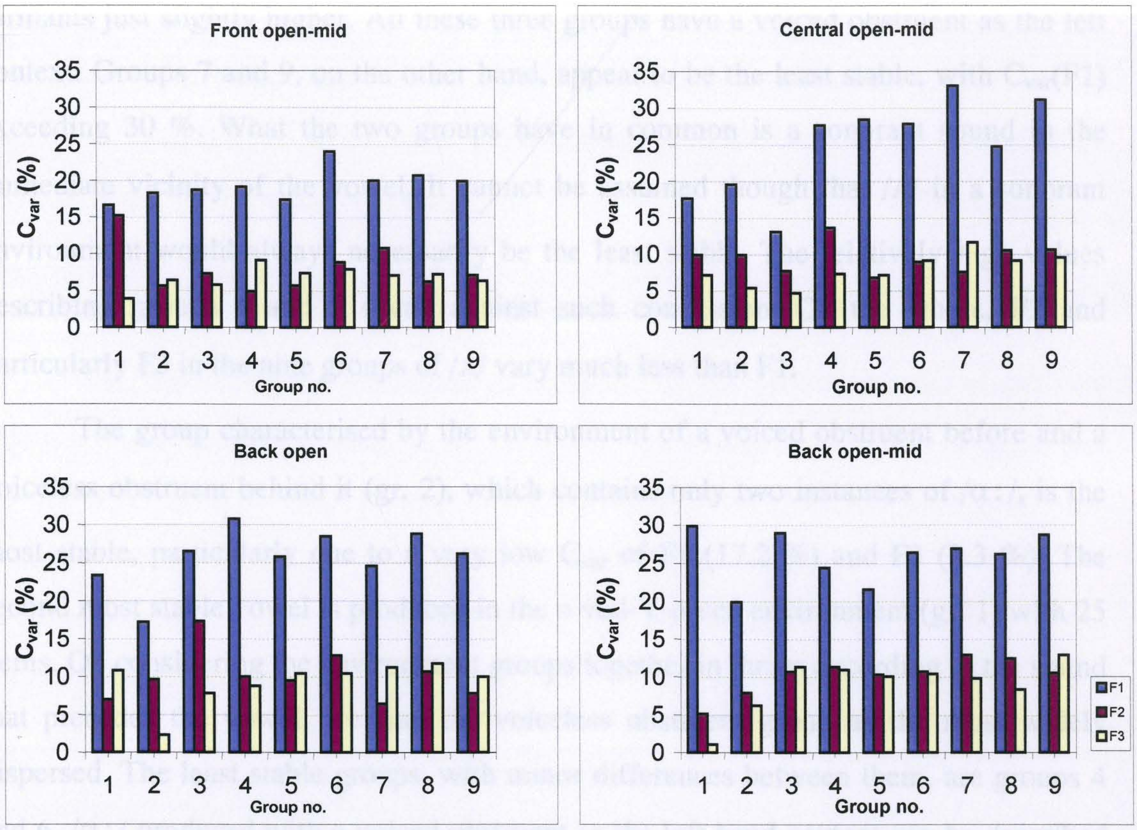
## 13.4 Dispersion of formant values in the context groups

The following two sections will attempt to describe the variability of the two sets of context groups.

### 13.4.1 Dispersion of formant values in groups differing in manner of articulation

As Figures 13.4.1.1 below show, the front open-mid vowel represents the most stable vowel of the four. It yields the most balanced F1 coefficient of variation ($C_{var}$) values for all the environment groups, none of which goes beyond 25 %. Also the $C_{var}$ values of F2 and F3 are the lowest for /æ/ in comparison with the other low vowels. The $C_{var}$(F3) figures never exceed 10 %. There are no major deviations in $C_{var}$(F2) values from the rest of the groups' values except for the $C_{var}$(F2) in a fully voiced context, which reaches a value more usual for F1 (15.2 %). Such inconsistency with the other values of $C_{var}$(F2) must be due to the low number of source data (n = 5). The same relation can be seen in gr. 3 of the back open vowel where the number of items amounts to 9. On the other hand, there are groups comprising an equally small number but they provide 'normal' values, e.g., gr. 2 of the open back vowel or gr. 4 of the open-mid back vowel. This only confirms the randomness of figures derived from poorly represented groups.

**Figures 13.4.1.1** The coefficient of variation of the first three formant frequencies in the groups of the four low vowels differing in manner of articulation (gr. 1=o vcd-V-o vcd, gr. 2=o vcd-V-o vls, gr. 3=o vcd-V-son, gr. 4=o vls-V-o vcd, gr. 5=o vls-V-o vls, gr. 6= o vls-V-son, gr. 7=son-V-o vcd, gr. 8=son-V-o vls, gr. 9=son-V-son).




/æ/ appears to be the least stable in the position between two voiced obstruents (gr. 1) and in the group where /æ/ is preceded by a sonorant and followed by a voiced obstruent (gr. 7). However, the two groups comprise too few items to lead us to the conclusion that they differ significantly from the other context groups. Between a voiceless obstruent and a sonorant sound (gr. 6), /æ/ appears to be the third most variable, although the number of items amounts to 109 in this set. If we examine the other $C_{var}$ values of the formants of /æ/ in the immediate neighbourhood with a sonorant we realise that these also produce comparatively high figures. Group 5 (o vls-V-o vls) along with groups 2 and 3, which both employ a voiced obstruent in the left context of the open-mid front vowel, come out as the most stable, the actual differences between them being negligible.

Apparently, group 3 (o vcd-V-son) belongs to the most compact groups of the central open-mid vowel with the lowest $C_{var}$ (F1)=13 %. However, it must be taken into consideration that this group lists only eleven items and therefore it is questionable whether environment of this type always produces numbers with such a low dispersion or whether it is a mere coincidence. Group 1 and 2 follow with $C_{var}$ figures of the formants just slightly higher. All these three groups have a voiced obstruent as the left context. Groups 7 and 9, on the other hand, appear to be the least stable, with $C_{var}$(F1) exceeding 30 %. What the two groups have in common is a sonorant sound in the immediate vicinity of the vowel. It cannot be assumed though that /ʌ/ in a sonorant environment would always necessarily be the least stable. The relatively high values describing groups 4 and 5 speak against such conclusion. On the whole, F2 and particularly F3 in the nine groups of /ʌ/ vary much less than F1.

The group characterised by the environment of a voiced obstruent before and a voiceless obstruent behind it (gr. 2), which contains only two instances of /ɑː/, is the most stable, particularly due to a very low $C_{var}$ of F1 (17.2 %) and F3 (2.3 %). The second most stable vowel is produced in the o vcd-V-o vcd environment (gr. 1) with 25 items. On considering the environment groups together in threes according to the sound that precedes the vowel, we find the voiceless obstruent group as the most widely dispersed. The least stable groups, with minor differences between them, are groups 4 and 6. /ɑː/ produced with a voiced obstruent as the left-hand context can be described to have the least consistent values of formant $C_{var}$.

The $C_{var}$ figures of the first three formants of the back open-mid vowel in the first two groups, comprising 2 and 10 items, respectively, deviate in character from the remaining groups in that their $C_{var}$ (F2 and F3) reach notably lower values. Particularly the $C_{var}$ (F2) in groups 3 to 9 is more or less steady reaching slightly above 10 per cent. If we take into account all three formants together, the group o vcd-V-o vls (gr. 2) containing 10 instances of /ɒ/ wins the place with the lowest degree of variability, i.e., /ɒ/ in this context it is the most stable. The opposite pole is occupied by the vowel in a fully sonorant environment (gr. 9 characterised by the highest $C_{var}$ of F3) and in the context o vcd-V-son (gr. 3).

Generally, the four low vowels differ in the degree of variability of the first three formants. /æ/ has the lowest $C_{var}$ values, the nine groups of /ɑː/ and /ɒ/, on the other hand, give the overall highest figures. Each vowel behaves in the same environment differently, i.e, we cannot state that a certain environment always produces the four vowels with, e.g., the lowest variability, although the contexts in groups 1 and 2 are sound candidates for the position of environments accountable for the highest stability of the four vowels. Unfortunately, the low number of items prevents us from making generalisations. The nine groups of the central open-mid vowel differ most from each other in the degree of variablity, the front open-mid and the back open-mid $C_{var}$ values for the three formants in all environments fluctuate less than in /ʌ/ and /ɑː/. F1 is the most variable formant of the three for all vowels in all environments, F2 tends to vary more than F3.

### 13.4.2 Dispersion of formant values in groups differing in place of articulation

The figures of the coefficient of variation of the open-mid front vowel (see Figures 13.4.2.1 below, in order to see the exact values refer to Appendix) suggest that it is the most variable when preceded by a velar and followed by a coronal sound (gr. VIII). In contrast to that, the coefficient of variation reaches the lowest values, i.e., /æ/ is the most stable, in the vel-V-vel group (gr. IX), but it consists of 8 items only. The second least dispersed /æ/ is in the group lab-V-vel (gr. III) containing 32 instances of /æ/ and group VII (vel-V-lab). Group I (lab-V-lab) and also IX (vel-V-vel) produce somewhat different figures from the rest. In the entirely labial environment /æ/ seems to be more dispersed along the backness – frontness axis compared to the other eight environments with $C_{var}$ (F2) at slightly over 10 % (the rest are below this level). $C_{var}$ (F1) of /æ/ between two velars is the lowest of all the $C_{var}$ (F1) values, the F1 range does not go beyond 250 Hz. However, both these groups consist of less than eleven items.

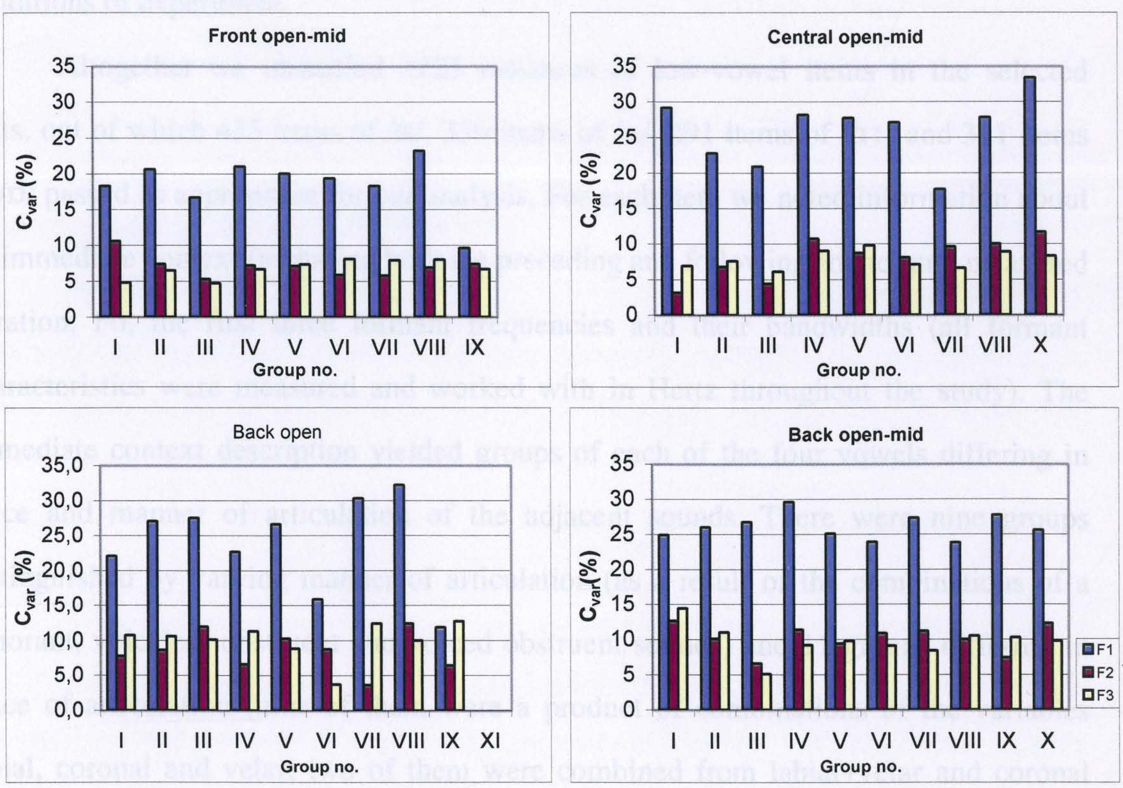
F1 and F2 of /ʌ/ vary most in words such as *one* from group lab+vel-V-cor (gr. X). Undoubtedly, the central open-mid vowel is the most stable in a group of words containing the lab-V-vel environment (gr. III), but it is poorly represented (only 3 items). Therefore we searched for a more numerous group and found the vel-V-lab context (gr. VII), where /ʌ/ reaches the lowest $C_{var}$(F1) of all the context groups (17.7 % as opposed to the highest value = 33.4 % presented by gr. X), but at the same time one of the highest $C_{var}$(F2)=10 %. The context groups with a coronal sound before the open-mid central vowel all have a very similar variability. Group X (lab+vel-V-cor) comes out as the most variable.

Also some of the groups of the back open vowel are deficient in data: cor-V-vel (gr. VI), vel- V-vel (gr. IX), cor-V-lab+vel (gr. XI). Not taking these into account, /ɑː/

varies most between a velar and a coronal sound (gr. VIII); /ɑː/ preceded by a velar and followed by a labial (Gr. VII) has the second largest dispersion from the mean F1 (after gr. VIII), but at the same time it can boast of the lowest variability along the F2 axis ($C_{var}$=3.6 %). Groups I (lab-V-lab) and IV (cor-V-lab) can be regarded as the most compact with respect to their $C_{var}$ values of all the measured formants. The cor-V-cor group (gr. V), which is the most abundant in number of items, classes among the average groups.

/ɒ/ in the context lab-V-vel (gr. III) is altogether the most stable, however, this group contains only four items. The next most stable group with /ɒ/ is gr. VI (cor-V-vel). The $C_{var}$ levels of the remaining groups oscillate between 7.4 and 12.6 for F2 and 8.4 and 14.4 for F3, i.e., they are fairly homogenous. Also $C_{var}$ (F1) values are comparable with a 5.8 % difference between the highest $C_{var}$ (F1) = 29.6 in gr. IV (cor-V-lab) and the lowest $C_{var}$ (F1) = 23.8 in gr. VIII (vel-V-cor). Groups I (lab-V-lab) and IV (cor-V-lab) represent the least stable of the 10 groups. Finally, the number of items in each group does not have any visible impact on variability for /ɒ/.

**Figures 13.4.2.1** The coefficient of variation of the first three formant frequencies in the groups of the four low vowels differing in place of articulation (gr. I=lab-V-lab, gr. II=lab-V-cor, gr. III=lab-V-vel, gr. IV=cor-V-lab, gr. V=cor-V-cor, gr.VI=cor-V-vel, gr.VII= vel-V-lab, gr. VIII= vel-V-cor, gr. IX=vel-V-vel, gr. X=lab+vel-V-cor, gr. XI=cor-V-lab+vel)



In summary, as we have seen in the previous section, groups deficient in number of items usually behave abnormally. Nevertheless, /ɒ/ provides fairly homogenous $C_{var}$ values across all context groups, i.e., the various contexts produce /ɒ/ of consistent variability. Similar degree of variability across different contexts (if we disregard the insufficiently represented group IX) and the overall low variability due to various place of articulation of the vowel's context distinguish /æ/ from the remaining low vowels. The lab-V-vel context (gr. III) has a tendency to accompany those items of vowels which vary the least. However, the validity of this result is weakened by the lack of items not only in group III.

## 14. Conclusion

At the beginning of this study we set a goal to investigate the formant field characteristics of low vowels in Standard British English. For this purpose we used approximately three-minute recordings of news presented by twenty BBC radio announcers. By doing this we obtained data which were part of connected speech and which can be easily extended without much apprehension about changing the conditions of experiment.

Altogether we identified 2223 instances of low-vowel items in the selected texts, out of which 435 items of /æ/, 350 items of /ʌ/, 291 items of /ɑː/ and 311 items of /ɒ/ passed as appropriate for our analysis. For each item we noted information about its immediate context (including both the preceding and following sound) and measured duration, F0, the first three formant frequencies and their bandwidths (all formant characteristics were measured and worked with in Hertz throughout the study). The immediate context description yielded groups of each of the four vowels differing in place and manner of articulation of the adjacent sounds. There were nine groups distinguished by varying manner of articulation (as a result of the combinations of a sonorant, voiceless obstruent and voiced obstruent sounds) and 11 groups differing in place of articulation (nine of them were a product of combinations of the variables labial, coronal and velar; two of them were combined from labial+velar and coronal sound).

All the vowel items were grouped so as to yield three main areas of results:

i. the formant field characteristics of the four English low vowels generally

ii. the formant field characteristics of low vowels in individual speakers

iii. the formant field characteristics of the low vowels produced in different environments

It was found out that the English low vowels are characterised by relative proximity, particularly in terms of openness, their distinction being largely secured by their second formants. The regions occupied by /ʌ/ and /ɑː/ overlap to the largest extent, i.e., these two vowels resemble in their quality more than any other two vowels in the low region, although the overlap between /ɑː/ and /ɒ/ is of comparable size. There was found a large area shared by the three backer vowels (unlike in any of the previous studies), while /æ/ remained the most isolated. In comparison with the earlier studies, all the low vowels in our sample reached the lowest values of F1. /æ/ was pronounced as more retracted than it had been before, on the other hand, the remaining sounds yielded higher F2 values than all but one study's results, which points towards a frontward movement of these vowels. Without surprise, we measured the closest values to those of Deterding's (1997), who used similar material for his analysis, i.e., he analysed vowels taken from connected speech (as opposed to the other studies). On the whole, the low vowels pronounced by the twenty male BBC speakers have a more centralised quality than the referential data.

/æ/ was the most stable of the low vowels in our study, it reached the lowest coefficient of variability values for all three formants. According to expectations, the first formant came out as the most variable of the three. The distribution of the low-vowel formant values was found mostly normal (between 61.8 and 75.6 % of all the formant values fell within the range of the mean +/- 1SD), although only approximately a third of all items of each vowel had all three formants within this range.

In the second part of our analysis we could see how the individual speakers contributed to the overall results. The examination revealed that appoximately a third of the speakers had /æ/ fully or nearly separate without overlaps with the backer vowels. In contrast to that, the three backer vowels never occupied their own areas without competing with the adjacent vowels. Although it seemed that /ʌ/ and /ɑː/ represented the most vulnerable sounds of the four in terms of perception, the comparison of their average duration values confirmed the opposite to be more plausible. However, another identification problem might arise with respect to the qualitative proximity of /ʌ/ and /ɒ/ noticeable in some speakers.

T-tests revealed numerous statistically significant differences in the quality of the low vowels between the individual speakers. The most differences (out of the 180 theoretically possible) were found between the twenty sets of /æ/ (43 significant differences), the fewest differences were identified for /ʌ/ (18 significant differences). Interestingly, there are the most differences between the individual speakers' groups of a vowel which is the most stable.

The levels of formant variability as expressed by $C_{var}$ in the speakers' four vowels differed considerably. Most speakers' F1 variability occurred between 10 and 30 %, for F2 the majority of the coefficient of variation values fluctuated between 5 and 15 %. F3 of the low vowels in individual speakers did not exceed the variability value of 15 %.

The mean values obtained for groups of low vowels differing in manner of articulation pointed to differences in quality between them, although inconsistent across the four vowels. Even though certain statistically significant differences were identified, these were not between groups characterised by symmetrical context, where the differences were expected to be the most pronounced. In addition, the differences between groups with symmetrical context did not harmonize with previous findings. On the whole, we concluded that immediate environment differing in manner of articulation had negligible effect on the low-vowel formant frequencies.

Unlike in the case of groups differing in manner of articulation, certain patterns of behaviour of particularly the low-vowel F2 in contexts differing in place of articulation indicated in previous studies were replicated in this study. Nevertheless, these differences did not appear to have any statistically significant value. No significant differences were found between groups with symmetrical contexts.

Generally, our analysis proved F2 to be more susceptible to coarticulatory changes, particularly to shifts in constriction location, than F1 (T-tests revealed more significant changes between the different groups for F2 than for F1). At the same time, we found more significant changes among the groups of vowels differing in place of articulation than in manner of articulation. The fact that the analysis did not identify more significant differences was ascribed to the character of data and method of analysis used in this study, i.e., data collected from connected speech and the measurements taken from a central steady-state part of a vowel.

Each vowel behaved in the same environments somewhat differently, i.e, we are unable to state that a certain environment always produced the four vowels with, e.g, the lowest variability. In comparison with the other vowels, /æ/ reached the lowest variability values across context groups of both types. Groups deficient in number of items appeared to behave abnormally, i.e., they produced values either notably lower or higher than the remaining groups, which made it impossible to draw further generalisations.

Undoubtedly, there are numerous ways the present work can be elaborated. Firstly, it covers only a third of the English vowel system. It would be worthwhile to gain a complete picture of the Standard British English vowels' mutual behaviour in the vowel space. Such an investigation would reveal whether the tendencies identified in the low-vowel region (particularly centralisation and overlapping of the vowels) apply to the whole system in connected speech. Secondly, our analysis is void of the BBC male speakers' counterparts. Since women have been reported to adopt different 'speech habits' in different social situations resulting in, e.g., narrower vowel space, it would be interesting to see whether some such patterns are traceable also in the speech of the BBC female speakers, or generally, how their vowels differ in quality from the male speakers and how variable their vowels are in comparison with the male counterparts. Having collected the data as we have just suggested, they can serve perception research. Specifically, they can be used to investigate the impact of vowel variability on speech perception. It will be possible to prepare perceptual evaluation tests using the material provided by this study. Last but not least, our data can be utilized to search normalization procedures leading to reducing successfully the variability of given vowels with regard to vowel perception.

## 15. Appendix – CD

The CD-ROM contains the following:

i. the transcribed texts read by the twenty BBC announcers

ii. the recordings of the full texts as well as recordings of the words containing the individual vowel items

iii. tables with all the measured and classified data (but also data that were excluded) organized according to individual speakers as well as the different contexts

iv. tables containing *p* values obtained to find out significant differences both between individual speakers' vowels and between the context groups, all the statistical data calculated for individual speakers as well as the context groups

v. graphs showing selected F2:F0 correlations and formant transformations designed in an attempt of seeing whether the dispersion of low vowels is as it is presented in the two-dimensional F1/F2 graphs

vi. additional tables and graphs either not specifically referred to from the text or those that already appear in the printed version of this study

vii. the text of this study

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