The vowel system of Danish and phonological theory

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0. Introduction

The goal of phonological theory is to determine the dimensions along which the sound systems of the world's languages are organized and the principles that regulate these systems.[1] It now seems widely agreed that distinctive features provide the cornerstone of phonological systems. Hans Basbøll, who over the years has made an important contribution to phonology, reminds us in his forthcoming book, *The Phonology of Danish*, that distinctive features have the following functions:

(1) *The functions of distinctive features*

(a) they should distinguish between contrastive segments;
(b) they should account for the phonetic manifestation of sounds, both regarding production and perception;
(c) they should account for the natural classes in natural phonological processes (rules or statements);
(d) they should also allow for an insightful formulation of the processes themselves.

As emphasized by Basbøll, features should not be used merely as a trick to achieve generalizations not grounded in phonetics and cognition. I fully endorse this requirement, which I would formulate as the Naturalness Assumption:

(2) *Naturalness Assumption*
Phonological primitives and generalizations (rules, processes or constraints) are natural. They are grounded in (a) phonetics and (b) cognition

While the Naturalness Assumption is a good methodological and heuristic principle, it is not altogether foolproof. It does exclude certain analyses: for instance, a Hjelmslevian position treating features as merely formal devices divorced from phonetic substance (see Durand and Laks 2002b). But it does not tell us, in the area we are going to explore, whether distinctive features should be binary, unary or scalar, whether they are organised geometrically or not, whether they are primarily based on perception or production or neutral between them, and so on. Moreover, while being committed to a cognitively-relevant approach, we cannot make it an absolute requirement that the constructs of phonology be accepted only if strongly validated by psycholinguistic or neurolinguistic tests. Given our limited knowledge of the brain (despite undeniable progress, see Durand and Laks 2002a), we have to operate much like astronomers describing systems far removed in space and time. On the basis of often limited evidence, we have to 'abduct' the principles determining the nature of phonological systems and offer the best possible conjecture as to what the primitives of linguistic sound systems might be.

[1] I wish to thank John Anderson, Chantal Lyche and an anonymous reviewer for useful comments, corrections and encouragements regarding this paper. All remaining errors are mine. Apart from small corrections, this version is the same as that published in Galbert Jacobsen et al. If, however, you wish to quote portions of this article, it is safer to see the published version.

In this paper, my aim is to discuss one issue in phonological theory, that of the representation of vowels and in particular the status of vowel height. I will not attempt to offer a comprehensive coverage of the question. Rather, I will examine the vowel system of Danish, arguably one the most complex systems presented in the literature, and try to examine the implications it may have for phonological theory. Basbøll's challenging work (to appear) on the question will provide the main reference point of my remarks. In broaching these issues, I will commit myself to another requirement that must be met by an adequate theory of phonology and which corresponds to (1)(c-d) above:

(3) *Expressiveness*
Phonological theory must render optimal the expression of generalizations (whether formulated as rules, constraints or processes).

2. Vowel systems: a brief historical sketch

In the nineteenth century, the descriptions of vowel systems converged on the idea that the most common dimensions were vowel height, vowel backness (or frontness) and lip-shape. Regarding vowel height, two positions, which have remained important to this day, were clearly delineated. The first one is what we shall refer to from now as the IPA position. The second one was adopted by Alexander M. Bell and Henry Sweet and anticipates the binary systems which have figured prominently in the literature ever since Jakobson, Fant and Halle's (1952) groundbreaking contribution: *Preliminaries to Speech Analysis.*

As soon as the International Phonetics Association gained momentum, its members agreed on a descriptive scheme which treated the vowel space as a kind of trapezium organized in terms of two main axes – close/open and front/back - with lip-shape acting as a supplementary parameter allowing further distinctions. This tradition finds its most precise definition in the scheme of 'Cardinal Vowels' put forward by Daniel Jones in *An English Pronouncing Dictionary* (1917) and *Outline of English Phonetics* (1918) and integrated thereafter in fundamental texts such as the 1949 *Principles of the International Phonetic Association* and the 1999 *Handbook of the International Phonetic Association*. In this scheme, the close-open axis (high-low from now on) was seen as a dimension merging two different physiological actions: tongue raising/lowering and jaw closing/opening. These were correctly identified as concomitant from a phonological point of view and, given that tongue movement was needed on the front/back axis, the tongue was taken as the 'prime mover' providing the phonetically relevant physiological actions.

Interestingly, the three main parameters forming the cornerstone of this traditional approach are not dealt with in the same way by the IPA. While high/low and front/back are treated as continua, lip-shape is not. It is true that, in his presentation of cardinal vowels in his *Outline of English Phonetics* (1918), Jones shows, with the help of photographs, that lip-position behaves as a continuum. In pronouncing the eight primary cardinal vowels /i e ɛ a ɑ ɔ o u/, the lip-position starts at fully spread for [i] and reaches the close rounding required for [u] through a series of intermediary lip-positions with neutral lip-position for low vowels. But the primary cardinal vowels reflect the statistically predictable relationship in the world's languages between backness and rounding. As amply demonstrated in surveys such as the UCLA Phonological Segment Inventory Database (UPSID), the front vowels are usually unrounded and the non-low back vowels are usually rounded (see Schwartz et al. 1997). Moreover, as a rule, the degree of spreading/rounding is mechanically correlated with vowel

height. Thus, if a vowel is round, the higher it is the more extreme its degree of lip-rounding. Phonologically, what seems to matter is whether a vowel is [round] or [non-round]. This is why lip-shape was not really treated as a continuum in the IPA tradition. For most vowel symbols we have a partner with opposite lip-shape and the diacritic for lip-rounding is not used to express a scale but rather over- or under-rounding for a given vowel height as in the 1999 IPA *Handbook*: "In some forms of English, e.g. Standard Southern British, over-rounded [ɔ] is found, e.g. *caught* [kɔ̹t]" (p. 24). The only cases which might require varying degrees of rounding are languages like Swedish or Norwegian where there are three vowels which are all high and all front but with different lip gestures; but the IPA notation offers no particular help here.

If we now turn to high/low and front/back, these two dimensions are not dealt with in the same way either by the IPA. Height is diagrammatically seen as a 'wider' dimension than backness. On the height axis, four main divisions are posited: high (CV [i y u ɯ]), mid-high (CV [e ø o ɤ], mid-low (CV [ɛ œ ɔ ʌ], low [a ɶ ɑ ɒ]). On the other hand, the backness axis gives rise to only three main divisions: front, central and back. Of course, the use of diacritics for advanced/retracted, centralized/mid-centralized and raised/lowered allows more fragmentations of the two continua but the fact remains that they are not considered as fully equivalent. If we look at the symbols offered, the height dimension provides more potential contrasts than front/back. As Ladefoged and Maddieson stress: "The full set of vowel symbols recommended by the IPA (1989) implies that there are seven levels. We doubt that any language uses this full range; but there are clearly more than three levels of the auditory property Height" (1996: 289).

The IPA account of vowel height has remained relatively stable over the years. One main apparent challenge to it has been on the question of its phonetic grounding. With the rise of acoustic phonetics, some specialists have argued that it was not articulatorily but auditorily based. Ladefoged (1967: 72) quotes Russell (1928) who went as far as to state: "phoneticians are thinking in terms of acoustic fact and using physiological fancy to express the idea". While it seems agreed that 'height' is not a simple articulatory feature based on the highest point of the tongue, it also seems undeniable that there is a physical *raising* component principally associated with the actions of the genioglossus and mylohyoid muscles combined with the muscles controlling jaw height. But whether vowel height is basically grounded in production or perception, its main characteristics from the point of view of the IPA tradition is the same. That is, the implicit theory in the IPA description is that vowel height is a continuum in a roughly quadrangular space. The number of possible distinctions on this continuum is presumably set by perceptual boundary conditions. While speakers can raise their tongues in an indefinite number of steps, hearers cannot make phonological (lexical) distinctions which involve more than **n** dimensions. Ladefoged and Maddieson (1999: 289-290) quote a study of the Bavarian dialect spoken in Amstetten (Austria) by Traunmüller (1982) which would appear to require five levels of vowel height and which does present similarities with the Danish system discussed below. If this is correct **n** would therefore be maximally set at the value **5**.

In the 19th century, another account of vowel height was however put forward. Both Bell (1867) and Sweet (1877) offer a description of the vowel space as basically organized along two axes with three divisions each (high-mid-low and front-central-back) to which lip-shape can be added. Given that vowel systems appear to present more contrasts on the height axis than the backness axis, the question arises of how to handle oppositions such as

e/ɛ or o/ɔ or ø/œ which are well-attested in the languages of the world. The Bell/Sweet account has to have recourse to other parameters. Bell used primary/wide which refers to the opening between the back of the mouth and the throat. Sweet modified this to narrow/wide which "depend on the *shape* of the tongue. In forming narrow sounds there is a feeling of tenseness in that part of the tongue where the sound is formed, the surface of the tongue being made more convex than its natural 'wide' shape, in which it is relaxed and flattened" (1877: 8-9). As can be seen in Fig. 1, taken from Sweet's *Handbook of Phonetics*, such a supplementary feature allows 36 vowel qualities to be distinguished.

NARROW			WIDE		
" high-back	**ih** high-mixed N. Welsh tag*u*	**I** high front F. f*i*n*i*	**A** high-back	***i*h** high-mixed Occ. E. pretty	***i*** high-front E. b*i*t
ɐ mid-back E. b*u*t	**eh** mid-mixed G. gab*e*	**E** mid-front F. *été*	**a** mid-back E. f*a*ther	***e*h** mid-mixed E.*e*ye (*e*h[ih])	***e*** mid-front Danish træ
ɒ low-back Occ. Sc. B*u*t	æh low-mixed E. b*ir*d	æ low-front E. *a*ir	ɑ low-back Sc. F*a*ther	æ**h** low-mixed E.how (æh[oh])	æ low-front E. m*a*n
NARROW-ROUND			**WIDE-ROUND**		
u high-back F. s*ou*	**uh** high-mixed Swedish h*u*s	**y** high front F. l*u*ne	***u*** high-back E. f*u*ll	***u*h** high-mixed Swedish *u*pp	***y*** high-front G. schützen
o mid-back G. s*o*	**oh** mid-mixed	**ə mid-front** F. p*eu*	***o*** mid-back N.G. st*o*ck	***o*h** mid-mixed F. home	ə mid-front N. G. schön
ɒ low-back E. s*aw*	ɔh low-mixed	**œ** low-front E. *a*ir	ɔ low-back E. n*o*t	ɔh low-mixed	***œ*** low-front

Fig. 1 Sweet's (1877: 16) basic organization of the vowel space

Both Jakobson, Fant and Halle (1952) and Chomsky and Halle (1968) have followed the Bell/Sweet tradition. That is, they offer schemes in which vowel height allows for only three positions. The adoption of binary features does however change the perspective since the notion of a continuum is abandoned. If we follow Chomsky and Halle, in the *Sound Pattern of English* (SPE hereafter), the relevant features are [+/-high] and [+/-low]. While these authors are committed to the view that distinctive features are binary at the classificatory level and within the phonological component but scalar at the phonetic level, it is far from clear how the notion of vowel height would be handled phonetically since it would involve the merger of two independent binary parameter into a single dimension. Leaving this problem aside, the prediction is made that no language would truly oppose more than three vowels in terms of height. Rather, what appears like an opposition between four or more degrees of height has to be handled in terms of other features: typically tense/lax (Jakobson, Fant and Halle, 1952, Chomsky and Halle 1968) or Advanced/Retracted Tongue Root (ATR/RTR) in more recent work. The feature tense/lax has however remained a topic of intense debate. Given that, in its standard definitions, it is presented as a mixture of properties (e.g. centralisation, length, tenseness) wherein the notion of muscular tension for vowels seemed the most debatable, a number of scholars have not fully endorsed it. It is for example significant that, in the IPA inventory, there has never been an official feature for tension. By contrast, Advanced/Retracted Tongue Root is now part and parcel of the IPA classificatory scheme. If we want to avoid a purely diacritic use of features (i.e. "descriptive tricks", in Basbøll's words), the empirical basis of our classificatory scheme is obviously a crucial issue (see Lyche, this volume).

3. Hans Basbøll and the Danish vowel system

The vowel system of Danish has long been recognized as posing a challenge for binary frameworks. In IPA terms, the short and long vowels of Danish appear to require at least four degrees of height. Ladefoged and Maddieson (1999: 289) offer the following set of minimal pairs based on Uldall (1933):

vilə	'wild play'	viːlə	'rest'	viːðə	'know'
menə	'remind'	meːnə	'mean' (vb)	veːðə	'wheat'
lɛsə	'load'	lɛːsə	'read'	vɛːða	'wet' (vb)
masə	'mass'	maːsa	'mash'	vaːðə	'wade'

Fig. 2 Words illustrating four degrees of vowel height in Danish

Over the years, Hans Basbøll is one of the linguists who has studied the Danish vowel system most extensively (cf. *inter alia* Basbøll 1968, 1984 and Basbøll and Wagner 1985). In his forthcoming book, *The Phonology of Danish*, Basbøll offers a detailed and well argued account of the Danish vowel system. Among the principles he adopts for distinctive features, beside the claim that they should be phonetically based, are the demands that features should be strictly binary and that the positive pole should be phonetically homogeneous. This last requirement, as he points out, brings him very close to unary accounts such as have been adopted in various frameworks and particularly Dependency Phonology (cf. *inter alia* Anderson and Jones 1974, 1977, Anderson and Ewen 1987, Anderson and Durand 1986, Durand 1986, 1990, Ewen and van der Hulst 2001).

The contrastive *full* vowels of Danish identified by Basbøll are: /i e ɛ a ɑ y ø œ ɶ u o ɔ ɒ ʌ/. Vowel length is also involved in a complete account of the Danish vowel system but, since it is best treated as a suprasegmental property (e.g. via bimoraicity), we can leave this question aside. In addition to these full vowels, Basbøll also recognizes two reduction vowels: /ɐ ə/. The inclusion of /ɐ/ in the set of contrastive vowels is also justified by the fact that Danish has /i̯ u̯ ɐ̯/ among its glides. If it is agreed, as is generally done in modern phonological theory, that these glides are simply the non-syllabic equivalents of /i u ɐ/, then these three segments (and hence /ɐ/) must be part of the inventory.

The full list of contrastive segments to be accounted for is therefore: /i e ɛ a ɑ y ø œ ɶ u o ɔ ɒ ʌ ɐ ə/. The symbol /ʌ/ used by Basbøll requires some explanation. It is not taken in its IPA standard cardinal value (i.e. mid-low, back, unrounded) but rather as a rounded pharyngeal vowel close to [ɐ] and [ɒ] (but not as retracted as the latter). If we provisionally discard /ʌ ɐ ə/, we seem to be dealing with a system with four vowel heights as in Fig. 3

	Front unrounded	Front rounded	Back unrounded	Back rounded
High	i	y		u
Midhigh	e	ø		o
Midlow	ɛ	œ		ɔ
Low	a	ɶ	ɑ	ɒ

Fig. 3 Part of the Danish vowel system

But if we wish to include /ʌ ɐ ə/, a scalar account becomes rather more complicated. One way of dealing with it would be to assume that it is structured as in Fig. 4 below:

	Front	Front	Central	Central	Back	Back
	-Round	+Round	-Round	+Round	-Round	+Round
5 High	i	y				u
4 High	e	ø				o
3 High			ə			
2 High	ɛ	œ	ɐ			ɔ
1 High	a	ɶ		ʌ	ɑ	ɒ

Fig. 4 A possible scalar description of the full Danish vowel set

Basbøll himself, given his commitment to binary features, offers an account based on the following parameters: [labial], [palatal], [velar], [pharyngeal], [approximant], [front] (respectively abbreviated by him as [lab], [pal], [vel], [pha], [apr], [fro]). Fig 5 presents his classification of the full vowel system. Empty cells have by definition the value '-' since Basbøll does not advocate an approach based on +, - and unspecified (Ø) as defended in some underspecification models.

	i	e	ɛ	a	ɑ	y	ø	œ	ɶ	u	o	ɔ	ʌ	ɒ	ɐ	ə
[lab]						+	+	+	+	+	+	+	+	+		
[pal]	+	+				+	+									
[vel]										+	+	+				
[pha]				+	+				+		+	+	+	+	+	
[apr]	+				+	+				+	+			+		
[fro]	+	+	+	+		+	+	+	+							

Fig. 5 Basbøll's classification of the full Danish vowel set.

Most of these features are well-known in general phonetics but [pha] and [apr] are worth commenting on. The feature [pharyngeal] is in part inspired by Sidney Wood's work on the question and the recognition of its importance among phoneticians and "concrete phonologists". Basbøll proposes that all low vowels /a ɑ ɶ ɒ ʌ/, plus /o ɔ/ should be classified as [+pha]. The class of approximants in Danish includes /i u ɑ y o ɒ/ as well as /i̯ u̯ ð l/. Basbøll describes approximants as resulting from the close approximation of two articulators without producing a turbulent airstream. As far as the Danish vowels are concerned, it applies to "narrow" or "constricted" vowels like /i u ɑ y ɒ ɐ/. The inclusion of /o/ and /ɐ/ in the set of pharyngeals by Basbøll is arguably controversial. But Basbøll points out that the approximation for /o/ is "particularly narrow in the upper part of the pharynx" and he treats /ɐ/ as the coalescence of schwa plus a pharyngeal glide. One of the advantages of this approach is that various oppositions are neatly captured: for instance, /ɒ/ and /ʌ/ can now be simply differentiated as [+apr] (/ɒ/) and [-apr] (/ʌ/).

As repeatedly emphasized by Basbøll, the aim is not simply to provide an economical characterization of the phonological oppositions within the language. One must also bear in mind the phonetic characteristics of the language and how features function in the expression of phonological generalizations (recall our methodological principles (1) Naturalness Assumption and (2) Expressiveness). In this context, we can observe that a possible characterization of the Danish vowel system in terms of the SPE feature set would be more economical:

	i	e	ɛ	a	ɑ	y	ø	œ	Œ	u	o	ɔ	ʌ	ɒ	ɐ	ə
Round	-	-	-	-	-	+	+	+	+	+	+	+	+	+	-	-
High	+	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-
Low	-	-	-	+	+	-	-	-	+	-	-	-	+	+	+	-
Back	-	-	-	-	+	-	-	-	-	+	+	+	+	+	+	+
Tense	+	+	-	-	+	+	+	-	-	+	+	-	-	+	-	-

Fig. 6 The Danish vowel system using SPE features

An alternative presentation of such an SPE-style classification is provided in Fig. 7, where the tense vowels are underlined.

	-back -round	-back +round	+back -round	+back +round
+high -low	i	y		u
-high -low	e,ɛ	ø,œ	ə	o,ɔ
-high +low	a	Œ	ɑ,ɐ	ɒ,ʌ

Fig 7 An alternative presentation of Fig 6.

Given that all these classifications can distinguish the vocalic segments of Danish, we need some independent arguments to settle the issue.

4. Danish "r-colouring"

As emphasized by Basbøll, one of the crucial and toughest tests for judging the adequacy of any feature system in Danish is the process of "r-colouring". As summarized by Basbøll, "r-colouring" has the following effects.

(4) "r-colouring"

(a) [a] > [ɑ(ː)] (before and after /ʁ/)
(b) [ɛ, œ] > [æ, Œ] (before and after /ʁ/)
(c) [ɛː] > [aː] (marginally)
(d) [œː] > [Œː] (before /ʁ/)
(e) [e(ː), ø(ː)] > [ɛ(ː), œ(ː)] (after /ʁ/)
(f) [ɔ, ʌ] > [ɒː, ɒ] (before /ʁ/)
(g) [u(ː)] > [o(ː)] (after /ʁ/)

(h) [ə] > [ɐ] (before and after /ʁ/)

There are many subconditions (both phonological and sociolinguistic) relating to this process. For instance, adjustment (g) is restricted to younger speakers. For reasons of space, they cannot be considered here and the reader is referred to Basbøll (to appear) for further details and extensive references. Basbøll points out that these rules are "so productive that it is hardly possible for a normal speaker of e.g. Advanced Standard Copenhagen to pronounce a clear [e] or [ø] after a tautosyllabic /r/, for example". But, as he also emphasizes these are not an automatic coarticulation effect. They have to be learned and, in that sense, they are part of the phonology and cannot be relegated to some interpretive phonetic component.

Two obviously related questions are: what is at stake in the vocalic mutations of (4) and how are they connected to the /ʁ/ environment. The Danish /ʁ/ is characterized by Basbøll as a "uvu-pharyngeal" segment and, in terms of the useful distinction made by Pike between "contoids" and "vocoids" (and integrated by Basbøll in his full descriptive scheme), it is not always clear whether the realisation of /ʁ/ is a true contoid or not. Be that as it may, Basbøll specifies /ʁ/ as a [pharyngeal] segment distinguishable from all the other consonants through this feature. Given that pharyngealization is also used in the characterization of vowels, it can be observed that a number of the changes in (1) are directly related to this dimension.

input	a [+pha]	ɛ [-pha]	e [-pha	œ [-pha]	ø [-pha]	ɔ [+pha]	u [-pha]	ʌ [+pha]	ə [-pha]
output	ɑ [+pha]	a [+pha]	ɛ [+pha	ɶ [+pha]	œ [-pha]	ɒ [+pha]	o [+pha]	ɐ [+pha]	ɐ [+pha]

Fig. 8 "r-colouring"

As Basbøll observes, what "r-colouring" intuitively does is bring vowels one step closer to the consonant /ʁ/ which is very close to the vowel /ɑ/. The main problem is that, while this process may be obvious to the linguist, a formulation based on the above features does not seem to allow an integrated formulation. Basbøll offers rules (leaving various conditions aside) such as:

(5) Some rules for r-colouring
For vowels adjacent to /ʁ/
(R1) [-velar, +pha] → [+apr]
[a] → [ɑ]
[ʌ] → [ɒ]
[ɔ] → [ɒ]

(R2) [-pal, -vel] → [+pha]
[ɛ] → [a]
[œ] → [ɶ]

[ə] → [ɐ]

(R3) [-apr] → [-pal]
[e] → [ɛ]
[ø] → [œ]

The problem is obvious: a unitary process is split into a number of unrelated generalizations which basically separate lowering and retraction under the influence of /ʁ/.

The SPE binary feature system outlined above would arguable fare even less well. Nor could it handle simultaneously lowering and retraction. Moreover, in the best cases, if an assimilation could be expressed it would be via the feature [-tense] (by assuming that /ʁ/ is [-tense]). As stressed by Basbøll, negative values in SPE refer to properties which are not homogeneous (e.g. absence of a feature vs. opposite polar value vs. complementary value). This is why Basbøll, like many other phonologists and particularly Dependency Phonology, commits himself to working with positive poles only. In any case, the phonetic basis for assuming that 'tension' is the relevant parameter is rather tenuous: if the distinction is that tense vowels are more peripheral than lax vowels, then /a/ and /œ/ should be tense. This might not appear problematic given that these two segments do not have a partner within the same box (cf. Fig 7 repeated below as Fig. 9 with /a/ and /œ/classified as [+tense]):

	-back -round	-back +round	+back -round	+back +round
+high -low	i	y		u
-high -low	e,ɛ	ø,œ	ə	o,ɔ
-high +low	a	œ	ɑ,ɐ	ɒ,ʌ

Fig 9 Alternative classification. Tense vowels underlined.

But now the changes from [ɛ] → [a] and [œ] → [œ] under the influence of /ʁ/ would be even less motivated since it would represent an increase in tension and it would be solely expressible as a lowering. As in many other languages, the phonetic feature 'tense/lax' which at first sight seems highly motivated does not appear to help much, unless we reinterpret it in moraic terms (as Lyche, this vol.) but this is no proof of its relevance as a phonetic parameter. On the other hand, a feature such as Retracted Tongue Root (close to Basbøll's feature Pharyngeal and seen as distinct from Advanced Tongue Root) seems much more satisfactory. It identifies a positive pole and it seems phonetically well motivated for a uvular /ʁ/ such as the Danish one. Fig 10 presents this alternative scheme based on RTR.

	-back -round	-back +round	+back -round	+back +round
+high -low	i	y		u
-high -low	e,ɛ	ø,œ	ə	o,ɔ

-high +low	a	œ	ɑ,ɐ	ɒ,ʌ

Fig 10 SPE-style classification with RTR vowels underlined

Once again, though, as the reader can check by going though the processes in (4), r-colouring could only be formalised as a set of unrelated generalizations: lowering, backing and changes in RTR-ness.

It might be thought that a scalar system (as presented in (3) and (4)) would be a lot more appropriate. Indeed, within such as system we can formalise the notion of increase by one or more steps. There are however serious problems with such systems. The closer they get to the phonetics, the less transparent the notation of the processes becomes. For instance, the simple integration of schwa as a fully central vowel (as in (4)) upsets the balance of the whole system. Secondly, if the scalar representation is expressed within a rectangular system, it faces exactly the same difficulties as the binary descriptions outlined above. That is, the retraction of [a] to [ɑ] can only be formalized as fundamentally different from the lowering processes.

The major difficulty faced by all the systems presented so far is that "r-colouring" in Danish is simply not fully compatible with a quadrangular organization of the vowel space. That is, the vowel /ɑ/ functions as the cornerstone of a vowel space which can be diagrammatically represented as in (6) below:

(6)

i y u

e ø o

ə

ɛ œ ɔ

a ɶ ʌ

ɑ ɒ

These difficulties are fully understood by Basbøll and to solve them he presents a scheme which allows the conversion of his binary features into a multivalued scalar system making /ɑ/ the cornerstone of a basically triangular organization of the vowel space. But as he himself admits (emphasis in the original): "**It is clear that the multivalued distinctive feature [distance] does not satisfy our demands of its positive pole being phonetically homogeneous**. This is an important shortcoming within our framework, and I shall therefore propose that it is not really a distinctive feature like the others, but an **indirectly defined feature** to fulfil a *specific descriptive task* (Basbøll, to appear: §5.4). In that sense, Basbøll's solution is a theoretical apparatus external to the notation much like marking conventions in SPE and falls under the same theoretical objections as them (see Durand 1990: 3.4). Section 6 argues that Dependency Phonology provides a possible solution to Basbøll's conundrum.

5. A Dependency Phonology alternative

Dependency Phonology (DP hereafter) is a phonological model which was initiated by Anderson and Jones' seminal work (1974, 1977) and was developed thereafter by various

researchers (notably, Anderson and Ewen 1987 and van der Hulst in numerous works: see Ewen and van der Hulst 2001, Anderson 2002 for references). This is not the place to review various developments around the core notions of DP or its relationship to similar models such as Particle Phonology or Government Phonology. In this section, I merely want to show some of the advantages of the central concepts of classical DP, a model I have myself adopted in various published works which were sympathetically reviewed by Basbøll (e.g. Durand 1986, 1990), even if he does not agree with many of the basic tenets of this approach.

DP assumes that phonological features are unary and therefore always present the positive pole of a property. Features are called components in classical DP but, since components have often been assumed to be structural 'ensembles' (the phonological component, the syntactic component, etc.), I will use here the term 'element' adopted in Government Phonology. The elements adopted in DP are not necessarily the same as classical features such as those put forward in the IPA or in the SPE tradition. In particular, it is claimed that the vowel system is structured around three basic elements, labelled A (low/compact), I (palatal/acute) and U (grave/round). In addition, several other elements are required: for example an element of centrality or energy reduction (@) and an element of tongue-root retraction (R). Once again, like Government Phonology, I use capital letters to distinguish as clearly as possible the symbols representing elements from the symbols representing various sounds. To illustrate our basic assumptions, if a language has only three vowels /i a u/, this can be represented by appealing to the I-A-U primitives alone: /i/ = {I}, /a/ = {A}, /u/ = {U}. A system such as /i e a o u/ can be represented by combining elements in a simple way (copresence is indicated by a comma): /i/ = {I}, /e/ = {I,A}, /a/ = {A}, /o/ = {A,U}, /u/ = {U}. As will be noticed the basic organization of such systems (see (7) below) is quite close to the schematization of the Danish vowel system offered in (6) above:

(7) /i e a o u/ systems in DP

One further crucial assumption made by DP is that the relation of government/dependency is available within phonological systems and is, indeed, necessary as soon as phonological systems reach a certain degree of complexity. In a system like /i e ɛ a ɔ o u/, while it is not denied that tongue root retraction may be involved, it is claimed that, for many of the world's languages, the evidence favours a representation based on government/dependency (symbolized here by a semi-colon): i.e. /i/ = {I}, /e/ = {I;A}, /ɛ/ = {A;I}, /a/ = {A}, /ɔ/ = {A;U}, /o/ = {A;U}, /u/ = {U}, where the semi-colon indicates that the element on the left governs/dominates the element on the right. The use of dependency allows us to model the notion of a scale: as we go from {I} to {A} in the previous example, we follow steps which decrease the presence of I and increase that of A. The maximum allowed by the theory is 5 levels as in : {I}, /e/ = {I;A}, /ɛ/ = {A:I}, /a/ = {A;I}, /ɑ/ = {A}. Note that in the middle position (/ɛ/ = {A:I}), A and I mutually govern each other. One basic consequence of the approach defended here is that the basic structure of vowel systems is triangular not quadrangular as in the IPA and the Bell-Sweet tradition. If we came across a system like /i e æ ɑ o u/, it would be modelled as inherently symmetrical in the SPE tradition:

	-back	+back
+high -low	i	u
-high -low	e	o
-high +low	æ	ɑ

Fig. 11 SPE /i e æ ɑ o u/ system

By contrast, it would be inherently skewed in a DP approach:

(8) DP /i e æ ɑ o u/ system

{I} /i/ /u/ {U}
{I;A} /e/ /o/ {A,U}
{A;I} /æ/
{A} /ɑ/

With these remarks in mind, we can once again turn our attention to the Danish vowel system and the process of r-colouring which provides an ideal testing ground for any model of phonology.

We will assume that the full vowel system of Danish at surface level can be characterized thus: /i/ = {I}, /e/ = {I;A}, /ɛ/ = {A:I}, /a/ = {A;I}, /ɑ/ = {A}, /ɒ/ = {A;U}, /ɔ/ = {A:U}, /o/ = {A;U}, /u/ = {U}, /y/ = {I,U}, /ø/ = {I,U;A}, /œ/ = {A:I,U},/ɶ/ = {A;I,U}, /ə/ = {@}, /ɐ/ = {A;@}, /ʌ/ = {A;U,@}. If we follow Anderson and Ewen (1987), the representation of /ʁ/ crucially involves the component /A/ and a component of tongue root retraction (RTR abbreviated as R here). Let us posit here that the representation of /ʁ/ is {A, R} at the phonetic level and possibly {A} alone at the contrastive level (if the difference between /ɑ/ and /ʁ/ in Danish can be solely attributed to the position within the syllable).

If the formalism of DP is right, we should be able to specify 'r colouring' quite naturally. This is indeed the case: 'R-colouring' is simply 'A-colouring' . Under the influence of /ʁ/, A-ness is increased by one step. Phonetic adjustments can be either structure-preserving or structure-changing. Let us assume that A-ness in Danish is structure-preserving: no new segments appear within the system apart from the members of the contrastive set posited by Basbøll. Given that DP uses dependency, such changes cannot be modelled by a simple change of feature-value (as in SPE or in Basbøll's approach). But the basic contention of DP is that increases (or decreases) in the preponderance of an element is achieved by any minimal change which is compatible with the structure of the system. This involves three operations: adding an element, deleting an element or changing dependency. If we take as an example the "r-colouring" chain-shift /ø/ →/œ/ → /ɶ/, it is formalizable as {I,U;A} →{I,U:A} → {A;I,U}. We can see that as we move from left to right that A progresses from a position of dependent, to that of mutual government before being finally promoted to governor. In the case of [a] → [ɑ], the representation goes {A;I} → {A}, as the only way to increase the preponderance of A is to delete I.

As far as /ʌ/ is concerned, the representation adopted here, {A;@,U}, does not yield a unique solution for 'r-colouring'. There are two ways of increasing the preponderance of A intra-systemically for this segment: one is to delete @, the other one to delete U. If we delete @ from {A;@,U} we obtain {A;U}, i.e. /ʌ/, which is the desired result in (4f). If we delete U, we obtain {A;@}, i.e. /ɐ/. It is interesting to note that in Basbøll's forthcoming book, this alternation is also repeatedly mentioned. Indeed, in some cases, the phonetic distinction between /ʌ/ and /ɐ/ would appear to be rather obscure.

Now, the process of A-colouring is by no means the only argument in favour of the DP notation. Central to the development of DP has been the need to account for the converse process of I-colouring (or I-mutation or I-attraction). That is, assimilation normally under the influence of an /i/ segment in the environment which as the following chain-effect : /ɑ/ →/a/ → /ɛ/ →/e/ and which is not satisfactorily formalised within the quadrangular space inherited from the IPA and the Bell-Sweet tradition (for a DP description, see Colman 1987, Anderson 2003). While sympathetic to the DP solution, Basbøll (1986, 1991) has pointed out some basic reservations to the DP approach and I will not attempt to answer them within the scope of this article. But it is hoped that outlining various solutions to the classification of Danish vowels and the expression of r-colouring has shown that DP has at least as much merit as the other contenders in the field, all the more so as I have not explored within DP various solutions based on the minimization of redundancy which would yield simpler and more insightful descriptions (see Anderson 2003, Anderson and Durand 1988a, b).

6. Conclusion

In this paper, I have reviewed a number of approaches to the question of vowel height and more generally to the structure of vowel systems. The system of Danish has been described in terms of competing frameworks (binary, scalar, unary) and various feature-systems have been outlined and compared. It has been my contention that Dependency Phonology in its classical form allowed an insightful description of Danish that fulfilled two conditions which are basic to Hans Basbøll's work and to an adequate theory of phonology: i.e. what has been referred to here as the *Naturalness Assumption* and *Expressiveness*. Whether the solution outlined above is superior to the one advocated by Hans Basbøll in his forthcoming *The Phonology of Danish* is for others to judge. Whatever the answer, Hans Basbøll's work deserves immense respect for the rigour and the thoroughness with which hypotheses and their implications are examined and the honesty with which problematic points for his account are explicitly acknowledged and discussed in his work. If this paper has at least gone some way to demonstrating these points, it has fulfilled its modest ambitions.

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