J. Linguistics 26 (1990), 165–174. Printed in Great Britain

NOTES AND DISCUSSION

Charm theory defines strange vowel sets[1]

JOHN COLEMAN

Department of Language and Linguistic Science, University of York

(Received 9 November 1988; revised 21 July 1989)

1. The KLV system discussed

> A typical grammar uses several distinct components which interact in a complicated fashion, providing a description of a language at a very high level. Although theoretical development can continue by focusing attention on only a small portion of the formalism at a time, confident prediction and validation of the correct coverage of any nontrivial grammar (and hence the global validity of the theory) is difficult and, if undertaken manually, prone to error. (Adapted from Evans, 1985.)

For the reason Evans alludes to, I have developed a collection of computational tools for the implementation and testing of phonological theories. I have recently used this testing environment to construct a faithful implementation of Kaye, Lowenstamm and Vergnaud's (hence forth KLV's) (1985) Charm and Government theory of phonology. The relevant parts of this computer program are published in full at the end of this note.

Charm theory maintains that the basic atoms of phonological representation are phonetic segments. For vowels (and only vowels have yet been described *in extenso*) there are five of these, the atoms v^-, I^-, U^-, A^+ and $ɨ^+$, phonetically [ɨ], [ɪ], [ʊ], [a], and [ɨ]. These basic elements are distinguished in having one and only one marked (or rather, in KLV's terminology, 'hot') feature (except in the case of v^-, which is maximally unmarked): respectively [−BACK], [+ROUND], [−HIGH], and [+ATR]. KLV further propose that other segments are constructed from combinations of these elements. Thus, [i] is composed of I^- ('frontness') plus $ɨ^+$ ('advancement'), in a manner reminiscent of Dependency Phonology. The combinator which KLV use, called 'fusion', works by substituting the value of the 'hot' feature in one segment (the operator) for that of the corresponding feature in another segment (the head). All the remaining features are those of the head. Fusion is denoted by the period or decimal point, $\cdot$. In the expression $A \cdot B$, A is the operator, and B the head. $\cdot$ is not commutative, since $A \cdot B \neq B \cdot A$. KLV employ fusion (a universal operation,

[1] I would like to thank John Local and Nigel Vincent for prompting me to make a number of beneficial alterations to this paper.

it is claimed) instead of language-particular transformational rules to characterize some phonological processes by recasting them as privative alternations. Two idiosyncracies of the theory are:

(1) at least one feature ([±low]) has no marked value, and therefore cannot be used as the hot feature of any operator;
(2) the new Boolean attribute 'charm' restricts the applicability of the fusion operation to elements bearing unlike charm.

As far as it goes, fusion is an immensely ingenious concept. Taken in conjunction with the proposal that phonological elements are fully specified phonetic segments, KLV have established an explicit mechanism whereby every phonological expression in their theory is provided with a phonetic interpretation of sorts, a challenge which related theories, such as Dependency Phonology and Schane's 'Particle Phonology' (Schane, 1984), have not yet met.

Charm and Government is a 'rule-free' theory. KLV (1985: 305) state: 'In this model, a phonological system contains no rule system'. In other words, like most current syntactic formalisms, Charm and Government aspires to be a DECLARATIVE theory (cf. also Bird & Klein, this volume). The normal fashion in which linguistic categories may be combined in most declarative or 'rule-free' grammar formalisms is by the purely non-destructive operation of UNIFICATION (Shieber, 1986). Unification of two categories is just like simple union of the two sets of features, except that each feature must not bear conflicting values in the two categories to be unified. In Charm theory, however, categories with conflicting values for a given feature may be combined, in which case it is the value of the marked or 'hot' feature of the operator which is selected in the 'fused' category. The fusion operator is similar to the operation of overwriting in the PATR-II Experimental System. Shieber (1986: 60) explains:

> Overwriting is a noncommutative operation akin to destructive unification except that, in the case of unification 'clashes', one of the operands (say, the rightmost) is given precedence.

In fact, in Charm theory, it is the leftmost operand which is given precedence in the fusion operation, but in either case the consequence of this departure from simple unification is that

> the use of overwriting [or likewise, fusion – *J. C.*] eliminates the order independence that is so advantageous a property in a formalism. (Shieber, 1986: 60)[2]

[2] Order independence is the property of declarative formalisms that the order in which smaller linguistic expressions are combined into larger linguistic expressions is immaterial.

The fact that the fusion operation induces order dependence made me suspicious of whether Charm theory lived up to its declarative intentions. I decided to put KLV's claims about universal phonetic categories to the acid test of exhaustive combinatorial enumeration. It is clear that the set of universal phonetic (phonological) categories defined in Charm theory is the closure of the set of basic elements under the operation of fusion, that is, the set of every logically possible combination A·B, where A and B are either basic or derived. This set is very small (compared with other theories of phonological categories), and very strange, as I shall show.

I evaluated the closure of the fusion operator on all pairs of segments defined by the theory as follows. Firstly, I worked out the result of applying every basic category to every other basic category, where the theory allows. There are five basic categories, but not all 25 logically possible combinations are permissible, since Charm Theory holds that only categories of unlike charm may be combined. Thus, the three negatively charmed basic categories can be applied as operators to the two positively charmed basic categories as heads, producing six derived categories. Only four of these are 'new' (i.e. extensionally different from all of the basic categories), however. Two of them have the same features as the basic categories A^+ and $Ɨ^+$: since these are already both [+ATR], the $Ɨ^+$ operator has no effect on them. The six products of applying the two positively charmed basic categores to the three negatively charmed basic categories are all 'new', however, making a total of ten derived catgories on the first round. These are shown in Table 1. (The three categories [ɨ], [i] and [u] appear to occur twice, but they are differently charmed in the two cases. The set of phonetic symbols used here, and their definitions in terms of KLV's distinctive features are shown in Table 2. The marked values of features are underlined.) The new categories all have either one or two marked features.

			Heads				
			v^- [ɨ]	I^- [ɪ]	U^- [ʊ]	A^+ [a]	$Ɨ^+$ [ɨ]
Operators		Charm:	–	–	–	+	+
v^-	[ɨ]					[a]	[ɨ]
I^-	[ɪ]					[æ]	[i]
U^-	[ʊ]					[ɒ]	[u]
A^+	[a]		[ɜ]	[ɛ]	[ɔ]		
$Ɨ^+$	[ɨ]		[ɨ]	[i]	[u]		

Table 1
First iteration

	[−ATR]				[+ATR]			
	[−BACK]		[+BACK]		[−BACK]		[+BACK]	
	[−RND]	[+RND]	[−RND]	[+RND]	[−RND]	[+RND]	[−RND]	[+RND]
[+HIGH −low]	[ɪ]		[ɨ]	[ʊ]	[i]	[y]	[ɨ]	[u]
[−HIGH −low]	[ɛ]		[ɜ]	[ɔ]	[e]	[ø]	[ə]	[o]
[−HIGH +low]	[æ]	[ɶ]	[a]	[ɒ]	[ɐ]	[œ]	[ʌ]	[ɒ̈]

Table 2
Key to symbols

After the first application, there are 15 categories in total. Some of these can be applied to each other once again, but not all, for two reasons. Firstly, as in the first application, elements of like charm cannot be combined. Secondly, the definition of fusion does not say what happens when a derived category A·B, which usually has two marked features (one from the head, one from the operator), itself acts as an operator. There are four logical possibilities:

(1) The marked features of BOTH A and B are 'hot'.
(2) The marked feature of A alone is 'hot'.
(3) The marked feature of B alone is 'hot'.
(4) (A·B) does not have any hot features, and thus cannot be an operator.

In KLV's exposition, 'hot' features are underlined. None of their examples of derived categories have any underlined features, which makes (4) the most faithful interpretation of KLV's position, with (possibly) one exception: where the head is the 'cold' vowel v^-, the two derived categories $A^+ \cdot v^-$ = [ɜ] and $Ɨ^+ \cdot v^-$ = [ɨ] have only one marked feature, and so to be generous to KLV, I shall assume this to be hot and add these to the set of operators. (The total set of categories would be even smaller and stranger if this were not so, which is why I consider this inclusion 'generous'. If (1) is admitted, then a NONSYLLABIC unadvanced front rounded mid vowel can also be derived from, for example, $(U^- \cdot A^+) \cdot I^-$, but this makes the total inventory even stranger!)[3]

For the second application, I applied the five basic categories and the two derived categories $A^+ \cdot v^-$ and $Ɨ^+ \cdot v^-$ to the five basic categories and the ten derived categories of the first application. Once again, not all logically possible combinations are permisible, and there is some duplication among the 24 resultant categories. Furthermore, since all the new resultants have two or three marked features they cannot be used as operators in subsequent applications. The results of the second application are shown in Table 3.

For the third application, the seven operators are applied to the 11 new categories derived by the second application. Although there are 46 legal resultant categories, there is extensive duplication, and only two of them are new. These are the maximally marked categories [œ] and [ø], in which all 'markable' features are marked. Recall that [±low] can be neither marked nor unmarked; the two maximally marked categories differ only in the feature [±low]. The results of the third application are shown in Table 4.

For completeness I applied the seven operators to the two new categories, but since they are already maximally marked, the fusion operator can do no

[3] In a recent presentation of Charm Theory (cf. Charette, 1989) the negatively charmed vowel elements are replaced by charmless elements whose features are, in all other respects, the same. I have tested this alteration too, and found that it does not substantially alter the yield of the fusion operator, with one exception: the two 'gaps' of Table 2 are filled, adding NON-NUCLEAR [ö] and [ʏ] to the set of segments defined by Charm Theory.

Operators		Heads														
		First application					Second application									
		v⁻ [ᵻ]	I⁻ [ɪ]	U⁻ [ʊ]	A⁺ [a]	ɨ⁺ [ɨ]	[æ]	[i]	[ɒ]	[u]	[ɜ]	[ɛ]	[ɔ]	[ɨ]	[i]	[u]
	Charm:	–	–	–	+	+	+	+	+	+	–	–	–	–	–	–
v⁻	[ᵻ]				[a]	[ɨ]	[æ]	[i]	[ɒ]	[u]						
I⁻	[ɪ]				[æ]	[i]	[æ]	[i]	[Œ]	[y]						
U⁻	[ʊ]				[ɒ]	[u]	[Œ]	[y]	[ɒ]	[u]						
A⁺	[a]	[ɜ]	[ɛ]	[ɔ]							[ɜ]	[ɛ]	[ɔ]	[eɜ]	[e]	[o]
ɨ⁺	[ɨ]	[ɨ]	[i]	[u]							[ə]	[e]	[o]	[ɨ]	[i]	[u]
(A⁺.v⁻)	[ɜ]				[a]	[ə]	[æ]	[e]	[ɒ]	[o]						
(ɨ⁺.v⁻)	[ɨ]				[ʌ]	[ɨ]	[ɐ]	[i]	[ɒ̈]	[u]						

Table 3
Second iteration

Operators		Heads: third application											
			[Œ]	[y]	[ə]	[e]	[o]	[ə]	[e]	[o]	[ʌ]	[ɐ]	[ɒ̈]
		Charm:	+	+	−	−	−	+	+	+	+	+	+
v⁻	[ɨ]		[Œ]	[y]				[ə]	[e]	[o]	[ʌ]	[ɐ]	[ɒ̈]
I⁻	[ɪ]		[Œ]	[y]				[e]	[e]	[ø]	[ɐ]	[ɐ]	[œ]
U⁻	[ʊ]		[Œ]	[y]				[o]	[ø]	[o]	[ɒ̈]	[œ]	[ɒ̈]
A⁺	[a]				[ə]	[e]	[o]						
ɨ⁺	[ɨ]				[ə]	[e]	[o]						
(A⁺·v⁻)	[ɜ]		[Œ]	[ø]				[ə]	[e]	[o]	[ʌ]	[ɐ]	[ɒ̈]
(ɨ⁺·v⁻)	[ɨ]		[œ]	[y]				[ə]	[e]	[o]	[ʌ]	[ɐ]	[ɒ̈]

Table 4
Third iteration

further work. Since the greatest change that fusion can effect is the addition of one marked feature to a category, there are at most four iterative applications of heads to operators, and hence the enumeration is complete.

The set of phonetic (phonological) categories in Charm and Government theory has many idiosyncracies. Firstly, there are no high front round unadvanced vowels, such as [ʏ]. This gap arises from the restriction on fusion of segments with identical charm – there is no positively charmed cold vowel with which to fuse I⁻ and U⁻. Secondly, the most unmarked vowels are [ɪ], [ʊ], [ɨ], [a] and [ɨ]. Are we really expected to believe that these are universally the most unmarked vowels? Thirdly, in a similar vein, in three-vowel systems of the form /i u a/, according to Charm and Government theory, two of the three segments are derived, rather than basic. This circumstance contrasts markedly with the related theory, Dependency Phonology, in which such vowel systems are analysed as consisting of the three basic, underived elements, |i|, |u| and |a|. And what are we to make of the principle of Charm and Government theory which holds that only positively charmed vowels may occur as syllable nuclei (i.e. as 'normal', syllabic vowels)? If this is true, then not only does it reinforce the need to analyse three-vowel systems as being composed of one basic and two derived segments, but it divides the set of segments enumerated above into 16 syllabic vowels (i, y, ɨ, u, e, ø, ə, o, ɐ, æ, œ, Œ, ʌ, a, ɒ and ɒ̈) and 12(!) non-syllabic vowels (i, ɪ, ɨ, ɨ, u, ʊ, e, ɛ, ə, ɜ, o and ɔ). This is an extraordinary proposal. Note, for instance, that [ɪ] and [ʊ] cannot occur in unbranching nuclei or as the head element of a branching nucleus, since nuclear governors have positive charm (Charette, 1989: 164). I assume that KLV would not like to be held to the consequences of this curious view of vowel systems, and can only assume that they have not thoroughly followed through the implications of their proposed formalism.

Such problems are not rare in phonological studies, and I do not wish to suggest that KLV's theory is exceptionally flawed. The lesson of this examination is that proponents of formal, combinatorial theories have a tool for the mechanical validation of those theories in computational linguistics, which they neglect at the risk of wasting much time, energy and space in journals.

2. Listing of test programs

The test program which follows was written in Poplog Prolog, although it may be used in a variety of Prolog environments. These predicates are taken from a powerful phonology 'toolkit' which I have developed over a period of several years. The following is made freely available for academic research purposes only, and may not be used for financial gain.

The predicate *result*/1 is used as a lemma to enable a sequence of clauses to be evaluated without using register variables. To test the program out, try evaluating the goal

```
''I−'*''A+', result (X).
```

or

```
''A+'*''v−', result (X), alias (Y, X).
```

with spypoints set if desired.

```
/* CHARM.PL — Govt. and Charm theory        */
/* John Coleman                             */

feature_order([rnd(_), back(_), high(_), atr(_), low(_), chm(_)]).

/*

[m rnd] = +
[m back] = −
[m high] = −
[m atr] = +

*/

alias('v−', [rnd(u), back(u), high(u), atr(u), low(−), chm(−)]).
alias('I−', [rnd(u), back(m), high(u), atr(u), low(−), chm(−)]).
alias('U−', [rnd(m), back(u), high(u), atr(u), low(−), chm(−)]).
alias('A+', [rnd(u), back(u), high(m), atr(u), low(+), chm(+)]).
alias ('H+', [rnd(u), back(u), high(u), atr(m), low(−), chm(+)]).
;;; H denotes 'I-bar'

:-op(22, xfy, '*').
```

```
Operator*Head:-
  call(Operator),
  result(Op),
  call(Head),
  result(Hd),
  fusion(Op, Hd, Result),
  asserta(result (Result)).

fusion(Op, Hd, Result):-
  member(Hot, Op),
  Hot = ..[Feature,m],
  Change = ..[Feature,_],
  rewrite_segment([Change], [Hot], Hd, Result).

fusion(Op, Hd, Hd).

:-op(21, fx, ').

/* evaluate an alias      */

'X:-
  alias(X, A),
  asserta(result (A)).

/* rewrite a segment      */

rewrite_segment([], [], X, X).
rewrite_segment(L, R, In, Out):-
  remove(L, In, Mid),
  add(R, Mid, Out1),
  feature_order(O),
  order(O, Out1, Out).

/* remove a set of features from a segment      */

remove([], X, X).
remove ([H|T], A, B):-
  remove_item (H, A, C),
  remove (T, C, B).

/* remove a feature from a segment      */

remove_item(_, [], []).
remove_item(H, [H|T], T).
remove_item(X, [H|T], [H|T1]):-remove_item(X, T, T1).

/* add a set of features to a segment      */

add ([], X, X).
add([H|T], A, [H|T1]):-
  add(T, A, T1).
```

```
append([], X, X).
append([H|T], A, [H|T1]:- append(T, A, T1).

/* reorder a segment in conventional order      */

order([], [], []).
order([H|T], X, [H|T1]):-
  remove_item(H, X, Y),
  order(T, Y, T1).

/* check a segmental SD against a segment      */

matches([], _).
matches([H|T], X):-
  member(H, X),
  matches(T, X).

member(H, [H|_]).
member(X, [_|Y]):- member(X, Y).
```

Author's address: *Experimental Phonetics Laboratory,*
Department of Language and Linguistic Science,
University of York,
Heslington,
York,
YO1 5DD.

REFERENCES

Charette, M. (1989). The Minimality Condition in phonology. *JL* **25**. 159–187.
Evans, R. (1985). ProGram – a development tool for GPSG grammars. *Linguistics* **23**. 213–243.
Kaye, J., Lowenstamm, J. & Vergnaud, J.-R. (1985). The internal structure of phonological elements: a theory of charm and government. *Phonology Yearbook* **2**. 305–328.
Schane, S. (1984). Two English vowel movements: a particle analysis. In Aronoff, M. & Oehrle, R. (eds.) *Language sound structure*. Cambridge, MA: MIT Press. 32–51.
Shieber, S. M. (1986). *An introduction to unification-based approaches to grammar*. CSLI Lecture notes number 4. Stanford CA.: CSLI.