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The Routledge Handbook of Phonological Theory

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Routledge
Taylor & Francis Group
LONDON AND NEW YORK

First published 2018
by Routledge
2 Park Square, Milton Park, Abingdon, Oxon OX14 4RN

and by Routledge
711 Third Avenue, New York, NY 10017

Routledge is an imprint of the Taylor & Francis Group, an informa business

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data
A catalog record for this book has been requested

ISBN: 978-1-138-02581-3 (hbk)
ISBN: 978-1-315-67542-8 (ebk)

Typeset in Times New Roman
by Apex CoVantage, LLC

MIX
Paper from responsible sources
FSC® C013985
www.fsc.org

Printed in the United Kingdom
by Henry Ling Limited

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Government Phonology

Element Theory, conceptual issues and introduction

Tobias Scheer and Nancy C. Kula

9.1 Introduction and conceptual issues

9.1.1 What you get is not what you see

Government Phonology (GP) grew out of developments of autosegmental phonology that characterized phonological research in the 1980s. Work by Jonathan Kaye and Jean Lowenstamm during that period (e.g. Kaye & Lowenstamm 1981, 1984) was condensed into what today is called Standard Government Phonology. A first step in 1985 concerned the internal structure of segments (Kaye et al. 1985; see sections 9.1.4.3 and 9.2.1, below) and a second step in 1990 regarded syllable structure (*Phonology Yearbook* 7.2 guest-edited by Jonathan Kaye, containing namely Kaye et al. 1990). There are three book-length presentations of the theory: Charette (1991); Harris (1994); and Gussmann (2002). The framing of GP within the architecture of grammar and the larger landscape of Cognitive Science is described in Kaye (1989), *Phonology: A Cognitive View*. Finally, there are two short guides to standard GP written from hindsight, by Kaye (2000, unpublished but available online) and Scheer (2004: §623).

GP as such may be divided into several periods. In an initial period, what today is called standard GP defined the conceptual essentials and accordingly built first versions of sub-segmental and syllable structure. This period closed with the publication of Charette (1991), which provides a snapshot of the state in which GP was then. This coincided more or less with the end of the Montreal group where Jonathan Kaye and Jean Lowenstamm had collaborated: Kaye moved to London, Lowenstamm to Paris. The former further developed sub-segmental aspects, the latter syllable structure. The Revised Theory of Elements then emerged from the work of Kaye and Charette at the School of Oriental and African Studies (SOAS) in London (whereby GP 2.0 is a more recent offspring thereof, following the same idea that the number of melodic primes need to be reduced), while Lowenstamm introduced CVCV (or Strict CV).

The choice of the word *cognitive* in the title of Kaye (1989) is programmatic: it was meant to take issue with so-called concrete approaches (Tranel 1981) which at the time opposed SPE-type abstractness, and with anything that grounds phonology in phonetics (a chapter

in the book is called "The Nonphonetic Basis of Phonological Phenomena"). For Kaye, phonology is a computational system (i.e. operating an input-output transformation based on a stored set of instructions) that, much in the spirit of Saussure's Langue, is self-contained and operates on purely cognitive units. These must relate to phonetic realizations, but the relationship is not one-to-one and the phonological (cognitive) identity of a unit cannot be predicted or derived from its phonetic properties. Even though phonological and phonetic properties sometimes coincide, the analyst will often be fooled when trusting phonetics: in French for example word-initial [w] may allow elision (*l'ouate* [lwat] where the definite article /lə/ is followed by "cotton wool") or may not (*le watt* [lə wat] where the definite article /lə/ precedes "watt"), despite the fact that the two words are phonetically identical ([wat]). Yet the two [w]s must be distinct. Kaye & Lowenstamm (1984) suggest that this difference is syllabic, rather than melodic: [w] belongs to a complex nucleus in *ouate* (and therefore a hiatus leading to elision is created), but to an Onset in *watt* (no hiatus occurs since the two vowels are separated by a consonant, the [w]).

This is why caution demands that phonological units never be based on their phonetic properties. Rather, the only source of phonological knowledge is phonological *behaviour* (this is what Kaye 2005: 283 calls the phonological epistemological principle). We have seen that the syllabic identity of French word-initial [w] is only betrayed by its behaviour (regarding elision). In the same way, the fact that [ɛ] is phonetically front does not entitle the analyst to deduce that it contains a phonological prime encoding frontness (e.g. [-back] in binary systems, |I| in unary approaches). But the fact that an [ɛ] causes palatalization of a preceding velar consonant (and to the extent that this process is managed by phonological computation, on which see section 9.1.4) does allow us to conclude that this vowel is phonologically front. Palatalization is a process denoting phonological behaviour, [ɛ] is a static pronunciation.

In practice, of course, this does not prevent the analyst from proceeding by trial and error, i.e. from making hypotheses based on static phonetic properties that turn out to be wrong. In Polish (and many other Slavic languages), for example, some [ɛ]s palatalize, others do not: given the nominative sg *lo*[t] "flight", compare *lo*[t͡ɕ]-[ɛ] "id., locative sg" with *lo*[t]-[ɛ]*m* "id., instrumental sg". Phonological behaviour thus tells us that the palatalizing locative [ɛ] must possess a frontness prime – but it does not provide any clues to the phonological identity of the non-palatalizing instrumental [ɛ]. Concluding that the frontness prime is absent from the phonological makeup of this [ɛ] is one option, but depending on additional evidence from the language, other analyses may be entertained: in Element Theory terms, Gussmann (2007: 56ff.) for example proposes that in Polish palatalizing [ɛ] identifies as I̲-A (Element Theory is introduced in section 9.2.1, below: |I| is the melodic prime representing frontness, |A| denotes the low position of the tongue, heads are underscored), while non-palatalizing [ɛ] realizes the empty-headed expression _-I-A (where "_" represents the empty head). Palatalization, then, is sensitive not to the presence of I, but to its status as a head or non-head (this distinction is introduced in greater detail in section 9.2.1, below).

9.1.2 Modular architecture

9.1.2.1 Spell-out and phonetic interpretation

Let us continue to examine the Polish pattern. What about the other analytical option whereby the frontness prime is absent from the phonological expression of a non-palatalizing front vowel? In such a scenario, why would this kind of vowel be pronounced as front? Is there a source of phonetic frontness other than a lexical or a phonological specification? The answer is yes, and this has to do with the way GP conceives the interface of phonology with phonetics (for more detail see Chapter 11.2). Since *Aspects* (Chomsky 1965: 15ff.), the generative architecture of grammar in form of the inverted T model (which is reproduced on the first page of Kaye et al. 1990, henceforth KLV 1990) is modular in the Fodorian sense (Fodor 1983) and consists of three independent computational systems.

In production, first morpho-syntax concatenates lexical items retrieved from long-term memory, then phonology and semantics interpret the result of this concatenation process. Since different computational systems operate on distinct vocabulary and are unable to parse ("understand") the idiom of their neighbours (a property called *domain specificity* in Cognitive Science, e.g. Segal 1996), they can only communicate through a translational process. Therefore, when morpho-syntactic structure is to be interpreted by phonology, it is translated into phonological vocabulary by so-called vocabulary (or lexical) insertion (e.g. Embick & Noyer 2007). This is undisputed in generative linguistics: a spell-out operation transforms portions of the morpho-syntactic tree (featuring categories such as number, person, animacy etc.) into phonologically meaningful units such as labial, occlusion etc. through a lexical (and thus arbitrary) specification (e.g. in English, past tense ↔ *-ed*).

GP takes the modular architecture of grammar seriously and holds that the interface with phonetics works exactly in the same way: a spell-out operation assigns a phonetic value to phonological primes through a lexical (and thus arbitrary) specification. This is called *phonetic interpretation* (Harris & Lindsey 1990, 1995: 46ff., see Chapter 11.2.1). In our Polish example, two lexically stored specifications assign a pronunciation to the two [ɛ]s: I̲-A ↔ [ɛ] and _-I-A ↔ [ɛ]. That is, the language pronounces two phonologically distinct items alike. This hard-wired and language-specific knowledge must be acquired by the child and has the same status as other parametric specifications, for example defining sound inventories.

Now let us come back to our original question: if a non-palatalizing front vowel lacks the phonological prime for frontness, why is it pronounced front? The answer is that spell-out may decide so. Assume a non-palatalizing [i] which phonologically identifies as an empty-headed structure without additional primes (_). Cast in surface terms (for the sake of exposition), this [i] is in fact /ɨ/ and therefore does not palatalize. It is pronounced [i], however, because there is a spell-out instruction specifying _ ↔ [i]. Dresher & Compton (2011: 222) describe Inuit dialects that have a palatalizing and a non-palatalizing [i] whereby the former (so-called strong i) comes from Proto-Eskimo i, while the latter (weak i) is a reflex of Proto-Eskimo schwa. They show that weak i not only does not palatalize, but is also subject to other processes such as assimilation, dissimilation and deletion. Dresher & Compton therefore conclude that weak i has no phonological substance: it is synchronically empty just like it was in Proto-Eskimo. The diachronic change, then, is only in the spell-out relation: the modern ([i]) and the ancient ([ə]) pronunciation realize the same phonological unit, schwa. That is, the diachronic evolution concerned the spell-out of that unit (_ ↔ ə > _ ↔ i). Its phonology remained untouched and is exactly the same in the modern and the older variety of the language. That is, there was no evolution that would have changed the phonological identity of the vowel in question: _ (↔ ə) > I (↔i) did not occur.[1]

The take-home message of GP, then, is that phonology does not work along the statement *what you get is what you see*: phonetic properties of a sound do not allow the analyst to conclude on either its syllabic affiliation (French elision) or its melodic identity (Polish/Inuit palatalization). Only their behaviour does.

9.1.2.2 Structural Analogy

The modular setup does not mean that different computational systems do not share any properties. GP is known for applying syntactic mechanisms to phonology, thereby joining the tradition of Structural Analogy developed in Dependency Phonology by John Anderson (1985, 1992 and following). In the formulation of van der Hulst (2000: 209), "grammar recapitulates, rather than proliferates, structures and principles". This takes on the following form in GP.

(1) "What is at stake here goes well beyond a mere search for interesting or suggestive similarities. Rather, if (some of) the same principles can be shown to underlie phonological as well as syntactic organisation, the idea that such principles truly express special, idiosyncratic properties of the mind (such as the kind of asymmetries typical of natural language) will be correspondingly strengthened."

KLV (1990: 194)

Accordingly, GP has imported several mechanisms from syntax, some of which are introduced below: the Empty Category Principle, Proper Government, c-command, a phonological version of the Minimality Condition, the Projection Principle and Structure Preservation.

9.1.3 The purview of phonology: small is beautiful

A question as old as phonological analysis is what exactly counts as phonology (or, to be precise, as phonological computation). This is what Ricardo Bermúdez-Otero (p.c.) calls the Holy Grail of phonology (Bermúdez-Otero 2007; Scheer 2015 provide overviews of the question). This issue is paramount and for obvious reasons must be decided before one can begin to build phonological theory: if you decide that your theory needs to account for a set X of empirical phenomena, it will end up wildly different according to the size of X. To anticipate, GP argues that only a very small subset (perhaps 10%) of what SPE held to be phonological is indeed managed by phonological computation. Much like current syntactic theory whose minimalist orientation also drastically reduces the set of truly syntactic phenomena, GP thus believes that *small is beautiful*.

Central to the calibration of X is the notion of overgeneration, both for GP and in the historical development of generative phonology during the so-called abstractness debate of the 1970s that was triggered by Kiparsky (1968–73). An SPE-type rule can describe any phonological process and its reverse, i.e. the set of existing processes (e.g. k → t͡s/__i,e) as much as all processes that are never produced by natural language (e.g. p → ŋ/__i). The basic ambition of the generative enterprise, as indicated by its name, is to generate *all and only* those linguistic expressions that occur. Therefore, a computational system like SPE that on top of all occurring processes can also generate all non-occurring events is in trouble. GP takes this problem very seriously at all levels: regarding the melodic makeup of segments (see section 9.2.1), syllabic constituency and the set of processes that instantiate phonological computation.

Note that there are also modern representatives of the reverse philosophy, i.e. those who argue that overgeneration is not a bad thing to have and indeed a property of all natural systems (only a small subset of what biological evolution can in principle produce is actually attested by past or present organisms). Hale & Reiss (2008) represent this SPE-defending line of thought as *big is beautiful*.

In practice, an alternation of some segment in two instances of the same morpheme may in principle represent one of the following situations.

(2) Alternations are produced by
  a. distinct lexical entries
  b. morpho-phonology
  c. allomorphy
  d. analogy
  e. phonology

For the sake of illustration, let us consider English velar softening, whereby the velars [k], [g] seem to be turned into [s], [d͡ʒ] before [i] (*electri*[k] – *electri*[s]-*ity*, *analo*[g]*ue* – *analo*[d͡ʒ]-*y*). The analytic option under (2a) considers both *electric* and *electricity* as single, i.e. morphologically non-complex, lexical entries whose pronunciation requires no concatenation and no phonological (or other) computation at all. The second analytical option (2b) refers to a computational system distinct from phonology that is entertained in traditional grammar as well as in structuralist and early generative approaches: morpho-phonology. Here computation takes into account morphological as much as phonological information (see Gussmann 2007: 10ff. for an overview, also historically). Velar softening is morphologically conditioned: it does not apply morpheme-internally (*king* is [k]*ing*, not [s]*ing*) and goes into effect only before a subset of i-initial suffixes, which Kiparsky (1982: 40f.) identifies as class 1 suffixes: -*y*, -*ity* and -*ism* (compare with class 2 suffixes such as -*ing* in *hik-ing*, which is not **hi*[s]-*ing*). Therefore velar softening qualifies for being managed by morpho-phonological computation (2b).

A third option is allomorphy (2c): there are two lexical entries *electri*[k]- and *electri*[s]- which are selected (through morphological computation) by purely morphological information (class 1 suffixes choose the latter, class 2 suffixes the former). Analogy (2d) also performs computation, but of a kind that some believe lies outside of grammar since it requires comparison with unrelated lexical items: *electri*[s]-*ity* has an [s] because the speaker knows that there are a number of other words that end in -*sity* and therefore modifies the lexical entry *electri[k]*- to become *electri[s]*-. Finally, phonological computation as under (2e) is another analytical option, whereby a grammatical instruction stored in long-term memory (a rule or constraint set) transforms [k] into [s] before [i] (in appropriate morphological contexts).

How could the analyst discover which mechanism controls particular alternations? As a consequence of the abstractness debate, much effort was put into establishing a set of formal criteria (called the "evaluation measure" or "evaluation metrics" in the 1970s, e.g. Kiparsky 1974) that allows us to decide whether an item that the analyst identifies as morphologically complex is really considered as such by the grammatical system, and if so, whether or not its computation is phonological in kind. All attempts failed, and the result in the early 1980s was a situation where everybody agreed that the position of SPE on the extreme big-is-beautiful end of the scale is not realistic. The whole thrust of the abstractness debate was to reduce this computational abstractness, shifting the analysis of a fair amount of alternations to other mechanisms. The question was to what extent the computational balloon of SPE needed to be deflated. Natural Phonology (Stampe 1972) and Natural Generative Phonology (Hooper 1976) were built around this question in the 1970s, and Lexical Phonology (Kiparsky 1982) may be argued to be an attempt to save the basic SPE architecture by shifting labour from phonological computation to the cyclic system (see Scheer 2011).

As mentioned above, in this landscape GP takes a radical position on the extreme small-is-beautiful end of the scale (akin to the natural phonologies; see Scheer 2015): most of what SPE held to be phonological are instances of some other mechanism among those mentioned under (2). In practice, then, what are the criteria that allow the analyst to decide whether a given alternation is the result of phonological computation or not? Standard GP decides along the lines under (3):[2] if an alternation is characterized by any one of the three properties, it lies outside of phonology.

(3) An alternation cannot be phonological
  a. if it is not 100% regular, i.e. surface-true OR
  b. if it has conditioning factors that are morphological and cannot be expressed by domain structure OR
  c. if there is no plausible causal relationship between the change observed and the triggering context

The proviso under (3a) is a consequence of Kaye's (1992: 141, 1995: 291) take on computation (on which more in section 9.1.4 below): phonological processes apply whenever the conditions that trigger them are met. This statement needs to be complemented with the fact that in Kaye's view there is only one set of phonological instructions. Lexical Phonology (Kiparsky 1982) has introduced the idea that different chunks of the linear string (which follow inside-out embedding and interpretation), called cycles, may be subject to different sets of rules, i.e. different phonologies. Hence given a (cyclic) structure [[[A]B]C], different computational instructions may apply to A (inner cycle, e.g. corresponding to the root), AB (intermediate cycle, e.g. corresponding to the stem) and ABC (outer cycle, e.g. postlexical phonology). There is a (depleted version of) cyclic structure in GP (the domain structure mentioned under (3b), on which more in Chapter 11.1.2), but all cycles/domains are computed by the same phonology. Hence all chunks of the linear string, wherever they occur in the cyclic/domain structure, will be subject to this unique computation,[3] which means that in the presence of a phonological k-to-s-before-i instruction that instantiates velar softening, all instances of the linear string will be modified. That is, there must not be any surface [ki] sequence at all: monomorphemes like *king* are impossible.

Velar softening cannot be phonological for yet another reason: there are exceptions such as *monar*[k] – *monar*[k]-*ism*, *patriar*[k] – *patriar*[k]-*y*. In the same way, it fails the productivity test with words like *Iraq*: native speakers seem unable to even parse *Ira*[s]*ity* ("the property of being typically like Iraq"), but are able to make sense of *Ira*[k]*ity*.

Finally, (3c) is called non-arbitrariness in GP and appears in KLV (1990: 194, see also Gussmann 2007: 30ff.; Pöchtrager 2006: 19ff.). The front vowel [i] is certainly a plausible candidate for triggering palatalization (unlike, say, [a] or [u]). But the fact that the other front vowels do not have the same effect begs the question. Also, the structural change itself needs to be inspected: [i] may be a good palatalization trigger, but a trigger for which palatalization exactly? Cross-linguistic (and also diachronic) experience leads the analyst to mistrust [k] → [s], since typical results of palatalization are [t͡s] and [t͡ʃ], or maybe [c]. At a previous diachronic stage of English, the palatalization at hand was actually [k] → [t͡s], but the (unconditioned) loss of affricates ([t͡s] > [s]) turned it into a suspicious alternation. This is the typical way for regular processes to become opaque while aging (see Bach & Harms 1972): through a context-free change that affects the input or the output of a process. The question, then, is whether phonological computation, which managed the original alternation, will be able to accommodate this kind of evolution. GP says no: it breaks down because the new alternation is no longer expressible in phonological terms.

It needs to be realized (though not always is by GP practitioners) that non-arbitrariness is theory-dependent: there is no pre-theoretical or surface-based definition of what exactly is "expressible in phonological terms". Depending on the theory of melodic representations, a front prime that enters a velar stop and turns it into an [s] may or may not be something that can be described. Given the initial melodic representations of GP, it cannot, and hence velar softening is rejected as being beyond the realm of phonology. The next question, then, is how the melodic representations of GP have come into being, and the answer of course is that they are designed in order to account for a number of phonological processes. Which means that there was a selection among all alternations, some of which were judged to be truly phonological (and hence informed melodic theory), while others were left aside. Rather than being circular, this is the regular dialectic between data (bottom-up) and hypothesis (top-down) that is the common ground of scientific activity. But this means that the criterion under (3c) does not judge alternations per se: it assesses them only given an already established phonological theory. And this theory of course can (and should) change over time, which may consider a previously non-phonological alternation phonological, or vice-versa.

The representation of velar consonants is an example of how a change in the theory has modified the set of alternations that are held to instantiate phonological computation. In the first version of consonantal representations in GP (Harris & Lindsey 1995: 67), velars do not contain the element |U|: they are empty-headed (see section 9.2.1.1). Therefore the variation of the Czech vocative (masc.) marker for example must be declared non-phonological: *-i* attaches to palatal-final stems (*Tomáš-i* "Thomas Vsg"), *-u* occurs after velar-final stems (*František-u*) and *-e* is found elsewhere (*Jakub-e*, *Milan-e*). Since u is made of |U| but velars do not contain this element, they cannot spread it to the suffix. Today most elemental approaches to the internal structure of consonants acknowledge the presence of |U| in velars (Backley 2011: 79ff.; see section 9.2.1), which means that the Czech vocative alternation is considered phonological in kind.

9.1.4 Computation in GP

9.1.4.1 Anti-serialism

Rooted in the properties of the universal Turing machine (Turing 1936–37), serialism (or derivationalism) lies at the heart of the standard theory of Cognitive Science that emerged in the 1950s, and whose application to linguistics produced generative grammar (see e.g. Gardner 1985). Serialism is the idea that computation in the mind involves a set of instructions that act on the input in such a way that it experiences step-by-step modifications which occur in a chronological and logical order where the output of step n-1 is the input to step n.

In generative grammar, serialism shows up as extrinsically ordered rules in phonology, and in early syntax as extrinsically ordered transformations. The latter were abandoned in the early 1980s when Government Binding (GB) theory introduced so-called move α, a system where movement (computation) is free in itself, but controlled by constraints on representations (e.g. Newmeyer 1986: 163ff.). Move α represents an important turn in syntactic theory away from restrictions on computation itself (Chomsky's 1973 original Strict Cycle Condition, extrinsically ordered transformations) in favour of a central role of well-formedness constraints on representations such as barriers, the ECP, case checking and so forth. The development of autosegmental structures in the 1980s follows the same track: representations are governed by well-formedness conditions such as the OCP or no line-crossing. While generative syntax thus abandoned serialism in 1981, the representational blossoming of the early 1980s left extrinsically ordered rules untouched in phonology: well-formedness conditions were added on top of them, and the result was a hybrid model (see Scheer 2011 for more detail). In the second half of the 1980s, though, a general discomfort with serialism arose, which was pervasive through the entire field.

GP participated in the anti-serialist movement, considering that extrinsic rule ordering was empirically vacuous. That is, examples where serial ordering of instructions is alleged to be critical are either based on erroneous data, involve misanalysis or concern processes whose properties disqualify them as instances of phonological computation. An example for erroneous data is Martin Joos' famous dialect B of Canadian English for which there is no evidence (Kaye 1990, 2008), but which was used by Bromberger & Halle (1989) as the litmus test for rule ordering. Examples for processes that are not phonological in nature are Trisyllabic Shortening (or other traces of the Great Vowel Shift) and the aforementioned velar softening.

While anti-serialism is an important feature of the early identity of GP, there is almost no trace of this programme in print: Kaye (1990) is only a brief comment about the non-existence of dialect B, and the GP literature of the 1980s (Kaye et al. 1985: 305; Lowenstamm & Kaye 1986: 97) heralds the programmatic claim that there are no rules (GP is a "no-rule approach"), but essentially leaves it at that. Kaye et al. (1985: 305) merely explain that they expect Principles and Parameters theory coming from the then freshly established GB syntax to take over 100% of the function of ordered rules (just like in syntax). They add that "at the moment of writing, this view of phonology remains a long-term objective of our research programme". The following section locates this ambition in the context of the time and fleshes out the little that the further GP literature contains about how exactly computation works.

9.1.4.2 Weakly developed constraint-based computation

The latent antipathy against serialism of the late 1980s reshaped the landscape in the early 1990s by producing three theories that are based on the anti-derivational mantra: Optimality Theory, Declarative Phonology and GP. In these approaches, computation is based on constraints. Constraints, however, do not have the same status in the tree theories: while they are ranked and violable in OT, they are absolute (i.e. non-violable) in Declarative Phonology.

GP is often referred to as a representation-oriented theory of phonology, and there is certainly good reason for this characterization. A correlate of the representational focus is the fact that the programmatic statement mentioned lain aside, there is not much to be found about how computation works and what a computational instruction looks like. The only indication that was available until the mid-1990s is Kaye's (1992: 141, 1995: 291) statement according to which processes "apply whenever the conditions that trigger them are satisfied". The constraint-based character of computation in GP has appeared only since the introduction of Licensing Constraints (Charette & Göksel 1994, 1996; Kaye 2001). To date, Gussmann's (2007) book on Polish appears to be the only detailed application of this constraint-based approach.

Constraints in GP thus apply whenever a form may be modified by them, but with no extrinsic ranking or ordering (hence unlike OT), and without being violable: the set of constraints (the φ-function in Kaye's 1995 terms) is (simultaneously and) iteratively applied to the string that is submitted to interpretation, and computation ends when no further modification can be made (this is a parallel with Harmonic Serialism and OT-CC).

Expressed using serial vocabulary, this system is thus able to handle a feeding relationship (the conditions for the application of a constraint are created by the modification of the input string by another constraint), but no other (i.e. bleeding, counter-feeding, counter-bleeding). A difference must therefore be made between serial computation (GP computation is serial in the sense that constraints may apply to the same string several times, and that intermediate steps may thus exist) and serialism per se (there is no extrinsic or logical ordering of instructions, i.e. classical extrinsic rule ordering).

Also, there is no ranking or prominence (dominance) relationship among constraints: all instructions are equally important, and there is no selective application. That is, all instructions of the φ-function apply when a string is computed: there is no way for just a subset of the phonological processes to apply at a given time and to a given string. Phonology is not divisible, and "do phonology!" (the way Kaye 1995 describes the application of the φ-function) means "do *all* the phonology!".

In sum, computation has not been a central focus of GP, nor could it be said that GP has provided major contributions to computational theory. Speaking in economic terms, the behaviour of GP in the overall landscape is counter-cyclic. Writing at the peak of the representational (autosegmental) wave and having observed the see-saw movement of phonology between process- and representation-oriented extremes in the history of phonology in the 20th century, Anderson (1985) extrapolated what would come next: another round of the computational extreme, in counteraction to the representational excess. Phonology was thus programmed to produce OT, which indeed entered the scene a couple of years later. Anderson predicted its arrival, but little did he know how extreme this round of "phonology is computational and nothing else" would get. When the mainstream thus set out to shift the labour that was done by representations onto computation (constraint interaction), leaving only a decorative role for the former (de Lacy 2007 for example is explicit on the intention and reality of this movement; see Scheer 2010), GP bet on the exact reverse setup: phonological patterns are best explained by a rigid representational theory augmented with well-formedness constraints. Computation was secondary in this project, and this is reflected by the fact that little was done to explain how computation works in the GP literature.

Today things have swung back more into a midfield position, i.e. the one that Stephen Anderson (1985) argued for: a sound theory of phonology needs a theory of representations *and* a theory of computation, and these need to be independent (none must be the slave of the other). In mainstream OT, the decorative remnants of representations used to be "emerging", i.e. the result of constraint interaction (see Scheer 2010). But since the mid-2000s, there is a body of OT-based literature arguing for a return to representations that are not just a toy (or the slave) of computation: they may e.g. be hard-wired by constraining Gen (Blaho et al. 2007; Oostendorp 2005; and others).

9.1.4.3 Independence of representations and computation

While a good case can be made (and is typically made by representatives of GP) for the interdependence of pieces of representational structure (piecing together a representation with items from GP and other theories produces a monster), the same cannot be said about representations and computation. I am unaware of evidence showing that the representations of representational theory X can only be managed by the computation of computational theory A (while B does not qualify, or while Y is incompatible with A). As long as the dualistic Anderson-standard is respected (there are theories of representation and of computation, and one is not the slave of the other), the accuracy of representational and computational theories appears to be a matter of independent evaluation (Scheer 2010).

For GP, this means that the core of its contribution to phonological theory is representational in kind, and that the management of GP representations is to be sought by the best computational theory around (which may or may not be the one that is based on GP's initial take on computation). Hence there are attempts to combine GP representations with OT computation (Polgárdi 2009). Also, the small-is-beautiful positioning of GP at the extreme end of the scale describing the number of alternations that are phonological (see section 9.1.3) partly depends on how computation works: namely the decision that there is only one phonology (i.e. one set of phonological instructions) does not follow from anything. Computation could as well be chunk-specific (root, stem, postlexical) or morpheme-specific (indexed constraints, cophonologies in OT): these options substantially increase the generative power of the system and hence augment the volume of alternations that can be described. Rejecting them is a matter of an independent decision that needs to be motivated.

An important related aspect that usually goes unnoticed is the fact that the granularity of the instructions that are developed by practitioners who implement computation into explicit formal statements is much greater than what is usually done in GP. That is, in GP computation is typically referred to in prose statements such as "and then the element spreads from the nucleus to the Onset" or "and then the suffixal vowel that sits in the final empty nucleus governs the preceding nucleus, which therefore remains unpronounced (government)". OT-type constraints would simply cast these prose statements in a more formalized and more fine-grained vocabulary.

9.2 Element Theory

9.2.1 *Background*

It is a generally accepted position in generative phonology since Jakobson et al.'s (1952) work that segments are decomposable into smaller units. For Jakobson et al. (1952); Jakobson & Halle (1956); and subsequently Chomsky & Halle (1968), these smaller units are features with the role of capturing both the distinctive properties of segments and the various phonological operations segments are involved in. While Jakobson and Halle used primarily acoustically based features, Chomsky and Halle developed more articulatory-based features. In both systems features are treated as having a polar opposition offering a positive (+) and negative (−) value of each feature. The number of oppositions offered in each system varies between twelve (in Jakobson & Halle 1956) to over thirty (in Chomsky & Halle 1968). Within the polar opposition of features both oppositions for some features like [+Voice] can be argued to be active in grammars to account for voicing assimilation, for example, while for a number of others like [+Nasal], one opposition [+Nasal] is more active than the other [−Nasal]. In fact the latter is not seen to be active at all with no processes targeting segments that are specifically [−Nasal].

The other property that segmental sub-units such as features aim to capture is the idea of natural classes, namely that phonological processes are seen to apply to a select set of features as triggers or undergoers to the exclusion of others. Again in a feature system this works well for some select features but not at all for others. There are two main issues in classic feature theory as developed in SPE that have led to alternative perspectives on sub-segmental units: the overgeneration problem and the lack of inherent natural class predictiveness. The greater the number of features that are assumed, the larger the set of phonological segments that are predicted to exist. Within the overgeneration problem lies the central question of whether sub-segmental units should have binary oppositions or be monovalent. As a way of dispensing with these concerns GP argues that segments are composed of elements which are acoustically defined monovalent cognitive units supporting a hearer-oriented phonological grammar. This crucially distinguishes elements from features that are defined based on articulation and is in this respect more in line with Jakobson. Other comparable approaches adopting non-feature-based sub-segmental units are Dependency Phonology (Anderson & Jones 1972; Anderson & Ewen 1987) and Particle Phonology (Schane 1984).

Anderson & Jones (1972) is also significant in introducing unary features in response to some of the challenges already raised above. This was quickly adopted in non-feature-based work but also more recently in feature-based representations as, for example, surveyed in Hall (2007). The significant difference between such unary feature systems and element-based representations is the ability to be independently pronounceable, which remains a property of only the latter system. Thus in element-based representations a segment may consist of only one prime, attesting to the independent interpretability of elements, while this is never the case for features.

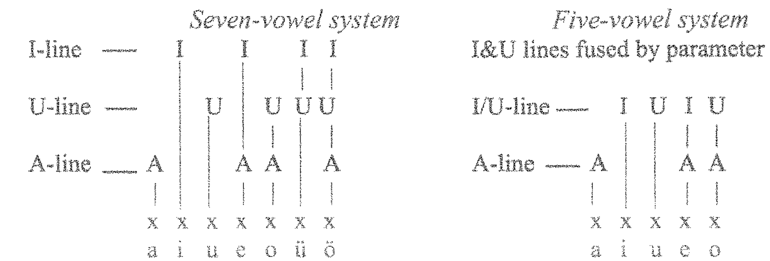
9.2.1.1 Elements and charm theory: the early days

Elements in GP were introduced in Kaye et al. (1985) where they more specifically elaborate on the representation of vowels. In this early work elements are defined as consisting of fully specified feature matrices but features are seen as only providing the phonetic interpretation of otherwise autonomous and independently pronounceable phonological units. The elements |A| |I| |U| are given as the three vowel elements from which other vowels can be derived by a combination of these basic elements. |A| |I| |U| are themselves independently interpretable as the segments /a/, /i/ and /u/. Within KLV's (1985) element representations the feature matrices of each element consisted of what they termed a *hot feature* which identified the marked feature in each matrix reflecting the dominant characteristic of each element. |A| |I| |U| had [−high], [−back] and [+round], respectively, as hot features. In this sense elements were embedded in markedness theory. In KLV (1985) elements are treated as residing on autosegmental tiers which connect with skeletal points in order to give the eventual representation of a segment. Combinatory possibilities between elements are regulated by the tiers on which they reside. Thus only elements that are on different tiers can combine while those on the same tier cannot. Tiers are defined according to the hot feature for which a particular element must be specified. In this sense the constraints that hold on individual vocalic systems are defined in the tier representations with elements that cannot combine in a particular language treated as conflating their tiers. Fused |I| and |U| tiers (Back and Round lines) are treated as the unmarked option in vowel systems based on the empirical distribution of vocalic systems. Elements on the same tier, like |I| and |U| in systems where the unmarked holds, cannot combine and OCP effects apply so that in contrast to Particle Phonology, a single element cannot be present more than once in the representation of a segment. Thus, while (4a–b) are possible compound representations, (4c) is not, with the latter represented as a single element attached to a single skeletal point. Tier conflation is depicted in (5) drawn from Cyran (1997), respectively depicting a seven- and a five-vowel system.

(4) Element combinations

a.	|A| + |I|	→	|A.I| /e/
b.	|A| + |U|	→	|A.U| /o/
c.	*|A| + |A|	→	|A.A|

(5) Tier conflation



Fusion operations as in (4a–b) are asymmetrical in that one element acts as head and the other as operator. In KLV (1985) terms the operator only contributes its hot feature to the head's feature representation, resulting in one feature matrix. With the head represented on the right this implies that |A.I| and |I.A| are not equivalent thereby providing the possibility of defining more oppositions in a system based on three primitives. Apart from these three basic elements for vowels there were two further vowel components assumed. The so-called *cold vowel* plays the role of an identity element whenever it occurs in combination with other elements as operator because unlike full elements it does not have a hot feature. Its realization as head results in reduced vowels like schwa. The other vowel element was the |ATR| element which was argued as not derivable from the other elements and having the hot feature ATR.

Although elements were treated as feature matrices, the crucial point was that phonological processes have no access to features but only to the elements, with features manipulated only indirectly in element combinations. Elements within GP therefore directly address the overgeneration problem by positing an initially minimal set of primitives whose possible combination, even including head relations, fare much better on actual attested, in this case, vocalic systems.

A second issue that was deemed significant for sub-segmental units is their combinatorial properties and whether natural classes could be defined. In feature theory natural classes were later captured by assuming feature geometry (Clements 1985) by which particular nodes could be referenced as the target of particular phonological processes and by which segments can be modified. Combinatorial capabilities of elements in KLV (1985) were captured by charm, with elements regarded as either positively or negatively charmed. Elements of like charm repelled each other while elements of unlike charm attracted. This charm idea was adapted from particle physics where particles also operate on the same attraction principles. In this way elements could be grouped based on their charm and thereby capture natural classes by barring particular combinations while allowing others. In compound expressions the charm of the head determined the charm of the compound. In vowels relevant elements (A and ATR (also N)) were treated as positively charmed, while (I U v° (the cold vowel)) were negatively charmed. Positively-charmed elements were cavity maximizing (oral |A|, pharyngeal |ATR| and nasal |N|), therefore allowing for high resonance and were as such regarded as unmarked so that markedness was defined both at the level of the phonological representation (read off the complexity of an expression) and at the elemental level. Thus to derive the unmarked minimal vowel system of {i u a} while adhering to elemental markedness, the ATR element was included as head to allow its positive charm to be propagated onto the phonological expression. An illustration is given in (6).

(6) Elemental expressions with charm

i	(I−.ATR+)
u	(U−.ATR+)
a	(A+)

In this sense vocalic systems based on positively-charmed expressions are more unmarked than negatively-charmed ones with the obvious proviso that having only two negatively-charmed representations as in a system with {i u e ɛ ɔ o a} is less marked than having a full-blown negatively-charmed set of expressions as is attested in ATR systems. The incompatibility of (A+.ATR+) consisting of two positively-charmed elements accounts for the predominance of nine-vowel ATR systems rather than those with ten, and for the universal impossibility of having low +ATR vowels. The ten-vowel ATR systems required some further stipulations to be derived, further pointing to the markedness of an ATR /a/.

These representations suggested for vowels are extended to consonants in KLV (1990) with charm modified to having three values: positive, negative and neutral. KLV's (1990) focus was on defining government with charm and was also used to broadly refer to segments with assumed details of consonantal representations only discussed as far as they provided support for the theory of government proposed. The best articulation of these consonantal representations is given in Harris (1990) who further motivates the structure of consonantal expressions by a treatment of lenition processes as involving element decomposition in a bid to provide a non-arbitrary relation between phonological processes and the context in which they occur. The acoustic correlations of consonantal elements are developed in Harris & Lindsey (1995). The element set given in Harris (1990: 263) includes |I°| ("°" indicates neutral charm) as defining palatality; |U°| as defining roundness in vowels and labiality in consonants; |v°| denoting unmarked high and back attributes which contributes velarity when it is head in consonants; |N$^+$| as present in nasalized vowels and nasal consonants; |ʔ°| as involving a decrease in overall amplitude achieved by a non-continuant gesture of the type that characterizes oral and nasal stops; |R°| as correlated with a second formant transition that is characteristic of a coronal gesture; and |h°| as a continuant characteristic treated as found in fricatives and approximants in KLV (1990) but which Harris (1990) treats as contributing a noise component in obstruents. The independent interpretability of elements is still assumed for consonantal elements: |ʔ°| is independently interpreted as a glottal stop which contributes constriction in compound representations, and |R°| is independently interpreted as a coronal tap. Thus fusion of |R°| and |ʔ°| produces a coronal non-continuant. The lack of any supra-laryngeal gesture in |h°| results in its independent interpretation as a glottal fricative. KLV (1990) propose |H−| and |L−| as source elements associated with stiff and slack vocal cords, respectively, defining non-spontaneous voicing in obstruents and tone on vowels. Neutral obstruents like in the Korean three-way obstruent system which have no active laryngeal gesture lack any source element. The full set of elements thus assumed is as given in (7) below.

(7) Set of elements (1990)

U° - labial	R° - coronal	N$^+$ - nasal
I° - palatal	ʔ° - occluded	H$^-$ - stiff vocal cords
v° - none	h° - noise	L$^-$ - slack vocal cords
A$^+$ - low		

In terms of distribution some elements are able to occur in both vocalic and consonantal positions while some are restricted to only consonantal positions, in particular |R° ʔ° h°|. Charm

theory also directly restricted the occurrence of elemental expressions (segments) whose charm value was determined by the head of the expression. Positively-charmed segments did not occur in consonantal positions while negatively-charmed segments did not occur in nuclear positions.

One motivation for these particular elements and their characterization is offered in the treatment of lenition given in Harris (1990). Harris treats lenition processes such as vocalization, spirantization and debuccalization as essentially involving the loss of complexity (or decomposition) in elemental compounds, where complexity is gauged as following from the number of elements that a particular phonological expression is composed of. Korean has a vocalization process affecting neutral stops that changes /p/ to /w/ and /t/ to /r/ which can in both cases be accounted for as loss of occlusion – element |ʔ°| – leaving only the place-defining elements |U°| and |R°|, respectively. Such processes in Korean motivate the representation of neutral /p/ as |ʔ°.U°| and /t/ as |ʔ°.R°|. Treating lenition as depletion of elements makes the prediction that the susceptibility of a segment to lenition will be limited by the number of elements that the segment has. This therefore provides a means by which segmental composition can be determined. Thus in trying to account for the common diachronic lenition trajectory in (8a), the elemental representations in (8b) account for the process and thereby motivate the assumed representations.

(8) a. Common diachronic lenition trajectory:

plosive > fricative > h > ø

b.

x	x	x	x
|	|	|	
R°	R°	|	
|	|	|	
h°	h°	h°	
|			
ʔ°			
[t]	[s]	[h]	ø

This approach to lenition, Harris argues, also specifically supports a monovalent approach to elements and their independent interpretability since it requires the pre-final position in a lenition trajectory to be interpretable. The approach also dispels any random substitution of features as may be permitted in a rule-based feature approach since the context of occurrence is non-arbitrary. The approach is also easily extendable to debuccalization as well as processes such as final obstruent devoicing and vowel raising which were previously considered as quite distinct from lenition. Harris further uses the notion of complexity as the basis on which governing relations can be determined, namely that governors are more complex than governees and it is probably fair to say that this led to the eventual demise of charm theory because it resulted in an incompatibility between markedness based on element complexity and inherent element markedness based on charm. This led to various different approaches to elements that aimed to address different issues specifically, but the central ideas that the approaches to be discussed below maintain is that elements are the central units of which segments are composed; they are monovalent and independently interpretable and employ some notion of headedness.

9.2.1.2 Phonetic interpretation and inventory size

The 1990s saw many changes in elemental representations in GP and extant element-based theories. With the loss of charm theory the idea of inherent natural classes was for the most part lost, and a number of approaches to elements aimed to replace this with another mechanism within a theory of segmental representations. One approach was to introduce tree dependencies akin to feature geometry, organizing elements in geometric representations (Harris & Lindsey 1995). This approach has remained in different forms in later element work (Kula 2002; Botma 2004; Nasukawa & Backley 2005). Another approach is to stipulate Licensing Constraints which monitor the combinatorial capabilities of elements (Charette & Göksel 1998).

The other issue of concern in the 1990s was the number of elements postulated and the inherent overgeneration of possible phonological units as opposed to actual attested segments. Related to the issue of overgeneration was the uncomfortable split between elements that only occur in nuclei and those that only occur in consonantal positions. Better parsimony would demand that all elements are able to occur in all positions, and one way of accounting for both overgeneration and distributional disparities was to dramatically reduce the number of primitives, leading to the so-called *Revised Element Theory* that uses between five and six elements (see e.g. Backley 2011; Charette & Göksel 1994/1996; Cobb 1997; Jensen 1994; Kaye 2001; Ritter 1997). A reduced set of elements is generally currently accepted and has led to a greater and different role of headedness in elemental representations (Backley 2011; Backley & Nasukawa 2009; Kula & Marten 1998; Nasukawa & Backley 2008) as well as the use of structural configurations to represent characteristics that may otherwise be subsumed by elements (Jensen 1994; Pöchtrager 2006). We will consider some of these issues in more detail below.

However, probably the most important change was a more precise characterization of elements as devoid of any direct association with articulatory properties. Starting in Kaye (1989) and further developed in Harris & Lindsey (1995), elements are defined as cognitive units fulfilling the grammatical role of encoding lexical contrasts, with the phonological component having a purely generative role of defining the grammaticality of phonological structures. The idea that elements and their corresponding phonological representations are characterized by full phonetic interpretation at all levels of derivation is the basis on which it is argued that there is no level of systematic phonetic representation. This follows from the fact that phonology does not involve the articulation and updating of abstract underlying representations which then have to be converted into physical phonetic objects since elements are always directly interpretable. Harris & Lindsey elaborate on how the phonetic exponence of elements are to be defined in acoustic terms, arguing that since the speech signal is the communicative experience shared by the speaker and the hearer, its primacy in phonetic interpretation cannot be in question. They propose acoustic signatures for elements as the patterns by reference to which listeners decode auditory input and speakers orchestrate and monitor their articulations (Harris & Lindsey 1995: 50). Backley (2011) provides further support and additional cues for these acoustic characteristics of elements. In Harris & Lindsey, where roughly the set {A I U (R) h ʔ ə (the replacement of v° above) (H L N)} are considered, the acoustic properties are partially as given in (7) above but with some refinements. The elements |H|, |L|, |N| were not tackled in Harris & Lindsey, and there

is scepticism expressed on the validity of having an element (R) representing coronality, on which see discussion in section 9.2.1.2.2.

(9) Updated element acoustic signatures

A	–	central spectral energy mass (convergence of F1 and F2)
I	–	low F1 with high spectral peak (convergence of high F2 and F3)
U	–	low spectral peak (convergence of low F1 and F2)
h	–	noise manifested as aperiodic energy
ʔ	–	abrupt and sustained drop in overall amplitude
@	–	neutral spectral structure (non-coronal, non-palatal, non-labial, non-low)
(R	–	coronality)
H	–	aperiodicity
L	–	periodicity
N	–	nasality

An acoustic signature for |R| has proved elusive and, as will be discussed in section 9.2.1.2.2, this was one of the motivations that eventually led to the loss of |R| as an element in future developments. The elements when considered in consonantal representations can be divided into three types in line with segmental representations: resonance (or place), manner and source (laryngeal). As noted above, the resonance elements |A| |I| |U| define place for pharyngeals, palatals and labials, respectively. Pharyngeals are seen to result in lowering of vowels and so are associated with |A|, with the option that |A| may also be used to represent uvulars depending on the language inventory. See, for example, Bellem (2007) for a detailed analysis of emphatics employing resonance elements as central to characterizing different Arabic dialects. Palatalization occurring before front vowels and labialization before back vowels lend support to the resonance characterization of |I| and |U|, respectively. |ə|, without the inherent properties of the other resonance elements, can be used to represent velar resonance. The lenition processes, already discussed above, involving the stripping away of resonance properties support the characterization of |h| and |ʔ| as source elements. |N| together with |L| and |H| are best treated as laryngeal elements with properties that form the outer shell of a segment providing nasality or voicing. The status and combinatorial capabilities of these elements within segmental representations will depend on the contrasts expressed in particular languages since not all languages will exploit the full range of options offered by the system. This means that particular combinations of elements must be barred in particular languages in order to capture the natural classes the phonological processes form. Apart from tier conflation barring elements on fused tiers from co-occurring, other mechanisms are also used to achieve this effect.

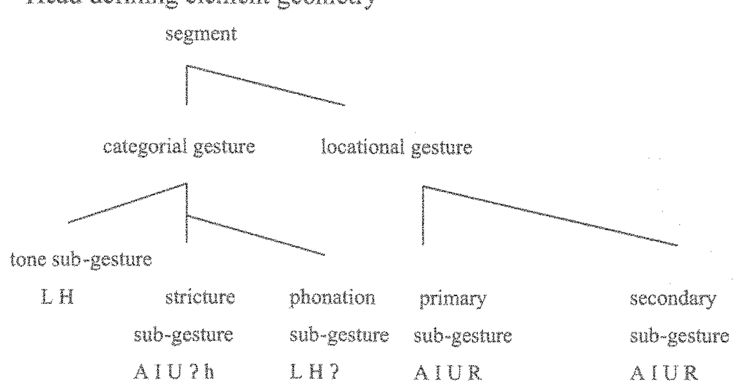
9.2.1.2.1 Natural classes: element geometries vs. Licensing Constraints

Elemental representations have also been concerned with the idea of natural classes and the ability of capturing the fact that particular phonological processes target specific sets of sounds to the exclusion of others. It remains a criticism of unary systems that it is not straightforward to, for example, refer to high vowels as a set since these do not share a characteristic element. An option is the less than ideal negative reference to those expressions that do not contain |A|.

In response to some of these challenges, including accounting for the fact that certain elements, e.g. place or source elements, do not routinely co-occur, feature geometry-like representations, akin to Clements (1985); Sagey (1986); and McCarthy (1988), among various others, have been attempted. Feature geometric representations allow reference to class nodes as a way of making reference to natural classes of sounds. There is a crucial difference, however, between feature and element geometries because, unlike features, elements do not require replacement of a deleted element in order to attain phonetic interpretability during the course of a phonological process because they enjoy independent interpretability. Thus while attaining phonetic interpretability is one of the intended outcomes of a feature geometry, this plays no role in an element geometry. An initial attempt at element geometries is given in Harris & Lindsey (1995) following the standard feature geometry groupings of laryngeal and resonance (place) nodes as class nodes containing the appropriate elements as terminal nodes. Manner elements attach directly to the root node. However, probably because an element geometry has more of an organizational function and the structure may be tacitly assumed, geometries have as such not played a very significant role in Element Theory. What it brings to the fore though is an explanation why certain combinations of elements are recurrent in representations of phonological expressions with a higher number of elements, and the connections that hold between different sets of elements. Thus rather than simply designating elements as being to do with manner, source or resonance – in the form of a statement – a geometry allows this to follow directly from a representation.

Geometries have also been used as a way of designating heads in representations in a principled way as motivated in the work of Smith (1988) and van der Hulst (1989), based on the premise that the same (combination of) sub-segmental units may acquire different interpretations depending on whether they are head or dependent. These ideas are further developed in Kula (2002) which aims to derive head relations by treating the characteristics which elements assume when they occur either as head or operator as following from their position in the geometry. Kula's (2002) geometry is based on Radical CV Phonology (van der Hulst 1994, 1995) which utilizes the notion of gestures as the organizing nodes of segmental structure. Under this view the segment is divided into two gestures: the categorial gesture and the locational gesture. The categorial gesture is further divided into three sub-gestures: the tone sub-gesture, the stricture sub-gesture and the phonation sub-gesture. On a par, the locational gesture is also divided into sub-gestures: primary location and secondary location sub-gestures. A particular quality of the assumed geometry is that the gestures and sub-gestures stand in a fixed head-dependent relation to each other: the categorial gesture is head of the locational gesture. Within the categorial gesture, stricture is head of the other two sub-gestures, and in the locational sub-gesture, primary location is head of secondary location. An illustration of a gesture-based head-dependent element geometry is given in (10) below where vertical lines identify heads.

(10) Head defining element geometry



A desired consequence of this element geometry with respect to the application of phonological processes in, for example, spreading processes, is that dependents will be able to spread independently, while heads must spread with their dependents. This, for example, explains the symmetry seen between the frequently spreading place features as opposed to the relatively stable stricture features.

In (10), the categorial gesture is chosen as the head of the whole segment because stricture distinctions generally determine the distribution of segments in syllabic organization. Within the categorial gesture, the representation of the tone sub-gesture as forming the outer shell of the categorial gesture characterizes its supra-segmental nature. The stricture sub-gesture contains elements that express different levels of stricture, such as absolute stricture |?|, non-absolute stricture involving some interruption in unimpeded outflow of air |h| and unimpeded outflow of air |A| |I| |U|. The phonation sub-gesture expresses glottal stricture and voicing, viz. glottal stricture |?|, glottal opening |H|, oral voice |L| and nasal voice |L|. The locational sub-gesture defines both consonantal and vocalic place articulations. The same place features are found in the primary and in the secondary sub-gestures with the difference that secondary place only occurs with some primary place specification.

Given this representation any elemental composition with a stricture element has that element as head and this defines the class of the segment as stop |?| or fricative |h| or vowel |A| |I| |U|. If a stricture element is specified and the phonation element |L| is added, |L| is interpreted as voice. By contrast, if no stricture feature is specified and |L| is specified in phonation, it acts as head and has the interpretation of nasality. In this way we collapse |L| into concurrently interpreting voice and nasality, depending on whether it is head or dependent. This perspective thus interacts with the issue of element inventory size taken up below. This kind of geometry aims to provide a universal perspective on the combinatorial capabilities of elements, subsets of which are utilized in particular language inventories. Alternative representations that cover the entire consonantal spectrum are offered in Cyran (1997); Harris & Lindsey (1995); Rennison & Neubarth (2003); Scheer (1996, 1999, 2004); and van der Weijer (1996).

The other perspective adopted in GP to capture elemental co-occurrence restrictions within particular language systems is by so-called *Licensing Constraints* (LCs henceforth) which capture elemental combinatorial capabilities based on the phonological processes that occur in a language. See also other implementations of this idea in e.g. Dresher (2009) and Steriade (2007: 145f.). Their main purpose is to define the lexical set of elemental representations permitted in a language from a larger set of possible and well-formed expressions. Kaye (2001) provides some discussion of LCs. In a sense LCs are another way of expressing tier conflation although they differ in that they also include statements about headedness and licensing and thereby also constrain processes. There are usually different sets of LCs for nuclear expressions and for non-nuclear expressions although there is no requirement that these must be separate sets of constraints. Charette & Göksel (1998), for example, utilize LCs to define the vocalic system of Turkish and thereby also capture the vowel harmony process. Their set of LCs is given in (11).

(11) Turkish Licensing Constraints
 (i) Operators must be licensed
 (ii) |A| is not a licensor
 (iii) |U| must be head

LC (11i) requires all compound elemental representations to designate one of the elements as head where the head is deemed to license operators. Thus no expression should be headless. (11ii) means that A cannot be head in any compound expressions, while (11iii) requires |U| to be head in any expression in which it occurs. Given that there are three vocalic elements |A I U|, these constraints mean that the only other possible head in a phonological expression is |I| but that if |I| and |U| co-occur in the same expression then |U| will be head given LC (11iii). An identity element is assumed to be present in every expression with its empty content no longer represented by any symbol, having transitioned from |v| (the cold vowel) and |ə| (the neutral element). This results in the following licit Turkish nuclear expressions.

(12) Turkish nuclear expressions

a	|A|	e	|A.I|
i	|I|	o	|A.U|
u	|U|	ö	|A.I.U|
ü	|I.U|	ı	|_|

Heads in these expressions appear on the right and follow from the LCs in (11). The data in (13) illustrate two vowel harmony processes in Turkish that result in the alternation of the plural suffix *-lar* to *-ler* and the 2nd person possessive marker *-ın* to *-in/-un/-ın/-ün* in particular contexts.

(13) Turkish vowel harmony

	stem	gloss	plural	2nd per possessive
a.	kil	'clay'	kil-ler	kil-in
b.	kül	'ash'	kül-ler	kül-ün
c.	kul	'subject'	kul-lar	kul-un
d.	kel	'bald patch'	kel-ler	kel-in
e.	köy	'village'	köy-ler	köy-ün
f.	kol	'arm'	kol-lar	kol-un
g.	kas	'muscle'	kas-lar	kas-ın
h.	kıl	'hair'	kıl-lar	kıl-ın

Charette & Göksel analyze vowel harmony in the plural as involving I-spreading from the stem nucleus to the suffix. All the plural forms that surface with *-lar* have no |I| in their stem vowel and so no harmony applies. In all other cases |I| spreads and is head in the resulting expression since according to LC(11ii) |A| cannot be a licensor. In the 2nd person possessive forms harmony involves |I| and |U| spreading which involves both elements spreading in forms where both are present in the stem vowel (13b,e). In resulting compound expressions |U| is head when it is present following LC(11iii). No spreading occurs when the stem does not contain a harmonizing element (13g,h). The point of significance is that the vowel harmony analysis proposed is not to be viewed as defined differently according to morphological processes but rather that the process globally involves both |I| and |U| spread. We do not see |U| spread in the plural because |U| only spreads into headless expressions, hence its spreading in the 2nd person possessive whose suffix is *-ın* with no element in the suffix vowel. The option to switch heads after |U| spreading is one not exploited by Turkish but which applies in other Turkic languages (Charette & Göksel 1994).

LCs for consonants are discussed and illustrated in Kula & Marten (1998, 2000) and Kula (2005) for some Bantu languages (Bemba and Herero) showing how the LCs proposed also feed into the analysis of assimilation and strengthening in NCs and nasal consonant

harmony. LCs therefore define language particular systems and provide a means by which phonological processes are derivable.

9.2.1.2.2 Inventory size: expansion vs. reduction

One of the all-time consuming issues in GP and Element Theory is the number of basic primitives that should be assumed. There has been a concern to control the expressive power of the theory to more approximately match the 100 or so speech sounds attested in the world's languages. There have been proposals to reduce the number of elements from around twelve primitive elements {A I U R h v/ə ATR ʔ N L H} to five or six {A I U ʔ H L}, with the choice of six seemingly gaining ground. While the avoidance of overgeneration is undoubtedly to be admired, this comes with a number of consequences to ensure that the limited set can still generate the requisite number of contrasts and account for the attested phonological processes.

At least all proposals have lost the neutral elements (ə, v) which were in any case always considered to be the representation of emptiness. The idea that there is an identity element or empty element remains but gets no symbol in order to more appropriately highlight that it is empty. Thus empty nuclear positions if they are phonetically interpreted get realized by a sound (schwa, ɨ, ı, etc.) that has no elemental content. The ATR element has also been lost mainly owing to the fact that its use was restricted to vocalic positions and its validity could not quite be extended to vowel systems that do not have an ATR contrast. In addition, as Harris (1990) argues, an ATR element results in an asymmetrical representation of the sets of ATR vowels vs. their non-ATR counterparts with the former always being more complex. Harris chooses to replace the ATR element with the neutral element |ə| understood as the acoustic baseline or canvas on which elemental patterns are superimposed, independently interpreted as schwa. In representations where |ə| is operator it contributes nothing as a neutral element and when it is head in vowels the elemental characteristics of |A| |I| |U| are somewhat backgrounded in operator role giving the phonetic output of non-ATR. This way the representation of ATR and non-ATR vowels are identical in terms of elemental composition/complexity and differ only in which element is head. In this sense ATR harmony does not involve the spreading of features but agreement in head, i.e. non-ATR vowels must all share |ə| as head so that all vowels in a harmonic span are head aligned. The same holds for the ATR counterparts which also share the element that is head in their harmonic span assuming that headship is assigned on the autosegmental tier of the element in question.

This idea of ATR harmony being captured by head alignment is developed further as the sole means of expressing ATR harmony after |ə| is discounted as an element (see e.g. Walker 1995). Under this revised approach where |ə| is treated as no longer part of the element set, ATR systems are represented in terms of headedness with the ATR set being all headless while the non-ATR set is all headed thereby still retaining a balance in the complexity of the two sets. Harmony is achieved as head-licensing where the harmonic span of a word is defined by the propagation of headedness to all nuclei in the domain emanating from the domain head. In this way morphological alternations triggering agreement in ATR are treated as agreement in head status achieved via head-licensing. Examples of ATR harmony in many West African languages that can be characterized in this way abound in the literature: Vata (Kaye 1982), Akan (Clements 1981), Yoruba (Archangeli & Pulleyblank 1989), among others.

The other element that has been strongly called into question is |R| representing coronality. Apart from the fact that a clear acoustic signature for |R| has remained elusive, Harris &

Lindsey (1995) argue that treating coronality as represented by |R| fails to reflect the special distributional attributes, behavioural characteristics and uniqueness of coronals as has been shown in Paradis & Prunet (1991) and much subsequent work. Backley (1993) also strongly endorses the loss of |R|, suggesting that perhaps coronals are placeless owing to their susceptibility to assimilation in contrast to other places of assimilation, including the fact that they behave transparently with respect to a number of processes. These concerns have resulted in the diminished use of |R| with coronality derived in different ways according to its distributional properties in different language systems.

Thus with the loss of {ə v ATR R} the elements {A I U h ʔ L N H} remain. Within this set |h| and |H|, on the one hand, and |L| and |N|, on the other, are merged so that currently the most dominant set of elements employed is one that assumes six elements viz. {A I U ʔ L H} in what is sometimes referred to as the revised set of elements (see e.g. Backley 2011; Charette & Göksel 1994/1996; Cobb 1997; Jensen 1994; Kaye 2001; Ritter 1997). Recall that |h| represented frication and |H| voicelessness while |L| represented voicing and |N| nasality. The merger of these pairs of elements is not to assume that the two properties concerned are indistinct but rather that there is a strong link between them which is considered as best captured as a difference in headedness. Thus |H| as head in a phonological expression represents frication but voicelessness as operator, and in the same vein |L| as head represents nasality but voicing as operator. A number of phonological processes that show a relation between each of these pairs of properties gain significant insight by this assumption, indeed motivate this representation. A number of studies have argued for the unification of voicing and nasality in the literature (e.g. Botma 2004, 2009; Botma & Smith 2006, 2007; Botma et al. 2013; Kula & Marten 1998; Kula 1999, 2002; Nasukawa 1995, 1998, 2005a; Ploch 1999).

Nasukawa (1997, 2005a), for example, considers the well-known facts of voicing in Yamato Japanese NC clusters and Rendaku (Itô & Mester 1986). There are two relevant sets of data: The first concerns post-nasal voicing and the second cases of (Rendaku interacting with) Lyman's law, which prohibits two voiced consonants in a domain. Consider the examples below.

(14) Japanese post-nasal voicing and rendaku

a.	shombori		'discouraged'	*shompori
b.	shindoi		'tired'	*shintoi
c.	kaŋgae		'thought'	*kaŋkae
d.	shin+te	γ shinde	'die' (gerundive)	
e.	kam+te	γ kande	'chew' (gerundive)	
f.	onna+kokoro	γ onnagokoro	'woman's heart'	
g.	kami+kaze	γ kamikaze	'divine wind'	
h.	ori+kami	γ origami	'paper folding'	

(14) shows that voiceless obstruents get voiced when preceded by a nasal (14a–e), thereby apparently indicating that the nasal has a "voice" element which spreads. On the other hand, the Rendaku data in (14f–h) contradict the idea of a "voice" element present in nasals since Rendaku, which requires the initial consonant of the second member of a compound to be voiced, still applies in apparent violation of Lyman's law if nasals are treated as bearing a "voice" element (14h). This apparent contradiction can be accounted for, Nasukawa argues, by treating "nasality" and "voicing" as reflexes of the same underlying element |L|, depending on whether it is head (voice) or operator (nasality).[4] From this perspective, the Rendaku facts can be explained as reflecting the fact that two |L|-headed expressions are disallowed

in the second member of a compound. Since the |L| element in nasals is operator it does not violate Lyman's law. Post-nasal voicing, on the other hand, is accounted for as rightward |L| spreading into adjacent onsets in a particular configuration, here onset-to-onset government. The spreading requires a change in headedness to achieve the voicing effect. The derivation of *shinde* "die (gerundive)" from the base *shin* plus the genitive suffix *-te* is as shown below (Nasukawa 1997: 418). Elements that are head are underscored.

(15) Japanese post-nasal voicing: /shin-te/ γ [shinde]

```
O N O N O N    →    O N O N O N
| | | | | |         | | | | | |
x x x x x x         x x x x x x
| | |   | |         | | |   | |
ʃ i n   t e         ʃ i n   d e
    [ʔ] [ʔ]             [ʔ] [ʔ]
        [h]                 [h]
    [L]                 [L] → [L̲]
```

(15) shows the rightward spread of |L|. |L| cannot remain as operator in the recessive Onset because in Nasukawa's analysis there is a constraint against the co-occurrence of element |h| and an operator element |L|, formalized in terms of tier fusion, namely, the two elements reside on the same tier. From this configuration we expect NC clusters to behave like voiced consonants in Rendaku since they bear an |L| head. Note that the change in headship could be accounted for along similar lines as Lyman's law, i.e. as an OCP-motivated constraint against two adjacent |L| operators. Needless to say the dual role associated with one element – here |L| – depending on whether it is head or not elegantly captures the interaction between nasality and voicing without the need of employing a voice specification in spontaneously voiced nasals.

Further merger in a way is expressed in the representation of tone. The laryngeal-source elements |L| and |H| are also used to represent tone based on the empirical evidence showing interaction between these elements and tone. In contrast to voicing, which is regarded as only occurring in consonantal positions, tone occurs in vocalic positions, in which case syllabic nasals that may bear tone are represented as partially occurring in nuclear positions. Used as tone elements the autosegmental nature of tone is captured by representing such elements on tiers as discussed above (see Kula 2012 for some discussion on tonal representations). There are a number of processes that show an interaction between tone and voicing that support the assumption that the two are represented by the same element. The classic example is depressor consonants involving the lowering of a high tone by a voiced consonant. Discussion can be found in Trail et al. (1987) for Zulu, Bradshaw (2003) for SiSwati, and Pearce (2009) for Kera, for example. The examples from Zulu in (16) below show a two-way contrast of high and low tone in its tone system. Voiced consonants are seen to depress (i.e. lower) the tone of the syllable in which they occur. High tone is indicated by an acute accent and low tone by a grave accent. In each of the paired examples showing a singular and a plural the nominals have an initial VCV noun class marker which has two high tones (HH) in the singular but a HL structure in the plural which contains a voiced consonant /z/.

(16) Zulu depressor consonants

a.	ísí-khwámà	'bag'
	ízì-khwámà	'bags'
b.	ísí-hlálò	'seat'
	ízì-hlálò	'seats'
c.	ísí-fúndò	'lesson'
	ízì-fúndò	'lessons'
d.	ísí-kòlè	'school'
	ízì-kòlè	'schools'

These facts are explained in Element Theory under the view that depressor consonants contain |L| and that this laryngeal specification must hold over the minimal licensing domain of onset–nucleus (CV pair). This implies that within the voicing specification of Zulu, voiceless sounds (as well as sonorants) are unspecified for a laryngeal feature while depressor consonants are specified with |L|. Since this specification causes a clash with a high tone, changing it to low, we must conclude that voicing and low tone are connected and must therefore be represented with the same primitives. In this case the voice specification of the depressor |L| is interpreted as low tone on the adjacent vowel. This thus demonstrates the full extent of oppositions for |L| as either voice or nasality in consonants and as either tone or nasality in vowels, with headedness used to create a contrast in each position. We return to the matter of headedness presently.

By comparison there has been much less discussion of the fusion of |H| and |h| although this merger has been assumed in element models adopting a maximum of six elements (but see the later discussion of Backley 2011 for some motivation). An alternative view on the status of |h| is offered in Cyran (1997, 2010) who argues for a parametric perspective on the presence or absence of |h| in a particular language system. This assumption allows for a more nuanced representation of voiced fricatives as following from the contrasts expressed in a particular language system in this sense contrasting Irish and Polish, for example. Thus while |h| may be considered to be parametrically present in Polish, which has both voiced fricatives and affricates, |h| is considered as not present at all in Irish, which has no voiced fricatives or affricates. This highlights an important issue in elemental representations, namely that different compositions of elements can result in the same phonetic object with the crucial factor being that representations are motivated by phonological patterning in particular languages.

Thus there remains two major sets of elements assumed in GP. One that is considered more traditional because it retains the use of |h| and possibly |R| in the set {A I U ? h (R) H L} and the reduced version that uses only six primes: {A I U ? H L}.

9.2.2 *Issues and directions*

Within sub-segmental representation a number of issues form part of current discussion in GP, extending the theory into new territory as well as reconsidering and refining issues that are central to the theory. We will consider three issues here: headedness, complexity and the nature of primes.

9.2.2.1 Headedness

The representation of segmental contrasts faces a number of challenges under the Revised Element Theory which currently assumes maximally six elements |A I U ? H L|. This has led to a revision of some previously held assumptions. The greatest challenge is being able to

express a sufficient number of contrasts while also maintaining the assumptions on independent interpretability of elements and treating each element as having its own identifiable signature as assumed in Harris & Lindsey (1995). In this sense headedness has always played an important role in the expressive power of Element Theory (KLV 1985). In complex expressions it signals that the characteristic of the element which is head is more enhanced in an expression. This, for example, captures the contrast between tense and lax mid vowels which are otherwise considered as containing the same elements. Under this perspective a complex expression only has one head, but see section 9.2.2.2 for possible alternative views.

We see headedness already beginning to take on a different role in the late 1990s in standard GP where Ritter (1997), for example, argues to replace stricture, in particular stopness expressed by |?|, with headedness. In this case a stop like /p/, which would be represented as |?.h.U|, gets represented as |h.U̲| with headedness used to contrast it from the fricative /f/, which has identical elements |h.U|. This move not only redefines headedness but also further reduces the element set by dispensing with |?|. In more recent work we see further redefinition of headedness as, for example, presented in Backley (2011) with precursors in Nasukawa & Backley (2005) and Backley & Nasukawa (2009). In this approach headedness is no longer viewed as the enhancement of a particular elemental characteristic within a complex expression but is rather equated to the identification of an independent acoustic signature identifying a distinct characteristic from its non-head counterpart. Velars, which often receive varying representations in different elemental analyses, are treated as represented, like labials, by |U| with only a contrast in headedness between the two places of articulation.[5] The symmetrical treatment of velars and labials echoes Jakobson et al.'s (1952) use of the acoustic feature [grave]. This representation is supported by the unity seen between velars and labials in different phonological processes attested in a number of languages. This observation of the affinity seen between [u, w] and both labials and velars has also been noted in Scheer (1999) who opts to represent labial and velar place with different elements owing to the fact that roundness (labiality) does not always go hand in hand with velarity. The intuition of this analysis is captured in Backley's (2011) representation of velars with |U| and labials with |U̲| with the consequence that headedness is no longer viewed as the greater contribution of a consistent phonetic characteristic of an element to its expression. While the interaction of [u, w] with labial consonants is well attested, there are similarly a number of examples demonstrating interaction with velars. Consider the following two examples from Moroccan Arabic and Czech discussed in Scheer (1999: 209). (17) shows broken plural formation in Moroccan Arabic where only velar and uvular consonants allow labial secondary articulation, whereas other places of articulation do not, so that *[s^w, d^w], for example, are unacceptable. In broken plural formation a labial [w] targets the initial consonant of the root.

(17) a. Labial secondary articulation possible

singular	broken plural	
kbir	k^{w}bar	'tall'
χurza	χ^{w}razi	'node'
quamiʒa	q^{w}amiʒ	'shirt'

b. Labial secondary articulation impossible

singular	broken plural		
amin	sman	*s^{w}man	'fat'
silla	slali	*s^{w}lali	'basket'
drif	draf	*d^{w}raf	'nice'

In Czech in (18) below we see a similar compatibility between [u] and velars in the distribution of three vocative allomorphs in consonant-final masculine nouns. *-i* occurs with palatals, *-u* with velars and *-e* elsewhere.

(18)		nominative	vocative	
	a.	kuuɲ	kɔɲ-i	'horse'
		tomaaʃ	tomaaʃ-i	'Thomas'
		zɫɔɟɛj	zɫɔɟɛj-i	'liar'
	b.	hox	hox-u	'boy'
		zdɛɲɛk	zdɛɲk-u	*a given name*
		ptaak	ptaak-u	'bird'
	c.	pɛs	ps-ɛ	'dog'
		dɔktɔr	dɔktɔr-ɛ	'doctor'
		ɦɔlup	ɦɔlub-ɛ	'pigeon'

Both examples show a compatibility between velars and [u,w] that supports a segmental representation that captures these distributional facts. Backley's (2011) representation of these two contrasting places of articulation as a difference in headedness suggests a reinterpretation of headedness. However, he continues to assume an asymmetry between headed and non-headed expressions, arguing that non-heads are more likely to be the target of assimilation processes and to occur in weak positions. He then treats this as the basis for deciding which of the two segment types (velars or labials) will be treated as having headed |U̲|. Examples that support the representation of velars as non-head are Selayarese (Malayo-Polynesian) where velar resonance may be over-ridden by another resonance property in reduplication processes where the place of a final velar nasal is changed to that of the following consonant of the reduplicant. Another example is given by Skikun, an Atayalic dialect of Formosan (Northern Taiwan) where Backley presents data showing an ongoing change in young speakers where labials are changing to velars only in coda position. Final /p, m/ are changed to their velar counterparts, reflecting that the change from labial to velar consists of a weakening process. In this sense headedness can be used to represent phonological weakness and strength, with non-headed expressions more likely to occur in weak positions such as the coda. A similar argument is presented for coronals and palatals which are both represented with |I| as their resonance element, the former being non-head and the latter being headed. In this case as well, the choice of coronals as being non-head follows from their susceptibility to phonological processes as is cross-linguistically attested and noted in earlier discussion. Thus the choice of head is not random but connected to phonological patterning (see Backley 2011: 72f. for some examples). Since the headed and non-headed counterparts of an element are argued to have their own independent spectral patterns, though they share a central characteristic, they are able to co-occur in, for example, doubly articulated segments such as the labio-velar approximant /w/. Since all elements are able to occur in both nuclear and Onset positions but take on slightly different characteristics when they are headed or not, every element has four different possible interpretations, two each in Onset and nuclear position. In this way headedness plays an important role in expanding possible contrasts while maintaining a relatively small set of primes. Note though that importantly headedness is restricted to resonance elements (as also argued in Scheer 1999). Backley's line of argumentation thus allows for the possibility that the "same" element may recur in a phonological expression and potentially opens the door to doubly headed expressions, otherwise barred in GP representations (though see Rennison & Neubarth 2003).

In a slightly different way source elements can also be seen to contribute different characteristics depending on the segment type in which they occur and importantly in the kind of language system in which they occur. Voicing contrasts are one classic example that demonstrates this variable interpretability of source elements. This is depicted for |H, L| in (19) below from Backley (2002: 8), providing a summary of the possible interpretations of |H| and |L| in generating segmental contrasts. Similar representations are argued for in Nasukawa (2005b); Cyran (2010, 2014); and Botma et al. (2013), among others.

(19)			
	a.	|H|	: high tone on vowels (e.g. languages with lexical tone)
		|H|	: aspiration in plosives (e.g. English, Korean)
		|H|	: audible friction in fricatives (e.g. most languages)
	b.	|L|	: low tone on vowels (e.g. languages with lexical tone)
		|L|	: nasality in vowels and sonorants (e.g. most languages)
		|L|	: full voicing in obstruents (e.g. French, Japanese)
	c.	|H,L|	: contour tones on vowels (e.g. languages with lexical tone)
		|H,L|	: breathy voicing in plosives (e.g. Gujarati)

This representation of voicing aptly captures the distribution of VOT cross-linguistically. As presented in Cyran (2010, 2014), languages without a voicing contrast have no voicing specification, those with lead VOT have only |L|, while those with VOT lag have only |H|. Systems with both VOT types imply a three-way contrast and languages like Hindi and Gujarati with a four-way contrast imply a combination of the two elements as (20) below shows with some example languages drawn from Cyran (2010: 16).

(20) Voicing contrasts captured with |H| and |L|

language	VOT opposition			representation	examples
Malakmalak		–		|_|	p
Spanish, Polish	lead	–		|L| |_|	b, p
English, Irish		–	lag	|_| |H|	b, p^h
Thai	lead	–	lag	|L| |_| |H|	b, p, p^h
Hindi	lead	–	lag, lead/lag	|L| |_| |H| |LH|	b, p, p^h, $b^ɦ$

An underscore is here used to represent absence of an element. Notice that with the use of underspecification, headedness is not invoked at all in generating voicing contrasts.

9.2.2.2 Complexity

The discussion of non-headed expressions occurring in weak positions and their counterpart headed expressions in strong positions raises the important issue of complexity and the representation of sonority effects in Element Theory which continues to be an important issue in current work. Sonority is generally argued to be responsible for the structure of the syllable: Onset clusters with rising sonority are considered to be unmarked because they maintain the desirable rising sonority profile for a syllable. From the GP perspective this adoption of an observation as explanatory is unsatisfactory because it does not follow from any general principles.

Recent GP work offers at least two possible ways of capturing the robust cross-linguistic patterns that are attributed to sonority. In both approaches it is essential that sonority effects follow from not only the internal structure of segments but also from the accompanying government and licensing relations that the segments are engaged in. Both sub-segmental and segmental relations derive complexity captured as substantive vs. formal complexity, respectively, in the approach adopted by Cyran (2010). In this perspective substantive complexity is the inverse of sonority and strength, following the basic assumption in Harris (1990) which captures complexity as transparently reflected in the number of elements of which a segment is composed. Obstruents with a higher number of elements are the most complex and therefore, from a standard GP perspective, act as governors of less complex liquids both within branching onsets (left-headed) and in coda–onset clusters (right-headed) (see Chapter 10, section 2).

Note that the notion of complexity is only available in an environment where primes are privative: when features are assumed, all segmental expressions are (or, in underspecification approaches, end up being) made of the same number of primes. It is only when primes may be either present or absent that a different number of primes can be responsible for their makeup.

Harris' work as discussed earlier infers the higher complexity of obstruents as following from lenition processes which are accounted for as the loss of segmental complexity (see the decreasing complexity of the lenition trajectory t → s → h under (8)). In this sense the strength attributed to stops is transparently captured by their greater sub-segmental complexity. Cyran (2010) argues that this complexity pattern (in conjunction with formal complexity concerning syllabic patterns) is the basis on which language inventories, phonotactics, typology, markedness and phonological processing are organized and can be explained. An important addition is that substantive complexity is treated as scalar, providing a non-arbitrary scale with cut-off points, although exactly where the grammar of a particular language chooses to place the divisions remains an arbitrary property of each grammatical system. In this way Cyran provides an analysis employing different complexity scales to define the segmental inventories of English, Polish and Irish showing how these different languages manipulate complexity in sub-segmental structures in a fashion that is most economical for each system and depending on the contrasts expressed in each system. What is crucial is that sonority effects such as syllable contact and phonotactics are still derivable from complexity in each system.

An alternative view is offered in Scheer (1999, 2004) under the consideration of the distributional properties of word-initial clusters. The approach adopted in this case also similarly argues that sonority effects follow from a number of general principles including Government Licensing (Charette 1990), the ECP (KLV 1990) and the initial empty CV (Lowenstamm 1999; Scheer 2004), rather than just the complexity of segments. On segmental complexity and adopting a strict CV approach, Scheer argues that for the purpose of the grouping of segments into Onset clusters only resonance elements count (A, I, U). Evidence from regular segmental alternations then shows that liquids (and sonorants more generally) possess more resonance elements than obstruents and are therefore governors. In Strict CV, Onset clusters (TøR) as much as coda–onset clusters (RøT) are separated by an empty nucleus – they are distinct because the empty nucleus enclosed in coda–onset clusters needs to be governed, while the one separating Onset clusters is circumscribed by a sonority-based relationship whereby the sonorant governs the obstruent. This relationship is called infrasegmental government (see Chapter 10, section 2.3, and Chapter 11, section 1.3). Hence the consonants of a TøR cluster do interact, while those of an RøT cluster do not. The fact that R governs T in the former (rather than the reverse) follows from Government Licensing (governors need to be licensed by the following expressed nucleus: in TøRV, the empty nucleus cannot government-license the T, but the V can license the R) and the basic principle

of standard GP that relations among constituents are head-final (in Strict CV constituents do not branch, hence there are no intra-constituent relations). This setup (as well as the initial empty CV site) captures the cross-linguistic distribution of word-initial consonant clusters as discussed in more detail in Chapter 10, section 1.7.

Finally, note that both approaches to complexity were worked out in the regular ten-element system of standard GP, i.e. before the reduction of this set as discussed above was undertaken. Reduction concerns the elimination of some elements (R, ATR, ə, h, N, eventually ʔ) and multiple function of others according to their syllabic affiliation and headedness (L, H). Since this concerns only non-resonance elements (with the exception of R), that is precisely those which make obstruents more complex than sonorants in Harris' approach, the complexity debate may need to be reassessed. Complexity being the pivot articulating syllable structure and melody, though, it is theory-specific and hence dialectically interleaved with specific assumptions on syllable structure.

It was mentioned that complexity is a fundamentally different approach to sonority than what is found in (all) other theories: only privative primes produce segmental expressions that are made up of a contrasting number of primes. As a consequence, there are no specific primes encoding sonority: items such as [±son], [±cons], [±voc] etc. do not exist in GP – their function is taken over by complexity. This means that sonority is not melody but a function computed upon melodic makeups (counting the number of primes). Therefore GP predicts that whenever melodic primes behave like a class and are opposed to non-melodic phonological properties, sonority will not behave like a piece of melody. This is reflected by the fact that sonority (and only sonority) may be read off regular autosegmental representations: sonority is the only "melodic" property that is projected at the syllabic level. Indeed, encountering a branching Onset reveals the relative sonority of the segments involved, and the same is true for coda–onset clusters. By contrast, syllable structure alone does not provide any hint as to whether the segments at hand are labial, dental or velar, voiced or voiceless etc. Hence sonority is visible from above the skeleton, while place and laryngeal properties are not.

That the non-melodic nature of sonority may be on the right track is shown by the fact that there are a number of phenomena that cannot take any melodic properties into account, but are sensitive to sonority. Phonologically conditioned allomorphy is a case in point (Scheer 2016), and so appear to be crazy rules (which are only ever segmentally crazy; Scheer 2015), category-sensitive phonology (i.e. specific phonologies applying to nouns and verbs; Smith 2011) and absolute agrammaticality (which appears to be only due to non-melodic properties).

That sonority is ontologically different from melody is also suggested by vocalic sonority. Summarizing his typological work on vocalic properties that influence stress placement, de Lacy (2002: 93) formulates the following amazement.

> One issue this typology raises is not why stress is sensitive to sonority, but rather why it is not sensitive to so many other properties. There are no stress systems in which subsegmental features such as Place of Articulation or backness in vowels plays a role in assigning stress. The same goes for features such as [round], [nasal], and secondary articulation.

This touches upon the issue of vocalic sonority: as it stands, complexity makes the correct predictions regarding the difference between high and mid vowels. The former are made of one prime, while two primes contribute to the latter (in the case of front rounded vowels the contrast is between two and three primes). That is, more sonorous vowels are more complex (which parallels Scheer's approach to consonantal sonority where also the more sonorous items are more complex). The typical low vowel /a/, however, is made of just one element and therefore fails to express this bit of vocalic sonority in terms of complexity.

9.2.2.3 Structural representation of primes

The number of elements used in GP and Element Theory continues to be an issue of debate even though the use of six primes has steadily gained ground. The reduction to six primes predicts 256 possible segments if all permutations are allowed (Jensen 1994). This has generated debate that an even smaller number of primes may be preferable, with five elements generating the more realistic 112 possible segments (assuming only one element can be head in any expression). Work in the early 1990s (see Jensen 1994) was particularly concerned with this notion of reduction of primes. Jensen (1994) thus argues that phonological differences which have been attributed to the presence of the glottal element |ʔ| can in fact be expressed by differences in constituent structure. It is particularly argued that the "stop" impression is the reflex of a branching rhyme structure preceding the relevant assumed |ʔ| containing phonological expression. The absence of such an environment results in the interpretation of the same phonological expression with a "fricative" impression. In this way |ʔ| would not need to be expressed as an independent element. This idea of replacing an element with structural configurations has not been much pursued in the GP/Element Theory literature, but recent work of Pöchtrager (2006); Pöchtrager & Kaye (2013); and Živanović & Pöchtrager (2010) in a version of GP they loosely term GP 2.0 take up this line of argumentation. The idea is to utilize hierarchical structural configurations (akin to minimalist syntax) to capture the properties of the elements |ʔ H A| which are argued to either show no generalizability to consonantal and vocalic positions or to display special characteristics that justify an enriched structural configuration. This implies that the element set is limited to the three remaining elements: |I U L|. This approach also abandons an autonomous melodic tier so that elements are now annotations on terminal nodes and are thus embedded in phonological structure. The role of melody is thus depleted with phonological phenomena previously treated as melodic now considered as structural. A discussion of the inventory and a number of phonological properties of Putonghua is offered in Živanović & Pöchtrager (2010), providing an illustration of the main tenets of this approach still in its infancy.

9.3 Conclusion

Element Theory within GP remains a competitive theory of sub-segmental structure. Like any theory it has undergone a number of changes, resulting in slightly different versions in current operation. The properties of privativity, unarity, cognitive import and independent interpretation remain representative of this approach. What makes the approach distinctive from other theories of melodic structure is the unary character of primes, i.e. their size. Indeed, |A I U| etc. are bigger than a single feature since they describe articulations that are made of several features (I for example is high, front and unrounded). Their size is also the reason why elements may be independently pronounced. Finally, elements are not based on articulation and involve a minimal number of distinctions. A reduced set of primes on grounds of avoidance of overgeneration is preferred and deemed theoretically more desirable. Overall much more work has been conducted on the representation of vowels, and the use of |A I U| as resonance elements has received much cross-linguistic investigation and exemplification, although the representation of resonance in coronals remains contentious. Work on consonantal representations, though present, would benefit from more systematic

investigation across a larger set of languages. Although universal phonetic cues are associated to each independent element, the phonological composition of a segment within a language remains motivated by the phonological processes therein, with the phonetic interpretation only becoming fully meaningful when viewed as part of a sound system.

9.4 Further reading

Kaye, Jonathan 1989. *Phonology: A Cognitive View*. Hillsdale: Erlbaum.
Conceptual underpinnings of Government Phonology: why there is phonology at all, the relationship with phonetics, the organization of the lexicon, parsing cues in perception.

Harris, John & Geoff Lindsey 1995. The elements of phonological representation. *Frontiers of Phonology*, edited by Jacques Durand & Francis Katamba, 34–79. Harlow, Essex: Longman.
Interface with phonetics: interpretational autonomy of phonology, no underspecification, no level of systematic phonetic representation. The output of phonological computation is directly converted into phonetic values through a dictionary-type conversion (phonetic interpretation).

Scheer, Tobias 2015. How diachronic is synchronic grammar? Crazy rules, regularity and naturalness. *The Handbook of Historical Phonology*, edited by Patrick Honeybone & Joseph C. Salmons, 313–336. Oxford: Oxford University Press.
Small is beautiful vs. big is beautiful: how much of the pool of surface alternations are phonological in kind?

Gussmann, Edmund 2007. *The Phonology of Polish*. Oxford: Oxford University Press.
How computation works in standard GP: no extrinsic rule ordering, but rather unviolable, unweighted constraints. Detailed application to palatalization in Polish (chapter 3).

Backley, Phillip 2011. *An Introduction to Element Theory*. Edinburgh: Edinburgh University Press.
The book offers a recent take on elements and important developments since the early work. Specific proposals on what role headedness can play in extending element sets is offered. A wide range of languages are investigated.

Cyran, Eugeniusz. 1997. *Resonance Elements in Phonology: A Study in Munster Irish*. Lublin: Folium.
A study that provides a good grasp of the central elements |A| |I| |U| not only as they are used in vowels but also in consonants drawing on the parallelism between the two segments types. Clear specific analysis and how they may vary are offered.

Nasukawa, Kuniya. 2005. *A Unified Approach to Nasality and Voicing*. Berlin and New York: Mouton de Gruyter.
The book discusses in the detail the option of merging some elements to have a dual identity, here with respect to nasality and voicing. A number of phenomena that support such a view are discussed.

Backley, Phillip & Kuniya Nasukawa 2009. Headship as melodic strength. *Strength Relations in Phonology*, edited by Kuniya Nasukawa & Phillip Backley, 47–77. Berlin and New York: Mouton de Gruyter.
This work takes up the issue of headship to show how it can be exploited to lead to specific interpretations of elements, with those elements that are head argued to acoustically have a stronger signature and by virtue of which they must make specific contributions.

Kula, N. C. 2012. On the representation of tone in Element Theory. *Sound Structure and Sense*, edited by Cyran et al., 353–367. Lublin: Wydawnictwo KUL.
An account of how the elements |L| |H|, which are also associated with tone, play a role in this autosegmental property of segments and how this interacts with voicing in consonants to result in depressor effects in a number of Bantu languages.

Botma, Bert, Nancy C. Kula & Kuniya Nasukawa 2013. Features. *Bloomsbury Companion to Phonology*, edited by Nancy C. Kula, Bert Botma & Kuniya Nasukawa, 33–63. London: Bloomsbury.
Gives more background on the difference between feature systems and element-based approaches and how these compare. A case study on the interaction of voicing and nasality is offered on Zoque.

Scheer, Tobias 1999. A theory of consonantal interaction. *Folia Linguistica* 32: 201–237.
This paper is gives further exposition on how relations above the segment may be affected by the elemental make up of segments, defining infrasegmental government. Some detailed discussion of elemental representations is offered.

Notes

1 Cases of this kind of phonology–phonetics mismatch are quite frequent. For a parallel case from Japanese where [ɯ] represents both |U| and an empty nucleus, see Nasukawa (2010).
2 See Bermúdez-Otero (2007) and Scheer (2015) for a comparison with other theories and the relationship with diachronic development.
3 With one exception applying to so-called analytic morphology, which is subject to a no-look-back device that in current syntax is called the Phase Impenetrability Condition (on which more in Chapter 11.1.4).
4 The choice between whether |L|-head instantiates voicing or nasality differs between different researchers reflecting that what matters is the opposition. Indeed, the use of |N| or |L| as the symbol for the merged element representing voice/nasality also varies. These differences must be treated as entirely superficial.
5 A number of analyses treat velar as empty as in e.g. Huber (2003), among others. This analysis has precursors in early Element Theory where velar was represented by the cold vowel |v| as in e.g. Harris (1990). See also Szigetvári (1994) on both the representation of velars and coronals.

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