Phonetic arbitrariness and its consequences

Tobias Scheer
Université Côte d'Azur, CNRS, Bases Corpus Langage (BCL)

ABSTRACT. This article discusses the consequences of phonetic arbitrariness, i.e. the fact that the relationship between a phonological category and the way it is pronounced (its phonetic exponent) is arbitrary. It is shown that phonetic arbitrariness is a necessary consequence of modularity (anyone who subscribes to modularity must also endorse phonetic arbitrariness), and that phonetic arbitrariness necessarily entails substance-free melodic primes, i.e. ones that bear no phonetic information in the phonology (pace Hale and Reiss where primes come with phonetic labels such as [labial], [coronal] etc.). It is only when both melodic primes and phonological computation are substance-free (with Hale and Reiss only the latter is) that phonology is self-contained in the Saussurian sense. Another issue discussed is how phonetic arbitrariness relates to the question whether melodic primes are universal and innate or language-specific and emergent (if you subscribe to phonetic arbitrariness, your primes are necessarily substance-free and emergent, but if you are committed to emergent primes they may be either substance-free or substance-laden). Finally, it is shown that a fully substance-free approach is a radical departure from current systems on the conceptual side, but does not change anything in the every-day practice of phonologists, who may happily continue to use the familiar substantive vocabulary when talking about sound patterns: these are simply shorthand for the true phonological structure where substance is absent and only comes in upon spell-out, just like chemists talk about *water* when they mean the real chemical object H_2O.

Keywords: substance-free primes, features, Elements, emergent features, phonetics-phonology mapping, arbitrariness.

1. Purpose

The relationship between a phonological category and the way it is pronounced (its phonetic exponent) is arbitrary (or conventional). This is what is called phonetic arbitrariness in this article. It is first shown in section 2 that phonetic arbitrariness is a necessary consequence of modularity. Rather than rehearsing empirical evidence supporting this view (relevant literature is mentioned), section 3.1. draws an inventory of voices which endorse phonetic arbitrariness in one way or another. These come from different quarters, cut across theories and conclude on phonetic arbitrariness for a variety of reasons. It is also shown that phonetic arbitrariness entails substance-free melodic primes (features, Elements etc.), i.e. which do not bear any phonetic information in the phonology. Section 3.2 contrasts this position with the regular approach where melodic primes are substantive but allow for some slack between the phonetic specification in the phonology and its actual phonetic realization.

The consequences of phonetic arbitrariness on the ontological status of melodic primes (universal and innate vs. language-specific and emergent) are discussed in section 4. Finally, section 5 shows that substance-free primes are a radical departure from the traditional position conceptually speaking, but in practice do not change a lot the life of phonologists: representations with substantive primes are merely shorthand for the substance-free reality.

2. Phonetic arbitrariness is a necessary consequence of modularity

2.1. Nobody doubts that the upper interface (with morpho-syntax) is arbitrary

Since its inception in the 1950s, the Chomskian enterprise is modular in kind: distinct computational systems using distinct and mutually unintelligible vocabularies concur to produce and perceive language. This perspective represents the application to language of the more general take on how the human cognitive system works: Fodor (1983) has condensed the Standard Theory of Cognitive Science that emerged from the so-called cognitive revolution of the 50s-60s (Gardner 1985). The modular view contrasts with the connectionist approach that emerged in the late 1980s and promotes indistinction (there are no distinct computational systems or distinct vocabulary sets: computation is not symbolic). Optimality

Theory applies the central connectionist tenet to language, parallel (instead of serial) computation (but not the non-symbolic claim: computation is symbolic also in OT).

The modularity of mind has a number of consequences when applied to language. The grammatical architecture resulting from this perspective is the so-called inverted T that was introduced in Aspects (Chomsky 1965: 15ff) where one concatenative system (morpho-syntax) and two interpretative modules (semantics and phonology) are distinguished (in production). The mutual unintelligibility of those systems is due to the distinct vocabulary that they process (a principle called domain specificity in Cognitive Science): things like person, number, animacy in morpho-syntax, against items such as labial, plosiveness etc. in phonology. As a consequence, modules are incommunicado as such and need a translation device in order to talk to each other: this is what interface theory is about.

In the history of generative linguistics the interface between morpho-syntax and phonology was always more developed than the one that relates phonology to phonetics. Regarding the former nobody doubts that the translational process is achieved through a lexical access (an operation called spell-out): a morpho-syntactic structure that describes, say, past tense of a weak verb in English is realized as *-ed* because there is a lexical entry stored in long-term memory that specifies this equivalence (past tense [weak verbs] ↔ *-ed*). Since lexical properties do not follow from anything by definition (at least synchronically speaking), the relationship between the input and the output of this spell-out is *arbitrary*: there is no reason why *-ed*, rather than, say, *-s*, *-et* or *-a* realizes past tense in English.

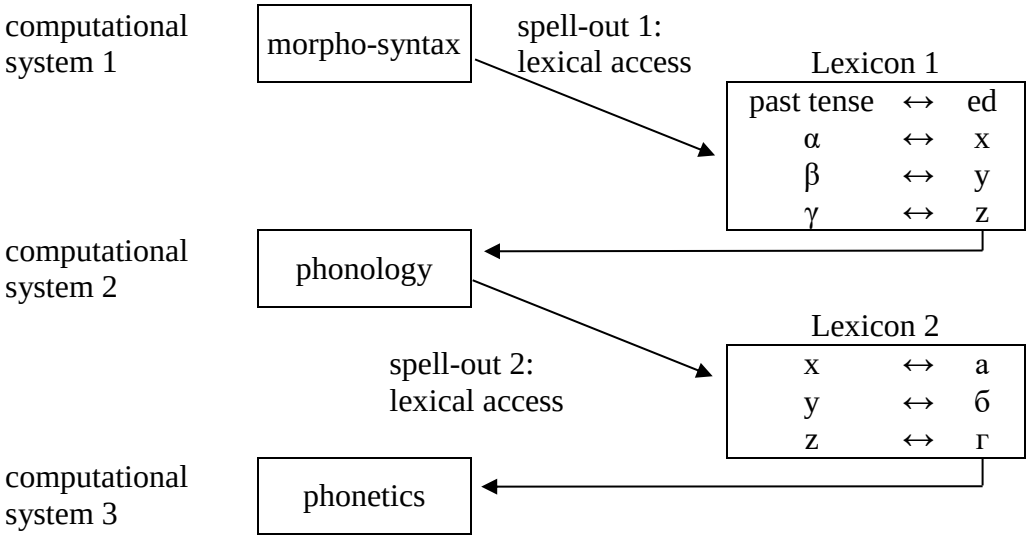
The arbitrary relationship of the categories that are associated through spell-out (one morpho-syntactic, the other phonological) is thus a necessary property of this process: it follows from the fact that vocabulary items on either side cannot be parsed or understood on the other side. By definition, the natural locus of arbitrariness is the lexicon: therefore spell-out goes through a lexical access.

2.2. The lower interface (with phonetics) must also be arbitrary

If grammar is modular in kind then all intermodular relationships must instantiate the same architectural properties. That is, what is true and undisputed for the upper interface of phonology (with morpho-syntax) must also characterize its lower interface (with phonetics): there must be a spell-out operation whose input (phonological categories) entertains an arbitrary relationship with its output (phonetic categories). That is, there is no automaticity or necessity for, say, [+labial] to be pronounced as a labial articulation [p,b,v,u,o etc.]. This prime could as well be pronounced as [χ] or [t]. Arbitrariness in the phonology-phonetics interface is counter-intuitive because unlike at the upper interface our experience is that the relationship is 99% faithful: what is labial in phonology is also labial in phonetics. There are distortions, though, which show that translation may be non-faithful, such as the variable pronunciation of the phonological sonorant /r/, which appears as [ʃ,ʒ] in Polish, [h] in Brazilian Portuguese or [ʁ,χ] in French and German and still in a number of other guises elsewhere (Chabot 2019).

The preceding is a short version of the argument made in Scheer (2014) where the issues are exposed in greater detail. The result is shown under (1) below: three distinct computational systems, each processing a specific vocabulary distinct from the two others, communicate through a translational device (spell-out) that is identical: an input item in some vocabulary is converted into an output item in another vocabulary through a lexical access. That is, correspondences between pairs of vocabulary items that belong to distinct vocabularies are stored in the lexicon (translation is list-based, not computational).

(1) fragment of grammar involving phonology



Scheer (2014) discusses two reasons to account for the fact that 99% of translational relations at the lower interface of phonology (with phonetics) are faithful (while faithfulness cannot even be expressed at the upper interface with morpho-syntax: the correlation of "past tense" with *-ed* is not any more or less faithful than if it were associated to *-a*, *-ub* etc.). One is about the ontology of morpho-syntax (only grammar-internal, no real-world categories involved) as opposed to phonetics (concerned with real-world categories that lie outside of the cognitive system). The other reason is the diachronic origin of non-faithful relationships at the lower interface (rules and phonology-phonetic mappings are not born crazy, they become crazy through aging, $Bach, 1972 #3509£ 1972).

3. Phonology-phonetics mapping: options entertained

3.1. Arbitrary mapping: convergence from different quarters

The divorce of phonological units and their phonetic exponent was commonplace in structuralist thinking, but typically phonemes were referred to by phonetic correlates, the ones that are distinctive. It is not always easy to look behind items that are referred to, say, as "E" or "k": are the phonetic properties used in order to refer to them present in the phonology, or are they just shorthand for naming phonological items that do not have any phonetic properties? Trubetzkoy (1969 [1939]) argues for the presence of phonetic properties in the phonology.

> "As regards phonology, it is clear that it must make use of certain phonetic concepts. For instance, the claim that in Russian the contrast between voiced and voiceless obstruents is used to differentiate between words, belongs to the field of phonology. […] Despite their fundamental independence, a certain amount of contact between phonology and phonetics is therefore inevitable and absolutely necessary." Trubetzkoy (1969 [1939]: 14)

But then he relegates the contact between phonology and phonetics to the "initial stages" (German *Anfangsteile* in the original, literally "initial pieces", appearing as "introductory sections" in the English translation) of phonological analysis, thus supposing a level of analysis devoid of any phonetic properties: "[b]ut only the introductory sections [Anfangsteile] (i.e., the sections on the base elements) of a phonological and a phonetic

description should take each other into account. Here, too, the limit of what is absolutely necessary should not be overstepped" (p.14).

Much more would need to be said about the variety of structuralist positions that were taken on the subject matter, but the focus here is on the generative perspective. Anderson's (1981) arguments explaining why phonology isn't natural are certainly a landmark for the idea of a self-contained phonology that has no clue how the items that it manipulates are eventually pronounced. In the same vein, Hyman (2001) argues against phonetic determinism on the grounds of so-called crazy rules, i.e. which do not make sense phonetically speaking.

At the heart of the issue, Boersma (1998: 461ff) contends that nothing is innate: all constraints as well as the mapping of phonology and phonetics are language-specific and learned. In principle any mapping can be learned. The quote below illustrates his position.

> "For instance, the need for perceptual contrast requires /u/ to be labial and velar; these two articulations are subsequently learned as a fixed coordination ([back] → [round]), which is arbitrary from the point of speech production: any other coordination is equally learnable, but may be less suitable for use in a system for human communication.
> Constraints are learned […], not innate. Children start with empty grammars. Each time a perceptual category emerges, the relevant faithfulness constraints come into being; each time that the child learns to connect an articulatory gesture to a perceptual result, constraints against such gestures come into the picture." Boersma (2008: 461)

This approach was developed into the BiPhon model (Bidirectional Phonology / Phonetics) as exposed in Boersma (2011), Boersma and Hamann (2008: 263) and Hamann (2011, 2014). In BiPhon the mapping between phonology and phonetics in production is done through a list: a phonological item is associated with a phonetic target in a constraint.

Mielke (2008) studies the sets of segments that appear in the statement of phonological computation (where they may undergo or trigger processes), i.e. what he calls phonologically active classes. He shows that they are recurrently unnatural cross-linguistically, i.e. lack any phonetic rationale that could unite or disunite their members. He concludes that melodic primes (i.e. features or bigger items such as Elements in Government Phonology) are not innate (there is no universal feature set) but learned on the grounds of environmental input (Mielke 2008: 18). Hence associations between phonological primes and phonetic exponents thereof are language-specific and arbitrary: they only depend on environmental input and if this input varies randomly so will associations. (Universal) grammar does not object to any match.

Another relevant strand of inquiry is known as substance-free phonology. The term was coined by Hale and Reiss (2000a and following). The idea is that phonetic categories do not play any role in phonological computation, which is able to turn any phonological object (defined by melodic primes) into any other object in any context and its reverse. That is, phonological computation is substance-free. Hale and Reiss do maintain phonetic substance in phonology, though, since in their view melodic primes (features) are substance-laden, universal and innate (Hale and Reiss 2003, 2008: 28ff, Reiss and Volenec 2018) (for reasons discussed in section 4.1).[1] That is, children are born with [lab], [back], [continuant] etc., i.e.

[1] Volenec and Reiss (2018: 253) say that "[w]e understand distinctive features here as a particular kind of substance-free units of mental representation, neither articulatory nor acoustic in themselves, but rather having articulatory and acoustic *correlates*" (emphasis in original). This suggests that they conceive phonological features as units which do not carry any phonetic information themselves but rather correlate with phonetic information through an interface (transduction in their system) whereby phonetic information is present on the

with both a universal set of primes and their phonetic labels. These phonetically labelled features are then present in the phonology, but their phonetic properties are somehow inactive since they will not prevent phonological computation from turning anything into any other thing in any context and its reverse (nothing withstands the phonological computation of, say, a "crazy" rule such as p → r /__ŋ). The only thing that phonetic labels do in Hale and Reiss' perspective is the definition of a stable phonetic correlate: primes will always be pronounced according to the phonetic label that they bear in the phonology.

Contrasting with Hale and Reiss' substance-laden primes, Carvalho and Klein (1996) argue for substance-free melodic units. They introduce "subsymbolic" items: "[t]he units of the subsymbolic level are the real phonological primitives. These primitives are pure forms; as such, they lack any intrinsic phonetic content" (p.97). Carvalho and Klein recognize two subsymbolic items, arbitrarily named x and y, which combine through the boolean operations *sum* and *product* in order to form particles (holistic primes of the Element type used in Particle Phonology, Schane 1984, Carvalho 1994). Particles are referred to as logical units p, q, r that are just as devoid of phonetic properties as x and y. For the sake of correspondence with familiar units, Carvalho and Klein refer to the six particles derived partly with phonetic symbols, though: A, I/U, E/O, Y, $ə^1$, $ə^0$. They are explicit that particles have no phonetic value: "why do particles have the particular content [= phonetic value] specified in (12), (13)? This is what phoneticians, and only phoneticians, can explain" (Carvalho and Klein 1996: 115).[2]

Carvalho and Klein (1996) and Hale and Reiss' work is complementary in that the former argue for substance-free primes (but are not concerned with computation), while the latter promote substance-free computation (and are firmly engaged in substance-laden primes). A more recent strand, radical substance-free phonology, extends the substance-free idea to both melodic primes and phonological computation: no phonetic property is involved in either. Since in this view phonology does not contain any phonetic information, the phonetic value of phonological objects (the way they are pronounced) is defined outside of the phonology by way of the spell-out discussed in section 1 or similar devices (cue constraints in the BiPhon model). It follows from this setup that any association of a phonetic and a phonological category is possible: associations are established by the child during L1 acquisition and exclusively depend on the environmental input. Anything dictated by the environment will thus be phonologized, and if the environmental input varies randomly phonological categories and their phonetic correlates will follow.

Radical substance-free phonology is exposed in, among others, Odden (2006, 2019), Blaho (2008), Samuels (2012), Iosad (2012: 6ff, 2017), Scheer (2017) and Chabot (2019).

---

phonetic, but absent on the phonological side (as in the spell-out system described in section 2.2). This impression is misleading: Volenec and Reiss' phonological features do carry phonetic substance in the phonology ([labial], [coronal] etc.) and hence are not substance-free (their position is exactly the one laid out in Hale and Reiss 2003, 2008: 28ff). This is made explicit in a post to the Language Faculty Blog dated 12th April 2019 (http://facultyoflanguage.blogspot.com/2018/04/arbitrary-or-dogs-and-cats.html) where Volenec explains that in his view features are substance-free as far as phonological computation is concerned (their substance has no impact here), but substance-laden when it comes to externalization (what he calls the phonetic implementation system): features bear phonetic information and the way they are pronounced is a direct function thereof. See further discussion on the Language Faculty Blog (reply by Chabot and Scheer dated March 26th, 2019).

[2] Like Carvalho and Klein's (1996) approach, Hulst's (1994, 1995, 1999) Radical CV Phonology also derives segmental identities (as well as syllable- and other higher structure) from two basic building blocks, C and V. Representing vowel- and consonanthood, C and V are substantive in kind, though: when occurring under the stricture node in Hulst's (1999: 95) Feature Geometry, C defines stops, C_V fricatives, V_C sonorants and V vowels. The same goes for other nodes of the structure (defining laryngeal properties and place).

3.2. All theories accept slack – how much slack exactly?

All theories of melodic representation must and actually do allow for some slack between the phonological representation of a segment and its phonetic realization. This is because of the trivial observation that the same segment (or phoneme) enjoys different phonetic realizations within a given language when pronounced by different speakers or by the same speaker. Also across languages, items that are phonetically distinct may or may not enjoy distinct phonological representations, depending on systemic and other analytical properties. The mid vowels [ɛ] and [e] in different languages for instance may represent the same phonological makeup. Another example are three-vowel systems i-a-u, which are thought of as being phonologically identical if there is no reason to believe that their systemic properties induce a difference. Hence the fact that the low vowel in typical Arabic varieties is pronounced [æ], rather than [a] as in other three-vowel systems, is phonologically irrelevant. Hence the featural specification [+low, -high] (or the prime A in holistic approaches) is invariant across a number of languages, but enjoys different pronunciations language-specifically.

Usually theories also accept some slack in the other direction, i.e. when different phonological objects are pronounced alike. Cases in point are the two different [i]s in Inuit (Dresher and Compton 2011) or Czech (one palatalizing, the other not, while being phonetically identical), or the three different [ɛ]s in Polish that Gussmann (2007: 56ff) identifies according to their behaviour.

Slack in the correspondence of phonetic and phonological objects is thus endorsed by all theories in some way or another. The question then is how much slack exactly should be allowed. As far as I can see, no theory has a systematic or principled answer to this question, which is usually not raised and in case it is asked drives phonologists into muddy waters. There is a broad agreement that, say, [-low, -high] (or A-I in a system of holistic primes) may be pronounced as [ɛ] or [e], maybe as [æ] – but can it also be pronounced [i] or [a] in some language? Or [u]? As the slack increases phonologists will intuitively say "oh no that's not a possible pronunciation", but they will be unable to draw the red line and come up with arguments why this much slack is admissible, but any more is not. When the amount of slack is too big they will talk about phonology-phonetic mismatches, which they will consider a serious violation of what is expected (while [ɛ]-[e]-[æ] variation will not fall into this category). Since phonologists know about the strange behaviour of "r", a well-documented case, they will allow for /r/ being pronounced in all kinds of unpredictable ways, as was mentioned above: [ʃ,ʒ] in Polish, [h] in Brazilian Portuguese, [ʁ,χ] in French and German etc. It thus appears that the rationale driving the gut feeling of phonologists is just the empirical record that they have been exposed to: it is fine for /r/ to be pronounced as about anything because they have seen many cases of that, but [-low, -high] cannot be pronounced as [u] because they have never come across this kind of funny match.[3]

Some theories such as Volenec and Reiss' (2018) or Government Phonology (Harris and Lindsey 1990: 46ff, Gussmann 2007: 25ff) have made explicit the post-phonological mechanism (called transduction in the former, phonetic interpretation in the latter case) which will decide about the phonetic variation that is encountered when a phonological object is pronounced. All of these theories are bound by some red line that may be more or less generous but exists ("this amount of slack is ok, but that amount isn't"). The reason for that is the fact that they work with substance-laden primes: the way phonological objects are pronounced is specified *in the phonology*, by the phonetic labels of the primes. Therefore a

[3] A case of a "really crazy" phonology-phonetics association is reported in South-East British English ("posh girls") where /uu/ is pronounced [ii] (*boot* is [biit]), while gliding in external sandhi (*see* [j] *it*) shows that this [ii] is still underlyingly /uu/: it produces w, not yod: *do* [w] *it* is pronounced [dii] [w] *it* (Henton 1983, Harrington *et al.* 2008, Uffmann 2010, Hamann 2014).

gut-based calculus of the distance between the phonetic value of the phonological object and its phonetic realization is possible.

Radical substance-free phonology simply takes the position that there is no red line: any phonological item can be pronounced in any way and its reverse. This is phonetic arbitrariness, which necessarily entails phonological primes that do not carry any phonetic information: the presence of such information in the phonology would be entirely meaningless since it would not have any consequences for either phonological computation or the pronunciation of primes.

As long as red lines separating admissible and non-admissible slack are randomly drawn according to gut feeling, rather than being the result of argument, there is no reason to believe they exist. In their absence, the phonology-phonetics relationship is arbitrary and melodic primes must be substance-free. This is the argument made by Chabot (2019) in greater detail, of which the preceding is a digest.

4. Innateness and universality of melodic primes

4.1. Universal and innate or language-specific and emergent?

Whether melodic primes are innate or emergent is a question that is intimately related to the issues of arbitrary mapping and substance-free primes. Somebody who believes that the phonetics-phonology mapping is arbitrary necessarily works with substance-free primes and must also hold that primes are not given at birth: they necessarily emerge in L1 acquisition through domain-general mechanisms (e.g. categorization) guided by environmental information (essentially contrast and phonological processes, see Odden 2019 and Dresher 2014, 2018). This is because phonetically substantive primes given at birth nail down possible phonology-phonetics mappings to the innate values (plus minus some slack).

By contrast, a defender of emergent primes may or may not warrant their substance-free nature: primes may emerge and be related to phonetic categories through environmental input, but these phonetic categories may then be carried into the phonology where primes will have phonetic labels. On this view (of which I could not name any representative), melodic primes are substantive (like Hale and Reiss'), but not universal or innate (unlike Hale and Reiss').

Hale and Reiss (2003, 2008: 28ff) argue that melodic primes could not possibly be emergent since the child would not know how to parse the sensory input: they must know in advance that they will encounter things like labial, occlusion, nasal etc., otherwise the environmental input will never be transformed into linguistically relevant categories. These learnability concerns are addressed by Samuels (2012), Odden (2019), Dresher (2014, 2018) and a number of contributions in Clements and Ridouane (2011), but the debate cannot be further explored here in the interest of space restrictions.

4.2. The constructivist option: universal but not innate

A variant of the classical position according to which melodic primes are universal and innate is constructivist in kind and comes down to the same result. So-called phonetically-based phonology that was an important strand in OT in the early 2000s (Hayes *et al.* 2004) originates in Hayes' (1999) inductive grounding and promotes the idea that phonology is based on phonetics. The central idea is that "constraints may be universal without being innate" (Hayes and Steriade 2004: 6). This is because phonetic difficulties in production and perception are the same for all humans, as explained by the following quote.

> "[C]ertain basic conditions governing speech perception and production are necessarily shared by all languages, experienced by all speakers, and implicitly known by all. This shared knowledge leads learners to postulate independently similar constraints. The activity of similar constraints is a source of systematic

> similarities among grammars and generates a structured phonological typology." Hayes and Steriade (2004 : 1f)

As a consequence, markedness constraints are not given at birth: in a Piagetian constructivist perspective (Karmiloff-Smith 1998), they are built by the L1 learner based on the environmental evidence, universal phonetic conditions in perception and production as well as innately provided (and domain-specific) devices that are used for the construction of constraints. In Hayes' (1999) account these include a generator of phonetic difficulty landscapes, a constraint generator and a constraint evaluator.

In this view, domain-general capacities such as induction, mimicking, analogy etc. do not suffice to discover linguistically relevant markedness generalizations of a given language: more is needed than just environmental input and inductive generalization (while Hale and Reiss 2000b believe this information is sufficient). This is what Bermúdez-Otero and Börjars (2006) (see also Bermúdez-Otero 2006) argue for at length: markedness constraints "cannot be discovered by inductive generalization over input data, for infants depend upon it to overcome the limitations of induction" (p.746). They maintain the universality of markedness constraints, i.e. their cross-linguistic invariability, even though they are not innate. This invariability, they argue, is due to the constraint construction mechanism which is the same for all humans: "[w]here all the relevant factors affecting development are universal, the emerging knowledge will be universal too" (p.750).

There is one factor contributing to constraint construction that is not invariable cross-linguistically, though: the environmental input. Bermúdez-Otero and Börjars (2006: 730ff) discuss the aforementioned crazy rules (ones which do not make any sense phonetically speaking, like p → r /__ŋ, Scheer 2015), which do emerge and are transmitted across generations: whatever the constraint constructing mechanism and its universal but non-innate ingredients, it allows them to exist. The question is thus what exactly the limitations are that the system based on universal but non-innate properties imposes: crazy rules appear to vary at random, whence their name.

If segmental patterns are indeed able to show random variation (even if craziness does not occur often), then it is unclear what exactly the labour is that the constructivist devices in the OT literature quoted afford: they are supposed to introduce universal bounds on variation, but the result is randomly variable.

In any case, the constructivist perspective is just as rigid regarding the phonology-phonetics mapping as the UG-based take where markedness constraints are themselves innate: there are universal limitations on the phonetic categories that can be related to phonological categories, the latter being thus phonetically informed, i.e. substantive.

5. Phonological representations without phonetic information

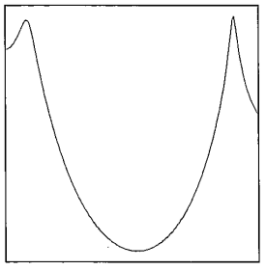
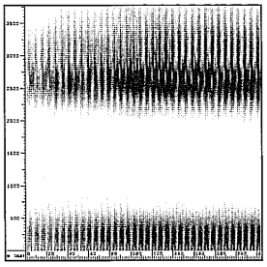
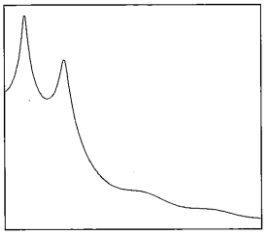
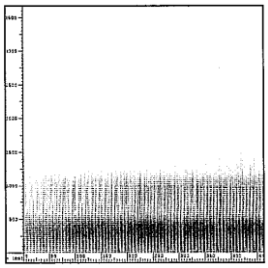
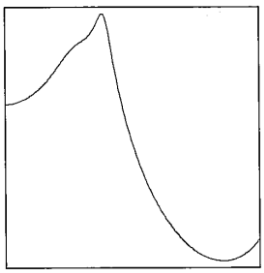
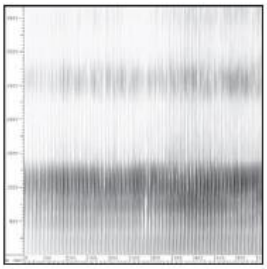
A consequence of both the modular workings (section 2) and the radical version of substance-free phonology where no phonetic anchor remains in the phonology (section 3.1) is a situation where melodic primes are unlabeled i.e. do not possess any phonetic property in the phonology. Hence instead of [labial], [continuant], [nasal] etc., segmental properties in the phonology are defined by colourless items, call them α, β, γ etc. Phonology works with this set of primes and has no idea what their phonetic value is or how they will eventually be pronounced.

The connection between phonological and phonetic categories is only made post-phonologically (in production), i.e. upon spell-out as described in section 1 (or by equivalent devices such as cue constraints in BiPhon).[4]

[4] The BiPhon model and Odden (2019) describe the modular workings in perception, i.e. when the auditory signal is progressively filtered down to phonologically relevant information.

Let us illustrate the difference between melodic primes that do and do not bear phonetic substance in the phonology. In traditional systems where melodic primes are phonetically substantive, their phonetic value is redundantly specified both in the phonology and in phonetics. Holistic primes like Elements for example have the phonetic correlates shown under (2) (descriptions and figures are taken from Backley 2011: 22-26, see also Harris and Lindsey 2000: 192-196). Everything that is said about them also applies to other types of primes, such as features. Note that Elements have an acoustic, not an articulatory definition. They are described by the mnemonic labels dIp (for |I|), rUmp (for |U|) and mAss (for |A|).

(2) Elements and their phonetic correlates

Element	acoustic value		spectral pattern	spectrogram
|I|	dIp	two energy peaks with an intervening dip. First peak at about 500 Hz, second peak at about 2,5 kHz.		
|U|	rUmp	concentration of energy at lower frequencies, falling spectral shape.		
|A|	mAss	mass of energy in the lower central part of the spectrum, peak at about 1kHz, with a drop in energy on either side.		

The substance-free version of this setup is one where the same phonetic correlates are associated to phonological primes that do not bear any indication of how they are pronounced. This is shown under (3).

(3)

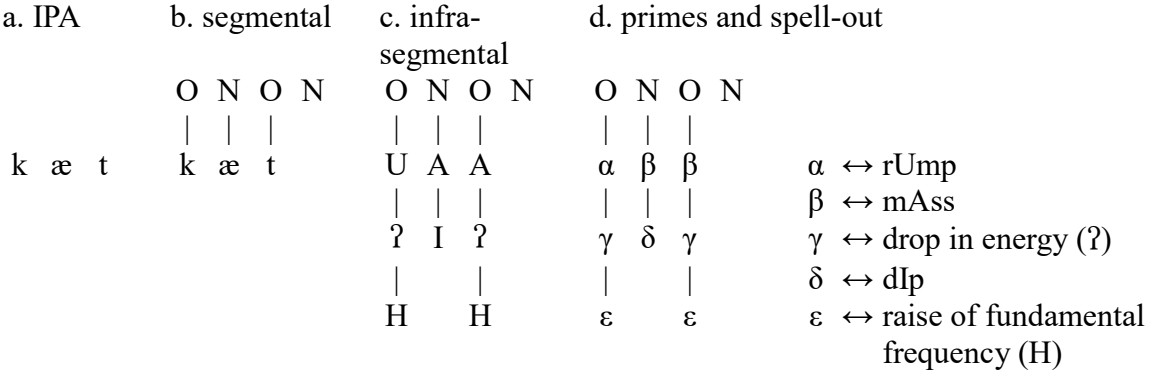
a. substantive	b. substance-free
|I| ↔ dIp	α ↔ dIp
|U| ↔ rUmp	β ↔ rUmp
|A| ↔ mAss	γ ↔ mAss

The difference is conceptually radical, but the substance-free perspective on melodic primes does not change the every-day life of phonologists: using primes with phonetic labels as under (3)a is just shorthand for the actual phonological structure (3)b, which is substance-free. Talking directly about |I|, |A| and |U| is easier than consistently saying "the prime that is spelt out as [a]", or "gamma". Greek letters or whatever other placeholders will of course

confuse people, and as the number of primes increases nobody will know anymore what they are talking about. This is avoided by resorting to the familiar |I|, |A|, |U| (or equivalent features), which are shorthand for the phonological objects just in the same way as chemists for example talk about *water* which is handy and shorthand for H_2O.

Shorthand representations are common in linguistics in general and phonology in particular. IPA transcriptions for example are shorthand for a complex phonetic reality (and they also encode phonological properties such as the difference between ts and t͡s). In the same way, IPA [kæt] "cat" under (4)a is shorthand for the representation under (4)b that provides syllabic but no infra-segmental information, which is turn is shorthand for (4)c where melodic primes are shown that confuse their phonological identity and the way they are pronounced. Finally, (4)d shows the most detailed representation where phonological primes and their phonetic values are shown in separate locations: the former in the phonological representation (which is thus truly phonological and not shorthand), the latter in the list-type correspondences that are stored in long-term memory and accessed upon spell-out.[5]

(4) representation of "cat" in increasing explicitness



Hence working with substance-free primes does not mean that phonologists will need to talk about alphas, betas and gammas when they describe languages, figure out generalizations, publish articles, talk to each other etc. All this can (and should) be done using the familiar substantive vocabulary. Having substance-free primes just means that when people talk about phonology with substantive vocabulary it is taken for granted that this is shorthand for (4)d, which at some point of the analysis will be fleshed out.

References

Anderson, Stephen. 1981. Why phonology Isn't "Natural". *Linguistic Inquiry* 12.493–539.

Backley, Phillip. 2011. *An Introduction to Element Theory*. Edinburgh: Edinburgh University Press.

Bermúdez-Otero, Ricardo. 2006. Phonological change in Optimality Theory. *Encyclopedia of language and linguistics, 2nd edition, vol.9*, ed. by Keith Brown, 497–505. Oxford: Elsevier.

Bermúdez-Otero, Ricardo and Kersti Börjars. 2006. Markedness in phonology and in syntax: the problem of grounding. *Lingua* 116.710–756.

Blaho, Sylvia. 2008. *The syntax of phonology. A radically substance-free approach*. Ph.D dissertation, University of Tromsø.

Boersma, Paul. 1998. *Functional Phonology. Formalizing the interactions between articulatory and perceptual drives*. The Hague: Holland Academic Graphics.

Boersma, Paul. 2011. *A programme for bidirectional phonology and phonetics and their acquisition and evolution*. Ms, University of Amsterdam. ROA #868.

[5] The primes and their acoustic properties that are used under (4) are Elements and the specific elemental makeup is roughly that of Backley (2011). But recall that the type of primes and their phonetic correlate are irrelevant for the purpose of the discussion: the situation is the same with features.

Boersma, Paul and Silke Hamann. 2008. The evolution of auditory dispersion in bidirectional constraint grammars. *Phonology* 25.217–270.
Carvalho, Joaquim Brandão de. 1994. What are vowels made of? The 'no-rule' approach and Particle Phonology. *Studia Linguistica* 48.1–27.
Carvalho, Joaquim Brandão de and Marc Klein. 1996. A subsymbolic approach to phonological primitives. *Current Trends in Phonology. Models and Methods I*, ed. by Jacques Durand and Bernard Laks, 97–121. Salford, Manchester: ESRI.
Chabot, Alex. 2019. What's wrong with being a rhotic? *Glossa* 4.article 38.
Chomsky, Noam. 1965. *Aspects of the Theory of Syntax*. Cambridge, Mass.: MIT Press.
Clements, George N. and Rachid (eds.) Ridouane. 2011. *Where do Phonological Features come from? Cognitive, physical and developmental bases of distinctive speech categories*. Amsterdam: Benjamins.
Dresher, Elan. 2014. The arch not the stones: Universal feature theory without universal features. *Nordlyd* 41.165–181.
Dresher, Elan. 2018. Contrastive Hierarchy Theory and the Nature of Features. *Proceedings of the 35th West Coast Conference on Formal Linguistics* 35.18–29.
Dresher, Elan B. and Richard Compton. 2011. Palatalization and “strong i” across Inuit dialects. *Canadian Journal of Linguistics* 56.203–228.
Fodor, Jerry. 1983. *The modularity of the mind*. Cambridge, Mass.: MIT-Bradford.
Gardner, Howard. 1985. *The Mind's New Science: A History of the Cognitive Revolution*. New York: Basic Books.
Gussmann, Edmund. 2007. *The Phonology of Polish*. Oxford: Oxford University Press.
Hale, Mark and Charles Reiss. 2000a. Substance Abuse and Dysfunctionalism: Current Trends in Phonology. *Linguistic Inquiry* 31.157–169.
Hale, Mark and Charles Reiss. 2000b. Phonology as Cognition. *Phonological Knowledge. Conceptual and Empirical Issues*, ed. by Noel Burton-Roberts, Philip Carr and Gerard Docherty, 161–184. Oxford: Oxford University Press.
Hale, Mark and Charles Reiss. 2003. The Subset Principle in Phonology: Why the *tabula* can't be *rasa*. *Journal of Linguistics* 39.219–244.
Hale, Mark and Charles Reiss. 2008. *The Phonological Enterprise*. Oxford: OUP.
Hamann, Silke. 2011. The Phonetics-Phonology Interface. *The Continuum Companion to Phonology*, ed. by Nancy Kula, Bert Botma and Kuniya Nasukawa, 202–224. London: Continuum.
Hamann, Silke. 2014. Phonetics-phonology mismatches. Paper presented at Old World Conference in Phonology, Leiden, 22–25 January.
Harrington, Jonathan, Felicitas Kleber and Ulrich Reubold. 2008. Compensation for coarticulation, /u/-fronting, and sound change in standard southern British: An acoustic and perceptual study. *Journal of the Acoustical Society of America* 123.2825–2835.
Harris, John and Geoff Lindsey. 1990. Phonetic interpretation in Generative Grammar. *UCL Working Papers in Linguistics* 2.355–369.
Harris, John and Geoff Lindsey. 2000. Vowel Patterns in Mind and Sound. *Phonological Knowledge, Conceptual and Empirical Issues*, ed. by Noel Burton-Roberts, Philip Carr and Gerard Docherty, 185–205. Oxford: Oxford University Press.
Hayes, Bruce. 1999. Phonetically Driven Phonology: The role of Optimality Theory and Inductive Grounding. *Functionalism and formalism in linguistics. Vol.1: General papers*, ed. by Michael Darnell, Edith Moravcsik, Frederick Newmeyer, Michael Noonan and Kathleen Wheatley, 243–285. Amsterdam: Benjamins.
Hayes, Bruce, Robert Kirchner and Donca Steriade (eds.). 2004. *Phonetically-Based Phonology*. Cambridge: Cambridge University Press.
Hayes, Bruce and Donca Steriade. 2004. Introduction: the phonetic bases of phonological markedness. *Phonetically based phonology*, ed. by Bruce Hayes, Robert Kirchner and Donca Steriade, 1–33. Cambridge: CUP.
Henton, C. G. 1983. Changes in the vowels of received pronunciation. *Journal of Phonetics* 11.353–371.
Hulst, Harry van der. 1994. Radical cv phonology: the locational gesture. *UCL Working Papers in Linguistics* 6.439–478.
Hulst, Harry van der. 1995. Radical CV Phonology: the categorial gesture. *Frontiers of Phonology: Atoms, Structures, Derivations*, ed. by Jacques Durand and Francis Katamba, 80–116. London & New York: Longman.
Hulst, Harry van der. 1999. Features, segments and syllables in Radical CV Phonology. *Phonologica 1996*, ed. by John Rennison and Klaus Kühnhammer. The Hague: Holland Academic Graphics.
Hyman, Larry. 2001. The Limits of Phonetic Determinism in Phonology. *NC revisited. *The Role of Speech Perception in Phonology*, ed. by Elizabeth Hume and Keith Johnson, 141–185. New York: Academic Press.

Iosad, Pavel. 2012. *Representation and variation in substance-free phonology. A case study in Celtic*. Ph.D dissertation, University of Tromsø.
Iosad, Pavel. 2017. *A Substance-free Framework for Phonology. An Analysis of the Breton Dialect of Bothoa*. Edinburgh: Edinburgh University Press.
Karmiloff-Smith, Annette. 1998. Development itself is the key to understanding developmental disorders. *Trends in Cognitive Sciences* 2.389–398.
Mielke, Jeff. 2008. *The Emergence of Distinctive Features*. Oxford: OUP.
Odden, David. 2006. Phonology ex nihilo, aka Radical Substance-Free Phonology and why I might recant. Paper presented at PHonological seminar, Tromsø, 6 December.
Odden, David. Ms (2019). *Radical Substance Free Phonology and Feature Learning*.
Reiss, Charles and Veno Volenec. 2018. Cognitive Phonetics: The Transduction of Distinctive Features at the Phonology–Phonetics Interface. *Biolinguistics* 11.251–294.
Samuels, Bridget. 2012. The emergence of phonological forms. *Towards a biolinguistic understanding of grammar. Essays on interfaces*, ed. by Anna Maria Di Sciullo, 193–213. Amsterdam: Benjamins.
Schane, Sanford. 1984. The fundamentals of particle phonology. *Phonology Yearbook* 1.129–155.
Scheer, Tobias. 2014. Spell-Out, Post-Phonological. *Crossing Phonetics-Phonology Lines*, ed. by Eugeniusz Cyran and Jolanta Szpyra-Kozlowska, 255–275. Newcastle upon Tyne: Cambridge Scholars.
Scheer, Tobias. 2015. How diachronic is synchronic grammar? Crazy rules, regularity and naturalness. *The Oxford Handbook of Historical Phonology*, ed. by Patrick Honeybone and Joseph C. Salmons, 313–336. Oxford: OUP.
Scheer, Tobias. 2017. Two ways of being minimalist(ic). Paper presented at Government Phonology Round Table, Budapest, 17-18 November 2017.
Trubetzkoy, Nikolai Sergeyevich. 1969 [1939]. *Principle of Phonology*. Berkeley: University of California Press.
Uffmann, Christian. 2010. The Non-Trivialness of Segmental Representations. Paper presented at OCP-7, Nice, 28-30 January.
Volenec, Veno and Charles Reiss. 2018. Cognitive Phonetics: The Transduction of Distinctive Features at the Phonology–Phonetics Interface. *Biolinguistics* 11.251–294.