Phonological Opacity as Differential Classification of Sound Events
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0. The idea

- In this talk, I will propose a slight modification of the "canonical" view of phonological representations.
- The consequences of this revision – termed "differential classification" – will be shown to make phonological opacity possible in Standard Optimality Theory without additional theoretical machinery.
- The modification proposed – essentially, the introduction of multiple levels of depth of abstraction in phonological representations – resonates with recent results from speech perception/production research, as well as ideas from Construction Grammar, Word-based Morphology, and Lexical Phonology.
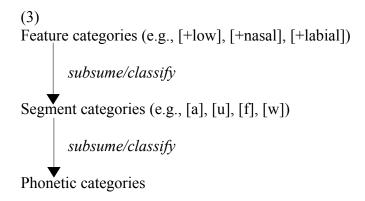
1. Introduction

- The (idealized) standard view of phonological representation holds that:
  - every phonological event is encoded in terms of phonological features, and only phonological features are relevant for phonology;
  - every segment is defined by the features that it is composed of (cf. Chomsky & Halle 1968).

- For instance, if a segmental position (however it is defined) has the features [+vocalic, +low, +back, -round], the value of that segment must be [ɑ], and cannot be anything else.

  (1) *standard view of representation*
  a. *necessary:* [+vocalic, +low, +back, -round] *stands for the phoneme* [ɑ]
  b. *impossible:* [+vocalic, +low, +back, -round] *stands for the phoneme* [ʕ]/[ɤ]/[a]/[ɒ].

- This is because, under the standard view, there is only one level of depth of abstraction, namely features.

- However, I propose that phonological representations contain representational elements of different levels of depth of abstraction.
- This means that more abstract and less abstract descriptions of the same sound event co-occur in phonological representations.

- In the current model, I will concentrate on two levels:
  - the segment as an atomic unit (for instance: [a], [u], [f], [w])
  - the feature as a label for a class of segments (for instance: [+low], [+nasal], [+labial])

- Segmental categories take the place of root nodes in standard autosegmental representations: I assume that there is a "segment tier" on which all segmental values reside.

- The difference between root nodes and segment values is that segment values fully specify the identity of a segment, independently of the features attached to them, while root nodes do not have this property[1].

(2) *Comparison between representations with root nodes and representations with a segment tier*

representation with root nodes	representation with a segment tier
---root------root-- ------[+lab]------ -[+vce]----[-vce] -[+voc]----[-voc]	----[u]-------[p]-- ------[+lab]------ -[+vce]----[-vce] -[+voc]----[-voc]

- Features, as used in this model, are purely classificatory labels: they have no inherent phonetic interpretation.

- Since features, as they are used here, are categories which range over segments, they may be seen as more abstract units than segments.
- Just as features are more abstract than segments, segments themselves are more abstract than phonetically detailed representations (which should probably include coarticulation, formant transitions, domain-final lengthening and many other regulated aspects of speech).

(3)
Feature categories (e.g., [+low], [+nasal], [+labial])

   subsume/classify

Segment categories (e.g., [a], [u], [f], [w])

   subsume/classify

Phonetic categories

- I will not attempt to define the nature and shape of phonetic categories and the grammar that regulates their combination – but this diagram makes two important points:
  - segmental categories have independent content, and
  - phonetics is "read off of" segmental categories, not off of featural categories.

- As was assumed above, features are classificatory labels without phonetic content.
- This means that there is no inherent connection between segments and features as they are defined in the current model.

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1   Some theories of feature geometry (for instance, McCarthy 1988) assume that the root node contains some features. However, this is fundamentally different from saying that the root node contains an atomic segment identity.

- Ergo: features are autonomous representational elements, not contingent on the value of the segment they are attached to.

- Given Richness of the Base (Smolensky 1996) – if taken to mean that any combination of independent representational elements should be a possible input – this means that inputs should be allowed to contain "incongruent" combinations of segments:

(4) *Some possible inputs in the "differential classification" model*

"correct" specification	"mismatching" specification			underspecification		underspec. + "mismatch"
---------[ɔ]-- -[-ATR]------ ----[+back]--	---------[ɔ]-- -[+ATR]------ ----[+back]--	---------[ɔ]-- -[-ATR]------ ----[-back]--	---------[ɔ]-- -[+ATR]------ ----[-back]--	---------[ɔ]-- -[-ATR]------ ---------------	---------[ɔ]-- --------------- ---------------	---------[ɔ]-- --------------- ----[-back]--

- If segments and features are allowed to "mismatch" freely in inputs, then there should be constraints that regulate the assignment of the desired features to segments.
- I propose that this work is done by regular, violable OT Markedness constraints, which penalize representations in which certain segments are not associated with certain segment values.
- For the set of inputs in (4), the relevant constraints could be the following:

[ɔ] → [-ATR]: Assign one violation mark for every occurrence of [ɔ] which is not associated with [-ATR].

[ɔ] → [+back]: Assign one violation mark for every occurrence of [ɔ] which is not associated with [+back].

- If such constraints are indeed on a par with other OT constraints, then they could also receive a low ranking, and be outranked by Markedness and Faithfulness constraints.
- If a segment-to-feature constraint is indeed low-ranked, then the winning output in a tableau could also have "wrong" feature specifications, if there is a combination of high-ranked constraints that prefers a "wrong" feature specification.

- For instance, in the case of the set of inputs given in (4), the combination of a constraint against [-ATR] in a certain context and a constraint preserving underlying [ɔ] segment values, both ranked above the segment-to-feature constraint [ɔ] → [-ATR], can lead to the "wrong" [ATR] value for the segment [ɔ]:

(5)

----------[ɔ]-- / Context -[-ATR]------	*[-ATR]/Context	Faith([ɔ])	[ɔ] → [-ATR]
----------[ɔ]-- / Context -[-ATR]------	*!		
----------[o]-- / Context -[+ATR]------		*!	
----------[ɔ]-- / Context -[+ATR]------			*

- In this tableau, the input is one in which [ɔ] is associated with [-ATR] and both occur in a context in which *[-ATR]/Context applies.
- The three output candidates shown are:
  - the fully faithful candidate, which is rejected because it violates high-ranked *[-ATR]/Context;
  - a candidate in which the underlying [ɔ] is changed to [o], so that [-ATR] can safely change to [+ATR] – this candidate is rejected because it violates high-ranked faithfulness to underlying [ɔ];
  - a candidate in which underlying [-ATR] is changed into [+ATR], but the segment value remains [ɔ], thus creating an incongruous segment and feature combination; this option violates [ɔ] → [-ATR], but because this constraint is low-ranked, and this candidate does not violate the two high-ranked constraints, this candidate is allowed to win.

- Thus, the sound event which sounds as [...ɔ...] is "differentially classified":
  - one the one hand, it is classified as the segment category [ɔ];
  - one the other hand, it is classified as the feature category [+ATR].

- It is this "differential classification" of sound events that makes an account of phonological opacity in Standard OT possible.
- As this section showed, differential classification arises as a possibility once features and segments (and, potentially, other pairs of representational elements that stand in a specific-vs.-abstract relationship to other another) are given independent statuses in phonological representations.

- In the following section, I will show how phonological opacity can be explained as differential classification on the basis of a case study of an opaque interaction in Yoruba.

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2. How does this derive opacity?

2.1 Opacity in the differential classification framework

- Phonological opacity is a phenomenon which is famous for the problems it poses for Standard OT.
- Various solutions to the problem have been proposed, including Stratal OT (Bermúdez-Otero 1999, Kiparsky 2000) and OT-CC (McCarthy 2007b), which both introduce sequential derivation into the original framework of Standard OT.
- However, I will show here that differential classification can account for cases of opacity (at least ones that range over segmental phenomena) without altering the basic, non-sequential architecture of Standard OT, while also making distinct empirical predictions with regard to the range of possible opaque interactions cross-linguistically.

- Opacity may be defined as follows[2]:

    (6)
    A phonological rule P of the form $A \rightarrow B / C\_D$ is **opaque** if there are surface structures with the following characteristics:
          a. instances of A in the environment C_D. [the rule is not surface-true]
          b. instances of B derived by P that occur in environments other than C_D. [the rule is not surface-apparent]
          c. instances of B not derived by P that occur in the environment C_D. [the rule is not surface-apparent]
    (after McCarthy 2007a:108 (9))

- At an intuitive level (and perhaps with some loss of accuracy), it can be said that an opaque generalization is one that has exceptions which are systematically created by the application of another generalization.

- From this latter, informal definition it can be seen why the differential classification framework can account for opacity:
    - when a phonological event is differentially classified, it has multiple contradictory representations, of which only one (namely, the most specific one) directly influences pronunciation;
    - an opaque generalization can then be predicated of the feature level, while the generalization that makes opaque can be predicated of the segmental level.

- Because features and segments are all independent units of representation, Markedness and Faithfulness constraints may refer to segments, features, or both.
- Thus, the opaque generalization must be triggered by a constraint that refers to the featural level, while the generalization that makes it opaque must be triggered by a constraint that refers to the segmental level.
- If the appropriate segment-to-feature constraint is sufficiently low-ranked, then the winning

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2 But see Baković (2011) for criticism.

candidate will satisfy both constraints by differential classification of some of its sub-events.

- The following section will show how this accounts for a case of opacity in Yoruba.

2.2 Case study: Yoruba

- Yoruba (Pulleyblank 1988, Archangeli & Pulleyblank 1989) has two processes which interact opaquely:
    - word-bounded (leftward) ATR harmony – as shown in (7), and
    - full assimilation of segmentally adjacent vowels – as shown in (8).

(7)
/o-ku/ → [oku] "corpse of a person"
/o-dɛ/ → [ɔdɛ] "hunter"
/e-ro/ → [ero] "a thought"
/e-rɔ/ → [ɛrɔ] "machine"

(8)
/ara ilu/ → [ara alu] "townsman"

- Vowel assimilation applies consistently, and creates exceptions to ATR harmony (which consequently underapplies, becomes non surface-true) – as shown in (9) below.
- In this manner, the interaction of the two processes is opaque by (6a).

(9)[3]
/ɛba odo/ → [**ɛbo** odo] "near the river"   (*[ɛ ... o] is normally not allowed)
/ile iʃɛ/ → [ile **eʃɛ**] "office"   (*[e ... ɛ] is normally not allowed)
/owo ɔmɔ/ → [**owɔ** ɔmɔ] "child's money"   (*[o ... ɔ] is normally not allowed)

- This opaque interaction can be accounted for if the vowels that violate ATR harmony generalizations because they undergo assimilation change only their segmental value, but their [±ATR] value does not change, even if this leads to an incongruous feature.

(10)

+atr	+atr	-atr	-atr		+atr	**+atr**	-atr	-atr
/ o	w o	ɔ m	ɔ/	→	[o	w **ɔ**	ɔ m	ɔ]

- If the opaque process (ATR harmony) should be represented as a feature-level process, and the process that makes opaque (vowel assimilation) is represented as a segment-level process, then mappings such as the one above will satisfy both the constraints triggering ATR harmony and the constraints triggering vowel assimilation.

- For this account to be implemented in OT, the following should be true:
    - the constraint triggering harmony (ATR-Harmony) should be defined over [±ATR] values;

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3   All tones have been omitted from the Yoruba data.

- the constraint triggering vowel assimilation (AssimV) should defined over adjacent segment values, and
- the constraints regulating assignment of [+ATR] and [-ATR] to vowels should be given a low ranking.

- Let us assume that the two triggering constraints look as follows:

  ATR-Harmony: Assign one violation mark for every pair of adjacent unequal values on the [±ATR] tier, if both members of the pair are in the same word[4].

  AssimV: Assign one violation mark for every pair of adjacent unequal values on the segmental tier if both of these values are associated with the feature [+vocalic][5].

- Each of these constraints must dominate the faithfulness constraint which is violated by enforcing the generalization they trigger.

- ATR-Harmony must dominate the faithfulness constraint NoChange([±ATR])[6]:

  NoChange([±ATR]): Assign one violation mark for every input specification on the [±ATR] tier which is not identical to its output correspondent.

(11)

+atr -atr / o - d ɛ /	ATR-Harmony	NoChange([±ATR])
-atr -atr ɔ d ɛ		*
+atr -atr o d ɛ	*!	

- AssimV must dominate the faithfulness constraint NoChange(segment) (which in reality should be replaced by a series of constraints against changing underlying vowel segments):

  NoChange(segment): Assign one violation mark for every input specification on the segment tier which is not identical to its output correspondent.

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4 I have grossly oversimplified the facts of Yoruba ATR harmony here, and in the original analysis in Nazarov (2012), there are several constraints which trigger ATR harmony; however, the constraint given here accounts for at least some of the facts.

5 I assume that there is a series of undominated constraints which demands that every vowel of Yoruba have the feature [+vocalic] associated with it.

6 The NoChange family of constraints replaces the familiar Ident(ity) family; see Nazarov (2012):section 1.2.

(12)

+voc +voc +voc +voc / a r a i l u /	AssimV	NoChange(segment)
+voc +voc +voc +voc a r a a l u		*
+voc +voc +voc +voc a r a i l u	*!	

- Finally, there must be a series of constraints which regulate the assignment of [±ATR] values to vowels; for the purpose of brevity, I will summarize these as the two following constraints:

  {ɛ, ɔ, a} → [-ATR]: Assign one violation mark for every instance of [ɛ], [ɔ], or [a] which is not associated with the feature value [-ATR].

  {e, o} → [+ATR]: Assign one violation mark for every instance of [e] or [o] which is not associated with the feature value [+ATR].

- As has been said before, these constraints must be low-ranked.
- More precisely, the two constraints must be ranked below ATR-Harmony, AssimV, and the faithfulness constraint NoChange([±ATR]).
- This is demonstrated in the two tableaux below, which show the opaque mappings /owo ɔmɔ/ → [owɔ ɔmɔ] and /ɛba odo/ → [ɛbo odo], respectively.

(14)

+atr +atr -atr -atr / o w o ɔ m ɔ /	ATR-Harmony	NoChange ([±ATR])	AssimV	{ɛ, ɔ, a} → [-ATR]	NoChange (segment)
+atr **+atr** -atr -atr o w ɔ ɔ m ɔ				*	*
+atr +atr -atr -atr o w o ɔ m ɔ			*!		
-atr -atr -atr -atr ɔ w ɔ ɔ m ɔ		*!*			**
+atr -atr -atr -atr o w ɔ ɔ m ɔ	*!	*			*

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(15)

-atr -atr +atr +atr / ɛ b a o d o /	ATR-Harmony	NoChange ([±ATR])	AssimV	{e, o} → [+ATR]	NoChange (segment)
-atr **-atr** +atr +atr ɛ b o o d o				*	*
-atr -atr +atr +atr ɛ b a o d o			*!		
+atr +atr +atr +atr e b o o d o		*!*			**
-atr +atr +atr +atr ɛ b o o d o	*!	*			*

- In both of these tableaux, the winning candidate has a second vowel which is differentially classified: the ATR value is not the canonical one for the vowel's segmental value (which has been completely assimilated to that of the following vowel).

- However, the fully faithful second candidates violate the high-ranked constraint AssimV.
- The last candidate in each tableau, in which the vowel assimilates and its underlying ATR value also changes so that canonical segment-to-feature match is maintained, is excluded because it violates ATR-Harmony (the first word has a [-ATR,-+ATR] or [+ATR,-ATR] sequence).

- Finally, candidates in which this violation of ATR-Harmony is avoided by harmonizing the first vowel with the second (cf. the third candidate in each tableau) are excluded by excessive faithfulness violations.
- Thus, differential classification of the vowel which undergoes assimilation is the preferred and grammatical option – which amounts to non surface-true opacity (cf. (6)).

- Of course, the differential classification situation only occurs in a winner when all else fails: if there is no motivation for "mismatch" between segment and feature, the segment-to-feature constraints will ensure that canonical classification is restored, as long as they dominate some faithfulness constraint.
- In this case, they could and should dominate the faithfulness constraint NoChange(segment) (cf. the preceding tableaux: no ranking arguments between segment-to-feature constraints and NoChange(segment)).

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(16)

+atr /b ɛ /	ATR-Harmony	NoChange ([±ATR])	AssimV	{e, o} → [+ATR]	{ɛ, ɔ, a} → [-ATR]	NoChange (segment)
+atr b e						*
+atr b ɛ					*!	
-atr b ɛ		*!				

- Differential classification, as in the second and fully faithful candidate, is excluded because it is cheaper to change the segment value from [ɛ] to [e] than to keep the differential classification from the input.
- Changing the segment value is preferred to changing the feature value because NoChange([±ATR]) is ranked higher than NoChange(segment).

- As seen in (14) and (15), opaque mappings are accounted for in this framework with parallel evaluation of candidates, thanks to the possibility of differential classification.

3. Broader context

3.1 Empirical predictions

- As can be seen above, the account of Yoruba as given in section 2 presupposes that ATR harmony has a grammatical representation at the level of the feature, while vowel assimilation has a grammatical representation at the level of the segment.

- The Yoruba data make this kind of interpretation plausible:
  - vowel assimilation can be described more easily if there is simply the requirement that two adjacent segment values be identical, than if there has to be a separate constraint (or a separate clause within a larger constraint) for every vowel feature to force feature values to be the same between adjacent vowels;
  - ATR harmony is more easily described in terms of featural labels than it is in terms of segment categories: instead of having separate constraints for every vowel segment combination that is prohibited, it is more economical to have a small number of simple constraints against certain sequences of feature values.

- On the basis of this, one could formulate a general principle that determines whether to represent a generalization with segmental or featural constraints – an Evaluation Metric of sorts (cf. Chomsky & Halle 1968).
- This evaluation metric should rule out grammars in which a process is represented with features while it could have been represented by fewer and simpler constraints if it were represented with segments, or *vice versa*.

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- If such an evaluation metric is assumed, then the differential classification account of opacity makes very specific predictions concerning the range of possible opaque interactions.

- Given the setup of the current model, a segmentally represented process cannot be made opaque by a featurally represented process (because phonetics is dictated by the segmental representation).
- If there is an evaluation metric as proposed above, then some processes will be bound to be segmental or featural – which means that certain processes will be blocked from interacting opaquely.

- One example of an opaque interaction predicted to be impossible is a hypothetical variation on the Yoruba example.
- In this Yoruba-prime, there is a process of vowel lowering, which turns the sequences /a+i/ and /a+u/ into [e] and [o], respectively.
- This process is most concisely represented with feature-based constraints, and is therefore bound to be a feature-level process.

(17)
/abala ili/ → [abala eli]
/awaba uyu/ → [ayaba oyu]
/awaba ege/ → [awaba ege]

- In addition, there is a process of complete vowel harmony between the first two vowels in a word (reminiscent of vowel harmony in Romance languages).
- This process is most concisely represented with a constraint ranging over segment. and is therefore bound to be a segment-level process.

(18)
/lo-ka/ → [loko]
/wi-lo-ka/ → [wilika]

- In Yoruba-prime, these two processes interact opaquely as in (19) below: vowel harmony makes vowel lowering opaque.
- However, the current framework predicts that this opaque interaction cannot be, since this means that a featural process makes a segmental process opaque.

(19)
/abala ili/ → [abala eli], *[abala ele]
/awaba uyu/ → [awaba oyu], *[awaba oyo]

- Whether opaque interactions of this kind are attested remains an open question, but at the very least the current framework gives a principled reason for asking this question.

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3.2 Theoretical precursors

- The central idea which allowed the current model to account for opacity in OT is the following:

    Representational elements of various degrees of depth of abstraction co-occur in phonological representations, and can be separately referred to by phonological grammar.

- The need for representational elements at various levels of abstraction to be referred to in linguistic computation has been advocated by various authors in various subfields of linguistics.

- Most prominently for current research in linguistic sound systems, recent literature in speech perception has advocated models of perception in which there is more than one level of abstraction.
- Most of this work has focused on the need for the presence of both exemplars and segment categories (see, for instance, Jesse, Page & Page 2007 and McQueen, Cutler & Norris 2006).
- A very interesting study involving imitation of exaggerated aspiration, as reported by Nielsen (2011), has also found evidence for the co-occurrence of exemplars, holistic segmental units, and featural units in the speech processing system.

- Apart from this very interesting and compelling evidence, there are also some salient theoretical precursors for the current model.

- Cognitive Construction Grammar (Goldberg 1995) has always embraced and endorsed the notion that both specific words and word categories occur in the grammatical representation of sentence structure.
- Word-based approaches to morphology (see, e.g., Harris 2009 and references therein) are another type of framework in which specific categories (words) and more abstract categories (morphological patterns) co-exist and work together to determine linguistic patterns.

- Within phonology itself, Lexical Phonology (Kiparsky 1982, 1985) can be seen as embodying different levels of abstraction: the principle of Structure Preservation, according to which lexical rules, but not post-lexical ones, are bound to a language-specific alphabet of contrastive sounds can be interpreted as saying that lexical rules refer to more abstract representations than post-lexical ones.

- Of course, the current framework relies heavily on earlier representational theories of phonological opacity, including Harmonic Phonology (Goldsmith 1993), Colored Containment (Oostendorp 2004, 2007, 2008, Revithiadou 2007, Nazarov 2010), and Abstract Declarative Phonology (Bye 2003).

4. Concluding remarks

- I have presented a slightly modified model of phonological representation, the "differential classification" model, which allows phonological opacity to be accounted for in Standard Optimality Theory.

- This model is in line with current developments in speech perception research, and some theoretical work.

- Some empirical predictions of this model have been determined, but it is not clear if these empirical predictions hold true of attested language typology.
- Furthermore, psycholinguistic and computational aspects of the theory should be explored in future research.

- One major limitation of the current model is that it cannot account for prosody-based cases of opacity, because differential classification at the prosodic level has not been modeled.
- This is another important topic for future thought.

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