Theories of categorization and their relevance to the acquisition of phonology
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1. Introduction

- Phonological data provides an enormously rich and complicated system of learned categories. Psychologists interested in categorization and in learning might benefit from acquainting themselves with the phonological data corpus, in order to exploit this testing ground for their theories.
- Theories of learning and categorization may be of great interest to phonologists, once they abandon notions of domain-specificity, and place the learning of a phonology in the broader context of learning and categorization theories.

- Phonological categories: the *physical distinctions* or *oppositions* or *contrasts* among morphemes that signal a change in *meaning*.
- Function of phonology: to communicate effectively. Therefore, functional factors in phonology are those which affect meaning distinctions: sound substitutions that change, maintain, or obliterate meanings.

1. Corsican voiceless stops (Dinnsen and Eckman 1977):

p̠eðe	'foot'	u b̠eðe	'the foot'
t̠engu	'I have'	u d̠engu	'I have it'

Corsican voiced stops

b̠okːɑ	'mouth'	ɑ β̠okːɑ	'the mouth'
d̠ente	'tooth'	u ð̠ente	'the tooth'
g̠olɑ	'throat'	di ɣ̠olɑ	'of throat'

- When viewed in functional diachronic terms, strong dynamic and self-organizational properties of the sound system clearly emerge which are synchronically active in the form of alternations; it would be counterintuitive to assume that the synchronic manifestations of this functionally motivated dynamism are not exploited by the learner.

- It is the system's very complexity—its myriad patterns of allophony and allomorphy—that may provide a sufficiently richly articulated structure for learners to master the system, and to effortlessly predict new forms. Language learners, upon daily exposure to the system in all its enormous complexity, come to master its form and fill in any gaps.

2. American English alveolar stops:

	lenis:			fortis:		
	form:	example:		form:	example:	
(a) word-initially:	t d̥	ˈtɑk ˈd̥ɑk	dock	tʰ	ˈtʰăp	top
(b) syllable- and word-finally:	t d̥	ˈnɑt ˈnɑd̥	nod	V̌t˺ V̌ˣt˺ V̌ʔ	ˈnăt˺ ˈnăᵍt˺ ˈnăʔ	knot
(c) word-internal stressed-syllable-initially:	d	əˈdɑpt	adopt	tʰ	əˈtʰăp	atop
(d) word-internal unstressed syllable-initially:	Vɾ V̌ɾ	ˈɑɾ̩ɹ ˈăɾ̩ɹ	odder (neutralized)	ɾ	ˈăɾ̩ɹ	otter
(e) following **s**:	form: t example: stɑp˺ ; stop (non-contrastive)					

3. Alternations

Lenis:	d - ɾ	addiction	addict
	t/d̥ - ɾ	bud	budding
	t – d	do	redo
	t - ɾ	disperse	redisperse
Fortis:	V̌ˣt˺ - V̌ɾ	butt	butting
	tʰ - ɾ	atomic	atom
	V̌ˣt˺ - tʰ	dictate	dictatorial

Syllable initially

4. Lenis stop:

tongue tip:	up	down
tongue body:	low	
vocal folds:	open	approximated
IPA:	tɑ	

← aerodynamically more natural

tongue tip:	up	down
tongue body:	low	
vocal folds:	open	approximated
IPA:	d̥ɑ	

← aerodynamically more natural

5. Fortis stop:

tongue tip:	up	down	
tongue body:	low		
vocal folds:	spread	approximated	← aerodynamically less natural
IPA:	tʰ ɑ		

Syllable- and word-finally

6. Lenis stop:

tongue tip:	down	up	
tongue body:	low		
vocal folds:	approximated	open	← aerodynamically more natural
IPA:	ɑd̥		

7. Fortis stop:

tongue tip:	down	up	
tongue body:	low		
vocal folds:	approximated	constricted	← aerodynamically less natural
IPA:	ɑ̆t˺		

Word-internal stressed-syllable initially

8. Lenis stop:

tongue tip:	down	u	p	down
tongue body:	central		low	
vocal folds:	approximated			← aerodynamically more natural
IPA:	ə	ˈd ɑ		

9. Fortis stop:

tongue tip:	down	u	p	down
tongue body:	central		low	
vocal folds:	approximated	spread		approximated ← aerodynamically less natural
IPA:	ə	ˈtʰɑ		

Word-internal unstressed-syllable-initially

10. Lenis stop:

tongue tip:	down	u	p	down
tongue body:	low		central	
vocal folds:	approximated			← aerodynamically more natural
IPA:	ˈɑ	ɹ	ə	

11. Fortis stop:

tongue tip:	down	u	p	down	
tongue body:	low		central		
vocal folds:	approximated				← aerodynamically more natural
IPA:	ˈɑ̆	ɾ	ə		

Following [s]

12. No contrast:

tongue tip:	close	up	down	
tongue body:	low			
vocal folds:	spread		approximated	← aerodynamically more natural
IPA:	s		tɑ	

13. American English alveolar stop alternation:

Context: ⇨	**(a)** word-initially:		**(b)** syllable- and word-finally:		**(c)** word-internal stressed syllable initially:		**(d)** word-internal unstressed syllable initially:		**(e)** preceding **s**:
Lenis/ Unmarked:	d̥/t (natural)	⇔	t/d̥ (natural)	⇔	d (natural)	⇘			t (natural)
	⇧		⇧		⇧		(V̌)ɾ (natural)	⇗	
Fortis/ Marked:	t^h (unnatural)	⇔	V̌t/ V̌^{V}-t/ V̌ʔ (unnatural)	⇔	t (unnatural)	⇗			

- Generalizations: In “good” locations, the fortis value is pushed to an aerodynamically less natural realization, while in “bad” locations, there is neutralization toward a more natural value.

On the evolution of change

- Variation is the engine of system-internal sound change. Antilla (1972:53): “variation is a prerequisite of change”; Hock (1991:648): “the basis for linguistic change lies in the same ever-present low-level variability of ordinary speech...”

- The natural tendency toward phonetic variation is typically delimited by phonetic naturalness (for unmarked values), and the functional force of contrast maintenance (for marked values), and that the existence of delimited variation itself possesses functional significance, as marked values may move toward those phonetic states which better maintain contrastive status with their neighbors both syntagmatic and paradigmatic.

14. Early pattern in Western Romance (intervocalic):

	more natural:			less natural:			less natural:	
prevalence		d			t			tː
	d		d	t		t	tː	tː
	d		d	d̥		t	tː	tː
VOT in ms.	-90	-60	-30	0	30	60	geminate stop	

Present-day pattern:

	less natural (?):			more natural:			less natural:		
prevalence		ð			d			t	
	ð		ð	d		d	t		t
	ð		ð	d		d	d̥		t
VOT in ms.	voiced spirant			-90	-60	-30	0	30	60

- Hockett (1968:83): “The distinction between system-conforming and system-changing events cannot, in principle, be made.” That is, the variation inherent in speech production at once obeys the synchronic requirements of effective transmission, and contributes to the process and direction of diachronic change.

- Teleology? There is no evidence that, under normal ambient conditions—that is, those conditions that predominate—speakers are *attempting* to communicate better when contrasts are at risk due to their positional status; there is no conscious manipulation of speech production to effect such changes. Rather, the change may be seen as a consequence of perception: particular tokens that are more clearly distinguishable from their paradigmatic neighbors will result in less ambiguity in the speech signal, and hence more effective communication. To the extent that effective communication is beneficial to the survival of a given phonetic realization, it is exactly the unambiguous tokens that are likely to take hold, be reproduced, and thus move the system towards its modified state.

- In English, the present-day lenis stop may have been truly voiced in coda position, inducing a moderate preceding vowel length distinction between it and its fortis counterpart. Upon diachronic de-voicing, the length distinction may have been functionally harnessed to serve a

primary contrastive role. This scenario might also explain the vowel length contrast in flapping environments.

- We might further conjecture that the aspiration contrast in utterance-initial position actually derives from an earlier voicing contrast. The tendency toward devoicing in this context may have resulted in increasingly aspirated "voiceless" forms being communicated more effectively, culminating in an overall shift to aspiration here.

15. Conjectural Early pattern (initial):

	less natural:			more natural:		
prevalence	d	d	d	d̥	t	t	t	t^h
VOT in ms.	-90	-60	-30	0	30	60

Present-day pattern:

	less natural:			more natural:			less natural:		
prevalence	d			d̥	t	t	t^h	t^h	t^h	t^h
VOT in ms.	-90	-60	-30	0	30	60	90	120	150

- Abramson and Lisker (1964): while VOT is clearly the primary determinant of the fortis-lenis distinction in initial position, category ambiguities (at around 20 msec VOT) can be partially resolved by manipulating fundamental frequency at stop release. A lowered F0 at release may induce the perception of the lenis stop, while a raised F0 may induce the perception of the fortis stop. Note that it is well established that F0 is typically lower at the release of voiced stop; higher at the release of a voiceless stop. Thus speakers might employ this articulatory strategy (including as well larynx lowering and overall pharyngeal expansion), and hearers might be sensitive to it, despite the fact that the lenis stop is typically voiceless in this context, and thus English speakers may be employing an articulatory posture that may have no proximal phonetic explanation.

- Teleology? Kingston and Diehl (1994:437) attribute such findings to the "phonetic knowledge" of speakers, in that they deliberately manipulate their laryngeal configuration—"introduced by the phonetic component, rather than phonologically"—to induce a pitch lowering, presumably in order to assist the hearer in recovering the abstract phonological category [+voice].

- Alternatively, the phonetic peculiarities of pitch perturbations in English stop releases may be seen as a historic relic of a time when the lenis series was indeed phonetically voiced in initial position. Forms which possessed these pitch effects even after voicing was lost were better communicated to listeners, and thus listeners were more likely to produce their own stops in a similar fashion. There is no teleology, either diachronically or synchronically.

Learning

- A diachronic consequence of these phonetically and functionally motivated delimited drifts is that allophones tend to possess a marked degree of phonetic similarity.

- Allophones within a category tend to be phonetically similar not due to a first principle of linguistic theory (the evaluation metric (Halle), correspondence/faithfulness (McCarthy/Prince/Smolensky), lexical conservatism (Steriade)), but instead due to the evolutionary forces that push toward phonetic naturalness and the maintenance of contrasts across differing phonotactic environments.

- Psycholinguists have attempted to tease apart the influence of phonetic versus psychoacoustic versus linguistic influences on changing ontological patterns of phone discriminability (see, for example, Ferguson and Farwell 1975, Aslin et al. 1981, Werker et al. 1981, Juczyk 1982, 1993, MacKain 1982, Best et al. 1984, Best et al. 1988, Best et al. 1989, Werker and Tees 1984, Werker and Logan 1985, Werker and Polka 1993).

- Phonetic similarity may initially serve to bootstrap categorization procedures, but it is ultimately the functional relevance (meaning-changing or meaning-preserving) of sound substitution which learners exploit in forming their linguistic sound categories.

- Learners begin classifying phonic distinctions along predominantly phonetic lines, but at the 10-12 month period (earlier for vowels) classifications begin to shift to ambient linguistic categories. While a psychoacoustic approach argues that the change in phonic categorization is due mainly to the use/disuse of particular *phonetic* distinctions (independent of their specifically linguistic function), the linguistic approach implicates the presence/absence of ambient *phonemic* distinctions.

- There is good reason to suspect that any initial boost that phonetic similarity may provide for category formation is insufficient for learners to master the full inventory of their languages' contrastive and allophonic relations, and that such phonetic categorizations yield to linguistically driven—not psychoacoustically-driven—categorizations. Evidence stems from an important typological fact about allophonic relations: two phones that are more similar to each other than they are to other phones sometimes belong to different phonological categories (cf. Corsican). Relatedly, sometimes phonetically dissimilar phones belong to the same phonological category.

16. Southern Min tone sandhi (Chen 1987):

___ #		~___ #
24	⇔	22
⇕		⇕
22	⇔	21
⇕		⇕
21	⇔	53
⇕		⇕
53	⇔	44
⇕		⇕
44	⇔	22

- A theory of category formation which relies exclusively on raw phonetic similarity is clearly unable to account for such patterns as Corsican stop allophony, or Southern Min tone sandhi. Instead, the functional identity of certain phonetic distinctions clearly overrides their phonetic dissimilarity.

- Categorization here cannot be a consequence of use/disuse, as the psychoacoustic approach predicts.

- Shepard, Holland, and Jenkins (1961) (pace French (1953): similarity and reinforcement may be independent variables affecting category learning): these researchers tested subjects' ability to group visual stimuli into sets that possess either similar or dissimilar members.

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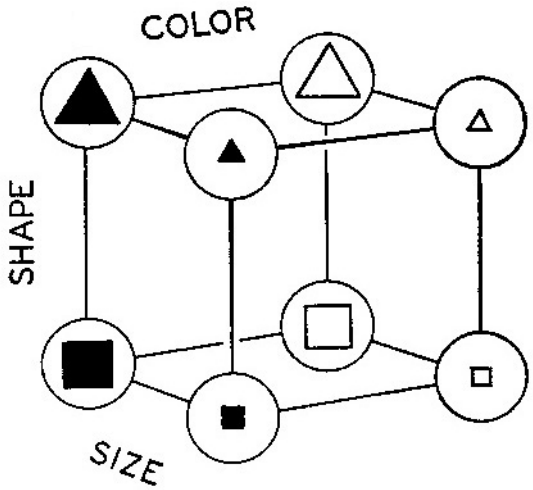

- Six logical breakdowns of the eight forms, each consisting of two groups with four members each:
- Group I: groups with members that are maximally similar (here, on the color dimension).

- Group II: groups with qualitatively less similar members (requiring two dimensions to be considered for classificatory purposes).
- Groups III-V: groups with maximally dissimilar members (requiring all three dimensions to be considered).
- Group VI: requires learning the qualities on all three dimensions for each individual member:

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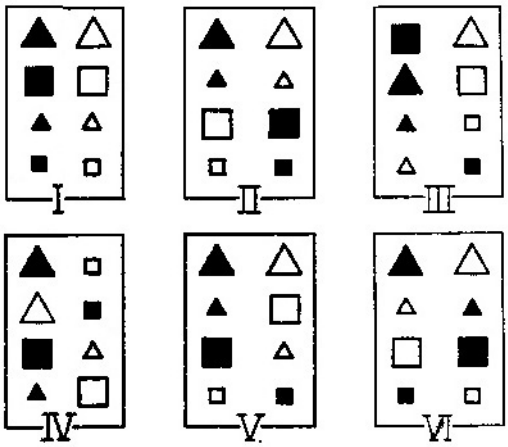

- Subjects went through a number of sets of stimuli, with each set conforming to one of the six group types. Ss were trained to associate a prescribed verbal response to each of eight stimuli within the given set. Four of the stimuli were associated with one verbal response; the other four, another. Ss were provided with immediate feedback as to the correct response to the stimulus flashed, and were then presented with the next stimulus, and so on. After exposure to one set, stimulus presentation moved on the next set, until 32 consecutive correct responses were produced.

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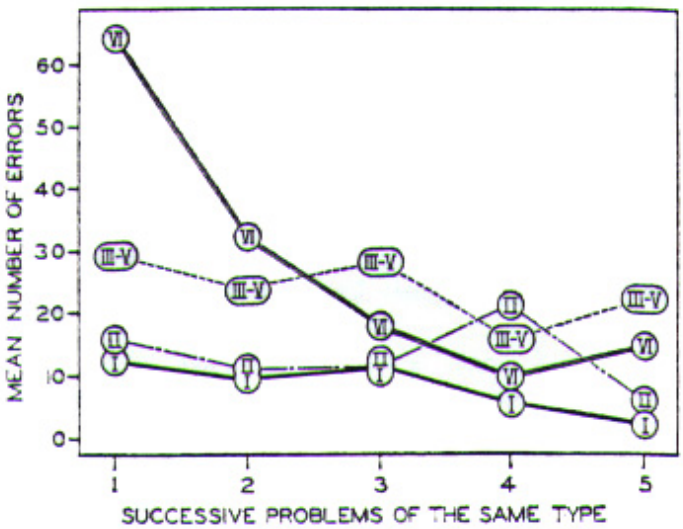

- Ss were successful at learning all six sorts of groupings, but showed a clear facility with learning groups consisting of more similar members (I, II). Learning the group with the least similar members (VI), while slowest, nonetheless improved most over time, and ultimately patterned similarly to all other groups in terms of learnability.

- Implications? Learners might experience an initial difficulty, but an ultimate success, in discovering which phonetically disparate allophones should be grouped together. That is, in such cases as the Corsican [t-d]/[d-ð] type alternation, and in those somewhat unusual historical circumstances when allophones have strayed far from each other in terms of their phonetic quality, the functional relevance of phonetic distinctness is yet learnable (that is, that the substitution is meaning-preserving).

- Despite the initial boost that similar stimuli apparently receive in terms of category grouping, this boost may ultimately be overridden by functional cues to category membership: initial semantic feedback regarding category membership may fall on deaf ears, as infants are unaware of the sameness or distinctness in meaning that accompanies such sound substitutions.

- But just as experimental subjects who, when provided with feedback are, over time, ultimately able to group unlike elements together, so too may language learners, over time, exploit the lexical semantic feedback provided them regarding meaning changes or non-changes, in order to replicate the functional categories employed in the adult system, regardless of the phonetic values of these elements.

Categorization

- Murphy and Medin (1985:310): "...[C]hildren form their first concepts through perceptual similarity; then, as they learn more about the world, they incorporate knowledge into their concepts, where it has increasing importance. On this view, the similarity-based views of coherence are correct for early concepts, at least, to the extent that we can ascertain built-in constraints on the perception of similarity."

- Werker and Lalonde (1988:682): "If we accept that the definition of a phoneme as a phonetic unit that is used to contrast meaning, then the beginning—just the beginning—of the emergence of a phonemic system around 1 year of age should come as no surprise. Certainly by this time, the infant has begun to construct a receptive vocabulary. Although it is far from clear how fully specified initial oppositions might be, logically the development of a receptive vocabulary and the initial emergence of a system of phonological contrasts should co-occur."

- Nosofsky (1986): selective attention for the purpose of categorization to particular features in multidimensional perceptual stimuli affects the acuity of stimulus categorization: perceptual distances along this functionally relevant dimension will "stretch," while perceptual distances along functionally inert dimensions will "shrink." In essence, similarity and dissimilarity are at least in part consequences of function—of categorization demands—rather than an inherent component of the stimuli themselves: "similarity is not an invariant relation but a

context-dependent one...Because of selective attention to component dimensions, there will be systematic changes in the structure of the psychological space in which the exemplars are embedded, and associated changes in similarity relations" (p.53).

- Schyns Goldstone, and Thibaut (1998): "features are identified by their functional role in cognition...are selectively weighted if they are diagnostic...[if they] facilitate discrimination between categories" ... "the individual knows what the categories are from external feedback, that is, the consequences of their miscategorizations."

- Given the possibility that history will take its toll on the phonetic order of a phonological system, why are not all phonological systems in a state of phonetically transmogrified disarray? A conceivable answer emerges when considering the learning curve involved in forming categories out of dissimilar elements.

- Categories with dissimilar members will take more time to master. Such categories may initially be mistakenly filled with similar members, which would be in keeping with the majority of the more readily learnable categories.

- Over time, such incorrectly formed categories may be "corrected" with sufficient feedback (sufficient exposure to allophonic alternations—which do not change meaning), but some incorrect regularities may take hold, and consequently change the system towards a more regular state.

- Which categories with dissimilar members should be most susceptible to a change toward regularity, and which categories should most likely maintain their dissimilar members?

- If there is a great deal of feedback in the form of exposure to frequently employed items, categories with dissimilar members should ultimately be successfully learned (e.g. common strong verbs).

- If there is little-to-no exposure to a given irregular pattern at early stages in the learning procedure, these irregularities too will probably be learned correctly later on, as feedback begins after the mature system is well in place.

- Irregular categories with only a modicum of feedback—again, in the form of moderate exposure to less frequently employed items—will likely be the most susceptible to regularization, as moderate amounts of feedback may be insufficient for the proper generalizations to emerge for the learner. The result is that the learner will fill the category with likely candidates—those that conform to the regularities of most other categories in that they possess phonetically similar members. Over time, the regularization may undergo lexical diffusion, perhaps ultimately pervading the lexicon. But also, lexical diffusion may be blocked to the extent that the "unnatural" alternation takes on morphological significance, as in Southern Min tone sandhi, or, say, morphophonologically conditioned umlaut system evolving into a purely morphological ablaut system. In this scenario, linguistic sound systems may be seen as being under a continual force of regularization, concomitant with the

possibility that phonological and morphological change might result in the emergence of certain irregularities.

Gestalten

- Köhler (1929) “In countless cases organization is a sensory reality without there being a corresponding physical unit.”

- “continuous sensory wholes may occur in the absence of a homologous physical unit” (p.171). In this sense, “a dynamical distribution will be rightly regarded as a functional whole...No part of this distribution will be self-sufficient; local processes depend throughout upon the totality of the distribution” (p.148).

- “Since ‘real form’ presupposes a segregated whole, the existence of ‘form’ depends upon factors of stimulation similar to those upon which the segregation and organization of wholes depends...As for the existence of segregated wholes, i.e., organization, certain *special* relations...are important and others indifferent; which are the important ones can only be discovered by the observation of real forms appearing under a given set of conditions...‘form,’ wherever it exists, is a *supra*local property of that part of the field; so the property of the underlying process must be a supralocal phase of it” (pp.202-204; italics in original).

- “Everywhere in nature dynamical events depend upon the properties of those processes and materials which exert influence upon one another” (p.120).

- Surely, given their highly complex and dynamically orchestrated functional interdependencies—the functional relevance of certain of their dynamic properties and the functional irrelevance of others—our capacity to learn linguistic sound systems naturally lends itself to a Gestalt-theoretic analysis.

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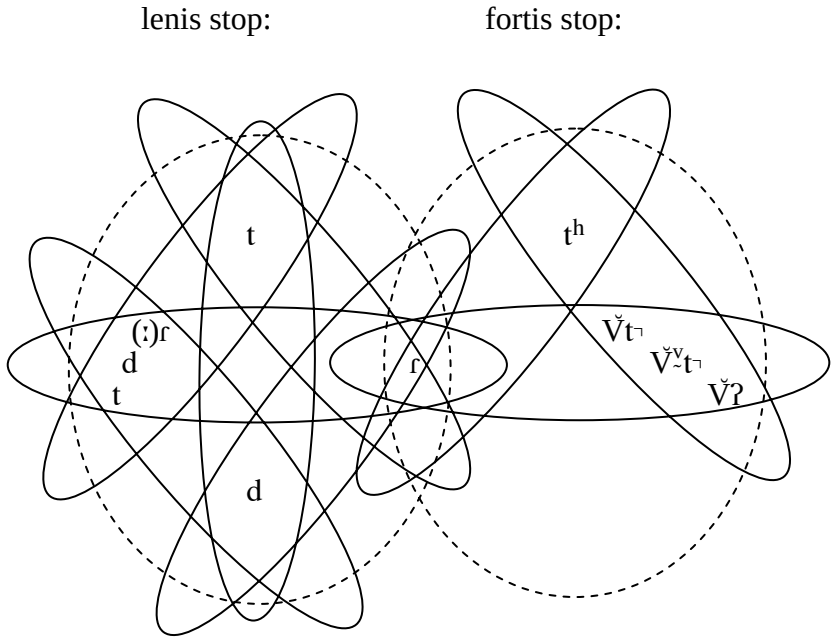

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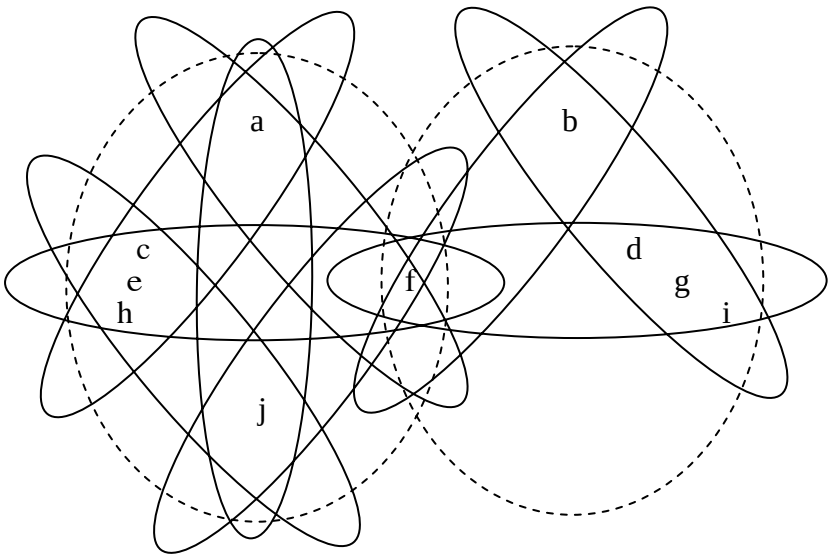

- In contrast to the richly articulated data array which provides learners with sufficient dynamic information to learn allophonic relations within the stop system, consider finally the English ŋ-h opposition.

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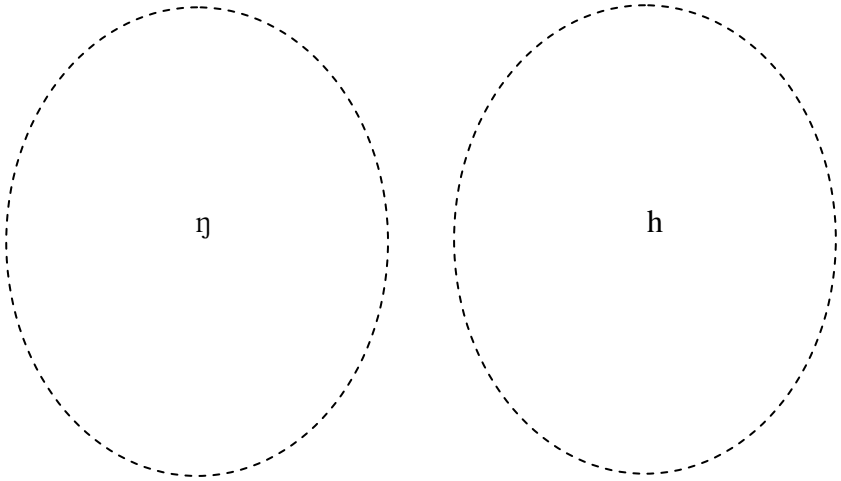

- Neither the phonetic dissimilarity of the velar nasal and the laryngeal, nor their complementary distribution, likely plays any significant role in establishing their functionally distinctive status for English learners. Their behavior betrays no evidence that any sort of allophonic relationship exists between the two values: there is no immediate dynamic component to their relationship, as substitution of one with the other is never present in the sensory field; mere complementary distribution may offer no evidence of functional identity, whether the sounds are phonetically similar or not. Alternation is what matters.

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