“History suggests that the road to a firm research consensus is extraordinarily arduous.”

(Kuhn, 1962, p15)

Commentary on Generalising over the Lexicon: the emergent paradigm in Laboratory Phonology

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Thank you

• To the organisers for the invitation to participate in LabPhon11 in this way
• To the researchers in this session for the stimulation of their papers
• To the LabPhon community for fostering such interesting investigation of human sound systems: especially Cohn (in press), Pierrehumbert & Clopper (in press), Dell (2000)

Summary of commentary

• A scientific paradigm has arisen in which we can locate/interpret/integrate the research of the LabPhon community
• Fundamental shared beliefs of LabPhon include
  – An embodied approach to human sound systems, including attention to the properties of human auditory, articulatory and learning systems
  – Awareness that human sound systems are shaped by multiple forces within and outside the speaker/listener and a need for theories that capture the relationships between these

Overview

The current challenge for LabPhon

Truly integrated models (LP10 10th anniversary session papers by Cohn and Pierrehumbert & Clopper)

The emergent LabPhon paradigm

1. Shared interest in mind-matter relationships
2. Theories that integrate hierarchical data structures on different time scales
3. Need to consider influence of multiple forces within and outside the individual
• with illustrations from papers in the session, “Generalising over the lexicon”
Introductory Remarks

My agenda for this paper started with Cohn, A. (in press) Laboratory Phonology: Past successes and current questions, challenges and goals. Laboratory Phonology X

LabPhon is an approach to investigating human sound systems using integrated methodologies within various (or no) theoretical frameworks, necessitating good dialogue across boundaries.

Goals and accomplishments

Core research question: What is the relationship between the cognitive and physical aspects of human sound systems?

Extensive research on topics summarized by the titles of the 10 LP conferences: e.g. segmental and suprasegmental phenomena, the relationship between phonetics and phonology, variation, sound change, acquisition of L1 and L2, psycholinguistic processing

Shared tools including ToBI, PRAAT

The next major challenge

To develop truly integrated models that account for such rich empirical data

- To be synthetic and collaborative
- To question assumptions & how we frame assumptions & models: the "foundational issues...to discuss explicitly, carefully & empirically"
- Shift from either/or debates to an inclusivity that avoids reductionist thinking, that doesn't lose sight of what is "almost right"

Truly integrated models require a scientific paradigm

In Kuhn’s terms, Cohn is expressing the need for LabPhon to have a paradigm: a conceptual framework that identifies and integrates the most important issues within a scientific field

Kuhn distinguishes the practice of science as qualitatively different Pre-paradigm vs post-paradigm

Cohn’s critique initially seemed to me to locate laboratory phonology at the pre-paradigm stage in Kuhn’s analysis...

Kuhn (1970) The Structure of Scientific Revolutions

Pre-paradigm research: fact-gathering by different schools

"pre-paradigm period" characterised by different schools in which "different men [sic] confronting the same range of phenomena, but not usually all the same particular phenomena, describe and interpret them in different ways."

(Kuhn, 1970, p17)

Fact-gathering may appear random or yield a "morass" of information that is hard to integrate

Example: “Pre-paradigm” investigation of electricity

"During that period there were almost as many views about the nature of electricity as there were important electrical experimenters....All their numerous concepts of electricity had something in common – they were partially derived from one or another version of the mechanico-corporeal philosophy that guided all scientific research of the day. In addition, all were components of real scientific theories, of theories that had been drawn in part from experiment and observation and that partially determined the choice and interpretation of additional problems undertaken in research. Yet through all the experiments were electrical, and most of the experimenters read each other’s works, their theories had no more than a family resemblance." (Kuhn, 1970, pp13-14)
Investigation of phonological representation

"...there were almost as many views about the nature of phonological representations as there were important laboratory phonologists. All their numerous concepts of phonology had something in common – they were partially derived from one or another version of the generative and information-processing philosophies that guided all linguistic research of the day. In addition, all were components of real scientific theories, of theories that had been drawn in part from experiment and observation and that partially determined the choice and interpretation of additional problems undertaken in research. Yet though all the experiments were about phonological representations, and most of the experimenters read each other’s works, their theories had no more than a family resemblance." (words in italics modified from Kuhn, 1970, pp13-14)

Pre-paradigm fact-gathering?

- Suprasegmentals and ethnic stereotypes in New Zealand
- How acoustically-reduced forms activate the lexicon: Evidence from eye-tracking
- An investigation of unaspirated dental and retroflex stops in Bangla
- Phonetic variation and phonological phrasing: Does the Accentual Phrase exist in Italian?
- Can auditory distractors disrupt speech execution?
- Greek-Australian bilinguals match the VOTs of Greek and Australian English native speakers depending on language context

Truly integrated models require a scientific paradigm

Paradigms (disciplinary matrices)
- common body of belief taken for granted
- shared assumptions & values
- agreement about important previous findings
- a group-licensed ability to see a variety of situations as similar
- guide the whole group’s research by permitting selection, evaluation and criticism of data, theory, and methodology
- are more successful than their competitors in solving a few problems that the group of practitioners has come to recognise as acute

(Kuhn, 1970)

What a paradigm is not

- shared theories or models (too specific)
  - There can be many theories and models, each framing the high-level assumptions of the paradigm in a manner that allows them to be tested in a specific context
- Conclusion: LabPhon has a paradigm that embraces a range of theoretical perspectives and models

LabPhon: "shared commodities in a free-trade zone"

3 commodities
1. Shared interest in mind-matter relationships
   "relationship between the physical reality of speech and the cognitive representation of language" p 5
2. Autosegmental-metrical phonological theory
   "hierarchical data structures from different time scales…analysed in a single theoretical framework” pp6-7
3. A new interest in “relationship between levels of representation and the social function and social context of language” p 6

(Pierrehumbert & Clopper, in press)

Commodity 1. Mind-matter relationships

Embodiment
- Physical properties of the body, sensory organs, motor system, structure of the task and environment are all important in shaping speech behaviour
  (Steels & de Boer, in press)

Current progress
- Experimental phonetics and psycholinguistics
- Connectionist and statistical learning models in many areas of interest to LabPhon - e.g. Rule-based Learner, Shortlist, TRACE, WEAVER, DIVA, Dell…
Connectionism: “nice effects for free” (Dell, 2000)

- Properties of
  - spreading activation and learning
  - distributed representations over many units & connections
  - outputs that are sensitive to constraints on the task and the input
- Elegantly explain frequency, similarity and sequence effects
- More broadly: "The kinds of theories that benefit most from a connectionist perspective are those that emphasise the role of learning and recent experience, graded rules, constraint satisfaction, and how knowledge is used in actual tasks. From what I’ve seen, that looks like current theory in laboratory phonology" (Dell, 2000, p 348)
- These emphases coincide with the acute problems that a paradigm identifies

Parallel distributed processing (PDP) network

Rumelhart, 1990, adapted from McClelland & Rogers, 2003

Category "bird" emerges from overlap between all instances

“bird” category structure is different to “trees & plants” category structure
Q. Is there evidence for or against the existence of abstract phonological categories?

A. Evidence FOR multiple levels of structure, including but not restricted to traditional phonological categories -
   - Walter: Observed vs expected co-occurrence of vowels vs consonants in Croatian (underattestation of co-occurring Cs but free co-occurrence of Vs) and Spanish (underattestation of co-occurring Cs and co-occurring Vs, weaker for Vs)
   - Elegant and persuasive evidence for a category of vowels that behave differently to consonants in respect to expected co-occurrence in Croatian and Spanish

Q. Is there evidence for or against the existence of abstract phonological categories?

A. Evidence FOR multiple levels of structure, including but not restricted to traditional phonological categories -
   - Cutler: abstract representations corresponding to phonemes allow generalisation of learning about unusual fricative production to untrained words produced by training speaker containing those fricatives supports abstract pre-lexical representations rather than extreme episodic models (Cutler’s results also not simulated by MINERVA-2)
   - Comment: specificity of learning compels a learning mechanism that is sensitive to speaker characteristics as one aspect of environmental structure extracted; lexical generalisation demonstrates that information about this structure is stored

Q. Is there evidence for or against the existence of abstract phonological categories?

A. Evidence FOR multiple levels of structure, including but not restricted to traditional phonological categories -
   - Beckman & Edwards: found some, but not all, of the correlations they predicted between articulatory complexity, frequency within and across languages, and production accuracy for consonants in 2-3 year olds acquiring Cantonese, English, Greek and Japanese
   - concluded that consonants that would be classified as the “same” under traditional phonological theory are based on different cognitive representations in each language – and, by implication, in each child - because these are learned on the basis of the content of the child’s growing lexicon

Q. Is there evidence for or against the existence of abstract phonological categories?

Comment: a major source of input to the child’s developing language system is lexicon of the language they are acquiring, and their statistical learning mechanisms are extracting the structure present in the lexicon

However

Beckman & Edwards also discussed some of the difficulties in developing equivalence classes that captured articulatory similarity across languages & noted the need for finer-grained distinctions than phonemic categories to capture consonant equivalence.

Comment: This would also suggest that the structures needed to analyse the data do not perfectly correspond to traditional phonological categories

Q2. What types of statistical generalisations emerge from the lexicon?

Pierrehumbert 2003: suggests that viable theories will contain “a ladder of abstraction” with each level having its own representational apparatus

Comment: maybe our theories of abstraction need to contain something more like a climbing wall than a ladder

• Chunks and lumps (probabilistic categories) of different sizes distributed over the available space emerge partly as generalisations over the lexicon of the language(s) you acquire
Q2. What types of statistical generalisations emerge from the lexicon?

- Frisch et al: well-formedness judgments reflect both size of vocabulary and relative strength of L1 and L2; phonotactic knowledge is based on “emergent generalisations based on the individual’s unique linguistic experience” p1
- Cutler: generalisations about prosodic structures are also learned

Kapatsinski: RBL simulations and human artificial language learning

- Competition between possible I/O mappings is resolved by comparison of relative reliability of mappings, “the number of words to which the rule applies divided by the number of words to which it could apply” p1
- Velar palatalisation rules estimated over the whole Russian lexicon do not know about the structure of English loan words, so although highly reliable for Russian, they fail for velars in English loan words

Comment: extraction of structure extends to morphological alternations correlated with differing segmental content in stems

Inability to account for non-local effects (e.g. vowel harmony) shows that eventual learning mechanism will be based on correlations that are more complex than linear strings of features, segments etc (discussion of Frisch’s paper also raised this issue)

Abstract phonological categories
...but not as we know them

These “nice effects” such as multiple levels of structure and gradient representations emerge “for free” from PDP architectures.

**Does this mean we do away with symbolic theories in Laboratory Phonology?**

**NO!**

We can still use them

We continue to work them for several reasons

1. Traditional categories have a lot of descriptive and predictive power and we can’t all run connectionist simulations

   BUT more importantly -

2. Essential to refine assumptions for statistical learning models - these models are only as good as their assumptions about I/O representations and architecture

   **And at the same time:** we need to acknowledge that verbal/symbolic theories involving discrete categories have limited ability to capture gradience in the data or to make quantitative predictions

   so the two broad methodologies (statistical learning models and traditional phonological analysis) can be complementary

Abstract phonological categories
...but not as we know them

**Do theories based on probabilistic learning mean that we have to do away with innate constraints?**

**NO!** (But maybe they will look different.)

Chater & Manning (2006): statistical learning does not necessarily entail a totally empiricist system - these models can also tell us when constraints must be innate because they cannot be learned/do not emerge from learning.

Commodity 2.
Hierarchical data structures on different time scales

- Pierrehumbert & Clopper (in press) autosegmental metrical phonological representations are multidimensional, consisting of independent tiers linked to each other. Need to incorporate social structure tier(s) in future.
- Dell (2000): “dream model” mappings between acoustic-phonetic units, articulatory units and lexical-semantic units

Plaut & Kello, 1999, Fig 1
2. Hierarchical data structures on different time scales

A crucial factor of both approaches is the mapping between different types of information that:
(i) Allows integration of qualitatively different data structures
(ii) This requires consideration of timing of operations within a data structure, and of how the use of information in different structures is co-ordinated

(ii) Integration of qualitatively different structures
Walter: Observed vs expected co-occurrence patterns differed for vowels vs consonants in Croatian and Spanish

Why are Vs different to Cs?
- Inventory size (French > Spanish, Croatian)?
- C PoA conveys more lexical information than vowels?
- C require more articulatory effort (so disprefer repetition)?
- Tracking V probabilities takes more computational resources so disprefer using this information?
- V vs convey most information on F0 channel including speaker-indexical information

Comment: language x articulatory properties x cognitive resources x indexical information may all contribute to this pattern in Walter’s data so need a model that can integrate them

2. Hierarchical data structures from different time scales

Cutler: segmentation then lexical competition effects are contingent on segmentation
Kapatsinski: critical effect of penultimate segment only found when the stem extension (-i, -a) is chosen at the same time as the decision to palatalise the suffix

Comment: Currently, models sometimes capture temporal and sequential properties of processes specific to one data structure. There is also some work on entrainment between systems, and on timing of the sorts of processing of information represented by independent tiers of an autosegmental model (e.g. availability of prosodic versus segmental information, Shelton et al at this conference). Eventually, if LabPhon begins to use information about brain function to constrain theories, time-course information can be obtained from ERP, MEG methodologies.

Commodity 3.
Multiple factors within and outside the individual

- A development of Commodity 2: a new-ish interest within LabPhon in the "relationship between levels of representation and the social function and social context of language" (Pierrehumbert & Copper, in press, p 6)
- view speech and the representation of language as part of bigger systems and constrained by them

Comment: need to know limits of each contributing factor

What is the contribution of each individual factor?

Comment: Cross-linguistic work can tell us to what degree are the emergent structures used in language processing due to the structure of the ambient language (and thus, what else still has to be explained)?
- Cutler, Beckman & Edwards, Walter: design of study involved investigation of same question across languages. Beckman & Edwards: what is due to biology & what to lexicon?
- Frisch et al: relative contributions of 2 languages in the same speaker
- Kapatsinski: applied RBL previously used to model English (Albright & Hayes 2002, 2003)

Summary

To understand the relationship between the cognitive and physical aspects of human sound systems, we need to understand relationships between human auditory, articulatory and learning systems, linguistic and indexical/speaker-specific data in the speech signal, performance factors (attention, executive processing), task demands and social context

Comment: This is complex
“The bottom line…

you have to do a lot of phonology and phonetics before your model is going to get off the ground.” Dell 2000 p 348...

• ...and we can do this within the multiple streams of Labphon given a shared paradigm that embraces shared assumptions about the acute questions and most important observations
  – Mind-matter relationships
  – Hierarchical data structures on different time scales
  – Theories that capture multiple factors within and outside the individual