

# Review of Dynamic Approaches to Phonological Processing

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## Abstract

*Dynamic Approaches to Phonological Processing* by Hunter Hatfield (2023) explores phonological processing from a dynamic psychological perspective, which is beneficial for the study of language attrition in the elderly population. Hatfield integrates insights from psycholinguistics, cognitive science, and dynamic systems theory to argue that phonological representations are fluid and continuously updated during speech perception and production, emphasizing the importance of temporally sensitive methods, such as eye-tracking and electrophysiology, to better capture the real-time unfolding of phonological processes. Topics addressed include lexical activation, gradient phonological representations, articulatory planning, and multimodal integration. Hatfield advocates for methodological and theoretical shifts in the study of phonology, encouraging a move away from rigid models toward approaches that reflect the complexity and variability of spoken language use.

**Keywords:** Dynamic approaches, Phonological processing, Lexical activation

## 1. Introduction

The book of *Dynamic Approaches to Phonological Processing* was written by Hunter Hatfield (2023), published by Cambridge University Press. It is one of the series of *Elements in Psycholinguistics*. Hatfield (2023) presents dynamic approaches to studying phonological

processing from a psychological perspective in his book *Dynamic Approaches to Phonological Processing*, which is divided into eight chapters. Grounded in the recognition of temporal aspects within natural language, the book argues that models in speech production, perception, and seriality offer valuable insights into understanding phonological structure. Hatfield hypothesizes that the phonological system interacts with mechanisms of speech production and perception at specific processing stages. Notably, the book contends that phonological derivation during speech processing transcends the structural calculation phase. Moreover, Hatfield highlights a key controversy surrounding dynamic models, namely their departure from hierarchical structures such as syllables. The book concludes with a summary of modalities in production, perception, and seriality, showcasing their capacity to effectively represent speech as a temporal process.

## **2. Contents of Dynamic Approaches to Phonological Processing**

Chapter One of the book delves into dynamic perspectives in phonological processing, serving as the primary focus of the study. It comprehensively addresses the temporality inherent in linguistic perspectives, contrasting common spatial metaphors employed in linguistic theories with the temporal nature of natural speech. The chapter advocates for mapping the relationship between phonological derivatives and cognitive processes such as speech production and perception. It illustrates sequential configurations influenced by factors like word length, vowel changes, and prosody. Moreover, the chapter discusses how production and perception systems interact with phonological representations, highlighting major temporal factors such as simultaneity and event ordering. It also scrutinizes whether a temporal view obviates the need for hierarchical structures like syllables. Additionally, the chapter critically examines background knowledge in phonetics, phonology, and psycholinguistics, using modern linguistic approaches to elucidate diverse concepts and evaluate proposals for different temporal phonological models and representations. It also discusses challenges that may arise due to this shift in chronological perspective.

Chapter Two outlines the serial ordering in both speech production and comprehension, focusing on constituent units such as phonemes and syllables and their contextual factors. The chapter illustrates that the selection algorithm operates on a competitive queuing basis, wherein items compete by activating their levels to be selected sequentially. The context of learning acts as a cue for setting up these activation levels. Specifically, the chapter introduces the dynamic OSCAR system, comprising oscillators with multiple frequencies to structure sound. OSCAR utilizes oscillator-based context features alongside phonetic feature vectors as item representations, facilitating the regeneration of serial recall information by incorporating the context signal to reactivate specific items. In addition, it simulates phonological encoding by employing oscillators for syllable-contexts or segment-contexts, with some oscillators potentially being repetitive to demonstrate similarities among different positions. Furthermore, the chapter discusses how such a system encodes order and identifies errors arising from noise and context similarity. This discussion leads to an examination of studies on similar models, such as articulatory phonology (AP), highlighting the broader implications of these findings.

Chapter Three introduces a theory that integrates AP and the task dynamics (TD) model as a comprehensive framework for speech production, tracking from phonological representation to detailed articulator movements and durations. Within the AP/TD framework, phonological representations are conceptualized as gestures defined over articulatory variables, with movements corresponding to narrowing in the vocal tract and leading to coarticulation effects due to spatiotemporal overlapping. The chapter explores how the task dynamics aspect of the model depicts the interaction of gestural scores in both time and space, drawing an analogy to mass-spring dynamics. Gestural coordination is described as the coordination of in-phase or anti-phase relationships of oscillators. Additionally, the chapter introduces the phonology-extrinsic timing (XT/3C) model of Turk and Shattuck-Hufnagel (2007) as an alternative approach. This model maintains phonemic representations by converting them into acoustic/duration goals, planned using optimal control theory and general tau theory. Moreover, the chapter briefly outlines the differences between dynamic models and feedforward phonological theories, emphasizing key components such as item representations, selection/coordination mechanisms, control processes, and production goals.

Chapter Four describes neuronal oscillations in speech perception and production, beginning with the TRACE model developed at MIT. The chapter then covers oscillations at gamma, theta, and delta frequency bands that correspond with linguistic units like phonemes, syllables, and stress groups, and can synchronize with speech rhythms for the sampling, ordering, and binding of acoustic input. The relationship between theta entrainment and developmental dyslexia, as well as noisy phonological representations, is discussed. The last segment proposes the co-excitation of biological populations in line with the quasiperiodic speech envelope, resulting in the creation of the context signal that maintains serial order and subsequently signifies a unification of oscillation mechanisms in the processing, production, and memory of speech. In addition, the fourth part interjects a question regarding explaining temporal processing with oscillation accounts, supporting the possibility of including oscillations in phonological theory as a catalyst for revising phonological representation and processes through the lens of dynamic modeling. The author hints at the fact that showcasing the temporal features of utterances is sufficient, but at the same time, insufficient to illustrate regular phonological phenomena like the syllabic stress system, phonological evolution, and non-local processes such as vowel harmony. Ordinarily, only a comprehensive oscillation view can be adopted for such structural phonological contexts.

Chapter Five illustrates Dynamic Intention Selection and Coordination (DISC), a dynamic approach primarily developed by Tilsen (2016), along with studies on dynamic systems and phonology. DISC is built upon AP/TD, incorporating a set of dynamic control mechanisms, with the neural dynamic fields being the most significant. Four key points of DISC, namely intentional planning fields, selection and coordination mechanisms, prosodic dynamic fields, and co-selection sets, are articulated. This chapter focuses on how DISC operates within a timeframe, emphasizing phonological representations as patterns of dynamic activation, suppression, and control over time, rather than static rules or constraints. The theory aims to elucidate how phonological knowledge and motor control are acquired, progressing from selection with external feedback to selection with internal feedback, and ultimately to

coordinated control of co-selected gestures.

Chapter Six deals with the impact of key issues discussed throughout the book on the learning of phonological forms and speech, particularly highlighting vibration oscillators as part of the rhythm mechanism implemented in various language models. The concept underscores the shared role of oscillations in time and language with rhythm, which can be mathematically described through a formal model of oscillation. Additionally, the chapter acknowledges potential challenges associated with oscillator-based theories and proposes additional factors contributing to climatic variations. Moreover, the chapter identifies six recurring concepts from previous literature, delving deeper into the speech perception/production loop and suggesting the incorporation of speed restrictions in models to improve functionality. It also emphasizes the importance of establishing a clear correspondence between acoustic values and articulatory representations. To enhance understanding, the chapter introduces graphics for Taskogram display, showcasing a combination of gestural scores, intentional field activations, and spectra diagrams, with key points exemplified.

Chapter Seven provides a comprehensive review of the contributions made by dynamic theories of phonology. It evaluates their efficacy in addressing a wide array of phonological inquiries, contributing significantly to the field while elucidating the composition of the lexicon. DISC, in particular, offers explanations across diverse domains such as timing, uptake, concord, phonological processes, syllable structure, stress, typology, and underlying linguistic/neurophysiological processes. The broad scope of implementation necessitates reformulation of foundational phonological hypotheses. Furthermore, the chapter explores the integration of phonology with speech production and perception, emphasizing its paramount importance. It showcases how Harper employs dynamic fields to model socio-phonetic variation, effectively tackling the challenge of unifying variable data stemming from phonological patterns. Addressing the issue of lexical representation, the chapter proposes a DISC-inspired framework wherein words are conceptualized as units of connection weights within semantic fields, with intentional planning serving as nodes. These connections, varying in strength, correspond to specific articulatory targets. Furthermore, the chapter explores the potential of a network-based lexicon in mapping serial order, summarizing the dynamic model's role in providing a comprehensive explanation of phonological patterns, the cognitive processes structuring these patterns, and the functional relationship linking production and perception aspects of speech. It offers fresh insights into various representational issues within the field.

Chapter Eight concludes by emphasizing the dynamic nature of phonological processing, highlighting its complexity beyond mere technological implementation details. It suggests that core phonological algorithms and operations may require complete revision. The chapter explains that the continuous activation observed in dynamic models such as DISC reflects an inherent property of the brain's dynamic nature. It discusses the concept of machine thinking in terms of energy flow constancy and patterns of energy movement. Furthermore, key ideas are explored, including the concept of creation arising from the organization of information to reduce initial randomness. The chapter discusses oscillations as essential ripples of

compressing energy waves necessary for brain function, as well as various models based on combining energy from different inputs. Additionally, the chapter examines language theory regarding constituents, advocating for a transition from conventional concepts to prioritizing control processes and activation dynamics. It encourages viewing language as a dynamic system characterized by energy and information flow over time.

### **3. Discussion and Evaluation**

In a nutshell, the chapter underscores the importance of considering not only time but also space in understanding evolving systems, viewing them as stemming from the motion of energy, which in turn drives various structural changes. This perspective prompts a shift in research interests and approaches, leading to the creation and investigation of control architectures for phonological patterns.

The book advances in phonological study and becomes a new influence on phonological theory. It is valuable for researchers who are experimenting with the dynamic and temporally-related branches of speech and phonological processes. The book is remarkable for its exemplary discussion of different approaches that represent the necessarily time-dependent nature of speech, often ignored by classical linguistic theory.

Hatfield's writing style is lucid and understandable through the categorization of concepts and clear examples. The discussion provides notable theories underlying dynamic phonological models, emphasizing seriality, gestural coordination, oscillator-based timing mechanisms, and the integration of perceptual and production elements. The analysis draws from both current and classical sources, establishing a strong theoretical foundation complemented by the most recent empirical findings and modeling advancements. This broad range is manifested in an understanding of the motivation and problems that dynamic approaches seek to address.

The book presents exceptional conceptions of phonological representations, moving away from static rules or constraints to dynamic layouts of activation and control over time. The idea of using energy flow operations and patterns to understand language computations is introduced, opening up prospective ways of investigating the neural control architecture behind phonology. For example, through the analysis of the DISC (Dynamics, Intention Selection, and Coordination) model, which features a fascinating set of control mechanisms like intention fields and joint coordination processes, a convincing argument is made about how phonological perception and the coordination of articulation muscles develop through external feedback to fine-tune intrusion. The connection between oscillator-based timing and gestural scorings, marked with competitive queuing, explains phenomena such as syllable weight, harmony processes, and the temporal dynamics of coarticulation.

### **4. Conclusion**

Overall, this book is beneficial for those seeking a thorough and stimulating discussion of neuroscience in language learning. Fundamentally, its implication is not just to redefine conceptual temporal phonology but to prompt readers to rethink the origin of language as a phenomenon based on the flows and forces of dynamic energy rather than rigid rules and

regulations, especially in light of the emergence of ChatGPT. Equipped with a sophisticated research methodology, informed analysis, and innovative viewpoints, Hatfield's book is expected to have a far-reaching effect on the development and further comprehension of linguistic theory that acknowledges the human mind's central role in speech processing.

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