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Articulatory Phonology: A Dynamical Approach to Phonological Representation

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Abstract

The Articulatory Phonology (AP) is a dynamic model of conceptualizing phonological representation in the importance of gestures, or coordinated motions of the vocal tract, in the construction of speech. AP is non-traditional with phonological units, in contrast to the traditional models which are based on non-continuous units or features, as being continuous, and gestural actions of a temporal organization, interacting with each other in a manner that is real-time during speech production. It combines the phonological theory with the biomechanical constraints, which put prominence on the articulators' movement being correlated by the linguistic and physical constraints. An important feature of AP is attention to gestural timing, coordination and recoverability of speech patterns across languages which shows the variability of phonological units in response to efficiency, distinctiveness and robustness trade-offs. Coarticulation and reduction are also natural conclusions of the task-dynamic control and prosodic structure accommodated in the model. In addition, AP enables combining multimodal information in order to identify the fine-grained articulatory processes and draw links between phonological theory and overt speech behaviour. The model provides information on the topic of language acquisition, speech disorders, and second-language-learning by placing AP in wider cognitive and neuro-biomechanical contexts. This paper presents the way in which AP offers a unitary perspective of phonology which is both language and physiologically based and gives further direction in conducting research in phonological modelling and speech technology.

Keywords: *articulatory phonology; audio-visual corpora; gestural timing; coupling; task-dynamic simulators; cross-linguistic aspects*

1. Introduction

Phonological structure of words used is usually said to be based on a finite number of underlying units which are assembled in language-specific manners. These units are represented as gestures in Articulatory Phonology (AP): they are both units of phonological contrast (combinatoric) and of action during speech production (Browman and Goldstein, 1986). It is such a dual role of gestures that distinguishes itself as a departure from the traditional phonological models, in which the mediation of the phonological representations occurs by grammatical structures. In comparison, AP assumes that phonological representation and its articulation in speech do not have any intermediate grammatical mediation. In its turn, the organization of gestures interacts directly with the processes of speech production (Browman and Goldstein, 1992).

Gestures in AP are characterized by the fact that they are coordinated in the speech production system, i.e. the control of constrictor systems in the vocal tract (tract variables). These tract variables are task-specific and abstract, and not in relation to individual articulator movements. AP describes the units of phonological representation as dynamic systems, which are the atomic gestures, and the larger coordinated systems (gestural molecules). They are,

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therefore, stable in form or resistant to perturbation in addition to being able to deform to accommodate varying performance dimensions (Goldstein, Byrd, and Saltzman, 2006). This dynamical system perspective provides a paradigm that explains the inherent variability of speech that has the coexistence of invariance as well as variation.

Body language is synchronized into a very organized network of gestures. This is where coordination of articulators lies at the core of the process of coarticulation, where articulators are recruited at the same time by rival gestures, which explains the variability observed in the spoken language (Ohala, 1990). In the Articulatory Phonology, it is possible to encode phonological contrast in three manners: the existence or lack of a gesture, dynamic parameterization of a gesture (target or equilibrium position of a gesture), and relative co-ordination of gestures (Browman and Goldstein, 1986). These formulations of the gestural control solve the issue of the variability of phonemes that has been long time observed by both phoneticians and phonologists (Ladefoged, 1993).

Even with these achievements, Articulatory Phonology still has a number of challenges it faces. The issue of how to explain the flexibility and variability in the expression of words in natural speech has long been a problem of traditional phonetics and phonology. AP offers a viable answer in that it is variably allowed at the level of performance but on a stable level of control (Saltzman and Munhall, 1989). Nonetheless, not all of the problems are solved yet, and one of them is the necessity to have a more extensive perception of the gestural dynamics, the specifics of coarticulation, and how the speech production is affected by the prosodic and cognitive factors.

One of the most formidable problems is extending the existing model of Articulatory Phonology so as to accommodate the phenomenon that do not easily match the existing model. As an example, the dynamical system models may need some modification to capture the interaction of speech gestures with higher-order processes like speech rate, prosody and phonological encoding in connected speech. Moreover, it is still debatable that the perception of the listener plays a significant part in the formation of articulatory gestures and it needs to be investigated further (Ladefoged and Johnson, 2011). Such a relationship between the production and perception highlights why it is necessary to have a more amalgamated look into the study of phonology, one that takes into account the perspectives of both the speaker and the listener.

Although Articulatory Phonology has managed to answer numerous of the classical questions in the field of phonetics and phonology, it is evident that the discipline still has several questions that would entail the development and growth of the theoretical and empirical framework. These are not only the problems of Articulatory Phonology but of any phonological theory. However, a more gestural theory of lexical representation can be able to help us find answers to these questions, particularly by giving us a more detailed explanation of the variability and coordination that involves spoken language. In that way, the further studies need to be aimed at the improvement of the gestural model, the elaboration of the new experimental methods, and the study into the connection between the speech production and perception.

2. The Articulatory Phonology Framework: Addressing Phonological Representation and Variability

A lot of studies in the Articulatory Phonology (AP) paradigm has been concerned with the phonological representation of words as well as the variability in their actualized forms and how this variability can be effectively encoded. The postulation of abstract, dynamically specified, and underlyingly stable phonological units is one of the major principles of AP. These units limit the number of potential variations of the forms of words, and they affect the way the variability that is present in speech can be accounted. These limitations have helped in the formulation of models explaining gestural overlap, reduction and cross-linguistic variation especially in the syllable structure and casual speech phenomenon such as assimilation and reduction (Browman and Goldstein, 1986).

Namasivayam et al. (2025) tested phonological error patterns in preschool children with speech sound disorders through the articulatory basis of these disorders. The researchers determined that motor limitations in jaw, labial-facial and lingual control are significantly correlated with certain phonological errors such as cluster reduction, deletion of final consonants and gliding using the advanced statistical methods like Mutual Information Analysis and Random Forest Models. Their results undermine the classical thinking on cognitive-linguistic approaches to understanding speech motor limitations through the significance of articulation limitations in explaining phonological

errors in children. This research paper emphasizes the fact that Articulatory Phonology is a more detailed perspective of speech sound disorders because of the interaction of motor control and phonological development.

The critical review created by Iskarous (2022) is devoted to the Articulatory Phonology and Task Dynamics, discussing their contribution and challenges in the 21st century. The paper does not present any new empirical findings, but it judges the progress in the theory and the current weaknesses of these frameworks. Iskarous explains the role of dynamical systems integration in transforming our perception of gestural coordination and phonological representation, and points to where more research is required. The development of this work can be valuable in placing the present position of AP in the larger context of the phonological theory, and it is significant to predict the prospective research in the spheres of speech production and speech perception.

Geissler et al. (2025) discuss the significance of gestural coupling and syllable pulse in the process of articulatory control that can make a significant contribution to the field of gestural coordination in Articulatory Phonology. It explores the role of gestures-syllable time organization interaction in the speech production dynamics. The researchers are able to examine the connections between different articulatory gestures and syllable structures, which would give a better insight into the process of speech production in real time. This paper lays emphasis on the significance of the study of time and space coordination in articulatory phonology to expose the mechanisms underlying the production of fluent speech.

Tandazo et al. (2024) dwell upon the computational simulations of the articulatory paths on the basis of phonological features as pseudo-motor commands in a speech perception-production loop. The researchers in their study examine the efficacy of different interpolation methods in producing smooth articulatory motions by emphasizing the importance of phonological characteristics in modelling articulatory movements. The results indicate that some of the interpolation techniques (especially natural cubic splines) are more consistent with the articulatory data, and it can provide information about how the phonological representations can be projected on to the articulatory acts. This project leads to the further development of computational models of speech production, especially in the context of the Articulatory Phonology.

Oh (2022) explores the incomplete neutralization phenomenon, in which the author examines the issue of palatalized consonants in Russian and English. The study is done using Electromagnetic Articulography (EMA), which is used to investigate the timing of articulators used in palatalization and the spatial placement of these articulators. The study by Oh shows that the coarticulatory effects affect phonological representations particularly in such a language as Russian where phonological representations of underlyingly palatalized consonants have not been completely neutralized in the speech production. This paper suggests a role of analysing articulatory evidence in making sense of the dynamic character of phonological operations and contribution of coarticulation to formation of phonological representations giving novel information about what Articulatory Phonology can say about neutralization patterns. These works are indicative of the recent work in Articulatory Phonology, all of which have contributed to the understanding of how the mechanisms of gestural coordination, motor control, and dynamical systems can be combined in order to describe the process of speech production and phonological patterns. They all emphasize the current developments and challenges in the direction underlining the significance of an interdisciplinary method of phonology study.

Allophony especially in the context of syllable structure has also been attended to. The recognition of syllable organization as a pattern of gesture coordination and not simply a position has contributed to a closer look of the variations in consonants in onset and coda. Indicatively, the internal timing and coordination are observed to vary among consonants in the onset and codas with reference to the syllable nucleus (Browman and Goldstein, 1992). The gestural relative timing has been used to provide a beautiful model of distributional patterns of light and dark /l/ and nasalized vowels in English (Goldstein, Byrd, and Saltzman, 2006). These results indicate that articulations of consonants and vowels in syllables are closely associated with gestures timing and coordination, which implies that timing is also a major factor in the expression of allophonic variation.

Nevertheless, there are still two major issues concerning the role of relative timing in phonological variation that are going to be resolved. One, a dynamical instead of rule-based description of relative timing patterns needs to be developed (Saltzman and Munhall, 1989). Although conventional rule-based methods offer a scheme of predicting

phonological patterns, they do not have the capacity of explaining the continuous and context-dependent aspect of gestural timing. A dynamical systems approach provides more detailed explanation of timing control and its variation in various speech situations.

The second difficulty involves the issue of the explanation of why some situational timing patterns have been developed, especially the syllabic positions, such as onsets and codas. It has been established that there are variations in pattern of gesture coordination in various languages, but the evolutionary and functional mechanisms behind such variation are not very clear. This question is concerned not simply with the synchronic structure of the gestures, but with the diachronic evolution of phonological structures (Ladefoged and Johnson, 2011). The problems notwithstanding, considerable progress has been achieved in this respect, and recent research has assisted in gaining a clearer view of dynamical nature of phonological timing and its place in allophony (Saltzman and Munhall, 1992; Byrd and Saltzman, 2003). The Articulatory Phonology framework has already given important information on the representation and variability of phonological units, while there are still difficulties in the comprehensive understanding of the nature of relative timing and development of contextually specific gestational patterns. As future work, dynamical explanation of gestural coordination can be further improved and the evolutionary forces which act behind phonological variation can be explored.

3. Challenges in Gestural Representation and Prosodically Structured Variability

The definition of prosodic variability is still one of the key issues of phonetic and phonological studies, especially in the context of the Articulatory Phonology (AP) school. This is complicated by the fact that it is difficult to identify articulatory kinematics with control mechanisms. Consequently, much of the recent research in this field is necessitated by the need to model in order to gain a more in-depth insight into the complex association between prosodic organization and articulatory action (Saltzman and Munhall, 1989). Although there have been studies that have examined various ways of manipulating the gestural parameters to explain the variability in prosodics, there have been recent studies that have challenged the validity of such mechanisms especially in term of phrase boundaries.

The problem of how phonological structures at the level of the word, especially the prosodic one, are coded and how they are connected with articulatory performance is one of the key problems of the Articulatory Phonology (AP) framework. Although a significant amount of research has been carried out in AP on the dynamic aspect of the atomic gestural units and the more complex gestural molecules, very little has been conducted on the interaction between the prosodic structure, such as juncture, intonation, lexical stress, and focus, and the expression of the gestural timing and activation (Browman and Goldstein, 1992). These facets of prosody are a comparatively recent area of exploration of the AP framework which has hereto focused on the gestural expression of individual words.

Prosodic organization may affect articulatory realization in a range of ways in terms of the Articulatory Phonology. According to one approach, the prosody may affect the gestural parameters directly (i.e. target values or equilibrium positions) and their relative timing. But this much is possible depending on the investment in the stability of gestational molecules as the medium of lexical representation. In case the gesture specification of a word can differs considerably in different prosodic contexts (e.g. stress or emphasis), the assumption of constant, canonical word forms would be in question. In order to maintain the idea of stable lexical representations, it can be assumed that values of gestational parameters can be restricted to lie within certain ranges of variation or windows of variation (Saltzman and Munhall, 1989). This would permit an account of the influence of prosodic structure over the gestural specification in these limited ranges which is principled.

The other possible methodology in a dynamical approach would be to modify the manner in which gestures are activated. Prosodic structure might have an effect on the dynamics of gestural activation paths, rather than changing gestural parameters or their relative timing. This would imply that the unfolding of gestural activation depends on the prosodic context which does not only influence the gestural parameters, but also influences the relative timing of the gestural parameters (Goldstein, Byrd, and Saltzman, 2006). Variations in patterns of gestural activation, associated either with particular prosodic locations or moments, can also cause changes in values of the continuing parameters of gestures and timing constraints among gestures.

In order to have a more insight about how a gesture score can be changed by prosody, one can consider a number of mechanisms that could be involved. First, prosody might modify directly parameter values or time interval in certain periods which terminate a prosodic event (prosodic gesture) (Browman & Goldstein, 1992). Alternatively, the prosodic structure may have an effect on the occurrence of gestural activation functions whether in particular prosodic position or in an interval that occurs that marks a prosodic occurrence. Such changes in the gestural activation can have far reaching implications both to the value of the parameters themselves, and also to the relative timing of gestures giving a more dynamic and flexible explanation of the interaction of prosodic information with phonological structure.

Nonetheless, the potential of these methods, even though considerable, still has many limitations to an overall model of the manner in which the prosodic structure is implemented in gestural phonology. With the evolution of the products of the relationship between prosody and gesture, the effects of the prosodic structure on the phonological realization will probably disclose significant information concerning the flexibility and variability of the speech. To continue, the incorporation of these features of prosody into the gesture system will demand further research on how the prosodic structure can alter the gesture timing and activation, and how it will impact the phonological representations.

Byrd and Saltzman (2003) also propose a less static model, proposing that the boundary of phrases be represented as being "p-gestures" (gestures of prosodic nature), which also have their own inherent temporal characteristics. Such p- gestures are believed to have a timing effect in the timing of speech by decreasing the central clock governing the activation paths of gestures. This model has been promising in the observation of kinematic patterns at the boundaries of phrases where manipulations of the gestural parameters are usually inadequate in explaining the articulatory behaviour that is observed (Byrd and Saltzman, 2003).

Outside of phrase boundaries, there are also prosodic variability effects of accent (focus) and lexical stress on the production of word forms. Durational and timing effects were also reported in kinematic studies examining the articulatory behaviour in the state of stress and accent, which have been attributed to linguistic prominence (Ladefoged & Johnson, 2011). These are the studies which point out the fact that stressed and accented syllables have dissimilar timing relationships to unstressed syllables and that there is a modification in the length and relative timing of gestures (Goldstein et al., 2006). But like in phrase boundary prosody, the dynamics of these changes is not so simple. It is likely that the control mechanisms on various parameters and/or gestural activation are in effect and this explains the complexity of prosodic structure and its influence on speech production (Saltzman and Munhall, 1992).

The important problem in explaining the variability of prosody is that it is important to combine these dynamic influences into a single model of gestural control. Though the research on the influence of prosodic elements on articulatory performance has been established, the mechanism behind this effect has not been identified. Further studies are required to determine the mechanisms of implementing changes in prosodic structure by stress, focus, and phrase boundary through the control of gestural activation and parameters values. Systematic dynamical systems model that would embrace all these factors would provide useful clues into the intricacy of prosodic variability in speech.

4. Sounds of the World's Languages and Biomechanics and Gestural Control

A major issue with the Articulatory Phonology (AP) system is the overall description of the sounds of all languages of the world. Although AP has achieved much in the modelling of speech production, it has failed to explain the full spectrum of linguistic sounds with some of them not falling within the usual pulmonic sounds of most languages. Other tract variables have to be defined to represent non-pulmonic sounds, such as clicks, implosives and ejectives. They pose more delicate model of types of constriction especially taking into consideration opposite phonation (e.g., creaky and modal voice) and tonal differences in languages with lexical or grammatical tone (Browman and Goldstein, 1992). What is more is that the existing size of the constriction location, degree, and orientation can possibly be extended to accommodate the varying constraints shaping of the fricatives, liquids and other intricate sounds (Ladefoged and Maddieson, 1996). More specific model of vowel representation is required also to explain contrasts like tense/lax and advanced tongue root (ATR) that are critical in languages like French and most African languages (Ohala, 1983).

On tonal structure, the intonational structure is open to the question of whether the same setup used in the lexical tone can be used to represent the articulatory gestures of intonation. In case such a task space were discovered, it may give an understanding of the way that the phonological representation of intonation, as proposed by Pierrehumbert and Beckman (1988) is enacted in a gestural context. This is a constant problem to AP since it tries to consider the lexical and the prosodic aspects of speech in a concerted approach. It is important to note that although a lot has been done in the study of the phonological primitives that produce speech, biomechanical plant is essential in the development of the kinematic and acoustic effects evident in speech production (Saltzman and Munhall, 1989). The interplay between the anatomical limitations of the vocal tract and the linguistic gestural model of Browman and Goldstein is a significant challenge in the future research studies. The main aim is to build a three-dimensional, interactive model of the vocal tract including the tongue and larynx and connected to an articulatory synthesizer so that an analysis can be done on the model. This would enable more precise simulations of the speech production mechanism and give more insight into the impact of biomechanical factors on the articulatory coordination.

Furthermore, the aspect of the ease of articulation that was previously thought to be simply a result of the physical properties of the plant (i.e. metabolic expenses of articulation) can now be incorporated into the abstract dynamical viewpoint of Articulatory Phonology. Articulatory ease, in this perspective, is an effect of dynamical efficiency at both systems and task levels, which can be used to offer reasons as to why articulation is optimized in a variety of languages and in a variety of speech situations (Pouplier, 2005). The biomechanical implications of AP models will contribute to our knowledge on the interaction between the physiology of speech and the phonological representation.

5. Activation Dynamics

Articulatory Phonology (AP) is a dynamic explanation of the phonological representation, in which time and the timing are important in the process of the speech production. Indicatively, it is impossible that a chemist could explain a chemical reaction without knowing the underlying atoms and molecules, which would be the same case with phonological patterns under the condition that phonologists do not have a proper conceptualization of the atomic units and their dynamic properties. Articulatory Phonology offers significant information about the nature of these phonological units and this can be used to shape the constraints in Optimality Theory (OT). Such observations also indicate what elements of the speech patterning are to be reflected in the constraint-based grammar and what elements can be produced by the lexical entries, underlying forms, and their articulatory images (Browman and Goldstein, 1992). As it discusses general phonological questions, Articulatory Phonology redefines the problems by defining the nature of vocal tract constrictions as linguistically relevant dynamic units.

The present models of gestural coordination are based on the rules defining the interruption between gestures. A more refined strategy though, would be to dynamically capture such relations so that overlapping patterns of activation can be created in a flexible manner as real-time speech is produced (Saltzman and Byrd, 2000). This would remove the need to have fixed rules that regulate the coordination of gestures and enable the synthesis of the syllabic, stress and prosodic structure in real time according to the dynamics of activation. In the behaviour of the gestural network, the traces of the activations of gestural units formed by the language structure would be manifested. This idea of dynamical activation has just started to be developed in the context of the AP and promises a lot of potential in terms of the fluid, dynamic character of speech production. Some steps toward this direction have been made by research by Byrd and Saltzman (2003), which models the prosodic events as non-tract variable p-gestures, in which the activation events are also dependent on the prosodic context. This dynamic approach to activation still requires further development because it can offer an even stronger and richer model of the manner in which linguistic structure is manifested in articulatory gestures.

The connection between lexical entries is one of the main problems of any phonological theory, such as the Articulatory Phonology. In particular, a theory should explain the effects of patterns of phonological units in and between morphological paradigms in the organization of individual words. This understanding can be ensured with the help of gestural approach which will help to give a more specific characterization of lexical entries. This may assist in the reason patterns in the forms of words are formed and sustained. More specifically, the place of similarity of forms of words becomes a significant issue. Although similarity has always been studied in terms of features or sound patterns, a gestural approach can use duration and time related features as a part of identity when having

similarity. As an example, the value of the stiffness parameter that has the potential to be equated with abstract duration may aid in the computation of similarity in a similar manner like constriction location and degree (Walker, personal communication).

The phonotactic limitation which regulates the combinations of sounds that can be used in a language must also take care of any phonological theory. In the case of a gestural approach, this would involve a knowledge of the language-specific gestures combinations that can be allowed in words and syllables and the time patterns that these combinations need to obey. The example of certain phonotactic restrictions being re-cast in a gestural framework has been demonstrated by Browman and Goldstein (1992), although in traditional terms they were seen as feature-based constraints. To illustrate, the phonotactic limitation of aspirate in English syllable onsets, in which only one laryngeal opening gesture is possible, can be simply and elegantly described in terms of the dynamic nature of the gestural model. This constraint explains why there is no occurrence of aspiration in the clusters such as [sC] in English because when a voiceless stop and a [s] gesture are activated the effect is that there is no production of an aspiration (Browman and Goldstein, 1992). This method offers a simpler and more dynamic explanation of phonotactic patterns as compared to the classical feature-based models. The gestural structure also implies that temporal patterns are one of the significant features of phonotactics. One cannot just tell what gestures can be done in what positions; the time and harmony between these gestures should also be determined. The dynamic character of gestural coordination in speech implies that phonotactic constraints can be impacted dynamically as a result of the time of gestures and their interplay. This observation creates new avenues in the understanding of language-specific phonotactic patterns and gives a better and more elaborate explanation of the structure of speech sounds in different languages.

6. Conclusion

Articulatory Phonology offers an influential approach to dealing with general problems in phonology since it deals with the dynamics and temporality of phonological representation. The depiction of phonological units as gestures that have inherent time characteristics makes AP shed light on the relations between lexical entries, phonotactic constraints, the relations between morphological paradigms. The framework also makes it possible to view phonological patterns in a more flexible and dynamic way, which may be determined by the timing and coordination of articulatory gestures. Since the theory is still evolving, it has the potential to provide answers to some of the long-standing questions in phonology and can also provide new insights into the nature of speech sound patterns across languages.

Phonological description involves a description of the formal relations, or correspondences, of phonological units of a word. These relationships may be local and long-distance e.g. in harmony between elements of a word form which must agree, or reduplication which asserts that there is a correspondence between elements of a base and its reduplicant (Harris, 1990). Such relations in traditional phonological theories are frequently characterized by features correspondences or alignment constraints. Nevertheless, with the Articulatory Phonology (AP) approach, there exist special problems and possibilities in the characterization of these relations in a dynamical, gesture-based model. Gestural unit explanation of the correspondence and alignment relations is one of the new directions in AP that are under exploration. The initial research in the field has produced some positive results in outlining patterns of consonant harmony, with Gafos (2002) suggesting a model whereby the activation of attractors of gestures is dynamically set, and thus may increase and decrease over time. This method permits a more fluid conception of the representations of phonological patterns like harmony with the gestural activation being associated with the movement or the modification of articulatory targets. We can mention the concept of activation dynamics, which allows explaining continuous variations in the timing and coordination of gestures which are essential to capture the local and long-range correspondence relations (Gafos, 2002).

In the context of Optimality Theory (OT), alignment has long been handled using constraints, by making higher levels of phonological structure (i.e. syllables or morphemes) correspond to lower-level segments or features. In AP, the issue is how to accommodate the fact that alignment when using phonological units should be temporal as gestures are. Gafos (2001) came up with a strategy of alignment which focuses on the use of articulatory landmarks-certain points in the gestural line which are essential in coordinating higher level phonological frameworks with the related articulatory occurrences. This correspondence is not entirely abstract and is based on the material features of speech gestures, therefore, relating phonological structure to the dynamics of speech production.

Another instrument that is offered in a dynamical systems approach is a system coupling, which can be utilized to provide a model of interaction and influence of various linguistic gestures on each other. Two systems act in a way, which may be influenced by the behaviour of another and this interdependence can be very fruitful in giving us comprehension of phonological relation. In an illustration, one instance of these interdependencies of gestures is the interdependence of the consonantal gestures in a word or phrase that can be explained by the use of gesture coupling. Minor studies of gestural coupling have been done previously (e.g., Saltzman and Byrd, 2000), but how gestures interact and affect each other across longer periods, or relations of coupling between larger gestural structures, which could be called gestural molecules, are an under-explored field. The knowledge of such relations of coupling both on the atomic gesture level, and on the larger gestural structure level, might serve to capture long-distant dependencies and correspondence across phonological units, a more detailed and testable model of phonological correspondence.

Thus, the new perspective to the correspondence and alignment relations should be suggested by Articulatory Phonology because of the dynamical framework. The concept of activation dynamics, the importance of articulatory landmarks, and the idea of system coupling are some of the aspects, which will likely help to refine our knowledge on the relationship between phonological units with each other, both locally and long-range. With a combination of all these tools into one model, we can proceed to a stronger and more dynamic description of phonological structure which ties the phonological theory to the biomechanics of speech production.

The Articulatory Phonology has gone a long way in the formulation and confirmation of the hypothesis that the atomic cognitive components of word representation are both phonological and phonetic. The dynamical approach provided by AP has already given meaningful contributions to the phonological patterns and structures. Nevertheless, there are still issues related to the complete characterization of correspondence and long-distance dependencies and alignment within this model. Further studies of these issues, based on the tools such as activation dynamics and system coupling, will result in a better understanding of phonological structure and its connection with speech production.

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