

The Syllable is Defined – At Last!

Highlights

- Discovery: the definition of the syllable
- Discovery of an unknown function of oral physiology
- Discovery: the syllable is not produced by language but by such oral
- Discovery: The physiological mechanism of alternation runs many body behaviors
- Discovery: the basis of this physiology is shared with other mammals

Abstract

Up to till now the syllable has been judged impossible to define. However, this paper at last supplies the definition and clarifies the problem in defining it. It reveals that the syllable is not a function speech, as it had been intuitively assumed, but the product of a thus far undiscovered aspect of oral biomechanics.

Keywords

syllable, definition of syllable, tongue, stress, speech

1 Introduction

1.1 Defining the syllable

It is puzzling why linguists have not been able to define something as intuitively simple as the syllable. This paper will give the reason for this and it will at last provide a definite definition, also explaining the difficulty met with defining it and why syllables exist in the first place.

Non-technical definitions go no further than stating that the syllable is a unit of spoken language (cf. Merriam-Webster), or that it is a single unit of speech (cf. Cambridge Dictionary). Such definitions merely describe its most evident aspect conveying little information, something that is actually not exceeded in the literature. Removed from defining the syllable the research focuses on topics such as syllable structure, the syllable in phonology, the relations of syllables and stress or pitch, syllables in non English languages, its role in second language learning, etc.

1.2 The syllable remains undefined

The only studies dealing with this topic published between 1958 and 2013 illustrate this situation:

“Stressed syllables are often discussed in phonetic literature. But...the **syllable** is often regarded as a unit which can be apprehended, **but is not easy to define.**” (Ladefoged et al. 1958). “The layman always knows that his language has syllables, but of course **he cannot define the syllable...**[and] one is inclined

to conclude, paraphrasing Voltaire's dictum about God, that *Si la syllable n'existait pas, il faudrait l'inventer.*" (Pulgram 1970).

Few linguistic concepts are at the same time so intuitively clear and so **hopelessly elusive as that of the syllable**. The density of research on this notion has grown relentlessly in the last two decades, but apparently this seems to have increased, rather than reduced, the fog surrounding it. (Bertinetto 2001). "Human beings have been aware of syllables as essential articulatory units for centuries.... While it is obvious that syllables are fundamental to human speech, they have become, as Haugen (1956, p. 213) put it 'something of a stepchild in linguistic description: While sooner or later everyone finds it convenient to use, no one does much about defining it'" (Ramoo 2013).

1.3 (Krakow 1999, Abstract) relates attempts to define the syllable:

The notion that the **syllable is a unit of articulatory organization** has long had intuitive appeal, although a series of studies spanning more than two decades failed to support this hypothesis (cf. Stetson, 1951; Draper, Ladefoged & Whitteridge, 1959; Kozhevenikov & Chistovich, 1965; Gay, 1978; Kent & Minifie, 1977; Harris & Bell-Berti, 1984), etc. [...] Some researchers appeared to give up on the idea that a physiological basis for the patterns would be found or that it was even worthy of further investigation. For example, in his widely cited dissertation on syllable-based phonological patterns in English, Kahn (1976) states that 'it is an unfair challenge to require hard physiological evidence of syllable organization from those that specify syllables as phonological domains, since it is the nature of speech production to obscure abstract and important units of phonological structure, such as the phoneme and the syllable (pp. 16-17).

The majority 'oneme correspondences is the best way to improve phonemic awareness. The alternative **syllabic bridge** hypothesis, based on the salience and early availability of syllables, assumes that learning to associate letters to phonological syllables enables phoneme units to be the mirror of the letters and to become accessible, thereby developing phonemic awareness of prereaders. (Mehler et al. 1981) examines the relationship of segmentation and the syllable. "In this study a monitoring technique was employed to examine the role of the syllable in the perceptual segmentation of words".

(Draga 2007, pp. 161-194) presents an elaborate analysis on the syllable's role in phonology, dealing with its vowel and consonant structures comparing them in a variety of languages: "The syllable has a central role in phonological theory as a constituent that represents phonologically significant groupings of segments [...] The syllable is an abstract phonological constituent without clear phonetic correlates

(Ladefoged & Maddieson 1996). Stetson's (1928) chest pulse theory – once considered the standard physiological characterization of the syllable – was shown by Ladefoged (1967) to be largely unsubstantiated". (Cullinan et al. 1977) recounts experimental results via formant behavior in the perception of syllables. "Recent findings indicate that the presence of formant transitions aids the perception of the order of stimuli in repeating sequences of vowels or consonant-vowel (CV) syllables. In this study, 12 listeners reported the perceived order of four vowels or CVs in repeating sequences." A connection between the syllable and its vowel-consonant content is investigated by O'Connor and Trim:

...the syllable may be defined as a minimal pattern of phoneme combination with a vowel unit as nucleus, preceded and followed by a consonant unit or permitted consonant combination. All longer sequences are to be analyzed as a succession of syllables, the relative frequency of occurrence of various syllable-initial and syllable-final consonant combinations furnishing a basis for determining the point of syllable division in cases where this is not immediately apparent from the above analysis. The syllable is thus established irrespective of accentual features, though it may subsequently be useful to relate the two together. (O'Connor & Trim 1953, p. 122).

(Davis & Zajdo 2010) deal with the relation of the frame-content theory to syllables without regard to a definition of the syllable:

The syllable is a linguistic primitive, a unit found in all languages. It is made up of vowels and consonants which are similarly ubiquitous in the world's languages. These entities are part of the 'starting points' of linguistic and phonetic inquiry. On the basis of their status as 'universals without exceptions,' they are not questioned. They are axiomatically postulated and serve as building blocks in the phonetician's and phonologist's attempts to explain speech and sound structure.

The above papers represent only a small portion of the literature on the syllable and its various connections to other aspects of speech but they amply document a lack of ongoing interest in the definition and etiology of the syllable.

1.2 The initial clue for defining the syllable.

The speech mechanism and its behavior are subject to rules of biomechanics, in which a fundamental behavior is **alternation**, to be outlined below. Alternation means that in a 2-part system first one part executes an action and next the other part executes an action, exchanging functions of the role of prime

mover.

First however, it is important to show that the device of alternation is recognized as a factor in speech production by three authors, (MacNeilage 1998), (Easterday 2019) and (Stetson 1928), although the specific clue leading to the definition of the syllable is only found in (MacNeilage 1998).

The significance of **alternation** is the foundation of MacNeilage's theory of speech evolution. He relates alternation to exchanges between vowels and consonants which together create the syllable in the context of his frame/content structure. While the present paper significantly augments the function of alternation to reach into several aspects of speech production including the etiology of the syllable, it is useful to consider MacNeilage's arguments. (MacNeilage 1998, pp. 499–546) proposes three basic ideas for the presence of alternation in speech, underpinning the definition of the syllable stated in the present paper:

- a. "The species-specific organizational property of speech is a continual mouth open-close **alternation**, the two phases of which are subject to continual articulatory modulation. The **cycle constitutes the syllable**, and the open and closed phases are segments – vowels and consonants, respectively. The fact that segmental serial ordering errors in normal adults obey syllable structure constraints suggests that syllabic "frames" and segmental "content" elements are separately controlled in the speech production process" (MacNeilage 1998, Abstract).
- b. Proposing alternation as both the source and etiology of the syllable is supported by the fact that "[e]volution does not build new structures from scratch as an engineer does. Instead it takes whatever is available, and, where called for by natural selection, molds it to new use" (MacNeilage 1998, Section 4.1: p. 503).
- c. Importantly (MacNeilage 1998: p. 506) points out that alternation is a feature of the body's motor system:

From this standpoint, the evolution of the mouth open-close alternation for speech is seen as the tinkering of an already available motor cyclicity into use as a general purpose carrier wave for time-extended message production, with its subsequent modulation increasing message set size. However, it has also been pointed out that the open-close alternation confers perceptual benefits. In particular, the acoustic transients, which are associated with consonants and accompany onset and offset of vocal tract constriction, are considered to be especially salient to the auditory system, e.g., (Stevens 1989).

Analogous notions on the role of alternation are offered by two other authors.

(Easterday 2019) similarly writes, in the context of consonants vs. vowels, that "**alternation** between

relatively closed (consonantal) and relatively open (vocalic) articulations is fairly regular: syllable patterns such as those in the English words *pillow*, *cactus*, and *tree* are crosslinguistically prevalent.” In a similar vein (Stetson 1928, p. 190) draws a parallel with McNeilage as he considers **alternation** as a fundamental action of the speech tract: “The most obvious thing about the functioning of the vocal tract apparatus is the opening and closing of the vocal tract.” Stetson’s diagram on p. 190 depicting consonantal and vocalic on/off states in the form of square waves, exhibits the opening and closing of the tract as being segmentally temporal relations of hold and release between the two states. It is inferable that alternation does occur simply because closing and opening possess two distinct frames interchanging places in succession.

1.3 Alternation in the animal body.

Seemingly removed from the topic of the syllable, it is the action of biomechanical alternation that provides the key to defining the syllable. Therefore it is useful to establish its essentiality in animal, and specifically, in human body mechanics. Alternation is a fundamental mode of physiological action that pervades human, mammalian, and more generally, vertebrate and non-vertebrate body organization.

Its presence in **protozoan** locomotion underscores the foundational nature of this process. Three types of protozoan movement exhibit **alternation**: in flagellation (*Euglena*), in ciliary movement (*Vorticella*) and in peristaltic movement (*Acantharia*), in all of which a back and forth motion by organelles enables locomotion. Cf. <https://www.notesonzoology.com/protozoa/locomotion-in-protozoa-4-types-protozoa/5713>. In **earthworms** “Locomotion is...accomplished through the **alternation** of passive extensions and active contractions of successive segments” (Morgulis 1910, p. 616). With **fly larva** (*Chironomus plumosus*, Diptera, Chironomidae) “instead of a longitudinally transmitting metachronal wave of body flexure, a simultaneous arching of the body, combined with the **alternating** use of the abdominal and prothoracic pseudopods as anchorage points, produces a form of locomotion analogous to caterpillar-looping.” Among **lobsters** “the contralateral appendages are able to walk in absolute coordination despite a large speed difference between the two sides (up to 4 cm/s). Under such a constraint, the walking legs alter its invariable parameters...to reach a common step period and steadily maintain the **alternating** pattern (Figs. 6 and 7)”. (Clarac & Chasserat 1986). **Insects** run **alternating** one set of three legs with another set of three legs: “when running, an insect moves three legs simultaneously [...] This is the tripod gait, so called because the insect always has three legs in contact with the ground...” (<https://genent.cals.ncsu.edu/bug-bytes/thorax/locomotion/>).

With regard to **fish**, “the usual method of locomotion in fish is now thought to depend on passing

alternating waves of contraction backward along the body muscles” (Lindsey 1978). **Frogs** typically employ parallel limb swimming and leaping, yet: “We demonstrate that **alternating**-leg swimming is used quite frequently and that it results in a significantly lower velocity to the one obtained by using in-phase leg movements” (Nauwelaerts & Aerts 2002).

Reptiles, like fish move with body undulation where body sections alternate in direction of inflexion. “Terrestrial snakes, aquatic snakes, and sandfish lizards are observed to adopt different configurations for locomotion, although they all employ the snake-like undulatory wriggling motion,” and in such motion body segments curve **alternately** bend in opposite directions (Zhu et al. 2021).

That wing strokes of **bird alternate** between up and down strokes is evidently obvious and thus there are no references to such action in discussing avian wing motions, cf. (Shreyas et al. 2011): “fig. 13: The wing motion of a Painted-stork depicting down-stroke with flat-wing coming down whereas during the upstroke the wings are bent to reduce resistance to upward motion...”.

1.4 Human walking

The accomplishment of mature locomotor movements relies upon the integrated coordination of the lower and upper limbs and the trunk. Human adults normally swing their arms and a quadrupedal limb coordination persists during bipedal walking despite a strong corticospinal control of the upper extremities that allows to uncouple this connection during voluntary activities [...] In eight neonates, we found the overt presence of **alternating** arm–leg oscillations, the arms moving up and down in **alternation** with ipsilateral lower limb movements (La Scaleia et al. 2018, Abstract). (Donker, S. F. *et al.* 2001, p. 87) states:

They started from the observation (cf. Craik, Herman & Finley, 1976; Webb & Tuttle, 1989) that at customary walking velocities the upper limbs swing in **alternation**, with each limb swinging forward and backward in phase with the diagonal lower limb, whereas at lower walking velocities the upper limbs swing in phase at a frequency twice as high as the stride frequency of the legs.

(Székely 1976) deals with alternation built into neural behavior and indicates that the design of the neural system of limb motion has been shown to operate with **alternation**: “Experimental results that isolated brachial segments are able to control coordinated limb movements, suggest that the motor output pattern is programmed in the structure of the limb segments of the cord. In order to control the *alternating* coordination of a pair of limbs, the limb segments must be in contact with the medulla...” Clearly, both non mammals and mammals cited above employ alternating

appendicular movements in one of their modes of locomotion. Within the human body various functions work with alternating steps, such as neural membrane potential (polarization and depolarization), respiration (inspiration-expiration), heart beat (systole-diastole), intestinal movements (peristalsis), walking, running, blinking, mastication, head gestures (affirmation-negation), and so on.

1.5 Alternation in speech

In speech alternation takes place along a forward directed serial timeline over which parallel actions of various open and closed apertures are superimposed.

Functions in the linear flow of speech arising from alternation include inspiration and expiration during speech, jaw movement, phonational oscillation, consonant-vowel exchanges and as will be shown here, syllabic action. How step-wise alternation in articulation leads toward the stage that creates the syllable can be listed below:

In voice production alternation first appears as the oscillation of vocal chords that creates the sound vibrations of phonation. Phonation is superimposed by two slower alternating movements derived from respiration and mastication give rise to articulation, presenting that tongue shapes in speech are consistent with, if not derived from, those seen in feeding, cf. “Rather, we are focusing on those shapes given the hypothesis in the Introduction which suggests that tongue shapes in speech are consistent with, if not derived from, those seen in feeding” (Hiemai and Palmer 2003, Section VII).

Articulation produces consonants, vowels and semivowels that typically alternate in opening and fully or partially closing the speech tract as speech progresses, cf. (Stetson 1928) This action then ultimately creates phonemic segments that are traditionally termed **syllables**.

1.5.1 As illustrated in Fig. 000 “Toward generating syllables”, p *******000**,

the syllable is a structure step-wise built up through consecutively superimposed stages of alternation. Thus, why syllables exist can initially be described as the last stage in successive steps of alternation leading up to speech, as follows:

- a. The process begins using the fundamental intrinsic body function of **alternation**.
- b. Respiration employs this as the two phase alternating cycle of inspiration and expiration.
- c. Respiration develops two additional products of alternation: a) phonation where the vocal cords vibrate alternately opening and closing, and b) mastication where the jaw alternately moves up and down
- d. Phonation gives rise to vowels that create specific tract apertures and to mastication that generates consonants as different tract closures supplying variously modulated channels of air in the respiratory tract.

- e. These two actions then produce **alternately** appearing segments of vowels and consonants in combinations such as CV, CVC, VC, VCV, etc., as well as vocalic diphthongs and consonant clusters.
- f. These distinct segments of vowels and consonant are what generally are considered **syllables**.
- g. Additional subfunctions superimposed on syllables, like intonation, stress or phrasing are secondary overlays.

2 Initial definition and the remaining question

At this point it can be concluded that the syllable is not comprehensively definable as a single unit of speech or some function connected with stress, pitch, phonology, frame-content theory or sound structure, and so on, except as the final stage of the articulation function reached through a sequence of superimposed levels starting from fundamental alternation through ascending levels of various applications of alternation. This is a lengthy and inelegant definition but it does definitely state what a syllable is at a basic level, a function of segmental alternation. The definition also offers a rationale for why the syllable exists: one channel in speech production consists of a sequence of alternations that is automatically generated in which the syllable is an innate natural occurrence.

Nevertheless, this definition of the syllable is incomplete because a **question** remains: if a series of alternating functions leads to the syllable, does alternation end at this point or does the syllable itself also operate with some additional form of alternation?

2.1 The answer is that the **syllable** indeed also operates with **alternations**, and the basis for this conclusion can be gathered from (Flemming 2003) and (Keating & Lahiri 1993), two papers focusing on the *markedness* in the association between groups of certain consonants and vowels. Flemming states that among consonants “coronals only condition vowel fronting if they are produced with a front tongue body (usually anterior coronals), and only coronals produced with a back tongue body (usually retroflexes) condition vowel retraction” and that “(t)ongue-body position is affected by the position of the tongue tip/blade, because these articulators are physically connected, so each type of coronal has a preferred tongue-body position that facilitates the production of the coronal constriction”.

2.2 Clearly as Flemming reports, there are **two** distinct phonologically determined anatomical divisions for coronals because selection of tongue portion is a factor. This implies that in articulation the tongue body is divisible into two parts as Flemming states, into a front and back part.

(Keating and Lahiri 1993) describes a study on types of palatals:

The articulatory data consist of X-ray tracings and palatograms taken from the literature. The acoustic data consist of LPC spectra of brief intervals at stop release and at vowel onset. These data indicate that all of these consonant types are distinct. Contextual fronting of velars is a gradient effect, less extreme than phonemic palatalization of velars. True palatals are **even further** forward on the palate and contrast with contextually fronted velars before front vowels. Thus these consonant types should not be collapsed by feature systems.

3 DICHOTOMY

Flemming states that among consonants “coronals only condition vowel fronting if they are produced with a front tongue body (usually anterior coronals), and only coronals produced with a back tongue body (usually retroflexes) condition vowel retraction” and that “(t)ongue-body position is affected by the position of the tongue tip/blade, because these articulators are physically connected, so each type of coronal has a preferred tongue-body position that facilitates the production of the coronal constriction”. Thus as Flemming reports, there are two distinct phonologically determined anatomical divisions for coronals because selection of tongue portion is a factor. Thus, it is inferred from (Flemming 2003) and (Keating and Lahiri 1993) that there is a **dichotomy** in lingual articulating position of palatals, manifesting as a definite contrast in markings in the conditioning of coronal consonants with front vowels, and in the conditioning of velar consonants with back vowels. Dichotomy infers a two part division, in this case of the tongue body and importantly for the present argument, because dichotomy is a basic property of alternation, once more we arrive at **alternation**.

3.1 Dichotomic alternations also turn up in respiration, in mastication and in the brain, cf. (Scharinger et al. 2011) as well as (Sakamoto et al. 2010) cited below.

A two phase alternating action occurs in **respiration**: “During expiration, the genioglossus moved posteriorly and during inspiration, it moved anteriorly...[and the] (g)enioglossus moved posteriorly in expiration in two consecutive segments and the airway aperture reduced in size. During inspiration, the genioglossus moved anteriorly back towards its initial position and opened the airway in that plane.”

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2652195/>

With respect to **mastication**: (T)he hyoid and tongue body are pulled sharply backward and somewhat downward... The bite, pulled back to the level of the last molars, is carried forward and upward toward the first upper molars as the jaws approach minimum gape...[and later] (t)he tongue marker reaches its most backward position...[and then] the tongue continues to cycle forward and then downward”... [importantly, the fact that] “Sagittal tongue cycling is found in all mammals studied with VFG”

indicates its presence in the human. (Hiemae and Palmer 2003, p.421.)

3.2 Neural evidence for lingual dichotomy in alternation

The presence of the dichotomy in (Flemming 2003) and (Keating and Lahiri 1993) relating to front and back consonants as being independent articulations is reinforced by (Scharinger et al. 2011) and (Sakamoto et al. 2010) and both attest neurally determined separations between the frontal and posterior lingual actions:

In this study, we mapped the entire vowel space of a language (Turkish) onto cortical locations by using the magnetic N1 (M100). We found that dipole locations could be structured into two distinct maps, one for vowels produced with the tongue positioned toward the front of the mouth (front vowels) and one for vowels produced in the back of the mouth (back vowels)...These sets have separate neural representation in the motor network of the speaker's brain. Articulatory commands may be transmitted over three neural control channels independently of each other (Scharinger et al. 2011).

The other source asserting a duality in the tongue's connection with the brain is (Sakamoto et al. 2010). This investigation communicates that "Anatomically, the anterior two-thirds and posterior one-third of the tongue are innervated by different afferent fibers (Kandel et al., 1991). Thus, we hypothesize that a difference in brain activity exists in somatosensory processing, depending on the area of the tongue stimulated." It is then concluded that having recorded "the human brain response after stimulating the postero-lateral part of the tongue, and compared it with the antero-lateral part of the tongue...[and we] showed that a difference existed in the somatosensory processing of the tongue, particularly around the SI [primary somatosensory cortex] and ACC [anterior cingulate cortex] (Sakamoto et al. 2010).\

4 The Question

Considering **dichotomies** shown by (Flemming 2003), (Keating and Lahiri 1993), (Scharinger et al. 2011) and (Sakamoto et al. 2010) as well as by the lingual frontal and posterior positions in respiration and in mastication (Hiemae and Palmer 2003, p. 421) it may be asked whether these contrasts also manifest as alternation in syllabic action. An affirmative answer is given in sampling English words of one or more syllables, shown below. The results in sampling indicate that alternation does occur with syllables where it takes place involving anterior and posterior parts of the lingual body.

4.1 THE EXPERIMENTAL SAMPLING

Since no previous studies have dealt this topic this paper needs to include an experimental survey that researchers are invited to examine. This experiment posts an inquiry whether alternation appears in syllables. The basis of the experiment is built on the facts that as (Flemming 2003) and (Keating & Lahiri 1993) state that the tongue uses its front vs. its back body in association with palatals vs. palato-velars, and as (Scharinger et al. 2011) and (Sakamoto et al. 2010) report that there is a neural dichotomy separating the frontal and posterior lingual actions. The two independently acting parts of the tongue body can provide a field for alternation.

The experimental survey will examine whether during articulation alternations involving syllables occur between the dichotomic anterior and posterior lingual body divisions in monosyllabic, bisyllabic and multisyllabic words.

To distinguish the anterior and posterior tongue body two symbols are used where the marks show direction like arrowheads: < for anterior placement, and > for posterior placement

4.2 To be analyzed is the following random selection of words in which anteriorly and posteriorly articulated tongue parts are marked and it is to be judged if the markings are correct:

<sew (verb)	<fear (v)	>hence
>knife (noun)	<cri>mi<na>li<za>tion	<un>der<stand
<ne>ttle	>ne<ce>ssa<ry	>kiss (n)
<prin>cess	<coy	>worm
>bread	>bread	<love (v)
>once	<break (v)	<ad>ven<ture
<ten>sor,	<jour>ney	<coun>try
<or>di>na<ry	>star	< la>dy
>e<ga ta<ri<an	>chore	<wa>ter,
<mist (v)	<cook (v)	>ar<ti>cle
>duck (n)	>af<ter>life	>now
<good	>ramp	>con<fu>sion
<in>vert	<phone (v)	>duck (n)
<o>ffice	>wil<der>ness,	>tree (n)
<is>land	<ir>re<gu>la<ri>ty	<thir>ty,
<peo>ple	<o>ran<gu>tan	>di<a>mond

<a>vo<ca>do	<sys>tem	>strike (n)
<a>ve<rage	<dream (v)	<sus>pence,
<ramp	>a<venge	<do>llar
>then	<di>ver<si>fi<ca>tion	>re<demp>tion
<hea>ven	<reed	>re<vol>ver
<short	<plant, (v)	<do>lley
>bridge	>chore	<she>perd
<ad>ven<ture	<cir>cum<vent	<na>ture
<gar>bage	>bee	<pic>tu<resque
<knit	<ward>robe	>stil<ted
<dream (v)	<ask	>grass<ho>pper
>bread	>pe<ninsu>la	>month<ly
<have	<watch (v)	<al>ways
>tree (n)	<sys>tem	>pal<mis>try

4.2.3 The conclusion

It is evident that monosyllabic words and syllables of polysyllabic words are spontaneously assigned to either the front or the back part of the tongue body. Monosyllables are either anteriorly or posteriorly produced by the tongue. In polysyllables consecutive syllables fall alternately into front or back lingual positions. This data positively indicates that alternation is present and integral in syllabification.

4.2.4 Verification

To verify the regular occurrence of alternation in the above sampled words it is advisable to observe the anterior or posterior lingual locations for each word or syllable being pronounced while looking at it divided into syllables marked with the symbols of location. Apparently the visual input has a direct physiological connection to articulation perhaps deriving from the evolutionary primacy of vision over sound production. Note that it is essential not to erroneously consider stress in positioning the syllable.

5 The final definition of the syllable

The definition of the syllable proposed here is neither grammatical nor linguistic but physiological and is the most fundamental one: the syllable is the terminal stage in the sequential levels of alternations through steps leading to word articulation. At this last step syllables are **alternately** allocated to either the **front** or to the **back** tongue body sections, as discreet segments, and thus syllables are partitions of

speech produced by inherent lingual alternation. This definition does not touch on any of the superimposed functions the syllable may take on, but it provides a precise designation of what a syllable is. The etiology and the reason for the existence of syllables are, in fact, the same. The origin of the syllable is the ultimate step in articulative and physiological progression—its existence is owed to biological design.

5.1 The historical problem for defining the syllable

It can now be understood why defining the syllable as an element in language has been elusive. The syllable is fundamentally not a function of speech but is the product of the physiological operation of alternation as the last step in the sequence of levels into forming and articulating syllables of words. The various roles connected to syllabification are secondary superimpositions over syllables which likewise alternately appear in the anterior and posterior sections of the tongue body. Delimitation, construction, juncture, durations, pitch, stress and other such functions are merely allocated over syllables, and thus the syllable built on the most obvious and readily intuitive rationale have been erroneously considered as either one or several of these overlaid behaviors.

6 Discussion

6.1 Innate lingual alternation.

It is beyond doubt that the tongue mechanism fundamentally operates with **alternation**.

This is concludable from its two most basic behaviors of respiration and of mastication where the genioglossus drives the tongue forward and backward. This is accomplished by the anterior genioglossus musculature which **extends** the tongue and the posterior one which **retracts** it towards the hyoid bone (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2652195/>) and (Hiemae and Palmer 2003, p. 421). In syllabic behavior the tongue merely reproduces its innate alternating movements, placing one syllable in the front lingual division and the next one in the back lingual division, and so the definition of the syllable implies that speech itself adapts to inherent alternation in the tongue.

6.2 It can be asked why not place a speech segment repeatedly into the **same** lingual position, in either the front or the back? Because tongue behavior like many other body functions, like respiration or locomotion, requires alternation. Proof of this is obtained when one articulates a segment repeatedly, either in the front or the back tongue body division, during one breath phrase, that is, without breaking the continuity of outward flow of speech respiration: both fluency of speech and speech respiration become **obstructed**.

6.2.1 The syllable may also be phonologically defined as a composite of phonemes that will fit into the

framework of the two lingual alternating units and thereby allow fluency. A group of phonemes not permitting such fit cannot be chosen to constitute a syllable. More specifically if the front tongue space is filled with certain phonemes and the back tongue part is not filled with the appropriately matching ones (and vice versa) the word constituted will not be coined. **For example** >ta<ble (/ˈteɪ.bəl/) works but artificial words like *<da<ble */deɪ.bəl/ or *<ta<kle */ˈteɪ.kəl/ do not, similarly “>mo<ney” vs. *>go>ney or *>mo>pey, etc. These substitutions would not exist in the language.

6.2.2 Another way of seeing this is as a balancing scale or as a children’s see-saw with the front or the back tongue parts loaded on either side. The scale will have equal weights on either side only if the syllabic phonemes on either side are appropriate when matched with the other. Thus, the creation of correct syllables is one of the major factor in creating words.

7 Appendix

7.1 It is observable in the articulation of syllables in the experimental samples, such as >di<a>mond, >wil<der>ness, <a>ve<rage, >grass<ho>pper, >ne<ce>ssa<ry, <a>vo<ca>do that there are syllables between the first and the final syllables which fall in either the front or the back tongue section, however they are biased toward the mid section of the tongue. This bias can be deduced in that if the front or back placement is canceled the syllable settles in the lingual mid section. Thus, within a word intermediate syllables occur in the mid tongue while they also possess secondary front-back alternation. The mid tongue is kinetically controlled by the antagonist actions placed on it by the intrinsic and extrinsic musculature, and can be defined both in geometrical terms and in kinetic terms. In the present topic the it is the latter that is of interest.

Traditionally the tongue is divided only into two parts. “Human tongue anatomy, while complex, has certain patterns that make it understandable. One helpful way to visualize the human tongue is that it is composed of two basic parts. A wedge shaped GG in the midline separates the tongue muscles into two longitudinal masse” (Sanders 2014). “The anterior two-thirds...is visible in the mouth, and the posterior one-third...extends into the oropharynx” (<https://anatomy.co.uk/tongue>) and it is the anterior two-thirds that is considered as the main organ of articulation. In turn this two-thirds section is considered to be of two parts, the blade (or tip or apex) and the body of the tongue and this two-part section is the region studied by (Flemming 2003) and (Keating & Lahiri 1993). However the recognition of a threefold tongue division is essential in analyzing articulation. This was in part done by (Perkell 1969) and (Öhman 1966).

7.2 Perkell aptly maintains the physiologically based fact that each consonant, taking in both coronal and velar varieties can occur in different **three** positions. This important point currently not much considered is emphasized by Perkell:

“We may probably regard the tongue as three separate articulation systems that share some muscles. The three systems may be controlled in a purely independent manner” (Perkell 1969, p. 52)...(C)onsonant production...as in the case of vowel production, the tongue body... must be positioned to enable a particular part of the tongue...to accom[lish the spedific articulation [...] (F)or example, the /k/ in the utterance /i'ki/ is palatalized, and /k/ in the utterance/u'ku/ is velarized. However, both /k/'s are articulated by a combination of movement of the tongue toward the place of articulation with a superimposed deformation of the central portion of the tongue to complete the closure” (Perkell 1969, p. 65). The existence of such three positions of consonants was also asserted by Öhman: “The production of the vowels and of the apical and dorsal consonants involve activity in three (probably partly overlapping) sets of muscles. These sets have separate neural re[presentations in the motor networks of the speaker's brain”. (Öhman 1966, p. 62)

7.3 The term “central portion of the tongue” needs consideration. The front, back and central lingual sections constitute the **three** active parts of the tongue. Perkell, Öhman and others view this configuration merely as a superimposition on a centrally set tongue without realizing that this behavior supplies a system of consonant articulation which operates in three lingual positions, frontal, central and posterior, as a united function of the oral mechanism. Papers deliberating whether certain consonants are more palatal or more velar overlook the simplicity evident in the so far unestablished fact that precisely like vowels consonants are articulated in distinct front, central and back positional settings. For instance in the case of the velar consonant /k/ they speak of /ki/ as being fronted velar and of /ku/ velar as being backed. This approach is artificial and it is technically simpler, as well as more correct, to speak of front, central and back /k/s, exactly as with front /a/, central /a/ and back /a/, respectively, as in “car”, “bar” and “tar”. This agrees with (Keating 2003) and (Keating & Lahiri 1993) in that “velars before back and before front vowels, palatalized velars, and palatals...these consonant types are distinct...[t]rue palatals are even further forward on the palate and contrast with contextually fronted velars before front vowels. Thus these consonant types should not be collapsed by feature systems”.

7.3.1 The mechanics of consonants articulating in **three different locations** is explained by noting that consonantal articulating positions, in exact analogy with the vowels, are determined by choice of the

agency of various internal and external muscles of the tongue. This point is affirmed by Perkell (1969, p. 52): “we may probably regard the tongue as three separate articulation systems that share some muscles. The three systems may be controlled in a purely independent manner.”

The muscular mechanics for such three articulating settings is well understood as the action of extrinsic lingual muscles. Fronting is primarily executed by the genioglossus, centrality by the opposing external muscles, the genioglossus and hyoglossus against the styloglossus, producing equal forwarding and backing, while backing is served by hyoglossus and the posterior genioglossus. Note that the genioglossus can impart both forward and backward forces. Elevations and depressions of the tongue are accomplished by the palatoglossus and the styloglossus in opposition to the hyoglossus. The actions of the three pharyngeal muscles also bias elevation and depression. These muscles which determine tongue positions generate **three equilibrial** resting positions for consonants, where they will readily connect with symmetrically positioned vowels. That two opposing forces create an intermediate meeting point, their center of mass, is basic physical and astronomical fact. These positions are stable and are maintained without noticeable strain as experienced in **respiration, mastication and speech**.

Recognizing this behavior obviates use of unnecessary classification and terminology. Any consonant in any of its articulatory regions can be produced and be connected to vowels of corresponding positions. In this manner “b” in /bi/ will be the frontal variant of /b/ as in “bitumen”, “b” in /bo/ will be the central variant as in “board” and “b” in /bo/ it will be the posterior /b/ as in “bovine”. Similarly, for the “g”s in “giddy”, “guard” and “indigo”. Labeling a consonant in one of its three positions may be denoted with superscripted initials, as for instance, /^fb/, for anterior /b/, /^cb/, for central /b/, and /^bb/ for posterior /b/.

7.3.2 (Flemming 2003) and (Keating & Lahiri 1993) recognize only front and back lingual placements without reference to the central one. This is explicable in that positions within or approximating the **central** division are easily misperceived as fronted or backed types of front and back consonants. The central lingual section, mentioned by Perkell (1969, p. 63) as the “semirigid tongue body”, is a kinesiological merger of various near equal percentages of front and back extrinsic lingual muscles. Vowels are assigned to front, back as well as to the well established existence of central positions. Central vowels are those that approximate the center but are not its exact residents. In English the closest to being the actual central vowels are the are /ə/ and /ʌ/. Actually an actual central vowel cannot exist in speech because such a point is the mid central anchoring point of the tongue around which its forces move and shape the tongue.

7.3.3 The absence of consonant mapping paralleling that of vowels implies that an important aspect of

lingual structural behavior has not been investigated, namely that the tongue can take **three** major **equilibrial** settings, as it does in respiration, mastication and speech. Inarguably one can continuously engage in each of these three functions and as with vowels continuous effortless repetition of consonants, except for stops, is possible. In the production of phonemes the additional lingual position subsettings in each function also include fronting, centralizing and backing the tongue.