Study of Paninian Alphabet in a Neurological Perspective –

Part I - The Consonants

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1. Introduction

Paninian alphabet[1] distinguishes itself as phonetic as against many of the commonly known alphabets like Greek, German, French, English etc., which are symbolic. The common alphabets are created to help record speech in glyph, a graphical symbol used as a token to assist in reading. The Paninian alphabet, on the other hand, is an acoustic alphabet purporting to represent the independent modes of sound production through the speech apparatus in the body. Panini classifies the characters through the process of creating the phonemes. Our goal in this paper is to study the neurological basis of the origin of the phonemes. We take up the case of the consonants in the first segment.

Panini's analysis is to examine the sound stream in the Vedic recitations and the prevailing language structure to decipher the acoustic groupings for comprehension. The important contribution is the scholarly compilation of about two thousand roots "*dhātu* धातु" (AsD I.3.1), which are treated as the etymological basis for the creation of words. While a *dhātu* itself is a sound unit, its semantic information is interpreted from the usage of the words it is ascribed to create. The relationship between the acoustic information in the *dhātu* to its assigned semantic information is not investigated.

While a normal *dhātu* is action-oriented, Panini observes a special use of a *dhātu* when an action helps define a state "*bhāva* भाव" (AsD I.3.13). He would use the technical term "*ātmanepadī* आत्मनेपदी" to denote the use. When an action is done by an agent, the term is "*parasmaipadī* परस्मैपदी". This observation makes the scientific implication that any action leads to a change of state *bhāva* either in the object or in the subject. We will explore this observation further in this paper.

The modification of an existing physical state *bhāva* is accomplished through time, space, instruments and objects. Expression of these processes of interaction is defined as the language of a human being. The language consists of the creation of words and their utterance through the oral cavity and the nasal opening by using the vocal cord. The utterance itself also can cause a mental *bhāva* produced through hearing and comprehension. One can create mental *bhāva* through thinking, contemplating or interacting with the rest of the universe. The description of the effects of these processes is accomplished through the *ātmanepadī* use of the *dhātu* in the Paninian terminology.

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The concept of *ātmanepadī* has been called "passive" in the technical usage in modern grammar. While the distinction between *parasmaipadī* and *ātmanepadī* is clear from a philosophical point of view, it gets distorted in a physical point of view. This distortion occurs because of an incorrect enunciation that all perceptions may depend upon a previous perception (James, 1900)[2]. The mistake has been to connect perception through a linguistic comprehension. As Indian scriptures, particularly the yoga literature, would observe: the knowledge is not a function of the language, but is achieved through an innate cognitive faculty inscribed in the human mind[3] (YS III.55). This has been the principle of *vāk* वाक्[4] as stated in the Vedas (BrAU I.5.8). As we can experiment ourselves, our thoughts or impressions are not dependent on a language.

In this paper, we will try to construct a schematic model of human speech with the assertion that the speech is a tool to express our internal *bhāva*. We would theorize that the speech is a mechanism to convert our mental understanding to acoustic signals. The conversion to the acoustic signal is a function of our intentionality and our utterance is a function of our "local" grammar. While we have not examined the possible nature and characteristics of a "cognitive grammar" (see below), we have reason to suggest that the phonetics of the utterance and the syntax structure are influenced by the local grammar that creates the local language. The semantics of the utterance as computed through the neural map is independent of the language used in expression.

The consonants in our model are the natural offshoot of our *bhāva* that affects our body through the reaction of the muscles. A consonant would then represent the affected state of the body and the modalities of the state would be rendered via the vowels through the voice mechanism. We create an engineering model for the expression of the consonant using the alphabet from the Sanskrit language.

2.0 Rasa and Language

In a paper[5] (Misra et al 2015-2) to the XVI World Sanskrit Conference at Bangkok, the authors presented the neurological and anthropologic evidence of the semantic origin of words. They showed from laboratory experiments that words that conveyed the same meaning but were in different languages did elicit the similar neural response as observed through the fMRI signals[6]. They further showed that the primitive human settlements developed their own phonetic expressions based on semantics rather than accepting new words or extra labels to be learned by training. We questioned the model of behavioral learning of language normally done through lexical drills and phonetic coaching. The language model as created by us is reproduced in Figure 1.

While the behavioral learning leads to local cultural understanding, we argued that human memory is cognitive than lexical. We showed that the same object would cause the similar cognitive impression in the brain irrespective of the person's land of origin or language of expression. Hence, our conclusion was that the cognition of objects and that of the environment point to an innate human signature, built in to the human brain. In a companion paper[7] (Misra et al 2015-1), we showed that the object cognition does get modified by the built-in neural imprints where the object cognition transforms itself to a subjective object impression.

Using the anatomical findings by the Danish scientists (Levelt et al 2004)[8], the above paper tried to map the stages of speech expression as presented in the Vedas and articulated in the writings of

Bhartṛhari (*vākyapadīyam*)[9] . The anatomical map of the brain distinguishing various steps in speech expression is reproduced in Figure 2.

Figure 1

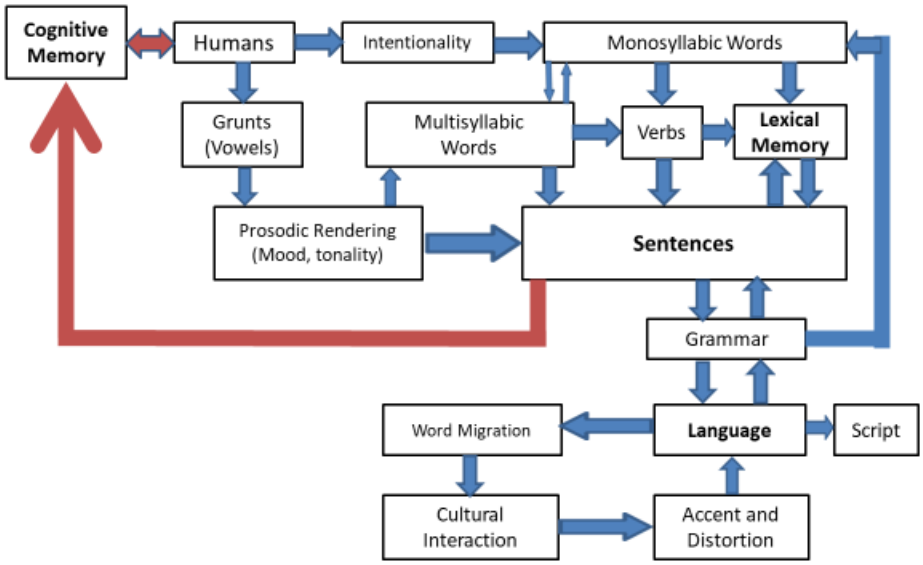
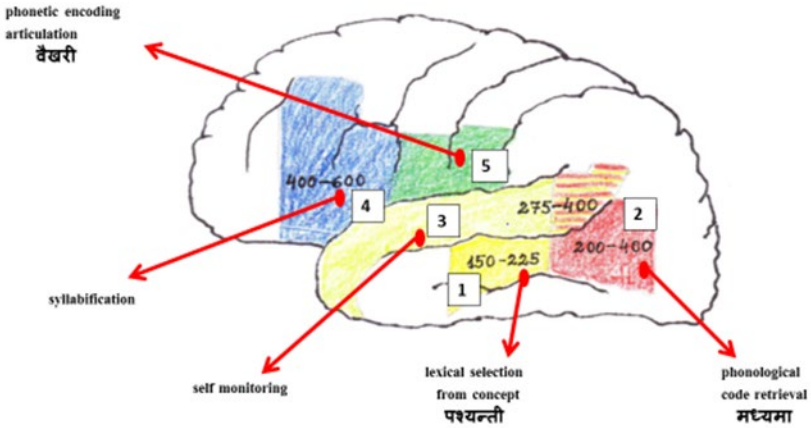


Figure 2



	Brain Area	Activity	Time-Scale	Indian Grammatical Term
1	Middle and inferior temporal gyri	lexical selection from concept	150-225 msec	पश्यन्ती
2	Middle temporal gyrus and parieto-occipital gyrus	phonological code retrieval	200-400 msec	मध्यमा
3	Superios temporal gyrus	self monitoring	275-400 msec	
4	Middle and inferior frontal gyri	syllabification	400-600 msec	
5	Pre-and postcentral gyri	phonetic encloding and articulation	600- msec	वैखरी

The basis of assertion in these papers is the philosophical observation in the *chāndogya upaniṣad* stating that the cosmological sound syllable "om ॐ" can be considered as the essence "*rasa* रस" (ChU I.1.3) of the universe[10]. This statement extends to the following concepts:

1. The universe has a *rasa* by which it is perceived by the physical objects. This perception is related to the existence of the object in the universe.

2. This perception can be expressed as an acoustic signal.

3. All objects in the universe carry their characteristic *rasa*. Objects exist in the field of *rasa* of the universe and contribute to the field through their existence.

4. Humans cognize the *rasa* through their cognitive faculty. The humans do have the faculty of cognizing the universe accurately, but their perception immediately gets degraded through recollections and memory functions.

Rasa is not a physical entity but a property that aids in perception. From the grammatical point of view, full immersion in *rasa* leads to the *ātmanepadī* mode, and when we separate ourselves away from the *rasa* we get to the *parasmaipadī* mode. As we shall see later, we are in *ātmanepadī* mode when our mind is fully engaged. In this analysis the mind is the channel to the universe. So, we consider mind as another sensing tool.

2.1 *Bhāva*, the Physical Experience

While the *rasa* is a property of the object, its effect in a subject is termed *bhāva.* Literally *bhāva* would mean "thinking", it is a direct physical response in the brain of the subject that maps the object. In the modern technical language, we can call it the "response function." From empirical reasoning and citation from the literature[11], we believe that the observable manifestation of *bhāva* is connected to *rasa* in eight categories: love, humor, disgust, anger, compassion, heroism, horror and amazement. While any *rasa* may have a myriad of strands compounded in it, it is possible that the human brain is wired to group the response in major experiential categories as cited above.

In engineering terms, we can say that the *rasa* is a stimulus that affects the neurons in the brain to cause *bhāva*. *bhāva* is a biological response on the body acted by the *rasa*. This response releases itself in two ways: (i) a muscle trigger causing palpitation, shivering, stillness or movement, and (ii) an acoustic release through a breathing response and speech. What we are interested is in understanding the latter transformation where the *bhāva* translates into a variety of sounds that constitute human speech.

2.2 Cognitive Memory

In the earlier paper we coined a phrase "Cognitive Memory" to distinguish the brain partitioning from its lexical memory. While the lexical memory is local and language specific, the cognitive memory is an innate characteristic of the human species. Imagination and creative thinking are the functions achieved through the cognitive memory which draws upon our accumulated knowledge including

intuition. It is also the residence of the *bhāva* response for all stimuli. Because of its role in human creativity, we claim that the cognitive memory is beyond the recollection memory.

3.0 Paninian Alphabet

In the beginning of his epic work, Panini cites fourteen aphorisms that have been accepted as the classical alphabet in Sanskrit. We do not have the analysis to derive the independent alphabetic sounds from the strings of human communication or the *vedic* recitation. A later work[12] purports to a parallel alphabet in Prakrit, which was the language of the masses at the time. This work indicates a set of sixty-four letters in use in both Sanskrit and Prakrit. *pāṇinīyaśikṣā* would ascribe the term *"varṇa* वर्ण" to indicate the letter.

With indicators at the end of the strings, Panini organized the letters in groups and used the groups to create the engineering mechanics of grammar. Two principal groups are "*ac* अच्" and "*hal* हल्" which have been identified as vowels and consonants in the literature. These are demonstrated in the Figure 3.

Figure 3
Panini's alphabet sounds
māheśvarasūtra

अ इ उ ण्।	a i u ṇ
ऋ ऌ क्।	ṛ ḷ k
ए ओ ङ्।	e o ṅ
ऐ औ च्।	ai au c
ह य व र ट्।	ha ya va ra ṭ
ल ण्।	la ṇ
ञ म ङ ण न म्।	ña ma ṅa ṇa na m
झ भ ञ्।	jha bha ñ
घ ढ ध ष्।	gha ḍha dha ṣ
ज ब ग ड द श्।	ja ba ga ḍa da ś
ख फ छ ठ थ च ट त व्।	kha pha cha ṭha tha ca ṭa ta v
क प य्।	ka pa y
श ष स र्।	śa ṣa sa r
ह ल्।	ha l

Red – svara - स्वर Violet - antaḥstha अन्तःस्थ Green - sparśa स्पर्श Dark Green ūṣman ऊष्मन्

The *hal* grouping is further subdivided into sub-groups called *sparśa* स्पर्श with twenty-five letters, *antaḥstha* अन्तःस्थ with four letters, and *uṣman* ऊष्मन् with four letters. From empirical reasoning it is established that each of these letters represents an independent sound unit. Panini would state that the sounds are produced by arranging different configurations of the vocal cord and the oral cavity along with the use of the nasal aperture. Panini's nine letters in the ac अच् group are expanded to twenty-one letters by expanding into their allotropic variations suggested through the duration of their utterance.

4.1 Significance of Paninian Alphabet

Panini's effort was to use the alphabet as the basic framework to help develop a grammar that could reproduce the Vedic sounds heard in recitation. Since the Vedas were ritualistic hymnals, there existed regulated tones and rhythms in reciting the material. The material was orally taught and was recited from memory. Efforts were made to retain the nuances in sound variation however small. There was a view that the recitation could create the experience of object realization.

As in olden days, the success of the performance of the Vedic rituals continues to be considered as a strong function of proper recitation and structured pronunciation. In course of time, there was analytic work to search for the nature of speech and it was connected to Brahman[13], the Ultimate Reality as conceived (ChU III.18.3). The idea based itself on the concept that the Brahman realization was possible through the proper cultivation of speech. Given the Vedic recitations, one would then postulate that the structured Vedic recitation was conceived as a tool to spiritual realization.

The credit of Panini was to dissect the Vedic recitation to a set of basic speech units as defined by the grammarians of his time. These units are not phonemes which are derived from the sound streams as developed in many languages. Panini defines them as independent speech units and uses them as the production units and not what is heard. While the externally heard string is the subject of analysis, his interest was in the creation of the string. Given the basic production units, he creates a web of suffixes and prefixes and rules of sound compounding to help create the grammar that has defined the structure of Sanskrit language.

4.0 The Science of Language

There is a prevailing school of thought in modern linguistics that all languages are learned[14]. We respectfully disagree with this school of thought. We align ourselves with the philosophical thinking of old India that the language is a tool to express our thoughts. Individual empirical experiments verify that thoughts themselves carry no language and are cognitively driven[15]. Many thoughts may not see external expression because of the individual intentionality.

When we wish to express a thought, the process becomes one of communication and we create a target to communicate. The target could be the cosmic forces as the vedic hymnals are, or the target could be a friend, a person at home. In either case, we choose a language and the associated grammar to communicate. We use words in the language of our choice to render our thought. While we may use various intonations and vocal tools to convey our thought, we do realize the information loss in communication[16].

The information loss in communication is maximum when we wish to narrate events and images unfamiliar to our target audience. Neurologically we can resort to metaphorical expressions which might get a better response. We can also use metaphorical expressions along with the thought-rendered expressions to enhance the quality of our communication. Such techniques have been studied as a tool of poetic ornamentation as a topic of interest in India.[17]

4.1 Poetic Expressions

Poetic expressions build on creative use of words. By manipulating words and rhythmic variations, a poet can narrate an event or tell a story. This gets more interesting when the narration is heard than when it is read. The realistic portrayal in narration is the skill of the poet, and that of the performer. Most of world's legends and cultural heritage are retained through oral literature.[18]

The composition of the narration and the eventual response by the audience can be summed up in the following steps:

(i) An accurate mapping of the original thought in the brain in the form of *bhāva* . As we have seen, the *bhāva* is the response in the brain due to the original *rasa*.
(ii) An effort to draw upon the words and the tools to help reproduce the *bhāva* through creative presentation.
(iii) Help convey the *rasa* by performing or delivering the *bhāva* through oral expressions or written compositions.

All creative presentations are self-expressions. The expression is successful when we express our *bhāva* completely. As we said earlier, it is a function of our own immersion in *bhāva .* Our own immersion on the other hand is a function of our own clarity and objectivity. An accurate rendering of the object is only possible when our mind is fully transparent.[19]

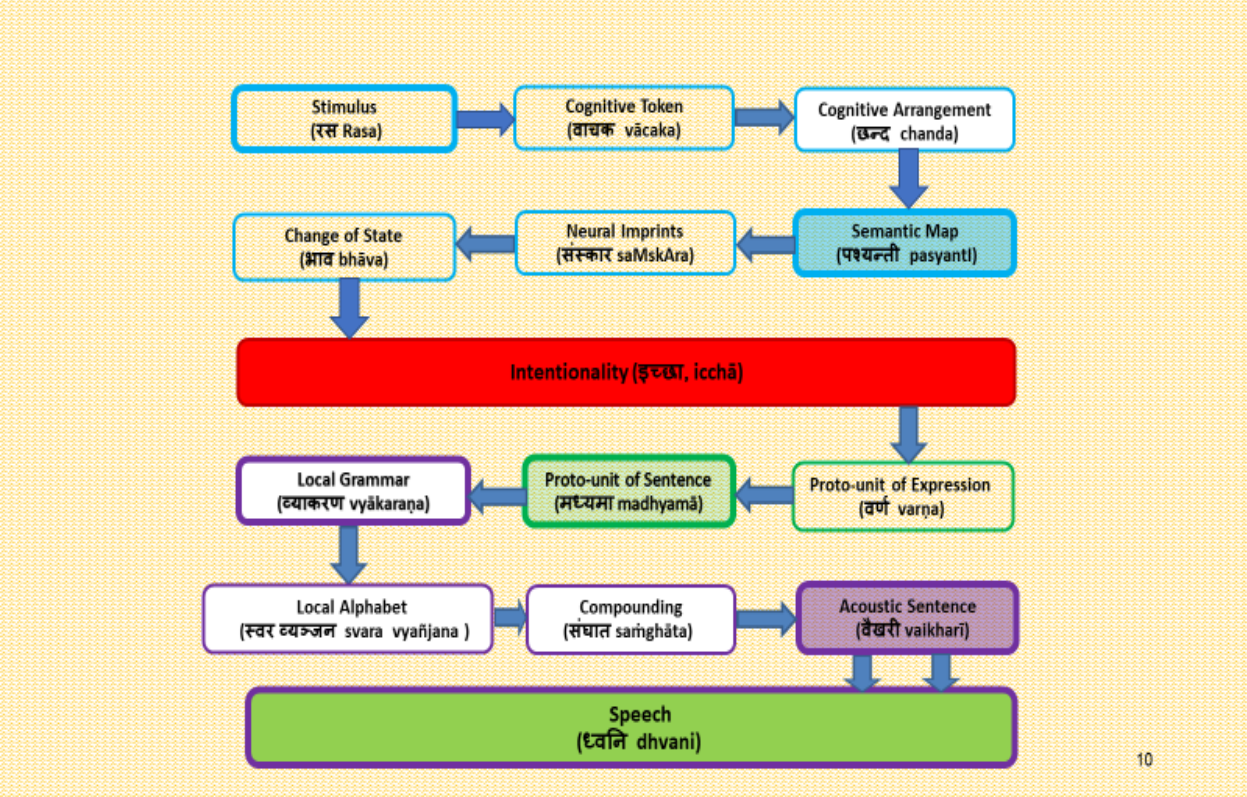
5.0 The schematic neurological view of language

Our goal is to understand the brain processes that help create the human speech. Understanding human speech, we find the gateway to Paninian consonants. We build the model with the following assertions:

(i) *Rasa* is the synthetic signal that creates perception in the humans.
(ii) The human speech is a tool that converts the perceptual thoughts in the brain to a communicable acoustic signal.
(iii) The thought itself has no "language" but has a neurological cognitive arrangement.
(iv) The biological response of the thought is an innately triggered muscle reaction.
(v) Speech is intentional and is controlled by the local grammar.

The sketch for the model is presented in Figure 4. We describe it below.

Figure 4



A. Model of Speech

(a) The impact of *rasa* is to create awareness, which leads to a cognitive object realization. Taking the cue from the visual perception, we hypothesize that cognition registers in neural excitations as individual tokens. We borrow a term from the literature and label the tokens as *vācaka* वाचक, indicating the object representation in us. The indication of neural association to awareness is shown in a recent animal experiment[20].

(b) While the detailed processes in the cognitive organization would take many more years to be revealed, we surmise that such organization is the genesis of the Vedic term *chanda* छन्द which is the product of our thought processes. Though organized as a melody, a *chanda* is multi-dimensional. It carries all the modalities that constitute the *rasa*. Normally *chanda* translates as rhythm, for us it is a neural arrangement.

(c) Though the contents of rasa are analog, the number of cognitive tokens that can be generated by *rasa* are finite. This is due to the brain limitations in processing information. Given the view of human reception, we hypothesize that the principal segmentation would be eight-fold. Among the eight, one would be an anchor, and together with the rest shall produce a spectrum. This spectrum represents the object capture in the brain. It helps to produce a semantic map[21] of the object through the neural configuration. This state of cognition has been called *paśyantī* पश्यन्ती in the literature.

(d) The cognitive map connects to the existing neural imprints[22] in the brain to create a *bhāva* as we alluded earlier. The existing neural imprints affect the cognitive spectrum automatically in the creation of *bhāva* . The latter is the eventual biological response of the *rasa* in the brain. It is translated as "emotion" in the literature. Each *bhāva* constitutes a body state and triggers an innate muscle response. The exercise of a speech response depends on the individual intentionality, which is a function of the organ control and a desire to communicate.

(e) The intentionality to express constitutes the process called *madhyamā* मध्यमा in the classical Indian literature. It is an executive function and we show a broad area in Figure 2 for the possible location. The process converts the sematic map into proto-units of expression. Borrowing from literature, we label them as *varṇa* वर्ण, the unit of expression. We assert that these units of expression form the basis of human speech expressible through the human organs.

(f) Human organs have limited degrees of freedom which influence the transformation of the original semantic map into proto-units of expression. Each unit carries its share of the modality information. Though a theoretical construct, we have reason to believe that such units would eventually be discovered. These units would need a local grammar to create the acoustic signal. The local grammar operates as a convolution window in transforming the proto units into acoustic sentences.

B. Model of Language

(g) The conversion of proto-expression units to speech syllables creates a language. The number of usable syllables in a language may vary depending upon the cultural need and the use of the language. While the speech syllables are assumed to be a function of endowed human capacity, their compounding in creating words is specific to a language. Such compounding results in utterances where the original syllables create sound strings that appear to be composed of arbitrary phonemes. This part of speech has been called *vaikharī* वैखरी.

(h) Eventually languages get defined by phonemes. We learn a language by learning the phonemes and by training our oral muscles to help create the phonemes. We then create memory listing of the words and draw upon them in our local communication. This is the principle of lexical memory as used in the literature[23].

(i) We refer to the Fig 3 depicting the speech syllables in Sanskrit. Sanskrit grammar warrants a complete representation of each syllable thus identifying the phonemes with the syllables. From this point of view, Sanskrit carries a unique position in the system of world languages.

6.0 The Meaning in Language

6.1 *sphoṭa* theory of Bhartṛhari

In a masterly three-volume study, grammarian Bhartṛhari[24] made a detailed analysis on the theory of semantics in Sanskrit language. He is dated to have lived in seventh century, but the exact dates remain uncertain. Through empirical reasoning, he concluded that the comprehension of any communication is a function of assimilating the full signal, called *vākya* वाक्य "sentence"in literature.

Bhartṛhari asserted that the meaningful kernel of a sentence resides in a tacit cognitive feature called *sphoṭa* स्फोट. *sphoṭa* is built into the *dhvani* "sound" in our speech model. *dhvani* is our utterance. He observed that *sphoṭa* is the mechanism by which a sentence is understood by the listener. While a sentence may be expressed in different voices by different people, the meaning it conveys remains the same. This meaning, he claimed, was because of the inherent *sphoṭa*.

Continuing the analysis further, he showed that the *sphoṭa* theory can be extended to the words शब्द and letters वर्ण. He based his analysis on the observation that the meaning of a word and the connotation of a letter are not functions of the individual voice but are dependent on the word or the letter. The word would then be defined as a given sequence of letters that together constitute the meaning kernel *sphoṭa*.

6.2 *sphoṭa* as a Cognitive Feature

We used Vālmīki's epic rāmāyaṇa to check the poetic depiction of *rasa* through the narrative play of words. Though we have not objectively analyzed, it was easy to observe that the description transitions through various *rasa* in sequence. The poet fits in the events to dwell on a *rasa* for several hundred stanzas until moving on to the next set of events for another *rasa*.[25] The amount of space allocation appears to be empirically established. We need detailed research to appreciate the scientific content in the poetic technique.

The dramatic development of the story through poetic narration has the similar effect as panning a scene slowly to enjoy the details. We surmise that the cognitive processes in both these situations are similar. Reading or listening to the sections of an epic would be as much of a stimulus as looking at a picture or witnessing the real event. The full story would contain many such images like the epic would have many such sections. All these would impact as *rasa* in our model sketched in Figure 4.

rasa through poetry is a composite effect. This would mean that each word in the section would be contextual and contribute towards the creation of the rasa environment. In this sense, the *sphoṭa* in each word would contribute to the total effect. If the meanings of the words would not register, the *rasa* stimulus would be diffuse and not impactful. From the poetic production of rasa, the rāmāyaṇa is exceptional.

6.3 *sphoṭa* in varṇa

As we have discussed in section 5 above, the basic cognitive unit in the speech is a *varṇa.* A *varṇa* is the proto-expression unit which eventually gets expressed as an acoustic syllable. Classical Sanskrit has identified sixty-four such syllables, while Panini's Aṣṭādhyāyī cites the principal ones

numbering forty-three, with nine vowel sounds and thirty-four consonant sounds. We analyze if these sounds correspond to the semantic map in the brain.

We apply the following logic:

i. There is an objective association of an articulated syllable to represent a unit of segmentation in the semantic map. The units of segmentation are unknown and might be discovered through reverse analysis.
ii. The articulable syllables do form a complete set to represent the semantic map. The local grammar allows compounding to help represent complex concepts. There could be information loss through the articulatory communication.
iii. The semantic content (*sphoṭa*) of the syllable is fixed but might appear different through vocal rendering.
((A mathematical model depicting the analysis is in preparation)

6.4 Experiment with the languages

We chose Sanskrit, Tamil and Hungarian as languages representing three different language families. We took Sanskrit language as a reference and tried to look for verbs in different languages with the same first syllable as being an articulable syllable in Sanskrit. We took the Sanskrit verbs from Kale's *dhātukoṣa*,[26] the Tamil verbs from Tamil Dictionary[27] and the Hungarian verbs from Hungarian-English dictionary[28]. The syllables that matched our criteria were "ka" and "pa". We tabulate the words in Table 1 and Table 2. The meanings in English are the commonly accepted interpretations in use as compiled in the source book.

We assume that the first syllable in an expression would carry the dominant cognitive element in the thought process. This is based on the principle that the neural processes would be economical in their computation. We choose the "a" sound (Sanskrit अ) to be the simplest of the vowels to enable the articulation. The *dhātu* list in Sanskrit is complete. We are adding the Tamil and Hungarian verbs for reference and for future examination.

While both "ka' group and "pa" group of verbs are a mix of *parasmaipadī* and *ātmanepadī* type conjugations, we observe the profusion of *ātmanepadī* types. The actions connoted by the "ka" group are more intransitive while the actions connoted by the "pa" types appear more transitive. We must qualify that these observations are broadly preliminary. However, the connotation spreads through all three language families.

Our goal in this exercise was to check if the syllabic sounds should be probed more to analyze their semantic content. First, we show that the syllables are not arbitrary and they have a genesis in thought and thought translation. As we see in the tables there are several entries for the content "to go". In the *ātmanepadī* context the subject has motion. In the "ka' context, the motion is by the subject moving himself while "pa" group would suggest that the subject moves with assistance. We will return to this analysis with further examination of *mīmāṁsā*[29] literature in building our mathematical model.

Table 1

Verbs beginning in "ka"

Sanskrit	Meaning	Tamil	Meaning	Hungarian	Meaning
kak	to wish (A)	kadikka	to bite	kacag	to laugh
kakh	to laugh	karka	to study	kacérkodik	to play coquette, to flirt
kac	to sound, to bind(A)	katta	to tie	kacsint	to wink at
kaṭ	to go, to live in hardship (A)	kaththa	to scream	kalandozik	to adventure, to roam
kaṇṭh	to remember, to be anxious(A)	kazhatta	to remove	kap	to get, to obtain
kaṇḍ	to separate (P and A)	kalaikka	to dismantle	kapcsol	to connect
kaṇ	to cry, to wink (A)	kakka	to throw up	kapál	To hoe, to hack
kaṇḍūy	to rub (P and A)	karaikka	to melt	kandikál	to peep
katth	to praise	kalakka	to mix	kalapál	to hammer
kath	to tell (P and A)	karakka	to milk	kavar	to mix
kad	to grieve (A)			kaszál	to scythe, to reap
kan	to shine			kajál	to stuff
kam	to desire (A)			kajtat	to rummage
kamp	to shake (A)			kakál	to cack
kamb	to go			kakaskodik	to strut
karṇ	to pierce (P and A)			kalandozik	to have adventure, to roam about
kart	To slacken (P and A)			kalauzol	to guide
kal	to sound (A), to go (P and A), to throw (P and A)			kantároz	to bridle
kav	to praise (A)			kanyarodik	to turn
kaś	to sound, to punish (A)			kap	to get, to receive, to obtain
kaṣ	to test			kapál	to hoe, to hack
kas	to go, to destroy (A)			kapar	to scratch, to scrape
				kapaszkodik	to climb, to grasp, to cling, to hold on
				kapcsol	to connect, to couple
				kapkod	to grip, to catch
				karatyol	to chatter, to splatter
				kaszál	to scythe
				kavar	to stir

In Sanskrit meaning column, A = *ātmanepadī*, P = *parasmaipadī*, default = *parasmaipadī*

Table 2

verbs beginning in “pa”

Sanskrit	Meaning	Tamil	Meaning	Hungarian	Meaning
paksh	to accept (P and A)	parakka	to fly	pajzánkodik	to caper
pac	to cook (P and A)	padikka	to read	pakol	to pack
paṇc	to make clear (P and A)	padukka	to lie down	papol	to chatter
paṭ	to move (P and A)	parikka	to pluck	palástol	to disguise
paṭh	to study	pagukka	to divide	panaszkodik	to complain
paṇḍ	to go (A)	paniya	to yield	parancsol	to command
paṇ	to bargain(A), to praise (A)	padhukka	to hide	paskol	to shoe
pat	to fall	parappa	to spread	patronál	to patronize
path	to go, to throw (P and A)	parimara	to serve	pajkoskodik	to be rougish
pad	to attain (A), to go (A)	pazhaga	to befriend	paktál	to conspire
pan	to praise (A)			palánkol	to fence
panth	to go (P and A)			palástol	to disguise, to cover
pay	to move (A)			pancsol	to splash
parN	to make green (P and A)			pattint	to knap, to chip
pard	to break wind (A)			pazarol	to squander, to waste
parv	to go, to fill				
pal	to move				
pash	to bind (P and A)				
paS	to go (P and A)				

In Sanskrit meaning column, A = *ātmanepadī*, P = *parasmaipadī*, default = *parasmaipadī*

7.0 Origin of Consonants – Pitch Experiment

7.1 Articulation in Paninian Alphabet

Among the scientific content in Panini's grammar appears a rule of articulate तुल्यास्यप्रयत्नं सवर्णम् *tulyāsyaprayathnaṁ savarṇam*[30] . This has important attribute in the classification of stop consonants into five distinct groups depending on the origin of their articulation in the mouth. The five locations of origin of articulation in the mouth have been identified as (i) *kaṇṭha* कण्ठ "throat", (ii) *tālu* तालु "palate", (iii) *mūrddhā* मूर्द्धा "head", (iv) *dantāḥ* दन्ताः "teeth", and (v) *oṣṭhau* ओष्ठौ "lips". The "nose" nāsikā नासिका can supplement in each group to produce a nasal variation.

Identification of organs in mouth and connecting them to the speech sounds is the significant anatomic contribution of the Indian grammarians as compiled by Panini. They recognize the independence of each of the organs and enunciate the independence of the sound quality produced through the organ. This becomes the basis of the definition of language as conceived by the Indian scholars that the language is an expression, so it is constrained by what we can express through our body organs.

We speculate that the only way such an alphabet could have been developed would be to test each organ independently to check its acoustic properties as a tool in articulation. We have no records on such testing except the broad philosophical observation that each syllable is an independent expression and is fully contained[31]. That each organ can act as a complete expression tool would have a basis to include all living entities into the mode of expression as an endowment in evolutionary biology.

7.2 Consonants as acoustic representation of *rasa*

Referring to our model in Figure 4 we note that the manifested *bhāva* in the body is expected to create an innate physical response through the muscular reaction. The body for an instant transforms to a different state as dictated by the *bhāva* . The *bhāva* response is full body immersion that leads to its acoustic release through pulmonary pulses resulting in a consonant.

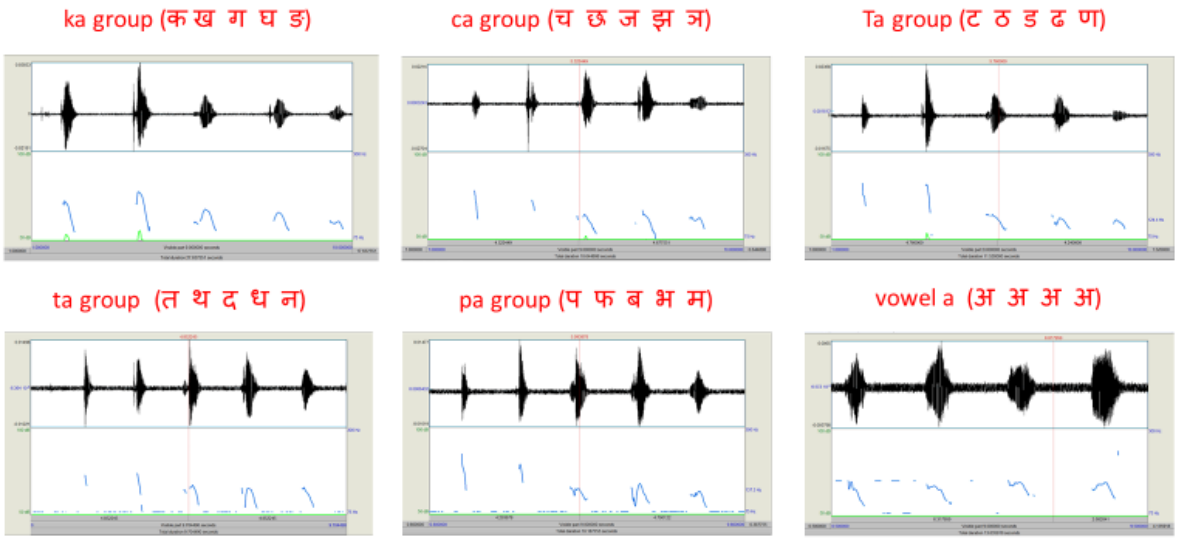
The openings that the body uses for the acoustic release are the mouth and the nose. In our model terminology we claim that the modalities connected with the *varṇa* get rendered through the associated vowels. Besides expressing the emotion, the rendering would include pitch and tone variation to express the fidelity of the *rasa* it tries to manifest. Each consonant in such scenario can be expressed through a high or low pitch with the appropriate tone variation to depict the rasa as precisely as possible.

7.3 Testing the Hypothesis with Pratt Software

We chose the complete set of हल् (hal) letters rendered with the vowel अ (a) in a standard speech modality. We used Pratt software[32] developed at the Phonetics Sciences group at University of Amsterdam in Netherlands. The background material on the physics and algorithm is given in by Paul Boersma[33], one of the developers.

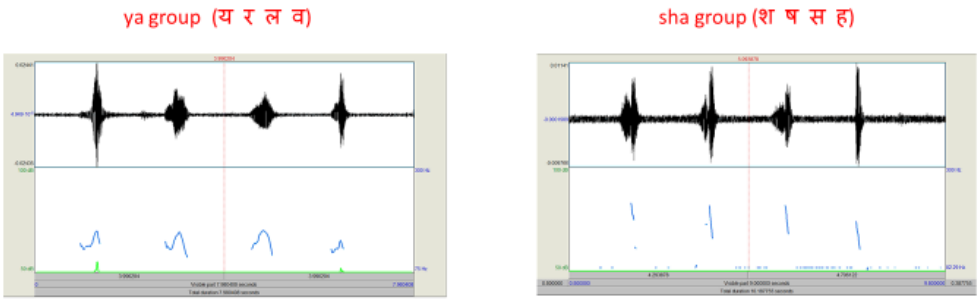
All our experimental recordings and analysis were done on an IBM Thinkpad with the mouth positioned about 18 inches from the system microphone. The primary vocal cord frequency for the Paninian स्पर्श (sparśa) consonants क (ka) through म (ma) are given in Figure 5. Figure 5 also gives the vocal cord frequency for a pure standard vowel अ (a). The difference between the frequency characteristics of the consonants is easily noticed in the picture. Each of them is also characteristically different from the frequency plot of अ, establishing the point that the consonant carrying its frequency at the source of the pulmonary exhalation.

Figure 5



The nasal consonants are computed to have the lowest pitch while the highest frequency shows up in प (pa). The cerebral consonants also have relatively higher vocal cord frequency. As you notice, we ignore the resonance and the higher frequencies through the channel vibration, but only concentrate of the fundamental frequency. The plots for the अन्तःस्थ antaḥstha and the उष्ण uṣṇa letters are plotted in Figure 6 with the vowel अ (a) reference. For the purposes of this paper we ignore the difference in two ह "ha" sounds which appear when ह appears in combination in special cases as analyzed by Cardona[34].

Figure 6



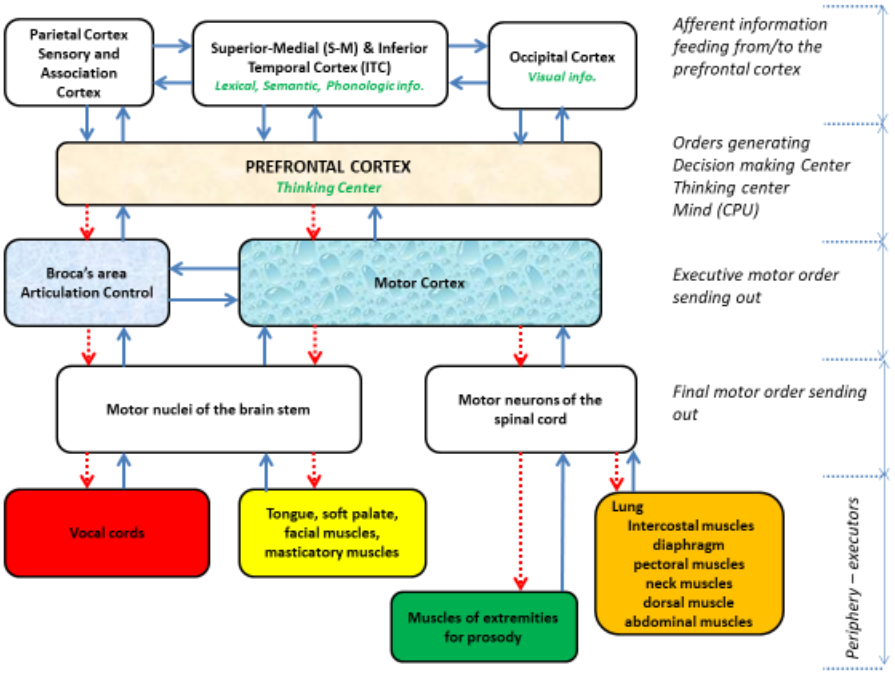
8.0 Neurological Model of Consonant production

From the neurological point of view, our thesis builds on the following three postulates:

(i) There is a universal cognitive translation of stimulus to multi-modal proto-speech units.
(ii) The intentionality in the brain helps to convey these units in muscular response and speech expression.
(iii) The cognitive faculty is universal, but the speech is local.

In Figure 7, we give a flow chart of the modern accepted view of neuro-functionality in the process of generating speech. The decision to express is created in Prefrontal Cortex where the proto-unit of expression resides in our model. Such decision then gets transformed by a local grammar residing in the Broca's area which has the capacity to render the content information in the cognitive unit to be converted to an acoustic signal. The signal goes to the vocal cords and the oral cavity to help produce the pitch, as we checked in section 7. In the Paninian system these are vowels अच् "ac" with the intentional time variation. The signal to the body muscles is routed via the Motor Cortex. This signal helps create the necessary breathing through the contraction of the participating muscles and produces intensity. In the Paninian system these are the consonants हल् "hal". In our terminology they carry the "static" information of the original *bhāva* in the cognitive unit. The modalities in the *bhāva* are rendered as prosodic contributions with the signal to the throat muscles and to the extremities.

Figure 7



We are working to create a quantitative model to translate the cognitive information to the acoustic signal and will report in a forthcoming paper.

9.0 Discussion

We hypothesized that a thought is driven by an object stimulus, termed *rasa*. Speech is an expression of our innate cognitive faculty of rendering our thought as an acoustic signal. These sound units map to a semantic location in the brain as indicated by neurological studies. The rendering is limited by our biological apparatus and the local grammar. While local language is a tool for expression for our thoughts, our thought or *bhāva* is independent of language. Sound units or syllables relate to cognitive tokens in the brain driven by intentionality leading to the utterance that purports to convey the meaning embedded in *bhāva*.

The exact mechanism from perception to rendering, *bhāva* to *varṇa*, is explored through the modern neuroscience. We show that each of the Paninian consonants carries a characteristic signature frequency in production. This frequency could convert to prosodic patterns through muscular actions commanded by the original *bhāva.* We are putting together a quantitative model to establish the melodic variations and we report in a forthcoming paper.

In a more concise sense, we tend to reflect the old Indian grammarian view that the language is a translator of thought. Chomsky's phrase[35] "infinite use of finite means" is applicable to our model except we think that it is the cognition which is universal and not the grammar. The cognition is infinite and our expressive capacity is finite. The expressive capacity can be trained to draw information from

the cognitive memory and this would be a function of human creativity in recreating cognition in acoustic signals.

Does the thought have a language that speaks through us? If yes, is the language universal? We remind ourselves the observations of the German philosopher Heidegger that the thought is an "engagement by Being for Being![36]"

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