# **A Hierarchical Model of Language**

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## Introduction

If one were to attempt to describe a hierarchical model of language based solely on observations and their ability to comprehend and participate in a vocal form of communication they would probably start with the most basic aspect of which one could think, the ability to create sound. The next logical progression of the model is the ability to manipulate that sound utilizing the parts of the body capable of such, as with the lungs, diaphragm, vocal cords, tongue, lips, etc. The next level that follows is the combination of the different sound manipulations to form complex tones used to describe objects and ideas, i.e. words. Note that in order for all that is said above and below, including this sentence as it is read, to make any sense to the receiver of the information, one would need to possess the cognitive ability to associate these combinations of sounds, known as words, with the objects or ideas they intend, or have been established, to describe. An example is the word "wood" which can be described as a material used for various purposes such as burning or building. We connect the word to a mental image in order to recognize it. Additionally observe that not only does one need to posses the ability to understand the word by itself but also to comprehend the combination of words in some structured format to create simple statements such as individual sentences (e.g. 'Bring me some more wood so I can make the fire larger.'). It follows then, that the observed highest level of a hierarchical model of language is the combination of sentences to form complex thoughts, such as those seen in paragraphs, speeches, and even more complex texts.

The above paragraph illustrates how one could model the hierarchy of language simply by exploring how they use language to communicate with others in their collective community. In order to make these observations advanced knowledge of linguistics is not necessary, rather just the ability to observe and to reason. When one hears the word 'sentence' they immediately associate it with a mental image of what the word means to them. They do not need to know the definition from a dictionary for their mind has already established a connection between the word and the mental image instilled in them through experience. However, if one thinks about the word 'sentence' briefly they will see that the word has multiple meanings used for different applications. Two different meanings of the word "sentence" come to mind. One meaning is the description of a set of words, a word in some cases, creating a question, a statement, etc. which is vocally expressed or written in some characteristic way. Another definition for sentence is a judgment as in a sentence for committing a crime. This ambiguity is not unique to words in spoken languages, as it exists, even more prevalently, in sentences. For example, "I like her cooking" "can mean among other things, I like what she cooks, I like the way she cooks, I like the fact that she cooks, even, I like the fact that she is being cooked" [1]. These ambiguities are not limited to the English language and are present in the many languages of the world. Ambiguities in languages among other topics are the driving force for individuals to pursue the science that studies language better known as linguistics.

Linguists, those who study linguistics, describe the structure of a language in much the same way as laid out in the first paragraph by starting with the smallest units (the sounds) and move up building larger and larger units (words, sentences, paragraphs, complete texts) [2]. However, linguists delve into greater detail concerning the different layers of a language including the mental responses involved in communication. Noam Chomsky is a world renowned linguist who revolutionized linguistics in the 1950's by attempting to explain why humans have the ability to create an infinite number of sentences from a finite number of words. He also attempted to explain the ambiguities present from multiple meanings of single sentences. Until Chomsky began to challenge tradition, linguists had studied language by observing it in action, describing structure through observed use. In the eyes of Chomsky this compared to a physicist simply accepting the fact that an apple falls from the tree because that is what is observed rather than asking why the apple falls from the tree [1]. Chomsky's challenge to traditional linguistics was analogous to the "apple falls" question. His ideas have been expanded upon and are widely used today. Structure of language is still described in Chomsky's model by assigning categories to each level of a language. However, the majority of his work is focused on grammar and syntactical representation of language. Each category can be studied in depth in attempt to classify all languages of the world. The levels of language hierarchy as describe by linguists are:

1. Phonetics – The sounds of a language

- a. Describes the functions involved in creating and manipulating sound and categorizes the sounds into what are called phonemes based on the manipulations in order to create an international alphabet capable of application to the worlds many languages
- 2. Words and their parts
  - a. Describes the combinations of phonemes into larger units, which are not necessarily words, referred to as morphemes.
- 3. The combination of morphemes to form sentences, also known as syntax
- 4. The creation of units larger than individual sentences, such as paragraphs and texts, made by combinations of sentences. Referred to as text linguistics and discourse analysis, by linguists [2].

### **Phonetics & Phonemes**

At the primary, and most important level, language is made of sounds. Phonetics is the term applied to the study of the sounds of a language in a physical sense. In other words how we produce sounds. Sounds, in human languages, have four components:

- 1. Quality or timbre (what makes the sound "a" different than that of "o")
- 2. volume (how loud sound is)
- 3. length (how long the sound lasts)
- 4. pitch or tone (high or low, involves frequency of vibration of the sound) [2]

Eleven organs are involved in the production of sounds for speaking: the diaphragm, trachea, velum, nasal cavity, roof of the mouth, lips, lungs, larynx, uvula, tongue and teeth (Figure 1) [2].



Figure 1. a.) the vocal tract, b) main places of articulation [2]

There are four processes in sound production in which humans utilize these eleven organs; they are:

- 1. air stream
- 2. phonation
- 3. nasalization
- 4. articulation

Combinations of these processes result in the ability to describe the four components of sound listed above.

Air stream involves use of the lungs, diaphragm, and trachea. Air stream is necessary for most sounds excluding clicking type sounds such as those produced by clicking the tongue on the roof of the mouth [2] (e.g. certain clicking sounds made in some African languages). Phonation describes how the vocal cords interact with the air stream to produce sound. The vocal cords consist of a duel membrane valve-like opening in the

larynx. When the vocal cords are open they do not vibrate and only the sound of the air stream is heard (i.e. normal breathing; also applies to whispering). When the vocal cords open and close very fast they produce a sound with a frequency equal to the opening and closing of the vocal cords, between 85 and 155 Hz for an adult male and 165 to 255 Hz for an adult female [3]. Whispering is also described by phonation as it is a form of speech in which the vocal cords are open and do not vibrate, however whispering still puts stress on the vocal cords [4]. Whispering is a form of voiceless sound whereas voiced sound is that in which the vocal cords are vibrating. Nasalization is not always involved in sound production but when it is the air stream flows, voiced or voiceless, through the nasal cavity and may or may not flow through the mouth, depending on the sound being created. Nasalization occurs when making sounds such as those created by the letters m and n and is possible via the opening or closing of the velum [2].

Articulation is the most important sound creating process as it involves the manipulation of the other three sound producing processes, usually in some combination. Figure 1b indicates the parts of the articulatory apparatus that are of greatest interest to the description of sound creation in humans. The articulatory apparatus contains three important areas or cavities: the pharyngeal cavity (throat); the oral cavity (mouth); and the nasal cavity (nose). The air stream coming from the lungs may be modified in these cavities in a variety of ways. Additionally, the larynx may also modify the air stream before reaching any of these cavities [5]. The larynx is a bony boxlike structure in the front of the throat, which contains and controls the vocal cords. The pharyngeal cavity acts as a resonating chamber for the sounds produced by the vibrations of the vocal cords.

By altering the size of the pharyngeal cavity the sound of these vibrations may vary considerably accounting for differences in other languages or dialects of the same language. The oral cavity acts as the greatest source of modifications of the air-stream in the production of sound. The uvula, lower lip, and tongue are mainly responsible for modifications in the oral cavity. The lower lip is moved to meet with the upper lip to create such sounds as at the beginning of the word bin or polymer. The lower lip is also brought in contact with the upper teeth to create sounds such as at the beginning of the word fog or the "ph," f, sound in morphology. Manipulation of the lower lip along with the upper lip is also used to create sounds such as ooh (pronounced ü). The tongue is very flexible in its use in sound manipulation. The back of the tongue can be raised to meet the roof of the mouth to produce k sounds such as at the beginning of cat. The forward part of the tongue can be raised to the roof of the mouth to create sounds such as at the beginning of stop. Additionally the tongue can be placed in between the teeth to create the "th" sounds such as at the beginning of the word there. The tongue can be manipulated in many different ways during vocalization and this manipulation is usually described using the back, center, and tip of the tongue and other parts of the mouth such as soft pallet, hard pallet, teeth and lips [5]. The nasal cavity, as mentioned above, is utilized when creating the sounds of m or n and is activated by the opening of the velum to allow airflow through the nasal cavity. It may be interesting to note that when someone has a cold or sinus problem in which air flow is restricted or completely stopped in the nasal cavity we have the tendency to refer to this as nasal speech when in fact it is quite the opposite [5].

In discussing the various mechanisms involved in sound production by humans it becomes clear that certain sounds have unique characteristics related to the manipulations by the articulatory apparatus. To represent these various sounds and to help identify those that humans are capable of making, regardless of spoken language, the International Phonetic Alphabet (IPA) was developed and is used by linguists for representation of the various languages of the world. The IPA consists of symbols representing various sounds humans are capable of making (figure 2) such as the sounds of the vowels [2] (figure 3). Figures 2 and 3 provide descriptions of how articulation is performed and example words in which the mechanism is utilized.

| Symbol           | Manner of Articulation           | Examples               |
|------------------|----------------------------------|------------------------|
| [p]              | bilabial voiceless stop          | pit, sip, apple        |
| [b]              | bilabial voiced stop             | bit, sob, about        |
| [t]              | alveolar voiceless stop          | tap, sot, about        |
| [d]              | alveolar voiced stop             | dip, sod, adult        |
| [k]              | velar voiceless stop             | car, tack, acorn       |
| [g]              | velar voiced stop                | go, log, agog          |
| [?]              | glottal voiceless stop           | button, mutton         |
| [f]              | labiodental voiceless fricative  | fluff, rough, ruffian  |
| [v]              | labiodental voiced fricative     | vest, love, lover      |
| [e]              | interdental voiceless fricative  | thin, death, ether     |
| [ð]              | interdental voiced fricative     | then, rythm            |
| [s]              | alveolar voiceless fricative     | snake, bass, decent    |
| [z]              | alveolar voiced fricative        | zoo, roses             |
| [š][ſ]           | palatal voiceless fricative      | shell, rush, ashes     |
| [ž][3]           | palatal voiced fricative         | jejune, rouge, closure |
| [h]              | glottal voiceless fricative      | have, hill, house      |
| [č][t∫]          | palatal voiceless affricate      | child, reach, hatchet  |
| [J][d <b>3</b> ] | palatal voiced affricate         | judge, ridge           |
| [m]              | bilabial voiced nasal            | man, mom, lamp         |
| [n]              | alveolar voiced nasal            | nasty, run, ant        |
| [ŋ]              | velar voiced nasal               | hanger, ringing        |
| [1]              | alveolar voiced (lateral) liquid | love, hill, plate      |
| [r]              | alveolar voiced liquid           | ring, floor, crow      |
| [w]              | bilabial voiced glide            | wood, awash            |
| [y]              | palatal voiced glide             | young, canyon          |

Figure 2: English consonants from the IPA [2]

| Symbol | Articulation     | Example                  |
|--------|------------------|--------------------------|
| [i]    | front high tense | beat, feet               |
| [I]    | front high lax   | bit, pit                 |
| [e]    | front mid tense  | day, pey                 |
| [2]    | front mid lax    | pet, net                 |
| [æ]    | front low lax    | cat, mat                 |
| [u]    | back high tense  | loot, you                |
| [U]    | back high lax    | put, foot                |
| [ə]    | central mid lax  | but, a, the (unstressed) |
| [o]    | back mid tense   | row, low, baugh          |
| [ɔ]    | back mid lax     | cop, not                 |
| [a]    | back low lax     | pasta, father            |

Figure 3: English vowels from the IPA [2]

To account for the differences observed in the production of the "same" sound by different humans, such as that between a man and a woman, the concept of a phoneme was developed. A phoneme is a mental image of a sound, in a language, as

well as the smallest unit of language that helps distinguish meaning [2], [6]. Phonemes are used to represent each symbol in the IPA and there are around 40 phonemes used to describe the English language [2]. Phonemes are generally represented with forward slashes, //, instead of brackets, [], to indicate a difference between the mental image of a sound and the description of the sound itself. Thus the primary level traditionally used by linguists to describe a language is centered on the phoneme which involves the ability to create and manipulate sound into different recognizable mental images for the receiver. Without the phoneme, language would not exist much like life on earth would not exist without amino acids.

#### Words & Morphemes

The second level described in the traditional model used by linguists consists of the combination of phonemes to create a larger unit known as a morpheme. A morpheme is not necessarily a single word but it can be. Additionally a single word may consist of

two or more morphemes. An example of a single morpheme that represents two words is the morpheme /putDf/ consisting of the phonemes /p/, /u/, /t/, /D/, /f/ and representing the short phrase "put off." An example of a single word represented by two morphemes would be "dogs" with morpheme representation of /d g/+/-z/ consisting of the phonemes  $\frac{d}{\sqrt{2}}, \frac{d}{2}, \frac{d}{2}$ . The  $\frac{-z}{z}$  is different from a phoneme and is considered a morpheme. The /-z/ morpheme is a plurality as well as a bound morpheme, that is it cannot exist alone in speech or writing. The morpheme /d2g/ in this case can exist alone in speech and therefore is termed a free morpheme often called root morphemes or stems. Bound morphemes are called "affixes" because they need to attach to another morpheme. For this reason the term "word" is not a technical term used in linguistics [2]. There are rules for the combination of phonemes to form morphemes mainly governed by the cognitive capacity of the individuals participating in communication to understand the meaning of the uttered morpheme or word and the ability to attach it to a mental object thus giving it meaning. For example, the combination of the following phonemes, /p/, /b/, /a/, /g/, /f/, /y/,  $/\theta$ /, produces the morpheme /pbagfy $\theta$ /. The sound of this particular morpheme, at least in the English language, is simply gibberish and produces no mental connection in the receiver. However the combination of the phonemes /s/, /k/, /u/, /u/, /l/ produces the morpheme /skuul/ and represents the word "school" which is recognizable in the English language and a mental connection to the meaning is made. As mentioned there are rules but they do not always have to be followed, for example someone could begin using the morpheme /pbagfy $\theta$ / to begin describing any object or idea they feel like and as long as they are consistent and others begin to mentally connect the morpheme or word to that object a new word could be invented. However, the majority of languages have

particular patterns and combinations of phonemes and morphemes in the makeup of words that act as guidelines for which combinations are acceptable for comprehension. There are other ways, besides invention, of creating new words such as derivation where a new word is derived from existing morphemes as seen in conversion from an adjective to adverb as in quick to quickly. There is also compounding where two words are put together to form a new one, blends such as the word "brunch", borrowing where words from other languages are used and clipping where new words are created by shortening existing words such as "phone" from "telephone" [2]. Regardless of the rules or quasi rules for combination of phonemes to form morphemes and the use of morphemes to describe words in the various languages of the world it is seen that the concept of the morpheme can apply to any language of the world and we recognize the morpheme as the secondary level in the hierarchical model of vocal language. Though the term word is not a technical term in linguistics it can be considered an intermediate of the hierarchical model of language between the morpheme and the next level which involves the combination of morphemes and words to form sentences.

#### Sentences & Syntax

When morphemes of the right kind are combined, sentences can be formed [2]. When a phoneme is uttered it generates a mental image of the sound but does not necessarily lead to association with any given meaning. The correct combination of phonemes to form morphemes can, however, lead to association with a given meaning of an object or idea. This alone is not enough to satisfy communication. The ability to combine morphemes to create sentences gives humans the power to create an infinite number of sentences from a

finite number of sounds and thus the ability to communicate complex thought to one another. This is known as the double articulation of language, or duality [2]. The ability to communicate complex thought could be compared to the ability of a protein to function through the correct combination of amino acids (phonemes) to form alpha helices and beta sheets (morphemes) and the correct folding of ordered chains of amino acids into functional proteins (sentences). Syntax is the term used to describe acceptable structure of morpheme combinations also known as grammar. A sentence is said to be grammatical if the speakers of the language agree that it is a sentence that they would produce under the appropriate circumstances [2]. The combination of morphemes to form complex thought leads to the necessity of classification of different morphemes which leads to the lexicons of grammar such as the noun, verb, adjective, adverb, etc. In the English language, as well as in other languages, there are certain guidelines for the combination of morphemes just as there are guidelines for the combination of phonemes to form morphemes. A tree diagram is traditionally used to represent the structure of the sentence and shows with branching lines the process of breaking down a sentence (figure 4) [2].



The S in figure 4 represents the sentence, NP stands for noun phrase, N for noun, VP for verb phrase, V for verb, PP for prepositional phrase, Prep for the preposition, Art for the article and Adj for adjective. Tree diagrams break a sentence down into its phrasal categories and further into its lexical categories to describe the words that

make up the sentence. The tree diagram provides a way to work back from the sentence to the words and from the words to morphemes and from morphemes back to the most basic unit the Phoneme. Thus the third level of the hierarchical model of language is the combination of words to form sentences.

#### Paragraphs, Speeches, Texts, etc...

Sentences do not usually exist by themselves as they are usually accompanied by other sentences whether in the form of a paragraph, conversation or a text. As with the formation of sentences from words & morphemes which themselves are composed of combinations of phonemes, formation of paragraphs, conversations or texts follow guidelines to ensure cohesion and coherence. If the guidelines are not followed gibberish may result, or possibly a derivatization of an existing language. This is analogous to a mutation of a biological cell that results from a different combination of amino acids, folding during protein formation, or combinations of proteins resulting in the death of the cell or possibly a cancerous cell. The outcome of deviating from the guidelines is not always bad, however, and changes could be made to a language which improves the properties of cohesion and coherence, much like the evolution of life. Cohesion essentially is the tying together of sentences in the text such as:

The dog snuck into the kitchen. He searched through the garbage for food. *The dog* is the noun phrase and is tied to the second sentence through the pronoun *he* thus creating cohesion between the two sentences and creating a combination of sentences that can be mentally understood. Coherence is essentially the meaning of a paragraph, conversation or text. It is the combination of cohesive sentences to form a larger unit that forms a point or main idea of some text. The point or main idea does not necessarily have to be stated explicitly in a text and can be gathered through interpretation of the overall content. It is easily seen that a text can be broken down into its component sentences which can further be broken down into words, morphemes and finally phonemes. Thus it is seen that the combination of sentences in a cohesive and coherent model is the highest level of the hierarchical model of language as the combination of texts or conversations could just be considered larger versions of the same thing.

#### **Closing Remarks**

In describing a hierarchical model of language based on ones experience with language will lead to a model which describes the language they are familiar with. However, inherent ambiguities make it difficult to apply the model to other languages. The linguistic principles popularized by Noam Chomsky attempt to account for the ambiguities and make it possible to describe the structure of language in such a way that it can be applied to any language of the world. Chomsky views linguistics as just like other scientific fields in which the tools described above are utilized to explain the variations of language in combination with mental responses to language. According to Chomsky actual speech performance is just the top of a large iceberg that makes up the science of linguistics [1]. However the foundation for linguistics is the hierarchical model from the most basic unit, the phoneme, to the most complex, the conversation and text.

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