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ABSTRACT

This paper advances answers to two questions: (1) Where do we stand now in terms of the contributions of physiology to the study of language? The answer to the first question is provided in the form of twelve propositions which review the contributions of physiology to the species specificity of language question, the neurological components of language question, the language development question, the language process question, and the language disorders question. The answer to the second question assumes the form of three propositions which predict that physiologists will adopt a language perspective, that the interdisciplinary nature of speech communication recommends the marriage of speech communication and physiology, and that physiology will characterize future language research. A 57-item bibliography is provided. (HOD)

THE ACTUAL AND POTENTIAL CONTRIBUTIONS OF PHYSIOLOGY TO THE STUDY OF LANGUAGE

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THE ACTUAL AND POTENTIAL CONTRIBUTIONS OF PHYSIOLOGY TO THE STUDY OF LANGUAGE

The purpose of this paper is to answer the following two questions: (1) Where do we stand now in terms of the contributions of physiology to the study of language and (2) What potential contribution can physiology make to the study of language. The answer to the second question rests upon the answer to the first and, consequently, the major focus of this paper is directed to the contributions of physiology to the study of language.

Three monographs have treated the contributions of physiology to the study of language and speech (Ranke and Lulius, 1953; Luchsinger and Arnold, 1959; and Van Den Berg, 1962). Ranke and Lulius wrote in German and this monograph has limited relevance to monolingual Americans. Luchsinger and Arnold focused on genetics and their monograph is only peripherally important for this paper. Van Den Berg limits his treatment to experimental phonetics and thus, is more relevant to speech than language. Accordingly, it appears that a need exists for a paper relating physiology to language.

The nature of the relationship between physiology and language dictates the organizational pattern for this paper. The paper includes a definitional section, a contributions section and a prediction section.

The definitional section distinguishes language from speech and delineates the relationship between language and memory. In addition, it treats the several types of physiology and the techniques of physiological research.

Using the definitional section as a basis an attempt is made to answer the first research question concerning the contributions of the discipline of physiology to the study of language. The contributions can be divided into the following areas: the determination of the species specificity of language, the isolation of language elements, the understanding of language development in the child, the description of language processes in the adult and the diagnosis of language disturbances. These contributions will assume the form of twelve propositions:

P_1 : Language is species specific to humans.

P_2 : Language results from the coded protein patterns of ribonucleic acid (RNA) components of cortical neurons.

P_3 : The neuron is the basic unit of language behavior.

P_4 : Language development awaits a level of development in the perceptorium, interpretatorium, and motorium.

P_5 : Modality specific internuncial neurons receive word and experience sensory information from the environment in the primary modality cortexes.

P_6 : Modality specific short term memory systems in the secondary association areas retain language relevant sensory information on reverberating circuits until completion of interpretation in the modality specific long term memory system.

P_7 : Polymodal internuncial neurons form the multiple modality memory system which combines language relevant sensory information from five modality association areas in order to interpret complex language relevant stimuli complexes in the common integratory area.

P_8 : The ideomotor region determines the content of language behavior.

P_9: The speech premotor areas govern the patterns of language behavior.

P_{10}: Internuncial motor neurons transmit language relevant stimuli from the premotor to the language relevant muscles by means of the motor cortex.

P_{11}: Subcortical structures play a significant role in language.

P_{12}: Organic disorders in the cortex and subcortex can cause language disorders.

The prediction section will answer the second research question: What potential contribution can physiology make to the study of language? The answer to this question relates to the answer to the first question in the sense that physiology will continue to aid understanding of the language areas to which it has contributed to date. Moreover, new research techniques and old research techniques used in novel ways will enable language theorists to investigate the language phenomenon in greater depth. The following propositions outline the potential contributions of physiology to the study of language.

P_{13}: Physiologists with a primary interest in language will conduct systematic research into the physiology of language and avoid the present state characterized by the mere tangential interest of physiologists in language.

P_{14}: The discipline of speech communication will provide the interdisciplinary atmosphere and macro theories of language into which current physiological findings might fit.

P_{15}: Physiological theories, procedures, and techniques will characterize future research in language.

Language

George Bordon (Bordon, Gregg, and Grove, 1969, p. 63) defines language as "an interassociation of word, concept, and experience memory traces." Miller and McNeill (1968, p. 670) hold that language is "a scientific hypothesis about a cognitive competence shared by members of a given language community." Both of these definitions recognize de Saussure's (1916) distinction between the 'memory' or 'cognitive' base of language (la langue) as opposed to the speech performance of the individual language user (les actes de parole). According to de Saussure, speech offers the evidence by which one can infer about those memory or cognitive processes. Physiology has contributed greatly to the understanding of speech processes and one may review this literature in speech and hearing books such as Levin (1962), and Zemlin (1968). However, it is the contributions of physiology to the understanding of the 'language hypothesis' that holds the attention of this project.

Physiology

Zemlin(1968) defines physiology as "a science dealing with the function of living organisms and their parts." Zemlin, as does this paper, distinguishes physiology from anatomy, morphology, pathology, and genetics. Anatomy studies the structure of organisms and the relations of the parts; morphology studies the form and structure of organisms; pathology treats dead tissues; and genetics investigates the transmission of chromosomes from one generation to another. It must be recognized that these distinctions are distinctions of emphasis rather than discrete categories. Thus, an investigation into the relationship of physiology and language would be rather abstract without consideration of the anatomical structure and morphological form of the language centers. Further, pathological investigation of aphasic brains has contributed knowledge to physiology and language. One must also recognize that transmission of chromosomes determines the physiological characteristics of humans and directly influences language (Luchsinger and Arnold, 1965). Accordingly this paper focuses on physiology and recognizes that some findings emerge from related disciplines.

Zemlin also distinguishes between animal physiology, applied physiology, cellular physiology, experimental physiology, and pathological physiology. Animal physiology deals with the functions of living animals; applied physiology deals with the application of physiology to medecine or industry; cellular physiology focuses on the functions of cells; experimental physiology manipulates organisms to discover their functions; and pathological physiology studies organisms modified by disease. To Zemlin's taxonomy of physiology one might add the subdiscipline of psychophysiology which combines the disciplines of physiology and psychology and neurophysiology which focuses on the functions of the brain and cerebral elements.

Physiology and Language

Physiology, the science of dealing with the functions of living organisms has and will continue to contribute to our understanding of language, the hypothesized cognitive interassociation of word, concept, and experience memory traces. The definition of language places language under the rubric of neurophysiology and this subdiscipline has contributed more to the understanding of language than any of the five types of physiology (Zemlin, 1968) combined. It must be realized, however, that animal physiology has enabled researchers to shed light on the species specificity of language; that cellular physiology has facilitated understanding of the neuronal components of language; that experimental physiology has aided conceptualization of the sensory and motor dimensions of language; and that pathological physiology has added knowledge to the study of language disorders such as aphasis and agnosia. It follows that this paper focuses its attention on the contributions of neurophysiology to the study of language and relies on the remaining subdivisions of physiology for supportative findings.

Physiology may be operationally defined in terms of the methodologies and technologies which characterize the discipline. These include the Electroencephalogram (EEG), the Electromyographogram (EMG), the Galvanic Skin Response (GSR), the sperometer, flometer, high speed photography, radiography, and stroboscopy, among others. The EEG falls into the subdiscipline of neurophysiology and demands extensive description at this point. The EMG, GSR, and remaining techniques have more relevance to general physiology than to the cerebral 'seat of language' and accordingly, are treated in a more fleeting manner.

Electroencephalogy (EEG) provides an indirect means of securing information about the functions of the central nervous system (Ven Den Berg, 1962), the seat of language. The EEG involves recording electrical potentials from the human's head by means of scalp electrodes placed on the skull(Best and Taylor, 1966) or needle electrofes which physiologists 'speak' into cerebral cells (Ziener, 1972). The electrodes are magnified and recorded on oscilloscopes.

Normal EEG ratings are characterized by three frequency bands: alpha, beta, and delta rhythms. Eight to 10 alpha rhythms occur per second and usually have a 50 microvolt charge. These rhythms characterize the brain in light sleep (Best and Taylor, 1966). Fifteen to 60 beta rhythms occur per second and the waves have a mere five to 10 mv. charge. Guyton (1967) claims that beta waves characterize the active brain which is in the process of eliciting muscle activity or other behavior. Delta waves range from one to five per second and possess higher voltage (20 - 200 mv.). These waves occur when the adult sleeps or in the state of wakefulness in the infant. The EEG is one of the few means of measuring central nervous system activity and has been used in language oriented neurological research (Morrell, 1969; Pribram, 1969).

Electromyography (EMG) involves recording electrical potentials of muscles and according to Van Den Berg (1962, p. 97) serves two main purposes "(1) to test the conduction of a certain muscle or part of that muscle and (2) to test the coordination of the activities of antagonistic muscles." The process involves the application of either surface electrodes pressed against the surface covering of the muscle by adhesive tape or suction, or needle electrodes introduced through the skin into the muscle.

The EMG can provide data about sensory and motor nerves, spinal reflexes, as well as muscles. It can also offer information about the nervous and muscular correlates of neural disorders. However, the EMG probably provides more data about speech behavior than about the language hypothesis. For example, Malmo, Boag, and Smith (1957) found that muscle tension fell rapidly after praise in an interview situation and remained constant in the criticism situation.

The Galvanic Skin Response (GSR) involves measuring the moisture level of the skin and contributes to the study of connotational meaning of language. Smith (1922) reported differences in GSR responses to emotional affective words and descriptive verbs and nouns. Statts, Statts, and Crawford (1962) and Maltzman (1968) conditioned words to shocks and harsh noises and evoked GSR responses. Curiously the literature reviews include the foregoing research under the rubric of attitude and attitude change (Shapiro and Cider, 1968; Kiesler, Collins, and Miller, 1969).

Other physiological research techniques fall into the speech and hearing area more than into that of language. Van Den Berg (1962) mentions the following respiratory measures: the spirometer and flometer, and the following vocalization measures: high speed photography, stroboscopy and radiography.

The definitions of language and physiology as well as a discussion of their relationship complete the first section of this paper. The second section delineates the contributions of physiology to the study of language.

Section II

The Contributions of Physiology to Language

The second section of this paper offers an answer to the first research question: Where do we stand now in terms of contributions of physiology to thestudy of language? As predicted above, the answer involves describing the contributions of physiology to the species specificity question, the language development question, the language component question, the language process question, and the language disorder question. The propositions and their physiological support follow.

Proposition 1

The species specificity of language stated in proposition 1 has long served as a tenet in the belief of language theorists (Lenneberg, 1967; Brazier, 1967).Some debated this position following the demonstration of effective tactile, chemical and auditory communication among ants (Allee et al, 1949), the communicative "wagging dance" of bees reported by von Frisch (1950) and Thorpe (1950), and examples of animal cooperation on complex tasks (Nissen, 1951). For example, Hayes and Hayes (1951) argued that the chimpanzee may well be close to a limenal level which would make language possible. Hebb and Thompson (1968) resolve the debate by distinguishing three levels of communication: reflexive communication such as that demonstrated by the ants and bees, purposive but nonsyntactic communication, such as that demonstrated by Washoe, the symbol learning monkey (Calder, 1970), and syntactic and usually purposive communication such as that demonstrated by language using man.

Recent works by Lenneberg (1967a, 1967b) and Brazier (1967) marshall the arguments of those who hold the species specificity of language belief. Lenneberg (1966) bases his arguments on the functional specialization of <u>homo sapiens</u> language oriented neurophysiology, such as oropharyngeal morphology cited by De Brul (1958), cerebral dominance (Ajuriaguerra and Hiecaen, 1949), specialization in cer ebrocortical topography (Calder, 1971), special coordination centers for motor speech (Penfield and Roberts, 1959), specialized temporal pattern perception (Zemlin, 1968), special respiratory adjustment and tolerance for prolonged speech activites (Lenneberg, 1967a), and a long list of sensory and cognitive language perception prerequisites (Zangwill, 1960; Everett, 1971).

Mary Brazier (1967, p. 65) argues that "Neurophysiologically, the two phenomena (vocalization of animals, and language) have two totally different mechanisms in the brain and only share the most peripheral apparatus for articulation." Animal vocalizations have subcortical bases. Thus, stimulation of the animal brain stem produced primitive vocalization (Magoun, Atlas, Ingersoll, and Ranson, 1937); stimulation of the midbrain produced laughter like vocalizations (Brown, 1915); stimulation of the hypothalamus and midbrain produced facial-vocal responses, stimulation of rostral brain stem and periaqueductal grey area evoked crying (Shanzer and Wagman (1960); (Skultety, 1963); and stimulation of the hyppocampus and amygdala evoked emotional cries (Kaada, 1951). Thus, animal vocaliations emerge in subcortical regions.

Several of man's language related neurophysiological characteristics distinguish his language behavior from primitive animal vocalizations. First, lateralization characterizes human language functions whereas bilaterality characterizes animal communication functions (Lenneberg, 1967a), Second within the dominant cerebral hemisphere (left hemisphere in nine out of ten cases) motor and sensory mechanisms display an anter-posterior polarization such that language motor behavior tends towards the anterior and language sensory behavior tends towards the posterior. The numerous subcortical bases of animal communication fail to demonstrate the localization demonstrated by human language oriented neurophysiology. Brazier (1967, p. 66) argues the third point that "Conveyance of the 'particular' message had to await man's development of a language with symbols expressive not only of hypothalamic experiences but of his much prized neocortical experiences". Finally, Lenneberg (1967a, b) takes pains to point out specialized physiological equipment that language using man possesses such as the highly specialized vocal tract characterized by such unique traits as the risorius Santarini about which he argues:

> One muscle risorius Santorini has no undisputed homologue in any subhuman form, and in the muscles of the lips (orbicularis oris) the fibers around the oral margin (pars marginalis) assume an anatomic prominence not found elsewhere among primates. (Lenneberg, 1967a, p. 37)

Combined, these data support the long held belief that language represents a uniquely human capacity. The distance which man's close phylogenetic relatives have to travel to achieve language remains to be determined by means of future physiological and neurophysiological research.

Proposition 2

Proposition two holds that long term memory traces and the language built upon long term memory traces (Bordon, Gregg and Groce, 1969) results from the coded protein patterns of ribonucleic acid (RNA) components of cortical neurons. RNA is a protein chain composed of four amino acids: adinine, cytosine, guanine, and uracil and it appears that long term memory involves changes in at least three of the four acids. Best and Taylor (1966) review several studies and report that long term memory involves an increase in adenine and a fall in cytosine while Dingman and Sporn (1961) found that the substitution of a similar substance for guanine will cause forgetting.

The RNA base of memory was discovered in 1959 when Hyden demonstrated that stimulation of brain tissues caused neuronal RNA increases and that significant changes took place in RNA after learning. Babich et al (1965) offered support for the RNA-memory connection when he transferred RNA from trained to untrained rats and discovered that untrained rats injected with RNA learned faster than those which were not injected. Finally, Flexner et al (1963) offered results indicating that injections suppressing RNA's protein synthesis function disrupted previously acquired memory traces.

It appears that long term memory traces and the language built on long term memory traces does result from the coded protein patterns of ribonucleic acid (RNA) components of cortical neurons. However, RNA functions as part of the neuron, a larger organism and has significance only as a component of the neuron.

Proposition 3

The third proposition holds that the neuron is the basic unit of language. Neurons have three main functional classiciations: sensory neurons carry information from the environment to the central nervous system. Internuncial neurons carry information within the central nervous system and efferent neurons carry information back to the behavioral muscles. As one might infer, neurons are unidirectional. Neurons in the central nervous system, which are the focus of this paper, possess dendrites, cell bodies, axons and synapses. RNA functions only within the cell of the neuron and relies on the remaining intra and extra cellular parts of the neuron to function.

RNA preserves learned or experiential structure by imposing the memorized form on the new protein molecules which the cell of the neuron continually produces. Nisel bodies also take part in protein production and are "numerous flattened vesicles, tightly packed and communicating; their vesicles . . . lined by extremely delicate membranes of which the surface . . . is covered with RNA granules." (Elliot, 1963, p. 18)

Memory, and consequently, language resides in the eell of the neuron. While dendrides carry stimulations the raw material of memory (and language), axons carry the responses away to other parts of the memory (language) syste.. The dendrite reveives information at the synapse and carries it to the cell body. Anatomically, dendrites can range from a few microns to several milimeters in length, taper as they branch, and do not possess the myelin sheath. Axons, on the other hand, conduct responses from the cell body to the synapse for transmission to the next neuron. Each neuron has only one axon, as opposed to multiple dendrides, and these axons range from a few microns to a yard in length, and possess a myelin sheath. The dendrite receives and the axon transmits information at interneurons connections called synapses.

Elliott (1969, p. 71) defines the synapse as "the point of contact between an axon terminal of one neuron (the presynaptic) and a dendrite of the cell body of another (the post-synaptic)." Chemicals called transmitters inhabit the submicroscopic gap between the pre-synaptic and post-synaptic neurons. Some of these transmitters contain acetylchlorine and fire the post synaptic neuron when a super threshhold collection accumulates. Some of these synapses contain Y-aminobyric acid (GABA) and inhibit transmission by raising the threshhold.

Physiologists have determined that the post-synaptic neuron fires when its excitatory potential has reached its threshhold and the information travels through the next neuron with the aid of the 'ion pump'. This pump conducts sodium ions in through the permeable axolema covering the neuron and pumps potassium ions out through the axolema which has a negative charge inside and positive charge without. The electrochemical discharge of the synapse fires the neuron and the conduction direction of the ion pump reverses the directions of the sodium and potassium ions. Differential rates of sodium and potassium movement through the permeable cell membrane causes a systematic electrical sign change as the excitation travels along the neuron. After the excitation has passed, the sodium and potassium ions return to their inactive states.

The neuron is the basic unit of memory, language, as well as the central nervous system. Physiologists have isolated specialist neurons which can receive, interpret and transmit language oriented messages in the central nervous system. Several have suggested that this specialization is a prerequisite for the existence of language in the child.

Proposition 4

Proposition four holds that the development of language awaits a level of maturation in the perceptorium. interpretatorium, and motorium. Travis (1971, p. 689) claims that a certain level of organismic development must exist prior to the existence of language . . . the result of simultaneous maturation of the perceptorium, the vocalization mechanism, and the general motorium. Travis' maturational specifications parallel those proposed by Meumann (1908): a level of sensory, motor, psychomotor, and intellectual maturation. The perceptorium relates to the necessity of eye-ear-hand sensory coordination (or in more physiological terms, the coordination of the visual, auditory, and tactile sensory cortices); the vocalization system such as the respiratory, phonetory, and articulatory subsystems. The development of each of these specialized areas awaits the myelinization of the cortical neurons and their connection awaits development of intercortical neurons. This usually happens around 18 months in the human infant after modality specific sensory neurons have joined.

Proposition 5

The fifth proposition holds that modality specific internuncial neurons receive word and experience memory traces from the environment in the primary modality areas of the cortex. Each sensory modality has specific neuro-anatomic areas for cerebral treatment of incoming sensory information. As Guyton (1967, p. 254) explains:

> The sensations of vision, hearing, taste, and smell, like thesomesthetic sensations, are each transmitted from the receptor organs to small circumscribed areas in the cerebral cortex, each of the areas having a different location. These areas are called the primary cortical areas for sensations, and from each primary area the impulses go to an association area.

Three of the five cortical sensory modality areas bear relevance to the physiology-language topic of this paper since humans receive information in the auditory, visual, and tactile modalities.

Addressing the question of sense modality relevance to language Zangwill (1960, p. 1710) adopts the following views of the phenomenon: "The understanding of speech is to be regarded properly as a problem in auditory physiology." Zangwill might add that language behavior also adopts the form of print and that graphic language must be encoded and decoded in the visual modality. Finally, the tactile-sensory modality carries brail encoded language behavior to the blind and any comprehensive review of the influence of physiology on language must include the somesthetic cortex. Thus, the following pages treat the physiology of auditory, visual, and tactile language behavior in that order.

The primary auditory cortex lies in the frontal superior part of the temporal lobe. Auditory sensations travel from the ear, through the subcortical thalamic area, to the primary auditory areas on the counterlateral hemispheres. A mere 20 percent of the auditory input from one ear travels to its own hemisphere. The primary auditory cortex relays incoming information to the secondary auditory area.

The primary visual cortex is located in the calcarine fissure in the posterior part of the occipital lobe on the medial side of each hemisphere. The primary visual cortex serves as a relay station for visual sensations sending them to the secondary visual cortex.

The primary somesthetic cortex lies in the midpoint of the posterior part of the central fissure and can differenciate miniscule patterns of bumps comprising the brail alphabet. The primary somesthetic cortex transmits information to the secondary somesthetic area for interpretation.

Physiologists have focused on the specific neuronal functions within modality cortexes. Jung (1969), for example, distinguished five neuronal types in the visual cortex and labeled them alphabetically. A neurons comprise less than half of the neurons in the visual cortex (Baumartner and Jung, 1955) and subgroups among this heterogeneous group respond to flickers (Creutzfeldt and Baumgartner and Schoen, 1957), light stimuli (Akimoto and Creutzfeldt, 1957-8), and moving stimuli (Hubel, 1953). B neurons deal with brightness and number about a quarter of the total within the cortex. C neurons show inhibition to lights (on, off) and number from three to five percent of the total. D neurons show strong initial inhibitory reactions to flashes of light and are slow to react. They mediate information about darkness. E neurons play inhibitory roles also.

Likewise, the auditory and somesthetic cortex has neurons which can distinguish variations in sound and touch respectively. Therefore modality specific internuncial neurons do receive word and experience sensory information from the environment in the modality specific primary and secondary sensory areas of the cortex. Of these five areas, the auditory, visual, and tactile areas provide the words and experience upon which language builds. This sensory information must undergo interpretation and the short and long term modality memory systems aid in this process.

Proposition 6

Proposition six holds that modality specific short term memory systems in the secondary association areas retain language relevant sensory information on reverberating circuits until completion of the interpretation in the modality specific long term memory system. Best and Taylor (1960) describe this principle when they argue that repeated excitation of neurons in reverberating circuits of feedback loops maintains the sensory information until interpretation and the RNA changes underlying the fixation of memory traces has been completed. In such a reverberating circuit, the first neuron is fired by the input and in turn fires the second and the third until the first is fired once more. While the short term memory holds the sensory input in the holding pattern a search is conducted through the long term memory populated by neurons organized into schemata. Schemata are RNA based memory traces organized around some common quality and sensory information will meaningfully fixate in the memory only when it coincides with some existing schemata or engrams (Terwellinger, 1968). The secondary auditory, visual, and somesthetic sensory areas play influential roles in the interpretation of language relevant information.

The auditory association area surrounds the primary auditory cortex from which it receives information. Guyton (1968, p. 255) distinguishes functional parts of this area:

> One part of the association area determines whether the sound is noise, music, or speech; then other parts determine the thoughts conveyed by the sound. To interpret the meaning of speech, the auditory association area first combines the various syllables into words, then words into phrases, phrases into sentences, and finally sentences into thoughts.

The interpretation of words involves a process of relating them to those heard at other periods in the individual's life (Everett, 1971). This relational process can be viewed as a matching process between the sounds or word stimulus and a generic sound or word model (Brazier, 1967) found in the RNA based modality memory of the auditory association area. Worded in a different manner, this process involves the comparison of incoming sounds to a related schemata, temporally organized around sounds (inflections), morphemes, phonemes, words, grammar, or syntax (Bordon, Gregg, and Grove, 1969). The sensory information becomes part of the modality memory if such a match occurs or new sensory data is sought in the common integratory area if no match evolves.

The visual association area anterior to the primary visual cortex integrates data in a spatial manner and performs a rudimentary sort by means of pattern perception and figure-ground relationships. Everett (1971) reports that :

> stimulation of the peristriate area (secondary visual cortex) produces integration of the more primitive impressions . . . into geometric figures; stimulation of the frontal part of the visual association cortex introduces colour and definitive forms of familiar objects.

One of the most important functions of the visual cortex lies in its interpretation of written language behavior. To accomplish this feat the area must discern the light and dark parts of the letters, the words from the combination of letters, and the sentences from the patterns of words.

Interpretation of written language involves an association between the reverberating circuits carrying visual impression of written language in the left hemisphere with the visual memory schemata stored in the right occipital lobe, as well as the schematization of concretes stored in the right temporal lobe (Milner, 1962).

The somesthetic association area functions according to a similar principle to determine the significance of tactile sensory input such as brail. Guyton explains:

> Many of the memories of past sensory experiences are stored in the somesthetic association area, and when new sensations similar to the old ones arrive in the brain the parallel nature of the two sensations is immediately discerned.

Novel sensations travel to the common integratory area for interpretation, as explained by proposition five.

Proposition 7

Proposition seven holds that polymodal internuncial neurons from the multiple modality memory system which combines language relevant information from the five modality association areas in order to interpret difficult language relevant stimuli complexes in the common integratory area. The common integrative area is located in the angular gyrus (left hemisphere in 9 of 10 humans) of the brain midway between the auditory, visual and somesthetic association areas as well as the taste and smell association areas. Guyton explains that:

> thoughts from the different sensory areas are correlated and weighed against each other for deeper conclusions than can be attained by any one of the association areas alone (Guyton, 1967, p. 255)

The polymodal neuron plays a leading role in the functioning of this area.

Polymodal neurons react to input from different senses and play a crucial role in interpreting multiple sensory inputs. Morrell (1966) offered a comprehensive description of the functions of this type of neuron in the visual association area. The polymodal neurons in the visual cortex respond to auditory and tactile stimuli as well as visual stimuli. These neurons represent 10 percent of the total number of neurons in the visual cortex and respond to auditory stimuli, such as clicks, sensory stimuli, such as shocks, as well as visual stimuli such as flashing lights. Morrell's results correspond to those reported by Murata, Cramer, and Bach-y-Rita (1965) and Jung (1967) in reference to thevisual cortex as well as multimodality characteristics of lateral geniculate neurons (Chow and Lindsley, 1969), the reticular formation (Yoshi and Gaura, 1960), the thalamus (Kamikawa, McIlwain, and Adey (1964). Wiengarten and Spinelli (1966) have demonstrated changes in the retinal ganglion cells as the results of sound or tactile stimulation, thus indicating the phenomenon exists at the extraceptory as well as at higher subcortical areas.

The existence of polymodal neurons in the common integratory area can explain the multi-modal integrative functions of this area. MOreover, the auditory, visual and tactile representations of language units may very well develop associations with their sensory correlates by means of polymodal neurons situated both in the secondary modality areas as well as the common integrative area. If such is the case one might predict that the association area polymodal neurons would integrate language and concrete experiences while the common integratory area would handle more abstrct multi-modal word experience relationships. Unfortunately physiologists have offered no definitive data yet.

Proposition 8

Proposition eight holds that the ideomotor region determines the content language behavior. Guyton (1967) argues that this area formulates the thought appropriate to an interpreted stimulus configuration and sends syllable or word impulses to the premotor area for language behavior. The actual modus operandus of this high level cerebral activity remains a mystery which physiologists must yet explore.

Proposition 9

Proposition nine holds that speech premotor areas govern the patterns of the language behavior. Guyton (1967) explains that the premotor language area

> controls the larynx and the mouth. This area is called Broca's area, or it is sometimes called simply the speech center . . . . it is here that the muscular patterns for forming different sounds by the larynx and mouth are controlled. Impulses arriving from the ideomotor area set off a sequence of patterns, and these in turn form the words. In addition to controlling the larynx and mouth, Broca's area sends impulses into an allied region of the premotor cortex that controls respiration. At the same time that the laryngeal and mouth movements occur, the respiratory muscles are contracted to provide appropriate air flow for the speech process. (p. 269)

Neural physiologists have located Broca's area in the parietal-temporal -occipital area of the brain and the area consists of large cells in the third and fifth cortical layers surrounded by and partly overlapped by the homotypical isocortex. Gerschwind and Levitsky determined that the majority of humans had larger speech areas in the left side of their brain than in the right. The area is similar to that identified by Wernicke a hundred years ago as being in the higher analysis of speech sounds (Caulder, 1971).

Damage to this area causes permanent loss of speech. Apparently, other speech areas exist, one in the side of the frontal lobe which aids in utterance formations and a third area located in the upper areas of the frontal lobe. Damage in the second area causes long term but not permanent damage to speech, and damage to the third area causes short term verbal problems. (Penfield and Roberts, 1969)

Proposition 10

Proposition ten holds that internuncial motor neurons transmit linguistic stimuli from the premotor cortex to the vocalization muscles through the subcortical neural system and nervous system. Penfield and Roberts (1959) stimulated different sections of the motor cortex along the anterior part of the central gyrus and reported that various part of thehuman responded. It appears that parts of the body have an inverse representation in the motor cortex, such that stimulation of the superior part of the gyrus activates the toes while stimulation of the inferior part of the gyrus activates the face and mouth. Moreover, different parts of the body possess differential spatial allotments in the motor cortex, such that muscles used on numerous occasions have a greater cover, a greater amount of neural area than those which aren't used often. Of special interest is the fact that the mouth has more cortical representation than nearly any other part of the anatomy except for the hands. The internuncial motor neurons demonstrate specialization much as do the internuncial sensory neurons.

Proposition 11

Proposition 11 holds that subcortical structures play a significant role in language. · Human language behavior depends on subcortical structures for, as Guyton (1967, p. 236) claims, "the thalamus seems to be the main control center for eliciting cortical activity." Penfield and Roberts (1959, p. 207) concur in a most explicit manner in the following hypothesis:

> It is proposed as a speech hypothesis, that the function of all three cortical speech areas (Broca's , Wernicke's, and thesupplementary motor speech area) in man are coordinated by projections of each to part of the thalamus, and that by means of these circuits, the elaboration of speech is somehow carried out.

Thalamo-cortical projection fibers originate in the sensory relay nuclei or the association nuclei and project to the cortex with little lateral spread. The specific thalamic-cortical projection fibers travel to the primary visual cortex in the posterior section of the parietal lobe, to the primary auditory area in the anterior part of the temporal lobe, and to the primary somesthetic area posterior to the centural fissure among other areas. These fibers carry incoming sensory data upon which language behavior responses eventually rest. This follows from Lenneberg's (1967a, p. 63) statement that:

> The temporo-parietal regions of the cortex which are implicated in non motor aspects of language are connected by fibers to the latero-posterior nucleus of the thalamus and pulvinar.

These fibers operate in a loop like fashion. They comprise part of the reticular formation and serve a cortical stimulation function. They are widely distributed over the cortex surface and even branch to the primary and secondary sense reception areas. It should be noted that these non specific thalamo-cortical fibers take an indirect route to the cortex causing a longer response latency than the specific fibers. For example, the response latency for the specific fibers is approximately one to five msec. while the non specific fibers range from five to several hundred msecs. Thus, the non specific system sets the excitability level of the cortex for the incoming data carried by the specific thalamo-cortical pathways.

The thalamus determines the sense modality of the incoming stimulus and transmits the incoming sense data to the appropriate cortical primary sensory reception area. Best and Taylor (1966) distinguish two types of thalamic pathways to the cortex: the specific and non specific systems.

The specific thalamo-cortical interconnections reach the motor areas as well as the sensory areas (Lenneberg, 1967a). Support for the position comes from Hartman and Monakow (1965) who report that surgical diencephalic lesions cause speech and language disorders, that pallidotomy and thalamotomy cause pure jargon.

Physiology has greatly aided our understanding of the cortical and subcortical processing of language as well as increased our understanding of language disorders. Specialists have divided language disorders into two categories: functional and organic. Physiology has offered little knowledge to the investigation of functional disorders such as schizophrenia but has contributed greatly to understanding of organic disorders such as aphasia, aprexia, agnosia and agraphia. Organic disorders follow some disturbance in the central nervous system such as a wound or injury. Consequently, the following proposition is offered.

Proposition 12

Proposition 12 holds that organic disorders to the cortex and subcortex may cause language disorders. The most prevalent disorder is aphasia. Aphasia "is applied to those disorders resulting from defects in the nervous mechanisms underlying the comprehension and use of symbols (words, numbers), for the formation, transmission and reception of ideas"(Best and Taylor, 1966, p. 180). Aphasic like behavior takes place when the speech areas are electrically stimulated. Aphasia involves both motor and sensory areas of the brain affecting the symbol making and expression functions.

Four different classifications of aphasia exist: (1) those with verbal defects, (2) those with syntactical defects, (3) those with naming defects, and (4) those with semantic defects. The patient who has verbal aphasia has lost his ability to express words, except for the most simple phonemes, and may have difficulty reading and writing. The patient with naming defects has difficulty in the labeling process or finding the right word to express his meaning. This aphasia will describe the common phenomenon he can't name, and has trouble writing a coherent letter. The semantic aphasic can speak well but can't follow his own line of conversation meaningfuly nor can he understand meaning.

Different neural cortical areas are correlated with the various kinds of aphasia and Best and Taylor (1966, p. 182) describe these correlations:

> if the lesion is in the neighborhood of the lower part of the precentral and postcentural convolutions of the dominant hemisphere the speech defect tends to be of the verbal type. In injury to the temporal lobe the speech defect tends to be of the syntactical type. In a lesion in the region of the angular gyrus of the dominant hemisphere the patient has difficulty, particularly, in finding names for things; damage to the cortex in the region of the supramarginal gyrus results in a semantic defect.

It should be noted that these areas are merely convergence parts in the cortex related to some sensory-motor activity and not the unique contributors to the specific sensory-motoric activity. Thus, a wound to one of these areas will influence the entire brain including the other areas.

Apraxia relates to the inability to perform purposeful movements at will. Visual apraxia exists when the patient cannot recognize the significance of an object and cannot apply the object to its proper use and motor apraxia exists when the person has no conception of the muscle pattern required to perform tasks such as talking. Apraxia is a consequence of lesions in the association tracts connecting the precentural gyrus with the higher psychical regions (somesthetic association areas) where muscle impressions are received.

Agnosia results from the failure to interpret sensory impressions in a meaningful manner. Word blindness and word deafness are forms of agnosia. For example a patient with visual agnosia may see the word but is not able to interpret it meaningfully. The patient with visual agnosia usually has a lesion in the occipital lobe or the dominant hemisphere while the patient with auditory agnosia usually has an injury in the temporal cortex. Tactile agnosia results when the patient has lesions in the parietal lobe posterior to the poscentural gyrus and the patient retains his sense of touch but is unable to recognize the object of sensation. Visual agnosia usually relates to the state of agraphia or inability to write.

A discussion of physiological contributions to the understanding of language disorders completes the second section of this paper. This section discussed the species specificity of language, its components, development, process, and disorders. The following section predicts the future direction of the physiological study of language.

Section 3

The Potential Contributions of Physiology to Language

Section three of this paper answers the second research question: What potential contributions can physiology make to the study of language. A three part answer exists: (1) Physiologists with a primary interest in language will conduct systematic research into the physiology of language and provide the basis for an axiomatic, physiological theory of language, (Proposition 13); (2) Interdisciplinary academic areas such as speech communication will provide a receptive framework into which current physiological findings will fit (Proposition 14); and (3) physiological theories will characterize future research in language.

Proposition 13

Proposition thirteen recognizes the slight interest physiologists have demonstrated and continue to demonstrate in language and predicts certain physiologists will develop an interest in the future. The contributions physiologists have made to knowledge about language have emerged as they pursued non-language related questions. For example, The Handbook of Physiology fails to mention the word language in its indices and only presents a chapter on speech. Physiologically oriented experts in speech pathology, speech and hearing, and audiometry also share the focus on either the vocalization process or the extroceptors rather than language.

Proposition 13 predicts that the following types of physiologists will adopt a language focus (assuming suitable inducements). Neurophysiologists will treat the interassociation of cortical and subcortical processes formulating language paying special attention to the ideomotor region. Cellular physiologists will focus on the RNA base of language and the role played by the neuron in nurturing RNS. Cellular physiologists will also determine the role played by GABA in the synapse determining the influence of excitatory and inhibitory elements in the synapse. Both neurophysiologists and cellular physiologists will pursue the influence of drugs on language. Developmental physiologists will investigate the emergence of language in children and, finally, genetic physiologists will follow the path blazed by Luchsinger and Arnold (1965) and investigate the genetic base of language functions.

Physiological procedures and techniques offer the most exciting prospect on the language research horizon. Further knowledge will emerge from the electronic brain stimulation pioneered by Penfield and Roberts (1959). The EEG and its ability to collect electrical potentials from the scalp should provide further relevant data while spearing cells with micron electrodes provides an extremely exciting new direction in physiology. The physiological-pathological technique of analysing the functions of living cells outside of the brain will continue to prove valuable despite the ethical problems associated with its use. Finally, chemical dye and radiographic tracing has potential for the study of language.

Proposition 14

Proposition 14 notes the unfortunate impermeability of academic discipline boundaries and predicts that an interdisciplinary area such as speech communication will offer a theoretical housing for the ecclectic extant language relevant findings of physiology. The interdisciplinary nature of speech communication is demonstrated by the number of academic areas covered in the average programs of a speech communication student: psychology, social psychology, sociology, anthropology, philosophy and the like. Students of speech communication borrow theories, procedures and instruments from each of these disciplines, combine these borrowed theories, procedures, and instruments with their own, and produce a hybrid version of phenomena. Proposition 14 predicts that speech communication scholars will borrow physiological theories, procedures, and instruments, combine them with the current language theories, procedures, and instruments to produce a hybrid theory of language.

It should be noted that one could also combine physiology and any of the following disciplines: psychology, sociology, linguistics, speech pathology, audiology, or philosophy. For example, the linguist, Chomsky (1972) has developed a theory of language entitled transformational grammar which offers several statements about the nature of language in the mind yet provides no physiological data to support the theoretical statements. An application of physiological research might offer empirical support for a theorist such as Chomsky. Similarly, psychologists Skinner (1957) and Osgood (1967) might adopt physiological findings to support their theories as might the philosopher Katz (1966). Unfortunately two factors lower the probability of such interdisciplinary combinations: the impermeability of the discipline boundaries and the difference in the units of analysis. For example, no sociophysiological, linguistic-physiological or philosophic-physiological subdisciplines exist as each of these disciplines shares rather firm definitions of their boundaries. Moreover, sociology uses the group, linguistics uses language units, and philosophy uses dimension of man's nature as their units of analysis. These factors lower the potential for integration with physiology.

Proposition 15

Proposition 15 predicts that future language research will adopt a physiological perspective. Physiology offers a technique and instrumentation which has vast potential for language research. The minute unit of analysis and the precision with which physiological techniques can measure that unit recommend the technique to the study of language. Moreover, the combination of physiological techniques with computer technology will continue to offer language researchers new research directions and lead to the time when language hypothesis will yield to the definitive physiological language theory.

Summary

This paper has advanced answers to the following two research questions: Where do we stand now in terms of the contributions of physiology to the study of language and what potential contributions can physiology make to the study of language. The answer to the first question assumed the form of 12 propositions reviewing the contributions of physiology to the species specificity of language question, the neurological components of language question, the language development question, the language process question, and the language disorders question. The answer to the second question assumed the form of three propositions predicting that physiologists will adopt a language perspective, that the interdisciplinary nature of speech communication recommends the marriage of speech communication and physiology, and that physiology will characterize future language research.

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