

Review Article

Aphasia: Current Concepts in Theory and Practice

Donna C. Tippet^{1,2,3*}, John K. Niparko⁴ and Argye E. Hillis^{1,3,5}¹Department of Neurology, Johns Hopkins University School of Medicine, USA²Department of Otolaryngology-Head and Neck Surgery, Johns Hopkins University, School of Medicine, USA³Department of Physical Medicine and Rehabilitation, Johns Hopkins University School of Medicine, USA⁴Department of Otolaryngology-Head and Neck Surgery, University of Southern California, USA⁵Department of Cognitive Science, Johns Hopkins University, USA

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Corresponding author

Donna C. Tippet, Department of Otolaryngology-Head and Neck Surgery, Johns Hopkins University School of Medicine, 601 N. Caroline Street, Baltimore, MD 21287, Tel: 410-955-7895, Email: dtippet1@jhmi.edu

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Abstract

Recent advances in neuroimaging contribute to new insights regarding brain-behavior relationships and expand understanding of the functional neuroanatomy of language. Modern concepts of the functional neuroanatomy of language invoke rich and complex models of language comprehension and expression, such as dual stream networks. Increasingly, aphasia is seen as a disruption of cognitive processes underlying language. Rehabilitation of aphasia incorporates evidence based and person-centered approaches. Novel techniques, such as methods of delivering cortical brain stimulation to modulate cortical excitability, such as repetitive transcranial magnetic stimulation and transcranial direct current stimulation, are just beginning to be explored. In this review, we discuss the historical context of the foundations of neuroscientific approaches to language. We sample the emergent theoretical models of the neural substrates of language and cognitive processes underlying aphasia that contribute to more refined and nuanced concepts of language. Current concepts of aphasia rehabilitation are reviewed, including the promising role of cortical stimulation as an adjunct to behavioral therapy and changes in therapeutic approaches based on principles of neuroplasticity and evidence-based/person-centered practice to optimize functional outcomes.

ABBREVIATIONS

CNS: Central Nervous System; **rTMS:** Repetitive Transcranial Magnetic Stimulation; **tDCS:** Transcranial Direct Current Stimulation; **ICF:** International Classification of Functioning, Disability, and Health; **WHO:** World Health Organization; **LPAA:** Life Participation Approach to Aphasia

INTRODUCTION

Communication through language is central to the human experience. The essential role of linguistic interaction in daily function drives interpersonal connections key to health-related quality of life. Interest in the study of language, and its rehabilitation, is fueled by the considerable impact of aphasia on both public and personal health, and by societal costs. Recent estimates are that there are more than 795,000 strokes per year in the US [1]—the major source of aphasia incidence. Between 1997 and 2006, the number of individuals with aphasia grew by approximately 100,000 per year [2]. Aphasia is present in 21-38% of acute strokes and associates with higher mortality, morbidity, and healthcare resources consumed [3]. Costs for stroke-related healthcare exceeded \$25 billion in 2007 [1]. On

an individual level, reintegration into school, work, and family life may be unattainable given human dependence on the spoken word. Social isolation is a devastating and all too common consequence of aphasia [4].

Norman Geschwind wrote that “every behavior has an anatomy” [5]. Language is no exception. Though complex in its underpinnings, the study of the structural and physiological basis of aphasia has been a major focus of neurological investigation since the mid-nineteenth century. However, we are now witnessing a revolution in the understanding of language and its disorders. Recent advances in neuroimaging contribute to a combined understanding of the structural and functional correlates of language. In fact, in the morphometry and the dynamic functioning measured with neuroimaging have emerged highly refined models of the neurobiological organization of language. Extensive research has focused on the functional neuroanatomy of language, with current models modifying the neurological model of language and promoting a dorsal-ventral stream framework [6-9]. Similarly, advances in the study of treatment of aphasia have resulted in adaptation of evidence based and person-centered approaches to rehabilitation [10] as well as methods of delivering cortical brain stimulation to

modulate cortical excitability, such as repetitive transcranial magnetic stimulation (rTMS) and transcranial direct current stimulation (tDCS) [11,12].

In this review, we discuss the historical context of the foundations of neuroscientific approaches to language. We sample the emergent theoretical models of the neural substrates of language and cognitive processes underlying aphasia that contribute to more refined and nuanced concepts of language. Current concepts of aphasia rehabilitation are reviewed, including the promising role of cortical stimulation as an adjunct to behavioral therapy and changes in therapeutic approaches based on principles of neuroplasticity and evidence-based/person-centered practice to optimize functional outcomes.

HISTORICAL BACKGROUND

The study of aphasia and its associated lesions in the late nineteenth century by Dax [13], Broca [14,15], and Wernicke [16,17] led to many insights about the neural organization of the language functions. The most reliable finding was that individuals who had language impairments were later found to have damage to the left hemisphere at autopsy. Damage to the more anterior parts of the brain, particularly the left posterior inferior frontal cortex, was often found in those whose spoken output was limited or poorly articulated [15]; damage to the more posterior regions in the left temporal lobe was found in those whose spoken output was well articulated but meaningless [17]. These early observations established that language functions are localized in the left cerebral hemisphere and provided the groundwork for Geschwind's [18] seminal work on aphasia classification and associated lesion sites. These classic aphasia classifications, such as Broca's, Wernicke's, global, conduction, anomic, and transcortical aphasias, are vascular syndromes consisting of frequently associated deficits that reflect damage or dysfunction of regions of neural tissue supplied by a particular artery [19]. The characteristics of the classic aphasias are reviewed in detail by Damasio [20], Goodglass [21], and Hillis [19]. These syndromes are clinically useful in predicting areas of ischemia and patterns of recovery, and in selecting rehabilitation approaches [19,22,23].

Early accounts employed thoughtful correlations of site-of-lesion and manifested behavior. Thus, from the context of brain pathology, localization of normal function can be extrapolated [24]. It is important to note that individual variability in the shape of the brain as well as the patterns of sulci and gyri renders only approximate localization of function [25,26].

Beginning in the 1980's, advances in neuroimaging, including PET, functional MRI, and magnetoencephalography, expanded understanding of the functional neuroanatomy of language by specifying the anatomical and functional correlates of central nervous system (CNS) stations that support overall language function. Safe, noninvasive imaging of the brain reveals that areas in both hemispheres of the brain are activated specifically during language tasks, although the left hemisphere shows more activation in the majority of neurologically normal adults [27-30], and that more distant areas of the cortex, such as inferior and anterior temporal cortex [31] and the basal ganglia and thalamus [32], are also activated during language tasks. In addition, there

is increasing understanding of the complexity of language tasks, including underlying cognitive processes and representations that are needed to accomplish even basic tasks such as naming [33,34]. Recognition that focal neurodegenerative disease can cause primary progressive aphasia allows investigation of language deficits caused by cerebral atrophy of regions of the brain not typically damaged by stroke [35]. This approach to characterizing aphasia by disruption of specific cognitive processes is important for developing theories of how language is represented and processed [19]. Brain/language relationships are further elucidated by technologies which introduce temporary dysfunction or suppress overactive areas associated with CNS insult, such as inhibitory rTMS [36].

Contemporary paradigms of neural substrates of language

A principal concept of the functional neuroanatomy of language holds that the processing needed to interpret the complex and multidimensional information in language, and its context, requires an intricate division of bio-encoding labor. One compelling model characterizes a dual stream: a ventral stream for mapping sound onto meaning, and a dorsal stream for mapping sound onto motoric productions and articulation [6-9]. The brain computes a transform between thought and an acoustic signal transmitted across parallel, ascending pathways of the auditory brain stem and cortex [37] and executes parallel processing to synthesize input via interconnected neural networks [38]. Support for this complex neural circuitry is found in studies of the neocortex which show that there are vertically oriented columns of neurons perpendicular to the cortex [39].

A dual stream model of vision processing is well established. Studies of the primate visual cortex show that cells within a column respond similarly to an external stimulus [40]. In the original account, vision processing is divided into two streams: a ventral stream projecting to inferior temporal areas to process object identity (the "what" pathway) and a dorsal stream projecting to parietal areas to process object locations relative to the observer and other objects in the environment (the "where" pathway) [41]. Subsequently, the function of the dorsal stream is expanded to include integration of visual input and motor responses (the "how" stream) which facilitate reaching and grasping in visual space [42].

The dual stream model of afferent information processing is similarly applied to auditory processing in which the ventral stream processes "what" and the dorsal stream processes "where" [43], changes in the auditory signal over time [44], and auditory-motor integration in which a sequence of sounds are heard and then spoken, the latter much like that in the visual domain [4,45].

The dual stream model is extended to explain cortical organization of language. In this neuroanatomical model, proposed by Hickok, speech processing is defined as any task involving aurally presented speech; speech perception refers to any sub-lexical task; and speech recognition refers to the transformation of acoustic signals into a representation which accesses mental lexicon [7]. Speech perception involves auditory-responsive areas in the superior temporal gyrus bilaterally, left more so than right. The processing system then diverges into

two streams: a ventral stream which maps sound onto meaning, and a dorsal stream which maps sound onto articulatory-based representations to yield production. The ventral stream is thus a sound-meaning interface responsible for processing speech signals for comprehension. In the dorsal stream, acoustic speech signals are translated into articulatory representations, essential for speech development and production, involving auditory-motor integration. The dual streams are also thought to be bi-directional; the ventral stream mediates the relationship between sound and meaning for perception and production, and the dorsal system can also map motor speech representations onto auditory speech representations [6,7]

More recently, roles for the ventral and dorsal streams in forward prediction are proposed. The role of forward prediction in speech perception is obvious; perception is dramatically improved when one knows what to listen for as cued by awareness of speaker, time, place, circumstance, and myriad additional contextual factors. Forward prediction from the motor system (dorsal stream) on speech perception is less clear. For example, transcranial magnetic stimulation studies show that damage to the motor system does not result in deficits in speech perception as would be expected if motor prediction is critical. An alternative hypothesis is that ventral stream forward prediction enhances speech recognition [46].

The ventral stream projects ventro-laterally and involves cortex in the superior temporal sulcus and the posterior inferior temporal lobe. The dorsal stream projects dorso-posteriorly toward the parietal lobe and ultimately to frontal regions [6,7,45]. In contrast to prior models, speech processing is bilaterally organized, thus the ventral stream incorporates parallel processing, explaining why there are not substantial speech recognition deficits following unilateral temporal lobe damage [7]. The dorsal stream is strongly left dominant, accounting for speech production deficits that are seen with dorsal temporal and frontal lesions [47]. In addition, functional neuroimaging studies support bilateral organization of speech recognition as well as a neural circuit for auditory-motor interaction. For example, neurophysiologic recordings of normal subjects listening to speech stimuli uniformly show bilateral activation in the superior temporal gyrus [6]. Imaging studies show that the left superior posterior temporal region, located within the planum temporale, is activated during speaking, naming, and humming [7,47].

A spatio-temporal language processing model is proposed to resolve theoretical inconsistencies in the dual stream approach [48]. For example, as stated earlier, one interpretation of the roles of the dual streams is that the ventral stream maps sound to meaning and the dorsal stream maps sound to articulation. Alternatively, the dorsal stream is thought to process complex syntax whereas the ventral stream is thought to process simple syntax [49].

These divergent proposals are unified in a spatio-temporal model based on the Extended Argument Dependency model which assumes a cascaded architecture of language processing [50]. In this model, parallel systems process linguistic information that is both dependent and independent of temporal aspects of linguistic data flow. Ventral and dorsal streams are asserted to be engaged in sentence comprehension, with time-independent

processing associated with the ventral stream and time-dependent processing associated with the dorsal stream. The dorsal stream analyzes sequences of segments in time or space and integrates sensorimotor input to support production; the ventral stream extracts meaning independently of the temporal or special sequences of linguistic elements [51].

In addition, a novel dual lexicon framework, which builds on the dual stream model, is suggested to explain how and where words are stored in the brain. Two lexica are proposed to provide an interface between linguistic subunits. The ventral lexicon is an interface between phonetic and semantic representations. This area is not a store of semantic knowledge, but instead retains morphologically organized representations of words to link acoustic phonetic representations to semantic content. The dorsal lexicon is an interface between phonetic and articulatory representations and houses articulatory organized-word form representations, a concept not previously endorsed [52].

Cognitive processes underlying aphasia

Increasingly, aphasia is seen as a disruption of cognitive processes underlying language tasks, such as sentence comprehension and naming. Cognitive representations are distributed across regions of the brain and activation of these various areas is needed to evoke semantic representations. For example, the semantic representation of a horse includes features of how it moves (middle temporal visual area and middle superior temporal area), what it eats, and how it is used by humans [19]. Damage to specific areas of the brain may account for specific patterns of impairments, such as selective naming deficits. Examples include the inability of an individual with visual agnosia to name an item on visual confrontation, but demonstrate preserved naming in response to a verbal description, and the inability of an individual with optic aphasia to activate a semantic representation given a structural description despite full access to semantics given tactile cues.

Modality-independent lexical access is also proposed as a mechanism to explain anomia commonly seen in several aphasia subtypes. Individuals with anomia have intact semantic representations, but cannot access phonological and/or orthographic representations. Responses on convergent and divergent naming tasks can include both semantic and phonemic errors despite intact error awareness.

Treatment

Aphasia treatment is progressively more informed by advances in understanding of the neurobiology of recovery and learning. For example, tDCS is designed to facilitate synaptic plasticity [53]. rTMS can modify cortical excitability, increasing or decreasing activity in targeted areas of the cortex. Protocols employing rTMS improve naming in individuals with nonfluent aphasia. The mechanism proposed to explain this treatment effect is suppression of over-active right hemisphere homologues [54,55]. The promise of these methods relies on a full understanding of the anatomy of the neural networks underlying language and variables that influence potential timing and extent of structure-function reorganization.

The multi-dimensionality of cortical reorganization and

modifiability can be observed in the neuroplasticity producing clinical recovery observed in response to stimulation [56]. Plasticity studies reveal the functional importance of the “use it or lose it” principle and indicate that beneficial behavioral and neural changes can be effected through intense and repetitive practice [57]. Importantly, findings of recent investigations of aphasia therapy emphasize that intense treatment for short periods is more effective than a similar number of therapy sessions over longer periods [58]. The rationale for early intervention in aphasia is also based on these neuroplasticity principles such that therapy capitalizes on spontaneous recovery in the immediate post stroke period [59].

While prosthetic stimulation offers a potentially important adjunctive approach, behavioral therapy remains the mainstay for treatment of aphasia. Behavioral therapy is both restitutive and compensatory. Current practice standards dictate that therapy must be evidence-based and person-centered. *Evidence-based practice* refers to an approach in which current, high-quality research evidence is integrated with practitioner expertise and client preferences and values [60]. The hierarchy and generalizability of evidence are evaluated [61,62] and an individual’s life circumstances, preferences, coping mechanisms, and concomitant medical, sensory, behavioral, and psychological issues are considered when making treatment decisions. Because supportive, evidenced-based client-specific research can be difficult to identify, clinicians are advised to combine multiple, available studies of sufficiently good design, expert consensus, and clinical knowledge of anatomy and physiology to make reasonable judgments about the appropriateness and effectiveness of a specific treatment technique [63].

Principles of neuroplasticity support early and intense therapy, however, questions remain regarding specific intervention strategies given the variable nature of aphasia. Historically, clinicians base therapy largely on assessment data. Therapy tasks are developed to target specific domains, such as auditory comprehension at sentence level or word retrieval at a single word level. This approach follows a medical model which emphasizes impairment of function, and is therapist-, rather than patient/person-, centered [64]. This circumscribed approach suffers from multiple limitations. Clearly, increased ability to name pictured objects in a treatment task does not necessarily translate to a relevant outcome, such as improvement in functional communication [65,66]. In addition, in their consumer perspective, Dyke and Dyke [67] cite specific examples of the ways that impersonal approaches diminished the effectiveness of rehabilitation therapies, and how linking therapy “to the person that (General Dyke) was and is, rather than to a generic set of tools and techniques” (p. 150) maximizes outcome.

Application of principles governing brain organization and reorganization may contribute to the development of more meaningful therapy goals. For example, practice on a confrontation naming task may facilitate the ability to convey communicative intentions to listeners as a result of the adaptive property of the brain. Treatment goals may also be reframed based on the dual stream model of language organization. For example, in those with Broca’s aphasia, therapy may be directed at translating sound to motor speech productions to produce

simple sentences as disruption of the dorsal stream would be expected; and in those with Wernicke’s aphasia, therapy may be directed at processing speech for comprehension or meaning in sentences as disruption of the ventral stream would be expected. Further investigation is warranted regarding how the segregation of language functions described by this model suggests particular approaches that promote “use” most effectively. One suggestion is that ventral stream could be accessed by instructing patients to process the meaning of a target word during a repetition task in the treatment of conduction aphasia [68].

Given the limitations of medical/clinician-centered models of therapy, a social model of therapy has emerged which encompasses the authentic involvement of users (patients), creation of engaging experiences, user control, and accountability [10]. Person-centered practice “involves valuing the individual needs and rights of patients, understanding patients’ illness and health care experiences, and embracing them within effective relationships which enable patients to participate in clinical reasoning” [69, p. 68]. This practice is consistent with the conceptual framework for contemporary models of health care of the International Classification of Functioning, Disability, and Health (ICF) of the World Health Organization (WHO) [70].

The ICF is structured around the broad components of body structures and functions, activities (related to tasks and actions by individuals) and participation (involvement in life situations), and additional information regarding personal and environmental factors. Language, cognition, voice, and swallowing are body functions, and interpersonal interactions reflect the activity/participation component of the ICF, relevant to speech-language pathology. Family support and availability of communication partners are examples of environmental factors; premorbid personalities, such as reticence versus extroversion, are factors germane to cognitive/communicative intervention. This framework encourages patient-centered care, focusing on development of goals which address individual needs and circumstances. Therapy is a collaborative process. Patients, families, and caregiver identify goals which are important to them. Clinicians conduct formal assessment, and then negotiation occurs between patients and therapists to define a treatment plan. This is in contrast to therapist-controlled approaches; a genuine patient-centered approach allows patients, their families, and caregivers to lead the goal setting process rather than the clinician [64].

A critical approach to monitoring treatment effect requires that clinicians document goals and outcomes for any relevant component (e.g., body structure/function, activity, participation). Outcomes of treatment can then be measured for the specific modality that was treated, and/or at the activity/participation level consistent with the ICF framework. For example, an activity level goal may be “demonstrating the ability to speak in sentences” and the participation level outcomes are “engaging in a parent-teacher conference” and “giving a professional oral presentation” [71]. The Quality of Communication Life Scale, which examines the impact of communication disorders on various aspects of quality of life, including relationships with others, communication interactions, and participation in activities, captures components of the ICF health outcomes [72].

A specific example of a patient-centered approach is the Life Participation Approach to Aphasia (LPAA) [73]. “The LLPA places the life concerns of those affected by aphasia at the center of all decision making. ...and empowers the consumer to select and participate in the recovery process and to collaborate on the design of interventions that aim for a more rapid return to active life” (p. 279). Specific tasks can also be adapted to conform to a patient-centered approach. For example, the Activity Card Sort (ACS) [74] can be tailored to elicit information from individuals with aphasia about their level of engagement in meaningful activities as well as hindrances to participation, allowing clinicians to obtain qualitative information about interests, level of involvement, and priorities which could then be used to shape the direction of therapy [75]. The value of considering multiple sources of information, as well as daily life functioning and communication contexts, as part of the evaluative process, is echoed by the Academy of Neurologic Communication Disorders and Sciences Practice Guidelines Group [76]. Challenges abound in the implementation of evidence-based, patient-centered care which incorporates path-breaking discoveries in the functional neuroanatomy of language. These include how to involve individuals with aphasia in goal setting, how to reconcile clinician- and patient-targeted goals when discrepancies arise, and how to modify and supplement traditional modes of treatment to optimize outcomes. Evidence is preliminary, but promising, which shows the effectiveness of methods to deliver cortical brain stimulation; further research is indicated to establish the mechanism associated with language recovery after these novel treatments. Addressing these issues requires a sound clinical knowledge base, persistence, and creativity.

CONCLUSIONS

Science and theory influence practice. Advances in neuroimaging, development of new theories of language function, and changes in the standards of sound clinical practice must be incorporated into aphasia treatment. Ability to revise and adjust clinical care is the hallmark of an astute clinician.

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