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Minireview

Relationships between Aphasia and Apraxia

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Abstract

Aphasia and apraxia are two major neuropsychological syndromes that in most cases are caused by injuries in the left cerebral hemisphere. Clinical studies have revealed a double dissociation between aphasia and apraxia, and a strong correlation in their cerebral lateralization. These clinical observations suggest that aphasia and apraxia are independent syndromes. On the other hand, there are many parallels between language and praxis, including symbol representation and sequential motor control. The two syndromes are also similar in that their clinical variations can be classified into reception/production problems and semantic/nonsemantic problems. It appears that language and praxis systems make use of anatomically adjacent and possibly overlapping networks.

INTRODUCTION

Aphasia is a syndrome caused by damage to the neural language system. Patients with aphasia experience difficulty in expressing nonverbal ideas and thoughts as words and grammatically correct sentences. It generally affects all modalities of language abilities, namely speaking, listening, reading, and writing. The disturbance is called motor aphasia when it is predominant in language production (speaking and writing), and sensory aphasia when it is predominant in reception (listening and reading).

Apraxia is another major neuropsychological syndrome characterized by loss of the ability to carry out learned purposeful movements despite having the physical ability to do so. Apraxia is evaluated by testing intransitive (symbolic) gestures (e. g. , wave goodbye, salute like a soldier, and throw a kiss) and transitive (tool-based) gestures (e. g. , use a hammer, use a screwdriver, and use a key). These are all learned actions, but the distinction between the two classes of gestures is theoretically important in that intransitive gestures are for communication purpose, while transitive gestures imply actions that operate on specific target objects. When evaluating apraxia it is important to ensure that disturbed action execution on verbal commands is not due to impaired comprehension caused by aphasia.

The conceptual bases for the study of apraxia originate from Hugo Karl Liepmann who suggested a predominant role of the left cerebral hemisphere in controlling voluntary movements [1]. Liepmann assumed that gesture information passes through a conceptual stage located in the left occipitotemporal cortex, followed by a production stage where the appropriate motor programs are selected in the sensory motor areas. Ideomotor apraxia is a common form of limb apraxia that affects a gesture production. The disorder is visible when executing arbitrary or symbolic movements, such as a military salute and praying, that cannot be improved by the presence of an object. Another type of apraxia is ideational apraxia, which is characterized by inability to order a set of elementary movements that make up a complex action into their correct sequence. Patients will omit, add, or transpose elements in the sequence of movements used in pantomiming, such as eating soup with a spoon.

Aphasia and apraxia are generally thought to be independent clinical syndromes. This notion is supported by the presence of double dissociation—there are aphasic patients without apraxia and apraxic patients with normal language comprehension and production. However, it is also true that both aphasia and apraxia are associated with lesions in the left cerebral hemisphere in many patients, and their comorbidity is high. Thus, the relationships between these two neuropsychological syndromes remain largely unclear.

Speaking and writing are special forms of praxis in that they involve skilled sequential movements of the vocal apparatus and manipulation of a pen and keyboard. Conversation is often made in conjunction with co-speech gestures, which also suggests a close relationship between language and praxis. Primates established bipedal locomotion during their evolution, which consequently disengaged the upper limbs [2]. The elaboration of manual skills is inseparable from tool use and the establishment of hand preference [3]. It is therefore tempting to assume that the evolution of language from primitive gestures is the cultural background underlying neural substrates of language and praxis both being lateralized to the cerebral hemisphere contralateral to the preferred hand[4-6]. Infants acquire the ability to handle multiple objects in combination and in complex orders at a specific developmental stage at which basic linguistic grammar is also acquired [7]. This represents ontogenetic evidence that language production and tool manipulation share a common neural capacity. The relationship between language and praxis is an interesting issue in the fields of anthropology and neuroscience. For clinical neuropsychologists the issue is the degree to which aphasia and apraxia are independent. In this review we discuss the topic in relation to hand preference and hemispheric dominance.

Comorbidity of aphasia and apraxia

Since apraxia and aphasia often coexist, it is difficult to evaluate apraxia if the patients suffer from severe sensory aphasia. Apraxia was first reported in a patient with motor-dominant aphasia who used a pen upside down and used a knife as if using a fork [8]. In his historical study of 89 stroke patients, Liepmann investigated 14 apraxic patients out of 20 patients with right hemiparesis and aphasia [1]. The strong correlation between the severity of aphasia and apraxia suggests a common neural processing underlying both language and praxis. On the other hand, there is a viewpoint that language and praxis are often simultaneously involved after strokes because the two systems are anatomically adjacent, although being functionally separate [9]. Papagno studied 699 right-handed stroke patients with left-hemisphere damage, and found 149 aphasic patients without apraxia and 10 apraxic patients without aphasia [10]. The existence of double dissociation between aphasia and apraxia suggests that the networks of language and praxis do not completely overlap.

Handedness and its relationships to aphasia and apraxia

One of the explanations for the occasional dissociation between aphasia and apraxia is that the processing of language or praxis may be exceptionally lateralized to the right hemisphere or distributed in both hemispheres. As for language processing, its hemispheric lateralization is clearly related to handedness; the majority of right-handers (95–97%) exhibit left-hemisphere dominance for language, whereas left-handers show high interindividual variability in this regard, with hemispheric dominance being on the left in 60–70%, on the right in 15–20%, and bilateral in 15–20%. Occasionally, purely right-handed people develop aphasia after right-hemisphere injuries. This exceptional manifestation, known as crossed aphasia, is estimated to represent less than 3% of aphasia cases, and it is thought to reflect exceptional language lateralization to the right hemisphere [11,12].

Among the right-handed population, apraxia is mostly caused by injury to the left hemisphere. The incidence of apraxia is reportedly 34–51% after right-hemisphere stroke and 6–10% after right-hemisphere stroke. This led to the notion that acquired memory of manual praxis, known as action lexicon or praxicon, is generally stored in the left hemisphere. If praxicons are stored in the left hemisphere as a result of right-handedness, the praxicons of left-handers should be stored in the right hemisphere. In fact, the incidence of apraxia in left-handers is not high after right-hemisphere injuries. Thus, based on clinical observations, praxis usually appears to be represented in the left hemisphere, irrespective of handedness, and only in exceptional cases is represented bilaterally, or lateralized to the right hemisphere.

Hemispheric dominance for language and praxis is examined in some special clinical settings, providing ideal situations in which to try to determine how the two systems share their neural substrates. The Wada test is one of the methods used to evaluate the dominant hemisphere, in which an anesthetic agent is injected into the carotid artery of one side. In one study of presurgery epilepsy patients, application of the Wada test revealed that the rate of exhibiting ideomotor apraxia after left-carotid injection of amobarbital was higher in patients with typical language lateralization (to the left) than in those with atypical language lateralization (to the right or bilateral) [13]. Furthermore, people with atypical language lateralization tended to exhibit ideomotor apraxia after right-carotid injection rather than left-carotid injection during the Wada test. A recent functional MRI study also confirmed the correlation between lateralization of language and praxis [14].

If language and praxis are both lateralized to the left, verbal commands to use the left hand would be understood in the left hemisphere, and the activated motor command would be transferred to the motor-related areas in the right hemisphere via the corpus callosum. Consistent with this hypothesis, callosal lesions sometimes cause apraxia of the left hand. Patients with callosal apraxia do not exhibit aphasia, which supports the notion that praxis and language are independently processed. One experiment involved names, pictures, or real objects of tools being presented in one visual hemifield, and patients who suffered from callosal apraxia being asked to make gestures using tools [15]. Movement of their left hand was found to be inaccurate irrespective of their handedness or the position of the objects. Apraxia of the left hand was observed even when visual input was given to the right hemisphere that controls the left hand. One explanation for these results is that callosal lesions block the hand-motor area in the right hemisphere to access the praxis engram in the left hemisphere. That study supports the idea that the praxis engram is lateralized to the left hemisphere independent of handedness.

Conceptual models of aphasia and apraxia

Language and praxis share many features. Both processes involve signals of sensory inputs and motor outputs being integrated in the context of acquired semantics and concepts. Anatomically, the two systems generally colocalize in the same cerebral hemisphere. Although aphasia and apraxia often coexist, the two systems have been studied separately and their relationships have rarely been discussed. Here we contrast the conceptual models of aphasia and apraxia, and discuss their analogies.

The Wernicke-Lichtheim model is probably the most influential model of aphasia. This model allows classification of aphasia syndrome based on the clinical features of verbal fluency, speech comprehension, and word repetition (Figure 1A). The model postulates that the auditory center (Wernicke's area), which receives inputs from the auditory cortex, and the motor center (Broca's area), which sends action commands to the motor cortex, are connected to each other not only directly but also via the putative concept center. The arcuate fasciculus is thought to be one of the fiber bundles that directly connect Wernicke's and Broca's areas. Damage to this fiber bundle causes conduction aphasia, in which verbal comprehension and expression are both relatively preserved but word repetition is severely disturbed. This clinical manifestation can be interpreted as follows: the indirect route via the concept center preserves the capability of verbal comprehension and expression, whereas the impaired direct route causes phonetic problems during requests to repeat words.

Transcortical aphasia is another type of aphasia, in which word repetition is preserved in comparison to disturbed verbal comprehension or expression. The Wernicke-Lichtheim model explains the preserved ability for word repetition by phonetic processing through the direct pathway.

Consensus regarding the clinical classification of apraxia has not yet been reached, and various models have been proposed. Classically, Liepmann proposed two different types of apraxia: disturbance of action concept and disturbance of action production [1]. According to Liepmann, movement formulae—which contain "the time-space-form picture of the movement"—are stored in the center of action concept, and innervatory patterns are stored in the center of action production. The idea is analogous to the sensory-motor dichotomy underlying the Wernicke-Lichtheim aphasia model. A fundamental question is how much is shared between the language and praxis systems anatomically and computationally. The following three points may be relevant in discussing this question:

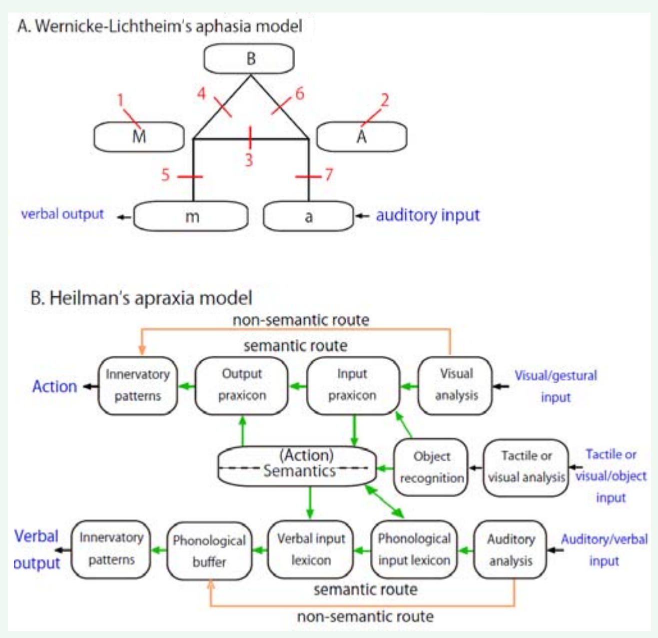

Figure 1 Diagrammatic models of aphasia and apraxia. A. Classical diagram of the language system. Block labels: A, acoustic word image center (Wernicke's area); M, motor word image center (Broca's area); B, concept center; a, auditory input; m, verbal motor output. Lesion labels: 1, Broca's aphasia; 2, Wernicke's aphasia; 3, conduction aphasia; 4, transcortical motor aphasia; 5, articulatory disorder (aphemia); 6, transcortical sensory aphasia; 7, pure word deafness. B. Diagrammatic model of limb apraxia. Modified from Heilman et al [26].

1. Is there sensory apraxia corresponding to Wernicke's aphasia?
2. Is there a type of apraxia corresponding to conduction aphasia, in which conduction praxis information is impaired with preserved comprehension and production?
3. Is there "transcortical" apraxia, in which conduction is preserved and comprehension/production is impaired?

In the following section we discuss comprehension, conduction, and production in aphasia and apraxia.

Disturbances of recognition and comprehension in language and praxis

It is important to recognize that the information included in both language and praxis is received as sensory inputs. Standard examination of verbal comprehension includes evaluation of object naming, word reading, and listening. Examining the comprehension of praxis may involve showing activities such as a pantomime gesture of hammering a nail and then determining whether patients can choose a picture of a hammer out of multiple pictures of tools. If a patient does not understand the pantomime of tool use and consequently fails to imitate the gesture, he is likely to have "pantomime agnosia," which is thought to be associated with lesions in the ventral visual association area in the left hemisphere. Aphasic patients often exhibit a variety of extraverbal deficits, such as understanding and making gestures [16]. Finkelnburg suggested that the term aphasia inadequately signifies the full extent of the disorder by only referring to verbal disturbances, and proposed the more generic term "asymbolia" to describe the common problem of symbol representation [17].

Some apraxic patients may be able to identify presented tools but not know how to use them; for example, they may correctly name a hammer but use it like a screwdriver—it appears as if the knowledge of tool usage is lost. This symptom, known as "conceptual apraxia," is an impairment of comprehension rather than motor output, and is sometimes seen in Alzheimer's disease and stroke patients. Conceptual apraxia may be considered to be a type of sensory apraxia.

Sensory feedback is important during transitive (tool-use) actions. The holding and manipulation of tools requires visual and somatosensory inputs to be integrated with motor commands. Gesture is conventionally thought to be represented in the left inferior parietal lobule (Brodmann's area 40), where sensory inputs of multiple modalities are known to be integrated [18]. On the other hand, speech processing relies on auditory input. Verbal recognition involving the conversion of phonemes into words and phrases is thought to occur in the left superior temporal gyrus including the Wernicke's area.

The dual-route hypothesis: ventral and dorsal pathways

Visual information is thought to be processed in two parallel pathways: (1) physical features, such as shape and color, are processed in the ventral pathway, whereas (2) object location and motion are processed in the dorsal pathway [19]. Such parallel computing may also occur in language processing. Clinical observations of aphasic patients suggest that phonetic and semantic impairments are functionally and anatomically dissociable. For instance, in transcortical sensory aphasia, words can be repeated without understanding them. Patients with sensory aphasia often exhibit semantic paraphasia, such as incorrectly saying "orange" when naming an apple. These symptoms may reflect semantic dysfunction with preserved phonetics. Conversely, patients with conduction aphasia exhibit phonetic dysfunction with preserved semantic processing. There is converging evidence that the language system has two anatomically segregated pathways [20,21]: (1) phonetic information appears to be implemented in the dorsal structures, including Wernicke's and Broca's areas connected by the arcuate fasciculus (Figure 2, orange), while (2) semantic information appears to be processed in the ventral pathway, including the frontotemporal region connected by the extreme capsule and uncinate fasciculus (Figure 2, green).

Praxis information comprises both symbolic and kinematic aspects. Thus, the principle underlying the aphasia model may also apply to apraxia. Temporal spatial control of movements is required for tool manipulation, which may rely on the dorsal route, and symbolic actions, such as salute, may rely on the ventral route. Testing gesture imitation in apraxic patients is analogous to testing word repetition in aphasia patients, in that it examines their nonsymbolic capacity for sequential motor outputs. Patients with ideomotor apraxia can often imitate gestures better than making gestures in response to verbal commands. However, there are apraxic patients who can make gestures in response to verbal commands but cannot imitate gestures [22]. The selective impairment of gesture imitation is called conduction (imitation) apraxia, by analogy with selective impairment of word repetition in conduction aphasia. Heilman and colleagues explained the symptoms of conduction apraxia using a diagrammatic model (Figure 1B) [23], which separate Liepmann's movement formulae into two modules of praxicons: input and output. The input praxicon allows recognition of a familiar gesture, and the output praxicon permits its production. Patients with conduction apraxia exhibit normal comprehension of gestures, and thus the input praxicon is presumed to be intact. Impaired imitation in conduction apraxia is thought to occur between the input and output praxicons after the observed stimuli are processed by the input praxicon. A different point of view attributes impaired gesture imitation to dorsal pathway dysfunction. Damage to the dorsal pathway may disturb spatial temporal control, making gesture imitation difficult. However, gestures in response to verbal commands may be preserved via the ventral semantic pathway. Recent studies show that the dorsal pathway, particularly the supramarginal gyrus, is important for both gesture imitation and word repetition [24,25].

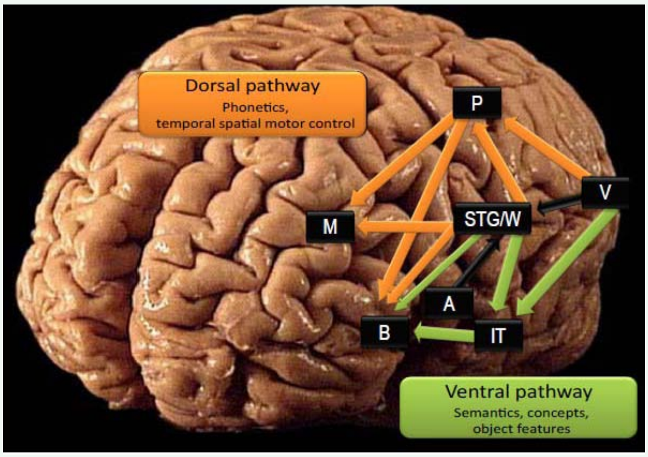

Figure 2 The dual-route hypothesis. The dorsal route (orange) comprises pathways from the parietal cortex (P) and posterior part of the superior temporal gyrus (STG/W) to the premotor area (M) and to Broca's area (B), connected via the arcuate/superior longitudinal fasciculus. The dorsal route may process phonetic information to produce verbal output without accessing word meaning. Word repetition may rely on this route, as evidenced by the phonemic paraphasia caused by damage to this pathway. The dorsal route may also be involved when guiding the hand to target objects via temporal spatial control combined with visual/tactile feedback. Damage to this route may impair gesture imitation. The ventral route (green) comprises pathways from the superior temporal gyrus (STG/W) to Broca's area (B) via the extreme capsule, and from the anterior part of the superior temporal gyrus (IT) to the frontal operculum via the uncinate fasciculus [21]. Injury to the ventral pathway may result in sensory aphasia. It may also cause apraxia accompanied with difficulties with actual tool use. A, auditory cortex; M, motor-related areas; V, visual cortex.

CONCLUSIONS

Clinical studies suggest that there is a strong correlation in the lateralization of language and praxis. This may be because language evolved from primitive gesture communication. Furthermore, the two systems share many functional features, such as sensory-motor integration and symbolic representation; thus, anatomical overlap of the two systems may provide computational advantages. The dual-pathway model is a simplistic view of the distributed neural networks with anterior (production), posterior (reception/perception), dorsal (phonetics/kinematics), and ventral (semantic) extensions. The model provides a unified view of the properties shared between aphasia and apraxia.

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