Carl Wernicke's Contribution to Theories of Conceptual Representation in the Cerebral Cortex

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A Current View of the Cortical Organization for Conceptual Knowledge

- Concepts are widely distributed throughout cortex
- Conceptual representation involves the same sensory, motor, supramodal cortical systems originally involved in processing that information
- Transmodal associations are mediated by "convergence zones" in multimodal cortex

“One large set of systems in early sensory cortices and motor cortices would be the base for “sense” and “action” knowledge, i.e., the highly multiregional substrate for “explicit” representations which are the key to our experience of knowledge.”

Damasio, 1994

“The patterns of neural activity that correspond to distinct physical properties of entities are recorded in the same neural ensembles in which they occur during perception …”

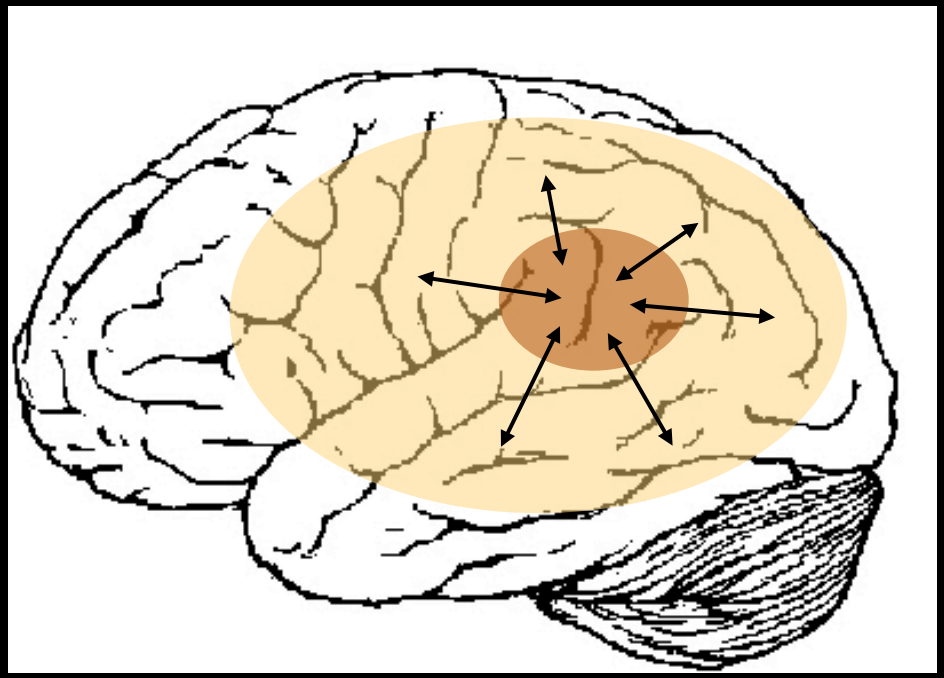
Damasio, 1989

“The view of memory that has emerged recently, although it still must be regarded as hypothesis, is that information storage is tied to the specific processing areas that are engaged during learning. Memory is stored as changes in the same neural systems that ordinarily participate in perception, analysis, and processing of the information to be learned.”

Squire, 1986

“Transmodal areas are not necessarily centres where convergent knowledge resides, but critical gateways ... for accessing the relevant distributed information.”

Mesulam, 1998



A (Modern) Connectionist View of Conceptual Representation

"Each entity is represented by a pattern of activity distributed over many computing elements ..."

Hinton, McClelland, & Rumelhart, 1994

Carl Wernicke's Theory of Conceptual Representation in the Brain

- Concepts are widely distributed throughout cortex
- Conceptual representation involves the same cortical systems originally involved in processing that information
- Transcortical fiber pathways provide the anatomical bases for association processes supporting conceptual representation

Wernicke began formulating these constructs in his early works

"The concept of the word "bell", for example, is formed by the associated memory images of visual, tactual and auditory perceptions. These memory images represent the essential characteristic features of the object, bell."

The Aphasia Symptom Complex:

A Psychological Study on an Anatomical Basis

Wernicke, 1874/1977

“ … the memory images of a bell … are deposited in the cortex and located according to the sensory organs. These would then include the acoustic imagery aroused by the sound of the bell, visual imagery established by means of form and color, tactile imagery acquired by cutaneous sensation, and finally, motor imagery gained by exploratory movements of the fingers and eyes.

Recent Works on Aphasia

Wernicke, 1885/1977

“Close association between these various memory images has been established by repeated experience of the essential features of bells. As a final result, arousal of each individual image is adequate for awakening the concept as a whole. In this way a functional unit is achieved. Such units form the concept of the object, in this case a bell.”

Recent Works on Aphasia

Wernicke, 1885/1977

Grundriss der Psychiatrie

Carl Wernicke

Leipzig

1900

Wernicke on memory trace formation:

“ … And in the cortex we can again ascribe this role to certain cells: a transient stimulus can cause lasting modifications in these cells so that some form of residuum of the stimulus remains, which we call a memory trace. … These facts prove beyond any doubt that memory traces are localized to their respective projection fields. “

Anatomical Basis of Transmodal Associations

The modern view is that there are cortical fields (association cortex, “convergence zones”) which bind together these distributed representations.

“Convergence zones trigger and synchronize neural activity patterns corresponding to topographically organized fragment representations of physical structure, that were pertinently associated in experience, on the basis of similarity, spatial placement, temporal sequence, or temporal coincidence, or combinations thereof. “

Damasio, 1989

Wernicke addressed this question
in The Grundriss

"The important point is that associative processes can only be explained if we postulate functional interconnections among the anatomical regions to which the memory traces of the individual sensory modalities are localized."

“The established anatomical basis for this assumption is found in the immense number of fibers present in the cortical white matter tracts and in the cortex itself. The function of these fibers is to connect one cortical region to another.”

“During the process of primary identification two regions within a projection field (or two regions of two different projection fields in the case of secondary identification) become activated simultaneously by the concurrent arrival of external stimuli in the projection fields.”

“Each time this happens, the connection pathway that lies between the two areas begins to resonate, so to speak, with the active regions. The more often this process is repeated, the smaller the resistance to propagation becomes, and the pathway is ground out, or as it is called nowadays, strengthened.”

“I am not saying that this pathway has to be a continuous one … on the contrary, there is evidence for a layer of cortical cells … which by their shape and position appear to belong to the association system. Thus it is likely that these cells are interposed in the association pathways between cortical regions.

“Every association cell has two nerve fibers which it sends out in opposite directions. The terminals of these processes connect to the cells in the projection fields which are to be associated with each other.”

“If we, then, step up from a simple memory trace and consider the more complicated cases of … associations between visual conceptions and memory traces of another projection field [sensory modality], our attempt to find a structural correlate for this process runs into colossal difficulties.”

“This principle of fully interconnected perceptual elements cannot possibly hold for the connectivity between memory traces. While the number of available connection fibers may be very large, it would still be dwarfed by the seemingly infinite numbers required for this purposed, as computed by a combinatorial calculation.”

"… the acquisition process for permanent associations between different sensory modalities usually is a slow and laborious one, but once acquired, they are handled with ease.
Therefore, it may not be surprising to find that complicated mechanisms are required to create association pathways in the brain."

"We already have noted Hebb's contribution of the Hebb rule of synaptic modification; he also introduced the concept of cell assemblies -- a concrete example of a limited form of distributed processing -- and discussed the idea of reverberation of activation within neural networks."

Rumelhart & McClelland 1986

"Some of the earliest roots of the PDP approach can be found in the work of the unique neurologists, Jackson (1869/1958) and Luria (1966). Jackson was a forceful and persuasive critic of the simplistic localizationist doctrines of late nineteenth century neurology, and he argued convincingly for distributed, multilevel conceptions of processing systems."

Rumelhart & McClelland 1986