WHAT PATHOLOGY TELLS US ABOUT LEXICAL ACCESS IN SPEECH PRODUCTION

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ABSTRACT

Language deficits which result from brain damage provide insights into the nature of normal speech production and perception. Aphasia data are shown to be of specific importance in revealing the structure of the mental lexicon, the manifold representations of each lexical item, how they interact, and the processes involved in accessing this lexicon during speech production.

1. INTRODUCTION

- As stated almost thirty years ago by Denes and Pinson, [4] speech communication may be viewed as a chain of events starting "in the speaker's brain (where) ... appropriate instructions, in the form of impulses along the motor nerves, are sent to the muscles of the vocal organs, the tongue, the lips and the vocal cords" causing movements which in turn produce speech sound waves. We know a great deal about the physiological, articulatory, and acoustic aspects of these stages of speech production as a result of experimental phonetic research. But we are still far from understanding the processes by which a speaker once he has arranged his thoughts, "puts what he wants to say into linguistic form ... by selecting the right words and phrases to express its meaning, and by placing these words in the correct order required by the grammatical rules of the language.." (p 3)

- One approach to investigating this complicated process is to see if deviant language, such as the speech of brain damaged aphasic patients can provide insights into the normal linguistic processing system.

- The entry into the area of aphasia research and brain-mind-cognition studies was a logical development of the goal to understand the nature and form of human linguistic knowledge and how this system of knowledge -- the mental grammar -- is put to use in speech production and comprehension.

- Interest in brain mechanisms underlying language and speech goes back about 2000 years. Aristotle's false view that the brain is a cold sponge whose primary action is to cool the blood was not shared by the Graeco-Roman physicians, who, writing in the fifth century B.C.E., recognized that the loss of speech and the loss of language could be distinguished. The Hippocratic view was that the brain is "the messenger to the understanding" and the organ whereby "in an especial manner we acquire wisdom and knowledge." [1]

- This recognition of the brain-cognition-language relationship which has endured through the centuries, led in the early part of the 19th century to theories of 'localization' suggesting that different human abilities and behaviors are traceable to specific brain structures. In 1861, in a meeting in Paris, language was specifically related to the left side of the brain in a paper presented by Paul Broca in which he presented autopsy evidence showing that a localized (anterior) left hemisphere lesion resulted in a loss of ability to speak, whereas focal lesions in

similar parts of the right brain did not. He managed to convince his Parisian audience (and most of neurology) that "On parle avec l'hemisphere gauche". [3]
- In 1874, Wernicke [12] pointed out that damage in the posterior portion of the left temporal lobe (now called Wernicke's area) results in a different form of language breakdown than that occurring after damage to the frontal cortex (Broca's area). These different kinds of acquired language loss -- aphasias -- continue to be corroborated.
- Aphasia research by linguists and phoneticians has been motivated in part by these findings that focal damage to specific brain areas results in the disruption of distinct cognitive functions as well as motor and perceptual abilities, and that the selectivity appears to be specific as to the parts of language which are effected. This supports a modular conception of the grammar itself, in which the components are interactive but independent of each other, since these components as well as the hierarchy of linguistic units posited by linguists appear to be just those parts which can be differentially destroyed or damaged. Given this fact, the study of the kinds of disruption which follows localized lesions, permits us to investigate the levels of representation at different stages in the memory.
- Jakobson [5] was the first linguist to conduct aphasia research, following up on the insights of de Courtenay in 1885 and Saussure in 1879 who had expressed the belief that a study of language pathology could contribute to linguistics. As this symposium will hopefully show, their views have been corroborated since such research is contributing to our understanding of both the representation and the processing of language and speech.

2.LEXICON

2.1. Lexical Selection

- Aphasia research has become increasingly concerned with lexical representation and access in the attempt to understand "how the right words" are selected. [see, for example, 7,9,10] Simultaneously, current linguistic research is being conducted on the lexicon and the morphological component of the grammar.

2.2. How Many Lexicons?

- In trying to understand the complex problems of lexical selection and phrase construction in speech production, one question of interest is how the lexicon is organized, and whether, for example, content words (open class items) are listed separately from grammatical morphemes (closed class items) -- inflectional and derivational, free and bound. Aphasia research (as well as speech errors produced by normals) supports the proposal that these two classes of formatives are processed at different levels of speech production [7, 8]. It is logical to assume that if this is so, the two categories of morphemes are also stored in separate lexicons.
- The speech output of Broca's and Wernicke's aphasia patients provide some evidence. Broca's aphasic speech is characterized by word-finding pauses, loss of both free and bound grammatical morphemes, and quite often, disturbed word order, but with access to content 'open-class' words. Auditory comprehension for colloquial conversation gives the impression of being generally good, although controlled testing reveals considerable impairments. The term **agrammatism** is often used as a term for Broca's aphasia.
- Wernicke's aphasia patients, on the other hand, produce fluent speech with good intonation and pronunciation, but with many word substitutions (both semantically similar and dissimilar), neologisms as well as phonological errors. They also show comprehension difficulties. Their utterances while often semantically empty (given their difficulties with major category morphemes, e.g. nouns, verbs, adjectives, appear to be well formed syntactically with inflection-

al and grammatical morphemes intact.
- Thus, these two major classes of aphasics reveal differential impairment in these two classes of morphemes. [2]
- Agrammatism and Wernicke's 'fluent' aphasia are not the only types of aphasia which show differential processing of lexical and grammatical morphemes. The language deficits of some patients after brain injury diagnosed as having acquired dyslexia primarily effect reading and writing, leaving the spoken language intact. These subjects also provide insights into normal speech production since lexical access which is impaired for many of them is involved in spontaneous speech as well as in the reading and writing processes.
- Again we find evidence for the separation of the lexicon into sub-lexicons, one storing major category content words and morphemes, and another where grammatical formatives are listed. A patient of Newcombe and Marshall [10], for example, shows differential impairment in reading words in these two major classes. Errors are made in reading content words, with substitutions of semantically and/or phonologically related words, but grammatical formatives can not be accessed at all as shown in Table 1.

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Table 1. Patient G.R. [10]

Stimulus	Response
WITCH	'witch'
WHICH	'no!'
BEAN	'uh...soup'
BEEN	'no!'
HOUR	'time'
OUR	'no!'
EYE	'eyes'
I	'no!'
HYMN	'bible'
HIM	'a boy? no!'
WOOD	'wood'
WOULD	'no!'
FOUR	'four'
FOR	'no!'
MOOR	'fog..mist?'
MORE	'no!'

- Dyslexics like G.R. who often substitute semantically related words, e.g. "prison" for JAIL appear to bypass any orthographic to phonological or pronunciation rules, going directly to what must be an orthographic sub-lexicon connected to a semantic sub-lexicon. The connection between the semantic and phonological representations remain, but in accessing the semantic "address" a misselection occurs. Thus we have evidence for the separation of components even within the major subcomponent of lexical content words.
- We find that this reading disruption problem is paralleled in normals in the kinds of semantically similar word substitutions which occur in speech errors, e.g. 'downtown' for 'uptown', 'wrist' for 'finger', 'behind my face' for 'behind my back'.
- Some of the substitutions both in the reading errors of acquired dyslexics and the speech errors of normals show phonological similarities between the target and the substituted word rather than or in addition to semantic similarities, e.g. 'fluency' for 'frequency' 'progress' for 'practice', 'persecuted' for 'prosecuted'. Such errors suggest the ways in which the entries in each sub-lexicon are listed e.g. by semantic feature or class in the semantic lexicon, by phonological form in the phonological lexicon. Since the number of phonologically similar substitutions which share initial word onsets is significant, it seems safe to conclude that words are listed according to such onsets. The fact that in addition to the onsets, substitutions show other phonological similarities, e.g. of segments and number of syllables, shows that these phonological factors play a role in both the organization and the access of the lexicon but the nature of the organization requires further investigation; the listing of words in the phonological sub-lexicon according to number of syllables and onsets for each subset seems to be a possible starting point.

- Additional information about the organization and processing of the lexicon is provided by a patient with whom I have worked over the last number of years, referred to as Kram and MS in the literature. [7, 9] Kram shows good language comprehension and fluent intelligible speech production, with greatly impaired reading and writing ability. For example, he will read the word 'fame' as [fɔɛmi] and write it to dictation as FAM; he can neither map the orthography onto a phonological representation in his mental lexicon nor use normal orthographic-to-phoneme rules; he uses his own idiosyncratic rules instead. Furthermore, he can understand the meaning of a word only through its phonology; when he produces nonsense forms, he is unable to state what the written form means or even if it is a 'real' word. If he does read a word correctly he understands what it means; if he reads a homophone correctly, he cannot determine which of the ambiguous meanings is represented by the spelling, as shown in Table 2.

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Table 2. Kram's pronunciation and comprehension of written homonyms.

Stimulus	Pronunciation	Meaning
sum	sum/some	"I've got some"
can	san	"don't know"
for	for/four	"I have four fingers and a thumb"
pig	pig	"oink oink"

- Other similar cases are reported in the literature [11]

-We see again that such deviant language, written as well as spoken, provides clues as to lexical representation, structure, and processing.

-The neologistic jargon produced by other aphasics also provides information about normal processing of speech. (1) and (2) are examples of such utterances:

(1) the leg vilted from here down
(2) This is the krebekacks where the frejes get out after the chuw.

- Note that the nonsense forms are well formed both phonologically and morphologically, i.e. appropriately inflected or derived. But some aphasics, i.e. the agrammatic patients with Broca's aphasia, have particular difficulty with inflectional affixes [2,9]; English speaking agrammatics may omit grammatical formatives completely; speakers of other languages, like Hebrew, do not omit bound morphemes but substitute other incorrect inflectional morphemes. This difference was accounted for by Grodzinsky [9] by an explanation of particular interest to those of us concerned with speech production mechanisms. He points out that vowels in Hebrew are predictable, according to inflectional and derivational morphological rules. For example, the vowel in the word for a single male child is "e" *yeled*, is "a" for a female child *yalda*; the plural for these two singular nouns is *yeladim* and *yeladot*, respectively. Since the roots of Hebrew words consist only of consonants, e.g. /y-l-d/ in the examples given, agrammatic aphasic Hebrew speakers would be unable to talk at all if they omitted the inflectional and derivational morphemes which are realized vocalically. Thus, these Hebrew speakers instead of omitting these morphemes, substitute incorrect vowels in words such as those above and omit free-standing grammatical morphemes. This shows the phonetic and speech production constraints which exist.

- The aphasic data which have been cited show us something about how a speaker "puts what he wants to say into linguistic form" even if the 'wrong' words or wrong inflections are selected, or if the right words are distorted. Denes and Pinson 's observations can be extended to cover the production of jargon if one posits that a speaker must first, prior to articulatory processes, generate a string of

phonological units, properly inflected according to phrase structures determined by the grammar, which string is then mapped onto the proper motor commands to move the articulators to produce sounds.

3.PRODUCTION MODELS

3.1 Lexical Models

-These data from pathological language and from normal but deviant (speech error) language have led to the construction of first approximation lexical models composed of phonological, orthographic, and semantic sub-lexicons. [9]. Each entry in each of the components is connected to its parallel representation through an addressing system. When the connections between the orthographic representation of a word and its phonological representation is blocked, a speaker is unable to read the word; when the connection between the semantic representation of a word and its phonological representation is disturbed, a semantically similar but incorrect substitute can be produced, or, as in the case of jargon aphasics, the entire phonology may be disrupted.

- The cases of jargon aphasia are particularly telling; it is seldom that the inflectional and free standing grammatical morphemes are mispronounced again supporting the notion of a major division into two lexicons, each, possibly with its own sub lexicons.

- Under conditions of pathology, access to either lexicon and the connections between the sub lexicons may be blocked. It must be the case, then, that these divisions exist in the normal lexicon as well and under certain conditions (which are not clear as yet) partial blocking may occur for normal speakers.

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