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SPEECH PRODUCTION: INSIGHTS FROM A STUDY OF PROGRESSIVE APHASIA

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ABSTRACT

Neurodegenerative disease can result in a primary language disturbance, typically called primary progressive aphasia, of which two distinctly different patterns have been described. Non-fluent and fluent progressive aphasia [1,2] bear some similarities to non-fluent and fluent aphasia resulting from cerebro-vascular accident (CVA), but often reveal especially clear-cut, circumscribed language deficits. In this paper, we focus on the object naming performance of two patients, one with each form of progressive aphasia. Both patients' naming showed a marked decline over a two/three-year period. The anomia of the fluent case can be explained entirely by progressive loss of features of knowledge representation for objects and words. The deficit of the nonfluent case reflects progressive difficulty in access to and retrieval from phonological representations for speech production.

THE SYMPTOM OF ANOMIA IN APHASIC SYNDROMES

Most patients with acquired language disorders display the symptom of anomia: difficulty in producing the correct name for familiar objects, both in spontaneous speech and on naming tests. Object naming is a complex task requiring several different cognitive components. Most accounts of anomia distinguish between primary deficits at one of two stages: a semantic component, where features of knowledge concerning the object to be named are represented; and a phonological stage, where the phonological specification of the word corresponding to the object's name is represented [3]. These accounts would predict a clear-cut difference in the types of naming errors shown by patients with semantic vs phonological impairments. Yet many anomic patients with vascular aetiology produce a mix of error types, such that it has not always been easy to achieve a clear separation of these two primary types of deficit in anomia [4]. Indeed, it has even been claimed that, when severity of anomia is matched across different sub-groups of aphasic patients, the groups do not differ in proportions of errors supposed to be diagnostic of semantic vs phonological deficits [5].

Although detailed, theoretically motivated analysis of the anomia in individual CVA cases has achieved considerable progress [3], another promising approach to the understanding of naming in particular and speech production more generally has recently come from the study of progressive aphasia due to neurodegenerative disease. Perhaps because such conditions tend to affect brain systems (while vascular lesions disrupt anatomical regions that cut across functional systems), one can often observe highly selective deficits in patients with progressive brain disease. In the present paper, we describe two cases of progressive aphasia, one fluent and one non-fluent, in which the anomia seems clearly attributable to a semantic impairment for the former and a phonological impairment for the latter.

	<u>JL</u>	<u>PG</u>
	Fluent	Nonfluent
Atrophy	Bilat Temporal	L Perisylv
Gender/Hand	M/R	F/R
Age/Yrs Edu	60/9	74/11
TROG (80)		
first; last	76; 65	60; 43
W-P match (40)		
first; last	30; 11	40; 33
Naming (48)		
first; last	17; 2	39; 14
Fluency (anim's)		
first; last	10; 3	12; 3

Table 1. Details of the two patients

CASE STUDIES

Table 1 shows some basic details of the two patients. JL, a successful company director, first presented with a 2-year history of difficulty in remembering the names of people and places. PG, the widow of a doctor (general practitioner), presented with a selective speech production problem. Neither patient had any relevant medical history. Also, neither showed any notable difficulty on tests of visuospatial perception, nonverbal intelligence, or day-to-day (episodic) memory, making generalised dementia (e.g., of the Alzheimer's type) an unlikely diagnosis. The first few entries in Table 1, listing location of atrophy on structural and/or functional brain imaging, gender, handedness, age and years of education, are self-explanatory. The remaining entries indicate performance on specific tests, both "first" (i.e., when we first tested each patient, in spring of 1991) and "last" (on the most recent testing session, which was in March 1993 for JL and February 1994 for PG).

TROG [6], the Test for Reception of Grammar, is an 80-item sentence-picture matching task (one spoken sentence, four picture alternatives) that assesses ability to understand sentences with varying syntactic structures and degrees of syntactic complexity. Although the TROG scores of both patients declined over time, PG, the non-fluent case, had a lower score at the *beginning* of the study than JL achieved at the *end*. Furthermore, on this test designed to distinguish between lexical and grammatical aspects of comprehension, JL made many lexical errors while PG's errors mainly indicated grammatical difficulties. The next test is a 40-item word-picture matching task [7] used to assess comprehension of individual nominal terms. Here, by sharp contrast with

TROG, JL's score was lower on first testing than PG's on last testing, indicating JL's severe deficit in single-word comprehension. In fact, by the last testing session, JL's performance was not significantly better than chance, while PG has shown only a relatively mild decline over three years.

The final two entries in Table 1 provide two different measures of anomia. In the first test, the patients were asked to name 48 line drawings of common objects from the widely used set of 260 Snodgrass and Vanderwart pictures [8]. In the second, they were asked to produce as many different animal names as possible in a period of one minute. Both patients showed a dramatic decline over time on both of these name production tests.

We turn now to our experimental investigations of the two patients. These investigations, designed to reveal the theoretically informative features of each case rather than to enable a direct comparison between them, were not identical. We will therefore present the two studies separately, but in a way that highlights the distinctly different bases for anomia in the two cases.

JL: PROGRESSIVE FLUENT APHASIA

Some patients with progressive fluent aphasia, also called semantic dementia [9,10], are so profoundly anomic that they respond "don't know" to virtually all attempts to elicit names for objects [11]. JL, despite his severe and increasing semantic dementia and anomia, continued to offer verbal responses to pictures throughout our longitudinal study, enabling us to evaluate the status of his semantic system with picture naming tests. He was asked to name the entire Snodgrass and Vanderwart [8] set of 260 pictures on four occasions between October 1991 and March 1993. The full corpus of his responses cannot be included here (see Hodges, Graham & Patterson [12] for further details), but Tables 2 and 3 present some illustrative data, using animal (mammal), bird and insect picture-subsets. The important features of these results can be summarised as follows.

The first thing to note is the striking longitudinal item-by-item consistency: once a name dropped out of JL's repertoire, it essentially never returned. In the data shown here, there was not a single instance where JL failed to name a particular picture on one session and then named it correctly on a subsequent session. In the entire corpus of 1040 responses (260 pictures, 4 sessions), there were only 7 instances of a correct naming response occurring after an earlier error on that item; and in most of these cases, the preceding incorrect response had been a semantically similar name (e.g., *dress*-->"suit") or a meaningful circumlocution (e.g., *tree*-->"in the woods"). A related point (which emerges more clearly from the whole corpus) is that, if JL initially succeeded in naming a picture, his first error response on that item was almost always a category coordinate or meaningful circumlocution. This pattern underlines the gradual degradation of semantic knowledge.

Two additional features supporting the same conclusion are (i) the longitudinal reduction in the number of specific responses: JL produced 10 different animal names in Sept'91 (9 correct plus *donkey* -->"pony"); a year later, his repertoire of specific animal names was reduced to 4; and (ii) the gradual loss of specificity in his incorrect responses. For example, his responses on the earlier sessions reflected a degree of knowledge regarding the size of the to-be-named animal (note that the actual line drawings give no clue to the animal's true size): in Sept'91 and Mar'92, a number of the larger animals were called either "big animal" or "horse"; knowledge of size was no longer so apparent by Mar'93. Another example of decreasing specificity over time can be seen in a comparison of JL's responses to mammals, birds and insects. On initial testing, JL's knowledge of insects had already deteriorated so much that he labelled them with the wrong specific superordinate ("bird"); and the highest-level superordinate label ("animal") entered his response repertoire very early for insects. His initial knowledge of birds was much better: on session 1, every bird was given a specific name, and the appropriate superordinate ("bird") was still his favoured response a year later. For both birds and mammals, the most general term "animal" emerged only on the last test session.

	Sept'91	Mar'92	Sept'92	Mar'93
horse	+	+	+	+
dog	+	+	+	cat
cat	+	+	+	animal
cow	+	+	horse	horse
pig	+	on farm	dog	dog
deer	+	horse	cow	vehicle
rabbit	+	cat	cat	cat
sheep	+	dog	dog	dog
elephant	+	horse	horse	animal
mouse	cat	cat	cat	animal
monkey	pig	cat	boy	animal
gorilla	big an	dog	dog	man
tiger	dog	dog	dog	dog
squirrel	cat	chicken	cat	dog
raccoon	dog	cat	dog	animal
lion	dog	dog	dog	animal
fox	dog	dog	cat	dog
bear	dog	big an	dog	dog
goat	dog	dog	dog	dog
leopard	dog	dog	dog	cat
skunk	dog	cat	cat	cat
donkey	pony	horse	horse	horse
zebra	horse	horse	dog	dog
camel	horse	horse	horse	dog
kangaroo	pig	horse	dog	dog
rhinoceros	eleph	horse	horse	dog
giraffe	big an	horse	horse	horse

Table 2. JL's naming of the S&V animals

A third notable feature concerns the similarities and differences between JL's performance on living things and man-made objects (responses to the latter are not illustrated here because of space limitations). There was no significant difference in JL's success at naming items from these two categories; and the main characteristics already displayed and discussed for animals (such as longitudinal item-by-item consistency, and the way in which his responses reveal gradual loss of semantic features distinguishing one object from another) were equally apparent for non-living things. The two interesting differences as a function of the living/nonliving distinction were as follows. (i) Clear prototype responses emerged for animals: JL began to call every mammal "dog", "cat" or "horse"; in Mar'93, he responded "dog" to 11 different animals (but "cat" to the real *dog*!). Prototype responses were much less in evidence for manmade objects, as one would predict from analyses showing greater structural similarities amongst natural kinds than manmade objects [13]. (ii) JL's responses to manmade objects often reflected knowledge of the broad function of the target object (*piano*-->"for making music", *roller skate*-->"ride on it", *basket*-->"to fill up"). Although these responses suggest degraded item-specific knowledge just as persuasively as *squirrel*-->"dog", it is notable that objects were described in terms of their functions whilst animals were labelled with coordinates or superordinates.

	Sept'91	Mar'92	Sept'92	Mar'93
bird (gen)	+	+	+	animal
chicken	+	+	bird	animal
duck	+	bird	bird	dog
swan	+	bird	bird	animal
eagle	duck	bird	bird	horse
ostrich	swan	bird	cat	animal
peacock	duck	bird	cat	vehicle
penguin	duck	bird	cat	part an
rooster	chicken	chicken	bird	dog
ant	bird	bird	cat	animal
bee	bird	animal	cat	d/k
beetle	bird	bird	cat	animal
butterfly	bird	bird	bird	animal
caterpillar	animal	animal	animal	piece
fly	bird	bird	bird	animal
grasshop'r	bird	bird	cat	animal
spider	pheasant	bird	animal	d/k

Table 3. JL's naming of the S&V birds and insects

The final point to emphasise is that, in contrast to many anomic CVA patients, JL did not produce a mix of all major error types in naming. In particular, there was never even a hint of a phonological error. JL failed to name familiar objects not because of an impairment in access to or retrieval from phonological representations, but because of a profound degradation in the semantic representations required to address the phonological system for speech production.

PG: PROGRESSIVE NON-FLUENT APHASIA

For the first few years of our longitudinal study of PG, we merely tracked the decline in phonological and syntactic aspects of her language system with our basic battery of tests. Recently, we have applied a more experimental approach to the nature of her impairment in producing the correct phonological forms of words, based on the following reasoning. If PG's deficit is in the speech production system itself, then her success in producing a target word should be largely independent of the original nature of the information specifying the target. That is, if she is trying to say "elephant", any disruption to the actual phonological representation for this word should have comparable effects whether PG is asked to name a picture of an *elephant*, to read the written word elephant, or to repeat the spoken word "elephant". If the deficit is (alternatively or additionally) at a stage preceding the phonological output system, then the success of output might well depend on the form of input.

In February 1994, over a sequence of three separate testing sessions, we asked PG to produce the same 180 words three times, once in a naming task, once in reading, and once in repeating. Because of the picture-naming task, the words obviously had to be object names. To make the reading task as uncomplicated as possible, we chose words with typical spelling-to-sound correspondences. Because we were interested in assessing the effects of phonological difficulty, we also manipulated word length in our stimulus set, using 1-, 2- and 3-syllable words (60 of each). On each test session, PG attempted to produce any given word only once; and in each session, one-third of the items were presented in each task.

The effects of task were analysed in two ways. First, we measured the percentage of trials, for each of the three tasks, on which PG attempted to produce the correct target word. These responses included both correct productions and inaccurate productions with sufficient phonological overlap between target and utterance to make us confident that she had accessed the appropriate phonological representation. Excluded were refusals (where PG simply said "no"), perseverations (a target word from a previous trial), unintelligible utterances, and cases where she produced a recognisable word that was not the intended target. In the second analysis, we measured the percentage of targets attempted that were correct responses. The results of both analyses are presented in Figure 1, which gives an unambiguous answer, or rather two answers, to the question of whether PG's speech production is affected by the nature of the speech task that she is performing. Success in *access to* the correct phonological representation is markedly related to the nature of the input; success in *production from* the phonological representation is markedly independent of the input.

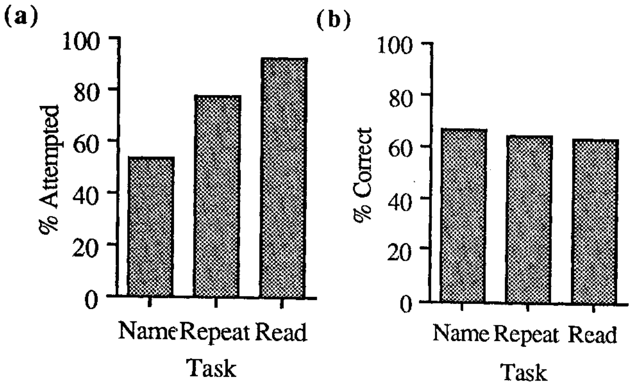

Figure 1. PG's performance as a function of task: (a) % targets attempted;(b) % correct of targets attempted

Our interpretation of Figure 1(a) is based on a concept of the degree of correlation between input and output. Because the relationship between an object and its name is completely arbitrary, there is essentially no correlation between the information given by a picture and the phonological structure for producing its name. An auditorily presented word, by contrast, is almost perfectly correlated with phonological structure for output. The written form of a word might be seen as offering an intermediate degree of correlation; however, (a) for a word in an alphabetic writing system and with typical spelling-sound correspondences, the orthographic form specifies the phonological form rather precisely; and (b) unlike the auditory presentation of a word, which is a highly transient event, the written form of a word remains in view. The differing percentages of targets attempted in the three tasks suggest that PG has a deficit in accessing phonological word forms. The more closely the information in the input correlates with or specifies the phonological information required for speech production, the better the chance that she will find her way to the correct phonological representation. Our further hypothesis that the advantage for reading over repetition was due to the difference in durability of stimulus presentation will be tested in future experiments involving brief exposure to written words.

We interpret Figure 1 (b) as indicating that PG also has a deficit in producing full, correct information from a phonological representation once it has been accessed. We predicted that an impairment at this stage should yield performance that was unaffected by the nature of the information specifying the target: after a phonological representation is activated, the source of its activation should be irrelevant. This prediction is confirmed by the essentially identical values for percent *correct* of targets attempted across the three tasks.

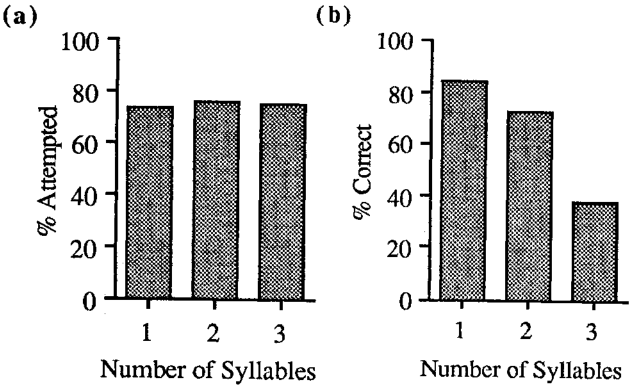

Figure 2. PG's performance as a function of word length: (a) % targets attempted; (b) % correct of targets attempted

The effects of word length were analysed with the same two measures and are displayed in Figure 2. On the basis of the same reasoning described above for task effects, we would predict that percentage of targets attempted -- our measure of *access to* phonological representations -- should be unaffected by word length; this is because the degree of overlap or correlation between input and output does not vary with word length. By contrast, the percentage correct of targets attempted -- our measure of *production from* phonological representations -- should differ as a function of word length. Both the identity and position-in-sequence of every phonological element in a word must be computed correctly to produce the whole correct response; and longer words have more phonological elements on which error may occur. It is clear from Figure 2 that both of these predictions were supported by PG's perfomance.

Two brief points about the nature of PG's errors: (i) The difference between naming and repeating/reading in percentage of targets attempted was largely attributable to more refusals, perseverations, and unintelligible responses in the naming task than in the other two tasks. This is in line with our interpretation that, owing to the poor correlation between input and output for object naming, PG often failed to access the correct phonological representation in naming, and then either said nothing or produced some unrelated content that happened to be available. (ii) We would not expect PG's phonological errors to be identical across tasks, or even in the same task on different occasions, because our interpretation of a disrupted phonological output system is not that individual words have been corrupted in a stable way, but rather that the whole system operates in a noisy fashion. We would however predict that the distribution of various types of phonological errors (deletions, insertions, transpositions, etc) should be roughly similar across the three input tasks; and this was indeed the case.

CONCLUDING REMARKS

Fluent (JL) and non-fluent (PG) progressive aphasia provide dramatic evidence of two distinctly different bases for anomia. JL's longitudinal naming performance revealed a complete absence of phonological errors and a set of decreasingly specific semantic errors reflecting a gradual loss of features from semantic memory. PG's naming revealed an absence of semantic errors, many phonological errors, and a pattern (in conjunction with results from comparable reading and repetition tasks) suggesting a progressive deficit in access to and production from phonological representations. Other aspects of progressive aphasia yield additional insights regarding language, such as the separability of semantic and syntactic components [11] and the relationship between semantic and phonological representations [14].

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