

NOTE

THE FAILURE OF LANGUAGE COMPREHENSION AT SENTENCE AND PHRASAL LEVELS IN A PATIENT WHO CAN SPEAK NORMALLY

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ABSTRACT

An unexpected dissociation between intact propositional speech and impaired language comprehension was observed in a right handed patient following a right hemisphere stroke. Although CHO's comprehension was intact at the single word level, his ability to comprehend a wide range of sentence structures was profoundly impaired. This deficit was observed in the context of normal sentence production both with regard to semantic and syntactic content. This case provides further evidence for the independence of on-line language input and output systems.

Key words: language, sentence comprehension, sentence production

INTRODUCTION

Aphasic difficulties may be observed at both the single word level and at the sentence level. A sentence conveys a meaning over and above that of its constituent words and this meaning is constrained by the rules of grammar in the most general sense. It is widely accepted that impairments of sentence comprehension and sentence production cannot be reduced to deficits in the comprehension of the individual words comprising the sentence. There is less unanimity regarding the organisation of sentence and phrasal levels of processing. An association of deficits has encouraged the view that there is a central processing mechanism used in both production and comprehension of multiple word expression. Thus agrammatic patients are observed to be impaired on tests that probe comprehension and production of sentences (e.g. Caramazza and Zurif, 1976; Heilman and Scholes, 1976; Schwartz et al., 1980).

Perhaps the most telling evidence against such a unitary position is the reports of patients in whom sentence production is syntactically faulty yet no deficit is observed on a range of sentence comprehension tasks (e.g. Caramazza and Hillis, 1989; Miceli et al., 1983; Nespoulous et al., 1988). In these instances the unitary system theory might be salvaged by recourse to a task difficulty argument, sentence comprehension tasks being possibly less demanding than sentence production. However the same argument could not be advanced to account for the opposite pattern of impairment of agrammatic comprehension with intact sentence production. This dissociation has been documented for complex sentence structures in patients with a reduced verbal auditory span (eg. Caplan and Waters, 1990; Caramazza et al., 1981; Saffran and Martin, 1990). Other aspects of sentence structure such as its lexical-semantic properties have not hitherto been considered in the context of this dissociation between comprehension and production of sentences.

The aim of this report is to put on record a patient in whom a grave impairment of sentence comprehension was observed, yet his propositional speech appeared to be normal and he was able to generate grammatically correct sentences. It will be concluded that there are independent input and output systems sub-serving sentence comprehension and propositional speech.

CASE REPORT

CHO was a 45 year old (date of birth 12.4.54) fully right handed security guard. In March 1995 he suffered a myocardial infarction and a ventricular clot, followed by a right cerebral hemisphere infarction. On examination there was a left hemiparesis and a left homonymous lower quadrantanopia. He was dysphasic, dyslexic and dysgraphic. He was admitted to the RNRU Homerton Hospital under the care of Dr. Richard Greenwood in May 1995. His walking had improved but he still had marked language difficulties, including dyslexia, dysgraphia and acalculia. In particular he was noted to have "fluent verbal output in lengthy monologues, often inappropriate to the current topic, perseveration of thought and word retrieval difficulties". Yet he was unable to understand simple questions such as "where do you live" and "how old are you". Even at this time it was noted that the severity of his comprehension deficit was masked by his fluent spoken output. He had occasional fits that were well controlled on Tegretol and he was discharged in October 1995. In November 1996 a C.T. scan showed low attenuation in the right temporal and posterior parietal lobes. In December 1998 he had a further cerebro-vascular accident again affecting the right temporal-parietal regions (see Figure 1). He had a left hemiparesis and language impairments which are described in detail below.

NEUROPSYCHOLOGICAL ASSESSMENT

CHO was referred for a neuropsychological assessment of his cognitive deficits at the National Hospital on the 21st of December 1998. He attempted selected tests of verbal, literacy and perceptual skills. At this time it was noted that he "does not demonstrate awareness of a conversational partner during social interaction". Additionally, he was very slow to understand test instructions.

Verbal Skills

His propositional speech in conversation was reasonably fluent. However word finding difficulties were observed on the Graded Naming Test (4/30 correct) and on the easier Oldfield naming test (17/30). In addition to circumlocutions (eg windmill- *arms go round*), it was noted that some of his errors were due to his failure to identify the object (e.g. tweezers). His digit span was accurate for only two items.

Literacy Skills

He was able to read short common words from the Schonell reading test accurately (10/10 correct), albeit somewhat slowly. He made occasional errors reading single letters (12/15 correct). He had grave difficulty spelling aloud the simplest words (e.g. cat-*kat*, milk-*malk*). He had considerable difficulty in reading arabic numbers (6/9 correct) and his ability to point to a named number in an array was inaccurate (7/9 correct). In addition he was unable to attempt the simplest oral addition (e.g. $3 + 1 = 5$).

Perceptual and Spatial Skills

He attempted several tests from the VOSP (Warrington and James, 1991) on which his performance was mildly impaired (Dot Counting 7/10, Object Decision 12/20 and Incomplete Letters 18/20). There was no suggestion of any unilateral neglect. On a spatial reasoning test, the Advanced Progressive Matrices, Set A, his performance was weak (3/12 correct).

Comment

At this early stage after his right hemisphere stroke CHO presented with all the hallmarks of a *dominant* parietal hemisphere syndrome; he was gravely dysgraphic and acalculic and his auditory verbal span was very impaired. He had mild anomia and dyslexia.

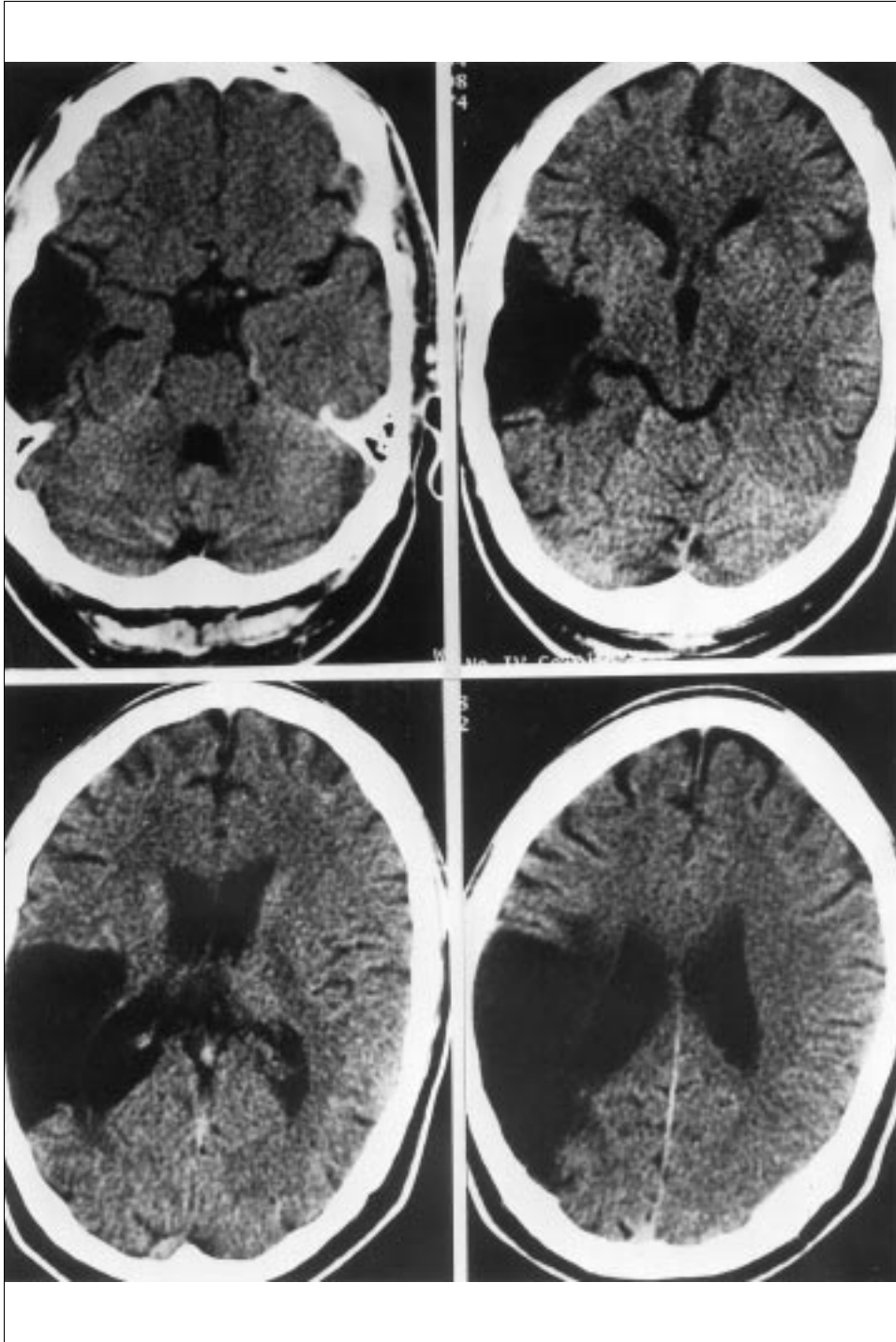


Fig. 1 – CT scan showing right temporo-parietal infarction.

Reassessment

CHO was reassessed 1 month later on January 22nd, 1999, and on 3 subsequent occasions before his discharge on March 7th. By this time there had been considerable improvement in his cognitive abilities. His propositional speech was fluent and he was able to repeat three-syllable low frequency words without error. His mild anomia, dyslexia and visual recognition difficulties had largely resolved. Thus he was able to identify and name 19/20 models of animals and 19/20 models of objects matched for frequency. He scored 26/29 on the Oldfield naming test. He attempted to read a subset of Brown and Ure corpus; 4, 6 and 8 letter words matched for frequency (high and low) and concreteness rating (high and low). He scored 68/72, misreading only 4 low frequency 8 letter words. He completed an information processing cancellation test at an average speed (22 seconds). On the Short Recognition Memory Test for Words (Warrington, 1996) he scored at the 50th percentile (24/25 correct). His score on the matrices test had improved to 5/12 correct. However he was still acalculic and dysgraphic. His digit span was still only reliable for two items. In the attempt to document the interaction of his very compromised auditory verbal span with his sentence comprehension skills an unexpected dissociation was observed. His comprehension of syntactically simple sentences was impaired, but nevertheless he was able to generate complex, syntactically correct sentences. Conversational exchanges were very disjointed; he appeared to misunderstand one's comment and reply at a tangent. It appeared that, as was observed after his first stroke, his good expressive skills masked the severity of his comprehension deficit.

INVESTIGATION OF LANGUAGE SKILLS

Speech Perception

CHO's auditory perception of verbal stimuli was assessed on word repetition tasks and word discrimination tasks. He was able to repeat 3-syllable, low frequency words flawlessly (e.g. porcupine, lubricate, wilderness). His repetition of non-words was creditable considering his very poor auditory span. He repeated 15/22 monosyllabic 4-letter non-words correctly and 5 of his errors were corrected with a second presentation. His ability to point to a named letter in an array of phonemically similar letters (BTPC and FSML) was fairly satisfactory given his ability to name these letters was insecure (23/28 and 19/20 correct, respectively). Similarly with arrays of two pictures with names that rhymed (e.g. jar-car, saw-paw) his performance was flawless in pointing to the named item. There were 8 such arrays and each stimulus was probed a minimum of 3 times (total correct 57/57). His performance on 2 arrays of 3 items each (e.g. nail, tail, pail), probed 4 and 5 times, respectively was also flawless (25/25 correct).

Auditory Verbal Short Term Memory

Digit Span

CHO repeated single numbers (5/5 correct) and pairs of numbers (5/5 correct) without error, however he was only able to repeat correctly 3/10 strings of 3 digits.

Sentence Repetition

His ability to repeat 3 word sentences (e.g. I like fish, coal is black) was weak (13/18 correct) and he made errors of omission (e.g. shops sell food – *shops food*). He failed to repeat any 5 word sentences correctly and the test was abandoned after 10 trials.

Delayed List Retention

Retention for meaningful and non-meaningful noun-verb pairs was tested after a filled interval of 15 sec during which he added '1' to a series of random numbers. The test stimuli

consisted of 15 meaningful pairs (e.g. dive-pool, burst-pipe), randomising the order of the noun and verb, and 15 pairs constructed from the same items rearranged in a random pairing (e.g. rob-fire, shoe-work). He scored 25/30 items correct for the meaningful pairs and 19/30 for the non-meaningful pairs, scores that are very comparable to those obtained in the original study using this material with span impaired patients (Warrington, 1978). This same task was then repeated without a delay using different stimulus pairs; he scored 28/30 and 27/30 on the meaningful and non-meaningful lists respectively.

Verbal Comprehension

(1) Single Word Comprehension

CHO attempted the short form of the BPVS and he obtained the satisfactory score of 27/32. On a stringent concrete and abstract word synonym test (written version) he obtained an average score of 44/50 correct (Warrington, McKenna and Orpwood, 1998). On a similarly stringent verb synonym test he obtained an average score of 40/50 correct (Manning and Warrington, 1996).

(2) Token Test

A simplified version of the Token Test was devised. In the two item condition there was an array of four coloured squares and he was required to touch or pick up a named colour (e.g. pick up yellow, touch red). He scored 27/30 correct. In the three item condition there was an array of 12 tokens; squares, circles and triangles, one of each of four colours. He was required to pick up or touch a named token (e.g. touch yellow circle, pick up green triangle). He found this task very difficult scoring only 7/30 correct.

(3) Sentence Comprehension

(a) CHO was tested on the TROG which assesses sentence comprehension using a sentence-picture matching procedure with 4 picture choices (Bishop, 1990). There are 17 types of grammatical construction and 4 examples of each type of sentence in a 'block'. A 'block' is scored as passed only if all 4 items are correct, otherwise it is failed. The distracter items are of three types in order of increasing difficulty; all lexical, 2 lexical and 1 syntactical and all 3 syntactical. Thus in the latter all 3 foils depict an incorrect syntactic interpretation of the sentence.

CHO's performance was very impaired (see Table I). He passed only 2 blocks, both of which had lexical distracters. His mean score on the failed blocks with lexical/syntactic distractors was 2/4 correct and on the blocks with only syntactical distracters his mean score was 1/4 correct. There did not appear to be an effect of sentence length per se (see Table I).

(b) Five blocks of these sentences (K, L, M, N and O) were represented in the written form. He found this task difficult, failing all 5 blocks and he refused to continue.

(c) He was also unable to attempt the Schwartz et al. (1980) 2 choice sentence comprehension task which uses reverse role syntactic distracters (e.g. "circle paints the square"). He obtained a chance score of 4 correct out of the first 10 items and the task was then abandoned.

(4) Naming from Description

His ability to comprehend descriptions of objects was compared with his ability to name pictures of the same objects. The test stimuli comprised 50 high frequency names from 5 categories and their verbal descriptions which were brief and syntactically simple. He had significantly more difficulty in the naming from description than in naming to confrontation (see Table II). Qualitatively it appeared that his ability to name from description was determined by the length and complexity of the verbal description, although they were all composed to be as simple as possible (contrast "What colour is grass?" with "What do people hit over the net in tennis?"). He had significantly more difficulty in naming from description than in naming to confrontation (see Table II).

TABLE I
Sentence Comprehension

Set	Syntactic construction and example	Distractors	Number of words	Score oral	Score written
D	Phrase/sentence (<i>the big cup</i>)	Lexical	3-4	Pass 4	
E	Negative (<i>the boy is not running</i>)	Lexical and syntactic	5	Fail 3	
F	Sentence with two nouns (<i>is the boy jumping over the box</i>)	Lexical	6/7	Pass 4	
G	Singular/plural personal pronoun (<i>they are sitting on the table</i>)	Lexical and syntactic	5/6	Fail 3	
H	Reversible active (<i>the girl is pushing the horse</i>)	Lexical and syntactic	6	Fail 2	
I	Masculine/feminine pronoun (<i>she is sitting on the chair</i>)	Lexical and syntactic	5/6	Fail 1	
J	Singular/plural noun inflection (<i>the cats look at the ball</i>)	Lexical and syntactic	5/6	Fail 3	
K	Comparative/absolute (<i>the knife is longer than the pencil</i>)	Lexical and syntactic	7	Fail 2	Fail 3
L	Reversible passive (<i>the girl is chased by the horse</i>)	Lexical and syntactic	7	Fail 2	Fail 1
M	In and on (<i>the cup is in the box</i>)	Syntactic	6	Fail 1	Fail 3
N	Postmodified subject (<i>the pencil on the shoe is blue</i>)	Syntactic	7	Fail 0	Fail 1
O	X but not Y (<i>the box but not the chair is blue</i>)	Syntactic	7-8	Fail 1	Fail 0
P	Above and below (<i>the star is above the circle</i>)	Syntactic	6	Fail 1	
Q	Not only X but also Y (<i>not only the bird but also the flower is blue</i>)	Syntactic	7/8	Fail 1	
R	Relative clause (<i>the girl chases the dog that is big</i>)	Syntactic	8-9	Fail -2	
S	Neither -nor (<i>neither the dog nor the ball is brown</i>)	Syntactic	7-8	Fail 1	
T	Embedded sentence (<i>the book the pencil is on is red</i>)	Syntactic	7-8	Fail 1	

TABLE II
Category Naming and Category Naming from Description (no. Correct)

	Objects	Animals	Colours	Parts of body	Countries
Naming	10/10	10/10	9/10	10/10	4/10
Naming from description	1/10	6/10	7/10	3/10	8/10

(5) Sentence Completion

CHO's ability to perform sentence completion tasks was assessed. An object name can form a high or low probability completion of a sentence frame. In the one case the terminal item is very constrained by the sentence frame (e.g. the water dripped from the ...), in the other there are many plausible endings (e.g. the man enjoyed his ...). In either case completion of the sentence frame with a plausible noun would not be possible unless the sentence frame had been processed appropriately. CHO attempted 2 sentence completion tasks:

(a) The Hayling Sentence Completion Task (part 1) consists of 15 sentence frames with a high probability terminal noun (Burgess and Shallice, 1996). The task is to complete the sentence with any semantically plausible noun (e.g. The boat passed easily under the ...). He scored 6/15 correct. For 7 of the sentences he made no response and 2 of the sentences were marginally misinterpreted (too many men are out of - *job*).

(b) High and low probability sentence completion. The stimuli consisted of 40 high probability (e.g. after dinner they washed ...) and 40 low probability (the girl kicked the ...) sentence frames (see Breen and Warrington, 1990, Experiment 2, for further details). He was able to give a semantically plausible response for 25/40 of the high and 19/40 of the low probability frames. Again his failures were almost entirely due to his inability to produce any response. Subsequently a set of pictures whose name was either the appropriate completion of the sentence or a plausible completion of the sentence were presented. He named 76/80 correctly.

SENTENCE GENERATION

(1) Sentence Generation from a Single Word Stimulus

CHO was presented with 5 single high frequency words and asked to produce a whole sentence that incorporated each of these stimulus words. He generated 5 syntactically correct sentences (e.g. table – “*set the table for supper*”).

(2) Sentence Generation from a Phrase

CHO was given the initial phrase of a sentence and asked to complete it to be a meaningful sentence. He scored 5/5 correct on this task (e.g. “in the evening – “*I went to sleep*”).

(3) Sentence Generation Given a Pictorial Context

The stimuli consisted of 20 pictures representing action verbs. He was asked simply to generate as complex a sentence as possible to describe the picture. He generated a correct sentence for all 20 pictures although in one instance an additional phrase was incorrect. His average sentence length was 7 words and for 5 of the pictures he produced sentences of 10 or more words in length (e.g. “*he is chopping the twigs in half*”, “*the little boy is bouncing up and down on the bed*”).

DISCUSSION

CHO was a right handed patient who after a right hemisphere stroke became aphasic, dyslexic, dysgraphic and acalculic. A profound impairment of sentence comprehension was recorded, yet many other aspects of his language skills appeared to be relatively intact. His naming ability for high frequency nouns was satisfactory, his comprehension of individual concrete and abstract words including verbs was average or above. In particular his propositional speech was fluent and grammatically correct. This dissociation of sentence comprehension and sentence production was observed in the context of a very restricted auditory span for verbal material. No significance is attached to the fact that this pattern of performance has been observed in a crossed lateral individual with a large right hemisphere lesion.

First it is necessary to consider whether he has a selective impairment of sentence comprehension. Alternatively, is it more appropriate to attribute his difficulty in interpreting sentential stimuli to impairments of other cognitive skills? There was no evidence of any significant word perception difficulties. On auditory word discrimination tasks his performance was satisfactory. His comprehension of both auditory and written stimuli at the single word level was good. Indeed he scored at an above average level on a stringent concrete word synonym test. His comprehension of the high frequency vocabulary of the sentence comprehension material used in this investigation was certainly intact.

The present series of observations were initiated in the context of CHO's very restricted auditory span for verbal material. It has been argued that certain aspects of sentence comprehension are compromised by an impaired verbal span (e.g. word order dependent sentences). Indeed hitherto the evidence of the dissociation of intact speech

production and impaired sentence comprehension is provided by studies of language comprehension in patients with a very limited auditory verbal span (see Saffran, 1990, for review). Nevertheless it has also been documented that many types of sentence construction can be comprehended quite satisfactorily by patients whose span is reduced to no more than 1 or 2 digits (e.g. Waters et al., 1991). In particular 2 patients with a reliable span of only 1 item, which is even more impaired than CHO, were able to score at a satisfactory level on the TROG, had no difficulty in the comprehension of reversible sentences in which animacy did not play a role, naming from description tasks or sentence completion tasks – all tasks which CHO failed (McCarthy and Warrington, 1987a, 1987b). Thus there is a dissociation between a reduced verbal span and the comprehension of a wide range of types of sentence construction. It is argued that it would be most implausible to attribute CHO's sentence comprehension difficulties to his impaired phonological short-term storage. Thus it appears that CHO's sentence comprehension deficit cannot be attributed to either an impairment of word perception, word comprehension or auditory verbal short term storage. He fails to comprehend even the most simple type of sentence structure including simple active declarative sentences. Yet his spontaneous speech was fluent and he was able to generate complete, syntactically correct sentences, using a full range of parts of speech, a wide set of verbs and a good variety of sentence types. How is this dissociation to be understood?

These observations provide a further challenge to the classical studies that demonstrated an association between agrammatic production and agrammatic comprehension (e.g. Goodglass, 1976; Caramazza and Zurif, 1976; Saffran et al., 1980). His comprehension of sentences was so gravely impaired and his ability to produce propositional speech so intact that an appeal to a resource artefact would be most implausible. Even under conditions without time constraints, as in written sentence comprehension, his performance was very impaired. Rather it is argued that CHO has a primary impairment of supra-lexical processing that cannot be accounted for by a reduced auditory verbal span.

Two patients have been described in whom there was a dissociation between their very impaired auditory verbal span for lists and their relatively good span for sentences. It was these two patients who were able to comprehend a wide range of sentence structures including passive sentences and reversible sentences (See above, McCarthy and Warrington, 1987). This dissociation between span for lists and span for sentences was accounted for in terms of the satisfactory operation of an anticipatory on-line language processor. Specifically, they emphasised the facilitatory role of correct syntax for their superior performance in sentence repetition tasks. For example their ability to repeat a complete sentence was superior to their ability to repeat the shorter but incomplete sentence – the same sentence, but without the high probability terminal noun. Indeed in the incomplete sentence condition the patients frequently displayed the 'anticipatory' properties of the system by failing to suppress a terminal noun. They concluded that the on-line language processors, that include an immediate memory component broadly comparable to a phonological store, mediate list retention.

For the present case, CHO, it is suggested that the operation of an on-line language processor is impaired. His repetition of sentences was as impaired as for lists. He scored very poorly on sentence completion tasks and he showed no tendency for anticipatory responses. It would appear that CHO has a double deficit, damage to systems that mediate retention of sentences in addition to retention of lists. It is the former that is assumed to be integral to an on-line language processor (for review see Tyler, 1992). Whether CHO's difficulty is in achieving a message level representation or whether it is due to a defective syntax parser cannot be differentiated with any confidence on the basis of the limited evidence it was possible to record. He was indeed very impaired in the comprehension of sentences which depended on mapping thematic roles and also on grammatic morphemes. However the observation that his error rate was greater on those items of the TROG which depended entirely on correct syntactical interpretation than on those items with both a lexical and syntactical component may merely reflect task difficulty. His deficits in sentence comprehension were more wide ranging, encompassing sentence types which did not depend on word order or syntax. He had great difficulty with the most basic conversational exchanges. His ability to complete a sentence with a high probability noun and to retrieve a

noun from its verbal description was impaired. These observations perhaps points to there being a profound difficulty in achieving a message level representation.

Many patients with impairments of auditory verbal span for lists also have impairments of sentence comprehension, although as discussed above this is not inevitably the case. Sentences in which word-order is critical or in which there are embedded clauses present particular difficulty. Indeed a causal relationship between the two has been proposed. The variability of sentence comprehension skills in span impaired cases may by the present account be attributed to the severity of additional damage within an on-line language processor.

There is some debate as to the core deficit in agrammatic comprehension. For example impaired thematic role assignment and morphosyntactic mechanisms and even lexical morphology have all been emphasised (for review see Caplan and Hildebrandt, 1988). CHO's performance was so impaired that a detailed comparison of different sentence types was not attempted. Indeed his comprehension of propositional speech appeared to be directly constrained by his word span which was reliable for only 2 items. Whatever the operational properties of the language parser, these processes are independent of those procedures required to generate a sentence frame and instantiate it in a grammatically correct form.

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REFERENCES

- BISHOP, D. *Test for the Reception of Grammar*. Medical Research Council. Chapel Press, England, 1990.
- BREEN, K., and WARRINGTON, E.K. A study of anomia: Evidence for a distinction between nominal and propositional language. *Cortex*, 30: 231-245, 1994.
- BURGESS, P.W., and SHALLICE, T. Response suppression, initiation and strategy use following frontal lobe lesions. *Neuropsychologia*, 34: 263-272, 1996.
- CAPLAN, D., and HILDEBRANDT, N. *Disorders of Syntactic Comprehension*. Cambridge, MA: M.I.T. Press, 1988.
- CAPLAN, D., and WATERS, G.S. Short term memory and language comprehension: A critical review of the neuropsychological literature. In G. Vallar and T. Shallice (Eds.), *Neuropsychological Impairments of Short-Term Memory*. New York: Cambridge University Press, 1990.
- CARAMAZZA, A., and HILLIS, A.E. The disruption of sentence production: Some dissociations. *Brain and Language*, 36: 625-650, 1989.
- CARAMAZZA, A., BERNDT, R.S., BASILI, A., and KOLLER, J. Syntactic processing deficits in aphasia. *Cortex*, 17: 333-348, 1981.
- CARAMAZZA, A., and ZURIF, E.B. Dissociation of algorithmic and heuristic processes in language comprehension: Evidence from aphasia. *Brain and Language*, 3: 572-582, 1976.
- HEILMAN, K.M., and SCHOLLES, R.J. The nature of comprehension errors in Broca's conduction and Wernicke's aphasics. *Cortex*, 12: 258-265, 1976.
- MCCARTHY, R.A., and WARRINGTON, E.K. The double dissociation of short-term memory for lists and sentences: Evidence from aphasia. *Brain*, 110: 1565-1578, 1987.
- MCCARTHY, R.A., and WARRINGTON, E.K. Understanding: A function of short-term memory? *Brain*, 110: 1565-1578, 1987.
- MANNING, L., and WARRINGTON, E.K. Two routes to naming: A case study. *Neuropsychologia*, 34: 809-817, 1996.
- MICELI, G., MAZZUCCHI, A., MENN, L., and GOODGLASS, H. Contrasting cases of Italian agrammatic aphasia without comprehension disorder. *Brain and Language*, 33: 273-295, 1983.
- NESPOULOUS, J.L., DORDAIN, M., PERRON, C., SKA, B., BUB, D., CAPLAN, D., MEHLER, J., and LECOURS, A.R. Agrammatism in sentence production without comprehension deficits: Reduced availability of syntactic structures and or grammatical morphemes? A case study. *Brain and Language*, 33: 273-295, 1988.
- SAFFRAN, E.M. Short term memory impairment and language processing. In A. Caramazza (Ed.), *Cognitive Neuropsychology and Neurolinguistics*. Hillsdale, N.J.: Lawrence Erlbaum, 1990.
- SAFFRAN, E.M., and MARTIN, N. Short term-memory impairment and sentence processing: A case study. In G. Vallar and T. Shallice (Eds.), *Neurological Impairments of Short Term Memory*. New York: Cambridge University Press, 1990.
- SCHWARTZ, M.F., SAFFRAN, E.M., and MARIN, O.S.M. The word order problem in agrammatism. 1. Comprehension. *Brain and Language*, 10: 249-262, 1980.

- TYLER, L.K. *Spoken Sentence Comprehension*. Cambridge, MA: M.I.T Press, 1992.
- WARRINGTON, E.K. The double dissociation of short and long-term memory deficits. In L.S. Cermak (Ed.), *Human Memory and Amnesia*. Hillsdale: N.J. Lawrence Erlbaum, 1982.
- WARRINGTON, E.K. *The Camden Memory Tests, Manual*. Hove, East Sussex: Psychology Press, 1996.
- WARRINGTON, E.K., and JAMES, M. *The Visual Object and Space Perception Battery (VOSP)*. Bury St. Edmunds, England: Thames Valley Test Co., 1991.
- WARRINGTON, E.K., MCKENNA, P., and ORPWOOD, L. Single word comprehension: A concrete and abstract word synonym test. *Neuropsychological Rehabilitation*, 8: 143-154, 1998.
- WATERS, G., CAPLAN, D., and HILDEBRANDT, N. On the structure of verbal short term memory and its functional role in sentence comprehension: Evidence from neuropsychology. *Cognitive Neuropsychology*, 8: 81-126, 1991.

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