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LEVELS OF PROCESSING IN CONDUCTION APHASIA

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Summary. The present work analyzes the hypothesis that repetition deficit in conduction aphasia is caused by an auditory immediate memory defect. Two conduction aphasics were tested on eleven memory trials. The results seem to suggest that conduction aphasia is a consequence of a limitation of information processing rather than a storing capacity limitation. This idea is discussed in the light of Craik and Lockhart's model.

The present work aims at a better understanding of the pathogenetical mechanism underlying the deficits of conduction aphasia, with particular reference to recent research.

Conduction aphasia was theoretically postulated by Wernicke in 1874 and has been confirmed by many subsequent observations. The syndrome generally shows phonemic paraphasias, increasing with word length, impairment of spontaneous writing and writing at dictation, but not of copying; it also shows severe paraphasias in reading aloud (particularly for difficult words) and, most of all, a gross deficit in repetition of both monosyllabic and, even more, longer words (Hecaen, 1972). There is good comprehension and performance in phonemic discrimination, even though written orders are often carried out only with limitation to the first one. Conduction aphasics, conscious of their disease, try to control spoken and written language production assuming a self-critical and self-correcting attitude which does not generally meet their purposes. Their spelling is almost always disturbed. According to Dubois and Hecaen (Dubois, Hecaen, Angelegues, Maufras du Chatelier and Marcie, 1964; Hecaen, 1972) disturbances of this kind of aphasia are essentially due to difficulty in word and syntagma programming, and are different from the typical disturbances of amnesic aphasia, in that the former depend on impairment of word production, rather than on difficulty in word search.

From an anatomical point of view the classical explanatory hypothesis is that the defect is caused by a lesion in the arcuate fasciculus connecting the posterior linguistic areas with the motor speech apparatus (Geschwind, 1965; Benson, Sheramata, Bouchard, Segarra, Price and Geschwind, 1973).

On the other side, from a psychological viewpoint, this disturbance has recently been attributed to an impairment of the storage capacity of the short-term memory, namely of the auditory short-term memory, the long-term memory being unimpaired (Warrington and Shallice, 1969; Shallice and Warrington, 1970; Warrington, Logue and Pratt, 1971). These authors explained the dissociation between short-term and long-term memory by making use of a parallel input model for the memory stores and, at the same time, by assuming that the transfer time from short-term to long-term memory is inversely proportional to the capacity of the former, hence, the smaller is the capacity of short-term memory, the longer is the transfer time to long-term memory. The hypothesis of mnestic etiology for this kind of aphasia has been reviewed in some more recent works. According to Strub and Gardner (1974) the deficit is only linguistic and is due to difficulties in phonemic processing, synthesis and ordering, i.e. in phoneme sequencing. For Beauvois and Lhermitte (1975) repetition deficits in patients with phonemic paraphasias are caused by impairment of the necessary apparatus for short-term evocation, rather than by fragility of phonemic trace: as a matter of fact, phonemes are often present, though in the wrong position. The same authors also observe that the conduction aphasics often use a semantic, rather than a phonemic strategy; this appears to be confirmed by the fact that some patients, unable to repeat a word, however are able to give a correct definition of it; this strategy, since it takes a longer time, is not suitable for a task of short-term memory.

It may also be interesting to note that Beauvois and Lhermitte (1975) as well as Shallice and Warrington (1970), observe a limitation of the recency effect which, according to the latter authors, is just a consequence of a reduced capacity of short-term memory.

Craik and Lockhart (1972) have recently proposed a more flexible model for the memory processes, based on processing depth, or processing level. According to these authors, perception involves a rapid examination of stimuli, carried out at various processing levels or stages; the initial ones dealing with an analysis of physical aspects, the following ones dealing with semantic associative aspects; these analyses result in a memory trace, whose persistence depends on the analysis level. The depth at which the stimulus is processed will be determined by the demands of the tasks, with semantic demands leading to processing at a greater depth than if the subject is just required to repeat back items. We must not confound processing levels with memory stores: they are not two different names for the same concept, but two different entities with different features. For example, the « processing level model » assumes that trace strenght is entirely dependent on the level of processing. Rehearsal may maintain a memory trace but cannot strenghten it; only deeper processing leads to an increase in the trace strenght. Moreover, in discussing their model, Craik and Lockhart (1972) assume that storage capacity is just a direct consequence of a limitation in stimulus processing. According to this, the specific defects proved with patient K.F. (Warrington and Shallice, 1969; 1972; Shallice and Warrington, 1970; 1974) may be due not only to impairment of auditory verbal short store, but also to defective coding at the adequate level of task demand.

Starting from Craik and Lockhart's model, and on the ground of previous observations on other cases of aphasia, our aim was to verify to which extent the auditory memory is implied in such disturbances. For this end a series of tests were made which had to measure: *a*) the learning ability; *b*) the immediate repetition capacity *c*) and the improvement of patients overall performance as a consequence of some specific aids (visual, semantic, ...). The « a » test measured the capacity to memorize a over-span list of words. The « b » tests were devoted to study the gravity of repetition deficit with different kind of material (digits, visual-tactual materials, letters, names). And « c » tests aimed to point out which aids were effective in improving the verbal memory span.

METHOD

Subjects

Our patients have been admitted in two different times to Mental and Nervous Department of the University of Padua. A.M. is a male patient, 62 year old, high school graduate, businessman; one month before, he had become aware that he was unable to articulate speech, even though he could comprehend spoken language, and that it was unable to read and write. He had no motor or sensitive deficits. On admittance to the Clinic the patient is lucid and oriented; his speech is fluent, though occasionally interrupted with paraphasias; his comprehension of speech and writing is normal; it can be observed a marked polymodal anomia; repetition is very poor, and the patient tries to correct himself by making use of a « conduite d'approche ». It can also be observed a marked disgraphy, with regard to both spontaneous writing, to writing at dictation and to copying. The neurological examination and the ordinary laboratory tests are normal; there are no alterations in the field of vision. EEG shows signs of left temporal pain; on the other hand a cerebral scintigraphy does not show any area of abnormal radio-isotope intercaptation. A deep speech examination, carried out by means of an Italian version of the Boston Diagnostic Aphasia Test (Goodglass and Kaplan, 1972) shows that the melodic line, phrase lenght and auditory comprehension are normal; deficits are observed in articulations agility, word search, reading and writing, where numerous paraphasias are present; articulation agility is poor, paraphasias are both literal and verbal; the greatest deficit are in immediate repetition of words and phrases. The patient's score in P.M. is 27/36 and in the Token test 19/36. Praxis is intact. G.V. is a sixty-year old right-handed woman who has attended primary school and worked as a secretary. She suffers from abrupt frontal headache, followed by moderate hindrance of motor apparatus; during the following hours speech difficulties arise, with particular regard to expression; though she has a fluent speech, she cannot make herself well understood, as her speech does not closely follow what she intends to express. On admittance to the Clinic the patient is lucid, space and time oriented; her muscolar form is good, but a slight hindrance is observed in the right hand fine motions. The neurological and usual laboratory examinations are normal; EEG shows signs of left temporal pain; cerebral scintigraphy reveals the existance of areas of hyperactivity in the surface left temporal region, with shaded contours. Left carotidography reveals a steromasic plaque at the origin of carotidic biforcation with normal intercranical picture. A detailed speech examination by means of Boston Diagnostic Aphasia Test, shows good auditory comprehension, fluency and grammatical form. Difficulties in word search and articulation are observed as well as literal and verbal paraphasias, both in spontaneous speech, in writing and reading. Also in the case of this patient, the greatest deficit is in immediate repetition of words and simple phrases. Her score is 27/36 in P.M test and 19/36 in Token test; praxis is intact.

Wholly considered, the clinical picture (good comprehension, fluent speech with paraphasias, impaired immediate repetition) let us to diagnose conduction aphasia in both cases. The neurological picture of both patients is summarized in Table 1.

Memory tests

After the neuropsychological examination was carried out both patients were administered a sequence of memory testing, that, as previously said, may be divided into three categories; *a*) learning test; *b*) immediate repetition tests; *c*) specific aids.

Tab. 1. *Summary of neuropsychological examinations.*

	A.M.	G.V.
Token test	25/36	19/36
Praxis test	Correct	Correct
P.M.	36/36	27/36
Aphasia examination:		
a. spontaneous speech: both patients had normal fluency (phrase lenght 7) with articulation errors and paraphasias:		
b. auditory comprehension	120/127	94/127
c. speech *	195/275	35/275
d. writing comprehension	35/35	32/35
e. writing	68/71	17/71

* The patients' performance was worst in the following subtests: verbal agility, recitation, singing, rithm, word repetition, phrase repetition, word reading, denomination.

a. *Learning test* (Beauvois and Lhermitte, 1975): the patients are presented two lists of eight very familiar words, which are repeated to them until they can reproduce them; no more than 30 presentations are allowed; the score is based on the difference between 30 and the number of presentations needed by the patients; both patients are presented same lists.

b.1 *Verbal digit span*: first, the patient is asked to immediately repeat an increasing number of digits in presentation order; then, he is asked to repeat them in reverse order; the score is given by the number of correctly repeated digits.

b.2 *Corsi's test*: this test is divided in two parts: first, the patient is asked to indicate in the same order a series of small cubes previously touched by the experimenter; then he is asked to touch them in reverse order; also for this tests, score is given by the number of successes.

b.3 *Immediate letter repetition*: the patient is presented a series of letters (vowels and/or consonants) to be immediately repeated; score is given by number of successes.

b.4 *Immediate bisyllable repetition*: the patient is presented a series of high frequency bysillables to be immediately repeated; the test has five increasing difficulty levels according to the number of words (2 to 6) to be repeated. Each level consists of three series havings the same number of words. A level is worked out when one out of the three series is correctly repeated; score corresponds to the number of words in that level.

b.5 *Immediate repetition of words having different lenght*: the patient is asked to repeat familiar words immediately upon presentation; five difficulty levels are given according to the number of syllables (2 to 6) of the presented words; every level is made of three words of the same length, and the score is given by the number of syllables of the words in each level worked out by the patient.

c.1 *Bysillable pairs with different interstimulus interval (ISI)*: the patient is presented pairs of words to be immediately repeated; repetition is successfull whenever both words of the pairs are repeated: three different interstimulus intervals between first and second word are used: 0.5 seconds, 2 seconds, 10 seconds; score is given by the number of repeated pairs in each situation.

c.2 *Immediate repetition of words with visual cue*: again, the patient is presented high frequency bisyllabic words, as well as with a series of pictures (20) which can be indirectly associated with each single presented word (e.g., if the word is « rain », the picture associated may be « umbrella »). Six difficulty levels are given, according to the number of presented words (4 to 9); the score is given by the number of recalled words.

c.3 *Immediate repetition of words with visual indication*: this test is similar to the previous one, but the word-picture association is now pointed out by the experimenter. Also in this case the score is given by the number of recalled words.

c.4 *Immediate repetition of word categories without notice*: four lists are given, each containing nine words; in every list the presented words belong to either of three categories (e.g., flowers, animals, instruments); the patient is asked to recall words immediately upon presentation; score is given by the number of correctly repeated words in every list.

c.5 *Immediate repetition of words with priming*: the only difference from the previous test is that the patient is explicitly informed that the presented words belong to three different categories.

RESULTS

Table 2 contains the results obtained by each patient in each test. At first sight we can see that learning capacity and nonverbal immediate repetition is normal. Learning results (A.M.=24.5; G.V.=22) are in agreement with related results by Warrington,

TAB. 2.

Test A	Learning Test			
	A.M.	1st=25	2nd=24	Average=24.5
	G.V.	1st=19	2nd=25	Average=22.0
Test B.1	Verbal digit span			
	A.M.	direct=4	reverse=3	Total=7
	G.V.	direct=2	reverse=2	Total=4
Test B.2	Corsi's Test			
	A.M.	direct=7	reverse=6	Total=13
	G.V.	direct=5	reverse=4	Total=9
Test B.3	Immediate letter repetition			
	A.M.	score=3		
	G.V.	score=2		
Test B.4	Immediate bysillable repetition			
	A.M.	score=3		
	G.V.	score=2		
Test B.5	Immediate polysyllabic repetition			
	A.M.	score=2		
	G.V.	score=3		
Test C.1	Bysyllabic pairs with different ISI			
	A.M.	0.5 sec.=2/11	2 sec.=4/11	10 sec.=4/11
	G.V.	0.5 sec.=6/11	2 sec.=9/11	10 sec.=9/11
Test C.2	* Immediate repetition with visual cue			
	A.M.	1st-3/4 2nd-3/5 3rd-5/6 4th-5/7 5th-8/8 6th-8/9		
Test C.3	* Immediate repetition with visual indication			
	A.M.	1st-4/4 2nd-4/5 3rd-6/6 4th-7/7 5th-6/8 6th-8/9		
Test C.4	Immediate repetition of words categories without notice			
	A.M.	average=5.25		
	G.V.	average=2.70		
Test C.5	Immediate repetition of words categories with priming			
	A.M.	average=6		
	G.V.	average=4		

* Due to time lacking, we could not test patient G.V.

Logue and Pratt (1971), and by Beauvois and Lhermitte (1975). Moreover, verbal repetition tasks show the classicaldatum reported for this kind of aphasia: repetition is limited to two or three items, although frequent and familiar material has been used. For example, verbal digit span is 7 for A.M. and 5 for G.V., which are both smaller than a corresponding average ($\overline{X}=8.5$) obtained from a group of 178 patients affected by cerebral disease (Pizzamiglio, Piperno and Zoccolotti, 1977). Finally, patient performance can improve when repetition is in some way « aided ».

DISCUSSION

On the whole, these data seem to support the idea that there is a dissociation between a disturbed short-term memory and an intact long-term memory as proposed among many others by Shallice and Warrington (1970). The results obtained in Corsi's test (a spatial immediate repetition test) point out, however, that in this case we are dealing not with a general problem about short-term memory, but rather with a limited problem about linguistic material processing; as a matter of fact, both patients' total performance (A.M.=13; G.V.=9) is much better than their verbal digit span performance (A.M.=7; G.V.=4).

As already noted in the introduction, Shallice and Warrington (1970) have proposed an impairment of the short-term memory as the basis of the above mentioned dissociation; this, in turn, would imply a corresponding increase in the time interval needed for the information transfer into long-term memory. On the other hand, according to Beauvois and Lhermitte (1975), these results may be due to the fact that conduction aphasics use a semantic strategy in order to overcome phonemic processing difficulties; this semantic strategy requires a longer time, and hence causes almost complete failure in repetition tests. Contrary to Strub and Gardner (1974) it does not seem to exist any difference between immediate digit repetition and single letter or bisyllable repetition tests. If we limit ourselves to patient G.V. we have a perfect agreement (score is 2 in such tests), while patient A.M. score is 4 in the first test, and 3 in the second and third ones.

Nonetheless, it may be interesting to note the general agreement between our results in immediate repetition tests, and other authors' results (Warrington, Logue and Pratt, 1971; Strub and Gardner, 1974). This seem to indicate the existence of a common pathogenetic mechanism, even if we do not think that is exactly the one proposed by Shallice and Warrington (Shallice and Warrington, 1970; Warrington, Logue and Pratt, 1971), i.e., impairment of auditory verbal short-term memory. According to those authors, the number of correctly repeated items is independent of the lenght of the words to be repeated by the patient. That is to say that in memory stores the information is organized in terms of « chunks », linked to the meaningfullness of the material. But our immediate repetition test for polysyllables does not seem to support this hypothesis, since both patients are unable to repeat words with more than 3 syllables (A.M.=2; G.V.=3). Further, if one considers that in both bisyllable and polysyllable repetition, high frequency words were used, it is natural to look for alternative explanations. As already noted, according to Craik and Lockhart (1972), in order to better understand the storing capacity of memory, one should think of a processing limitation; according to these authors, the limited storing capacity is a consequence of this more fundamental limitation of information processing. Strub and Gardner (1974)

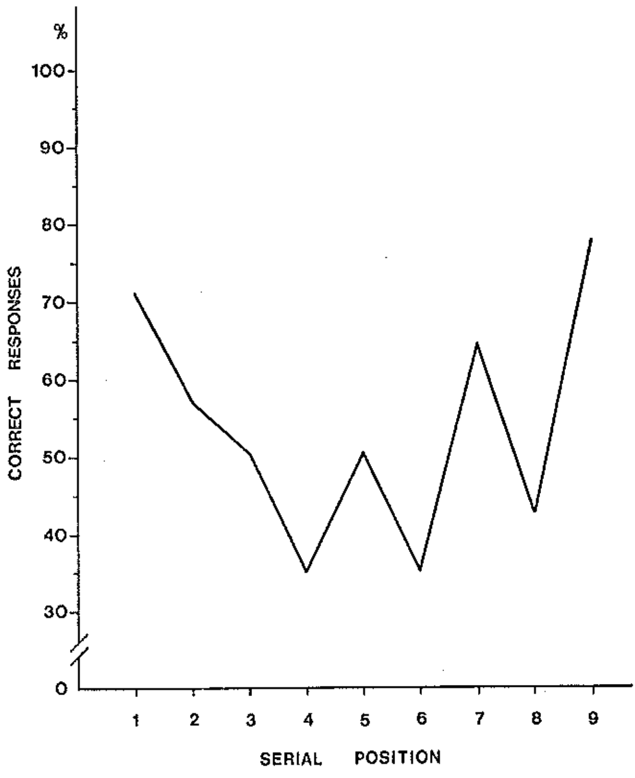

FIG. 1. Percentage recall as a function of serial position.

have already observed an improvement in repetition performance if the ISI is increased; they ascribed this to a longer processing time for each phonological item. Accordingly, in our trials (test C.1) both patients performed much better when passing from time interval 2; their performances, however, do not improve when passing to time interval 10.

Phonemic processing becomes easier if a longer interstimulus interval is allowed; in any case this process is possible if input items are isolated and no interference is introduced between successive items (Luria, 1973; Strub and Gardner, 1974; Hupper and Piercy, 1977). However, in our opinion such improvement in phonemic processing cannot be ascribed to long-term memory transfer, as further increase to 10 seconds does not improve performance; contrary to expectation, if it were a matter of long-term memory. As a further support to the hypothesis of a slowing down of phonemic processing, one can recall that recency and primacy effects are notable in both our patients (see fig. 1) and in many other observed cases (Shallice and Warrington, 1970; Warrington, Logue and Pratt, 1971; Beauvois and Lhermitte, 1975). The fact that primacy effect is limited to the first item and recency effect to the last one, might be due to both items being well distinct units, i.e., items which can be analyzed quite accurately without any interference from successive or preceding ones.

Many authors have frequently observed that repetition performance improves when dealing with familiar materials (Strub and Gardner, 1974; Tsvetkova, 1976). According to the former this is because such materials rouse a large number of associations, which eventually make word articulation easier. The results of our patients in tests C.2, 3, 4 and C.5 seem to further confirm this hypothesis: patient A.M. performs better whenever he can autonomously construct an association between words and pictures, as well as whenever he is pointed out such an association by the experimenter.

Finally, both patients perform better when the words to be repeated can be divided into categories: this means that they succeeded in rising semantic information: in other word, a deeper level of processing (most likely a semantic level) is available for them.

CONCLUSIONS

One cannot apparently refer to these results altogether as an impairment of auditory short-term memory; rather a wider explanatory model is needed, as given, in our opinion, by the recent hypothesis of Craik and Lockhart (1972). The limited capacity which seems to exist also in our patients might be just a consequence of a more fundamental limitation in frequency of phonemic processing. Such limitation, which essentially causes analysis to slow down, but does not break it off, has to do with phonemic items being analyzed at a lower level than for normal people. Because of the correspondence between analysis level and persistence of memory trace, there should follow, in limited time conditions, repetition difficulty. This difficulty seems to be partially overcome when the patient is given longer time for processing, as well as whenever items to be memorized can be inserted into a pre-existing cognitive set-up, which allows items to be analyzed at a deeper level in a shorter time and, hence, gives rise to much more persistent traces. Altogether, these data may have application not only for the understanding of pathogenetical mechanisms of conduction aphasia, but also for rehabilitating therapies.

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