ISCA Archive
http://www.isca-speech.org/archive

3rd International Conference on
Spoken Language Processing (ICSLP 94)
Yokohama, Japan
September 18-22, 1994

DISSOCIATIONS IN WORD DEAFNESS

Sue Franklin, Julie Morris & Judy Turner

Department of Psychology, University of York,
Heslington, York YO1 5DD, United Kingdom.

ABSTRACT

Four dysphasic patients were investigated who all had impairments in auditory word comprehension. Testing on auditory processing, phoneme discrimination and lexical tests suggested that each patient had a different pattern of deficit. JS was impaired at all auditory, non-speech tests as well as tests which required the processing of auditory speech sounds. TON's deficit was confined to speech sounds, but interpretation of this deficit was complicated by the fact that he had a mild hearing loss. MW was only impaired in the test that required semantic processing, and could thus be considered a word meaning deaf patient. DrO's comprehension deficit was similar to that of MW except for a specific problem in tasks requiring phonological processing.

This research was supported by the Medical Research Council. We are also grateful to the British Aphasiology Society for their support.

I. INTRODUCTION.

"Word sound deafness" or "pure word deafness" [1] is a specific deficit in understanding spoken words at the level of "auditory analysis", a level of processing which is rather poorly specified in most cognitive neuropsychological models of language [2]. It has been distinguished from post-lexical comprehension deficits in which repetition or writing to dictation are intact [3]. The exact deficit underlying word sound deafness is a matter of some controversy; Buchman et al [4], in a review of cases claimed that patients always had accompanying auditory deficits. Although many case histories exist, it is unfortunate that there has been no consistency of testing across patients. Saffran et al [5], on the basis of dichotic listening experiments, suggested their patient had a speech perception deficit at a "pre-phonetic level" Caramazza et al [6] described a patient who was better at natural than synthetic speech discrimination, and interpreted this as being a phonetic problem. Albert and Bear [7] suggested that word sound deafness is a problem in auditory temporal processing.

In this paper we describe four patients, all with impaired comprehension of words presented auditorily, and compare their performance on a series of non-speech, phoneme discrimination and lexical tests.

II SUBJECTS.

Four aphasic subjects were included in this study; their ages and occupation prior to retirement are shown in Table 1. All patients had had a single CVA between 1 and 2 years prior to testing. None of the patients had any history of any other neurological insult. The results of audiometric testing, carried out in the patients' homes, is also given in Table 1. An average was taken of the hearing threshold for the speech frequencies. Only one of the patients, TON, has any degree of hearing loss (33 dB).

Patient	Age	Previous occupation	Best ear hearing
JS	74	Tailor	20 dB
TON	66	Teacher	33 dB
DrO	63	Lecturer	5 dB
MW	65	Housewife	13 dB

Table 1. Age, occupation and average threshold for better ear on pure tone audiometry.

All the assessments were administered to 20 normal controls who were aged between 65 and 85 and had normal hearing.

The patients were selected on the basis of making errors on an auditory word comprehension test. In this "Synonym Judgments Test" the patient heard two words and had to judge whether they have the same meaning or not (eg "germ - bacteria", "jacket - city"). The results can be seen in Table 2. All patients perform considerably outside the range of the normal controls.

JS	100	TON	106
DrO	130	MW	92
N=160	Normal range 146-159.		

Table 2. Auditory synonym judgments.

III INVESTIGATION.

Three types of assessment were devised; a series on non-speech tests, which will be referred to as the "early auditory tests", minimal pair discrimination tests, and finally an auditory lexical decision test.

The patients varied considerably in the degree to which they had any speech output, but all could

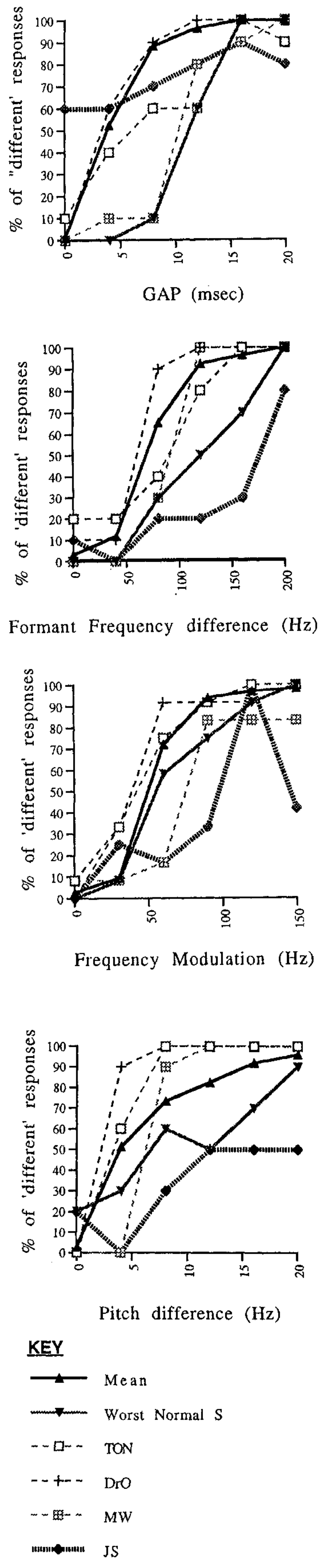

Figure 1 . Early auditory tests

respond "yes" or "no" reliably either by speech, pointing or gesture. All tests were therefore designed to have a "yes" - "no" or "same" - "different" response format. Speech items were digitized and output to DAT tapes, at a controlled level and rate, from a computer. Non-speech items were produced from computer-generated wave forms. The use of tape recorded stimuli enabled the experimenter to maintain a constant stimulus quality and prevented the use of lip reading by the patients.

It was anticipated that patients with word sound deafness would either be impaired at all tests, or only at tests involving the processing of speech Patients with a post-lexical "word meaning deafness" should not be impaired at any of the three types of task.

Early auditory tests.

Four tests were devised to assess aspects of early auditory processing important for speech recognition .

Gap detection was selected as a measure of sensitivity to temporal change of an acoustic signal over time. The stimuli used were two bursts of white noise, which were either identical or one of the pair contained a gap of between 4 and 20 msec. If the subject could detect the gap, they would correctly label the two bursts as different. This type of detection paradigm was used in the other three tests. Formant frequency detection was selected since formant frequency assists in the identification of vowels and stop consonants. Two tests were used. The first was to test sensitivity to whether the absolute formant frequency of two sounds were identical. The other test looked at the ability to detect rapid changes of formant frequency (varying the depth of modulation) while the overall formant remains constant. The final test, pitch detection, used pairs of same/different items of fundamental frequencies ranging from 125 Hz to 145 Hz.

Figure 1. contains the results for all four tasks. Each graph shows the mean performance for the control subjects and the performance of the worst normal, as well as performance by the four patients. The results are expressed as the number of times the pairs of stimuli were judged different. It can be seen that in every case, three of the patients, TON, DrO and MW performed within the normal range (confirmed by probit analysis) . JS on the other hand performed very poorly on all tasks. In gap test he judged 6/10 identical items to be different. In the formant frequency test he judged the majority of items as the same except in the case of the largest difference (200 Hz). The frequency modulation test showed a bizarre pattern of response. Pitch detection was never better than chance.

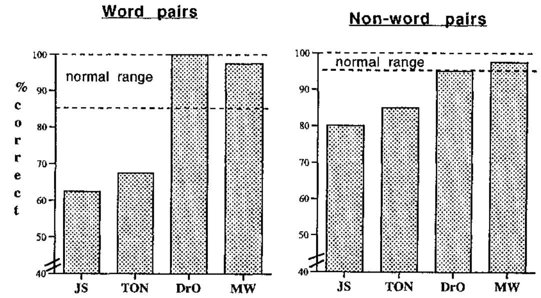

Figure 2. Minimal pair discrimination tests.

There is a clear dissociation of performance; three patients perform within normal range, while JS is severely impaired. It is unlikely that this pattern would be obtained by chance, since the same pattern is found in *all four tests*.

Minimal pair discrimination tests.

To test the patients ability to detect phonemes, two minimal pair tests were devised. Both tests comprised 40 CVC pairs. For the different pairs, either the initial or final consonant differed by one or two distinctive features. One test comprised real words, the other novel strings.

The results are shown in Figure 2. The control subjects' range of performance is expressed by the upper and lower dotted lines. It can be seen that, as with the early auditory tests, JS is outside the normal range for the word test, but this is also the case for TON. DrO and MW are both within the normal range. These results are replicated exactly by the non-word version of the test.

Different voice minimal pair discrimination tests.

A problem with the minimal pair tests described above, is that the test could be done successfully purely on the basis of acoustic identity; it does not necessarily require speech processing. In order to make the task more challenging, a new version of both the word and non-word tests were constructed, where for each pair of CVC strings one CVC was produced by a female voice, and one by a male voice. It was anticipated that JS and TON would not be able to do such a test since they cannot do the identity version (this was born out by their performance on a pilot version of the different voice versions of the tests) but how would DrO and MW respond?

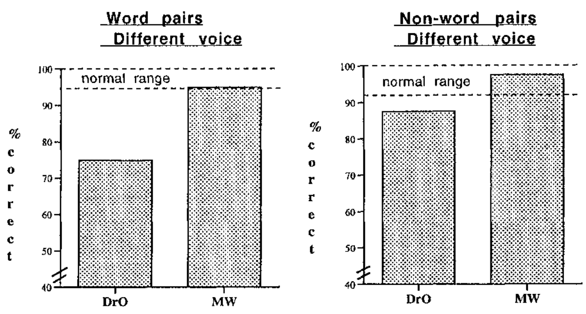

Figure 3. different voice minimal pair tests.

Figure 3 shows the results for DrO and MW, together with the normal range. For the word test, MW continues to perform within the normal range, but DrO is impaired at this task. This pattern is replicated in the non-word test.

Lexical decision test.

All patients were given an auditory lexical decision test, where the words varied in terms of frequency, imageability and phoneme length. The non-word items were constructed by changing a single phoneme in each of the real words. The test was also given in a written form, for the purposes of comparison.

It was predicted that JS and TON would be impaired at this test, given their impairments in processing speech, and that MW would not be impaired. Would DrO have difficulty with this task? If he had a mild word sound deafness, then he would have difficulty with lexical decision; if the different voice tests are difficult because they require some ability not necessary for on-line speech access, then he will perform normally on this test.

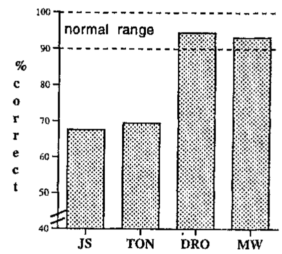

Figure 4. Auditory lexical decision.

The results can be seen in Figure 4. As before the control subjects' range of performance is expressed by the upper and lower dotted lines. As predicted both JS and TON are impaired. Since, for both patients, their performance on the written version of the test is significantly better than the spoken (McNemar Test, $p<.001$ in both cases), it cannot be the case that JS and TON fail to understand the task or are unfamiliar with the words used. MW and DrO perform within normal limits on both versions of the test; DrO's poor performance on non-identical phoneme tests is not reflected in a test of lexical access.

TON and DrO: further testing.

Despite performing well on the early auditory tests, TON is impaired in phoneme discrimination tests. Does this mean he is, like JS, a word sound deaf patient, but in his case it is a more speech specific deficit? It was noted earlier that TON does have a mild hearing loss (33dB); could his poor performance on minimal pair tests be simply due to this hearing problem? Nine subjects, with no history of neurological impairment, but with a mean hearing loss in the better ear of 30-50 dB were given the minimal pair tests and the auditory lexical decision test.

Test	H.I. Range	TON
Minimal pairs		
Same voice		
Non-words	100 - 93	85
Words	100 - 85	68
Different voice		
Words	100 - 88	73
Lexical decison	96 - 76	70

Table 3. Percentage correct on minimal pair and lexical decision tests; comparing TON with 9 hearing impaired subjects.

Table 3 gives a comparison of TON's performance with the maximum and minimum scores obtained from these hearing impaired subjects. In every case, TON is outside the normal range for the hearing impaired controls. It is unlikely his poor performance on these tests is solely due to his hearing impairment.

Dr O, from his good performance on same voice minimal pair tests and auditory lexical decision appears not to be word sound deaf. However he is impaired at phoneme tests which cannot be carried out on the basis of acoustic identity. In order to confirm that he was not word sound deaf, Dr O was given a repetition test. To confirm he did have some impairment of phonology, this repetition test contrasted repetition of words and non-words. Good word repetition would rule out a diagnosis of word sound deafness; a dissociation between word and non-word repetition is suggestive of DrO having some sort of sub-lexical deficit, which is not implicated in lexical access. Dr O was given 60 words to repeat (20 each of 3-4, 5-6 and 7-8 phonemes), 60 non-words of similar lengths which were constructed by changing real words by one phoneme, and 40 non-words which had no phonological neighbours ("invented" NW).

Examples of words and non-words:

Words	eg hospital
Wordlike NW	eg /pɨdʒəmɨd/
"Invented" NW	eg /θɨpətek/

Number correct:

	3-4 phon.	5-6 phon.	7-8 phon.
Words	19/20	16/20	13/20
Wdlike NW	4/20	1/20	2/20
Invented NW	-----	0/20	0/20

Table 4. DrO: repetition of words and non-words (NW).

The results can be seen in Table 4. Although not perfect, DrO's ability to repeat words is impressive, and there is a strong dissociation between his ability to repeat words and non-words, the latter being severely impaired. This is consistent with the notion that DrO does not have a deficit in lexical access but rather an additional deficit in sub-lexical phonology.

IV DISCUSSION.

The four patients described here all performed similarly on a test of semantic word comprehension. Two of the patients, JS and TON appear to have pre-lexical deficits in comprehension, and therefore may be described as word sound deaf. JS has clearly got an auditory processing deficit which is not speech-specific; neither is it confined to an impairment of temporal processing. TON is possibly a word sound deaf patient with a more speech-specific deficit. His slightly impaired hearing does not seem to account for his poor performance on the phonological tests, but is is possible that poor hearing could be interacting with some kind of post-lexical deficit; it requires testing of other patients to resolve this issue. The other two patients, MW and DrO appear to have post-lexical deficits and may be described as word meaning deaf patients. It should be noted that their impairments cannot simply be considered to be qualitatively the same but milder than JS or TON; MW was as impaired as they were in the synonym judgments test.

DrO, is clearly not word sound deaf in that he is able to repeat most words and can make lexical decisions on words. However his response to the different voice minimal pair tests suggests he has some kind of specific phonological problem. One might tentatively relate this to his severe impairment in non-word repetition. It is consistent with the data presented here that there are three types of pre-lexical deficit; an auditory deficit, a speech speech specific deficit, and a phonological deficit which is not directly implicated in on-line lexical access.

REFERENCES.

[1] Okada, S., Hanada, M., Hattori, M., and Shoyama, T. "A case of pure word-deafness." Studia Phonlogica, III, 1963

[2] Patterson, K.E. and Shewell, C. "Speak and spell: Dissociations and word-class effects." In M. Coltheart, R. Job and G. Sartori (Eds) The cognitive neuropsychology of language Hillsdale N.J.: Erlbaum. 1987.

[3] Kohn, S., and Friedman, R. "Word-meaning deafness: a phonological-semantic dissociation." Cognitive Neuropsychology 3, 291-308. 1986.

[4] Buchman, A.S., Garron, D.C., Trost-Cardamone, J.E., Wichter, M.D. and Schwartz, M. "Word deafness; one hundred years later." Journal of Neurology, Neurosurgery and Psychiatry, 49, 489-499. 1986.

[5] Saffran, E.M., Marin, O.S.M. and Yeni-Komshian, G.H. "An analysis of speech perception in word deafness". Brain and Language, 3, 209-228. 1976.

[6] Caramazza, A., Berndt, R.S. and Basili, A.G. "The selective impairment of phonological processing". Brain and Language, 18, 128-174. 1983.

[7] Albert, M.L. & Bear, D. "Time to understand: A case study of word deafness with reference to the role of time in auditory comprehension". Brain, 97, 373-384. 1974.