A case study of a spoken word recognition deficit

C. Jacquemot and E. Dupoux and C. Pallier
Laboratoire de Sciences Cognitives et Psycholinguistique, EHESS-CNRS. Paris, France

A.-C. Bachoud-Lévi
Unité de Neuropsychologie. Service de Neurologie. CHU Henri Mondor, APHP. Créteil, France and INSERM U-421-IM3. Faculté de Médecine Paris XII. Créteil, France

Introduction

Several models posit that two levels are involved in spoken word recognition: the sub-lexical level and the lexical level (Marslen-Wilson, 1984; McClelland and Elman 1986; Mehler et al. 1990; Norris 1994). The sub-lexical level is responsible for the transformation of the continuous acoustic signal into phonological entities (phonemes, syllables or features). The lexical level consists in the selection of the lexical form of the word and the retrieval of the semantic information associated with the selected entry. In neuropsychological studies several cases of patients with a lexical impairment without sub-lexical deficit have been documented (Blumstein et al. 1977a; Kohn and Friedman 1986; Franklin et al. 1996). Such patients have no problems with phonemic identification or discrimination tasks, but are impaired in word recognition. Interestingly, the reverse pattern of sub-lexical impairment without major comprehension deficits has rarely been reported (see one exception in Blumstein et al. 1977b). This is in fact expected in models where the sub-lexical and lexical levels are sequentially organized. Indeed, any deficit at the sub-lexical level should mandatorily translate into corresponding problems in lexical identification.

In this paper, we describe a patient who presents a strong dissociation between performance on sub-lexical and lexical tasks in the unexpected direction. While he was extremely poor in a sub-lexical discrimination task, he was only mildly impaired in lexical tasks. The patient had a global aphasia resulting from a left parieto-temporal ischemia. Tested with the French version of the Boston Diagnostic Aphasia Examination, he showed impairments in oral comprehension, and very strong deficits in naming and repetition. Here, we focus on his speech comprehension deficit and in particular on the relatively spared lexical processing level compared to the drastic impairment of the sub-lexical level.

This work was supported by a Cognitique PhD scholarship awarded to C. Jacquemot, a Contrat PRA awarded to A.C. Bachoud-Levi, a BioMed grant N° PSS*1046, a grant from the Groupement d'Intérêt Scientifique Sciences de la Cognition (99N35/0008), a grant from the ACI Cognitique, as well as support from an ACI Blanche awarded to Christophe Pallier

Severely impaired sub-lexical processing

Preliminary testing revealed that the patient had strong difficulties in identifying and discriminating speech segments. For instance, the examiner orally produced a vowel and the patient was asked to point to the corresponding written sound among a choice of six alternatives. The patient scored only 52% correct responses. Of course, vowel identification involves metalinguistic knowledge, and we tested sub-lexical processing in a discrimination task that does not explicitly refer to segments.

AX minimal pair discrimination

Thirty minimal pairs of words and 30 pairs of nonwords were constructed with a C1VC2VC3 structure (C for consonant and V for vowel). Each pair of auditory stimuli contained two items that differed by a single consonant (C1, C2 or C3) and were spoken in a male or female voice. Pairs of stimuli were presented over headphones and the patient had to indicate whether or not the second stimulus was identical to the first. Stimuli were either spoken by the same speaker or there was a change in speaker; the two types of trials were randomly mixed (N=60 for each type of trial).

We found that the subject was at chance (same talker: 53% correct, $\chi^2(1)$=.03, $p > .1$; talker change: 52% correct, $\chi^2(1)$=0.0, $p > .1$). There was no significant effect of lexical status, word and nonword condition did not differ from chance level (words: 55% correct, $\chi^2(1)$=.13, $p > .1$; nonwords: 50% correct, $\chi^2(1)$=0, $p > .1$), and no effect of consonant position ($p > .1$).

Partially spared lexical processing

The patient was severely impaired in his ability to discriminate minimal pairs. This ought to predict a large impairment in lexical processing. We tested this prediction in a lexical decision experiment.

Lexical decision

Words (N=64) and nonwords (N=32) differing by only one phoneme from words, were selected. Words were taken from two categories (concrete N=48 and abstract, N=16) and were matched for frequency (half of the words were low frequency and half, high frequency). The patient had to listen to the auditory stimuli over headphones and to decide whether it was a word or a nonword.

The patient was impaired in this task (68% correct) but results were significantly above the chance level ($\chi^2(1)$=7.8, $p < .01$). Results for high frequency words were significantly better than for low frequency words (70.3% correct versus 53.1% correct respectively; F(1,60)=4.4; $p < .05$). A concreteness effect was also found, showing an advantage for concrete words1 (69.8% correct for concrete words and 37.5% correct for abstract words; F(1,60)=11.6 $p < .001$).

The patient's results suggest a non-homogeneous impairment at the lexical level, with a more severe deficit for lower frequency and more abstract words. Yet, the patient performed better overall in the auditory lexical decision than in the phonemic discrimination task, and especially for the spared part of the lexicon (81.3% correct for high frequency concrete words). How could such a good performance be obtained? One possibility is that the patient succeeded in guessing what the input word was even with a very imprecise or vague phonological input pattern.

Well preserved phonological details in the spared part of the lexicon

We tested the precision of the phonological representation in the input lexicon using two tasks (auditory word-written word matching, and auditory word-picture matching) where we directly compared the performance on a target word to a control one-phoneme different item (word or nonword). In the two experiments we only analyzed a subset of the data containing high frequency concrete words, as suggested by the lexical decision experiment.

Auditory-written word matching

In the auditory word-written word matching task, the patient had to listen to a word presented over headphones and to select the corresponding one among a choice of three written items. The three written items were the target and two distracters (a word and a nonword). The two distracters were phonologically related to the auditory item and differed by one phoneme from the target. The patient performed 90.1% correct (N=44), which is significantly above chance level ($\chi^2(1)$=38.1, $p < 10^{-5}$).

Auditory word-picture matching

In the auditory word-picture matching task, the patient was presented a picture and an auditory stimulus, and had to decide whether they matched. The auditory stimulus could be the correct name of the picture or a phonological distracter (word or nonword) that differed by only one phoneme from the correct name. The patient performed quite well in this task (89.8% correct, N=48, $\chi^2(1) = 97$, $p < 10^{-5}$). The patient performed better with the two matching tasks than expected from the phonemic judgment task. If only a vague phonologic representation of the word was available at the lexical level, we would predict difficulties in selecting the target word and confusions with the phonological distracters. The accurate results suggest that a rather detailed phonological word form has been used.

Discussion

The behavior of our patient is paradoxical when it comes to sub-lexical processing. On the one hand, he seems to be totally incapable of discriminating a minimal pair contrast in a standard AX task. On the other hand, when tested with a subset of the lexicon (high frequency concrete nouns), he seems to have a well preserved, if not intact, ability to sustain minimal pair distinctions. We discuss two possible accounts.

The first account challenges the claim that sub-lexical processing is necessary for lexical access. According to direct access models and exemplar models, words are stored directly as acoustic patterns, without the need for any preliminary phonological processing (see Klatt 1979; Pisoni 1996). In such models, the patient could be impaired in phonological processing, while the direct route between the acoustic and lexical levels would allow intact word recognition (at least, insofar as the lexicon itself is unimpaired). Provided one believes in the independent plausibility of such direct access models, there still is one difficulty to account for: Our patient was impaired in the AX discrimination task to an equal extent whether there was a change in talker or not. Importantly, in the same talker condition, exactly the same acoustic token was presented when the two stimuli were identical. In other words, the AX task could have been performed at the acoustic level. Does the chance performance in this condition mean that the patient also has an impaired acoustic level?

The second approach, which we favor, proposes that the patient has no deficit in sub-lexical processing, but rather, a general deficit in reading out the information encoded at the acoustic and sub-lexical levels. A same-different AX task requires the patient's ability to consciously compare two representations and decide whether they are identical or not. We propose that the patient has impaired conscious access to the phonological details of speech input, while retaining the ability to process them for the purpose of lexical access. One could frame this proposal within the Shortlist model (Norris 1994), whereby the phonological representation used for performing detection and judgment tasks is separate from the one used for bottom-up word recognition. Under such an analysis, our patient could be compared to the cases of blindsight patients, who have access to some high level properties of the stimuli without being aware of low level ones (Farah 1994).

References

Blumstein, S. E., E. Baker, et al. (1977a). Phonologicalfactors in auditory comprehension in aphasia. *Neuropsychologia* 15: 19–30.

Blumstein, S. E., W. E. Cooper, et al. (1977b). The perception and production of voice-onset time in aphasia. *Neuropsychologia* 15: 371–383.

Farah, M. J. (1994). Perception and awareness after brain damage. *Current Opinion in Neurobiology* 4(2): 252–5.

Franklin, S., J. Turner, et al. (1996). A distinctive case of word meaning deafness. *Cognitive Neuropsychology* 13(8): 1139–1162.

Klatt, D. H. (1979). Speech perception: a model of acoustic-phonetic analysis and lexical access. *Journal of Phonetics* 7: 279–312.

Kohn, S. E. and R. B. Friedman (1986). Word-meaning deafness: A phonological-semantic dissociation. *Cognitive Neuropsychology* 3(3): 291–308.

Marslen-Wilson, W. (1993). Issues of Process and Representation in Lexical Access. *Cognitive models of speech processing: The second Sperlonga meeting*. G. T. M. Altmann and R. Shillcock. Hove East Sussex UK, LEA: 187–210.

McClelland, J. L. and J. L. Elman (1986). The TRACE model of speech perception. *Cognitive Psychology* 18: 1–86.

Mehler, J., E. Dupoux, et al. (1990). Constraining Models of Lexical Access: The onset of word recognition. *Cognitive models of speech processing: psycholinguistic and computational perspectives* G. T. M. Altmann. Cambridge Mass, MIT Press: 236–262.

Norris, D. G. (1994). Shortlist: a connectionist model of continuous speech recognition. *Cognition* 52: 189–234.

Pisoni, D. B. (1996). Some thoughts on “Normalization” in Speech Perception. *Talker Variability in Speech Processing*. K. Johnson and J. W. Mullenix. San Diego, Academic Press.