ABSTRACT

COMPREHENDING SPOKEN WORDS WITHOUT HEARING PHONEMES: A CASE STUDY

Charlotte Jacquemot[1], Emmanuel Dupoux[1], Christophe Pallier[4] and Anne-Catherine Bachoud-Lévi[1,2,3]

([1]Laboratoire de Sciences Cognitives et Psycholinguistique, EHESS-CNRS. Paris, France; [2]Unité de Neuropsychologie, Service de Neurologie. CHU Henri Mondor, AP/HP, Créteil, France; [3]INSERM U-421-IM3. Faculté de Médecine Paris XII, Créteil, France; [4]INSERM U562, Service Hospitalien Frédéric Joliot, CEA/DSV/DRM; IFR49, Orsay, France)

Introduction

Several models posit that two levels are involved in spoken word comprehension: the sublexical level and the lexical level (Marslen-Wilson, 1984; McClelland and Elman 1986; Mehler et al., 1990; Norris, 1994). The sublexical 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.

Several cases of patients with a lexical impairment without sublexical deficit have been documented (Blumstein et al., 1977a; Kohn and Friedman, 1986; Franklin et al., 1996). Such patients have no problem with phonemic identification or discrimination tasks, but are impaired in word recognition. Interestingly, the reverse pattern of sublexical impairment without major comprehension deficits has rarely been reported (see one exception in Blumstein et al., 1977b). This is expected in models where the sublexical and lexical levels are sequentially organized. Indeed, any deficit at the sublexical 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 sublexical and lexical tasks in the unexpected direction. While he was extremely poor in a sublexical 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 Boston Diagnostic Aphasia Examination, he showed impairment in oral comprehension, and strong deficits in naming and repetition. Here, we focus on his speech comprehension deficit and in particular on the relatively spared lexical level compared to the drastic impairment of the sublexical level.

Severely Impaired Sub-Lexical Processing

Preliminary testing revealed that the patient had strong difficulties in identifying phonemes. Of course, phoneme identification involves metalinguistic knowledge, and we tested sublexical processing in a discrimination task.

Cortex, (2002) 38, 869-873

AX Discrimination Task

Sixty pairs of words and sixty pairs of nonwords were constructed with a $C_1VC_2VC_3$ structure (C for consonant and V for vowel) differing or not by a single consonant (C_1, C_2 or C_3). Pairs were presented over headphones and the patient had to indicate whether or not the two stimuli were identical. Pairs were either spoken by the same speaker or by two speakers.

We found that the subject was at chance (one speaker: 53% correct, χ^2 (1) = .03, p > .1; two speakers: 52% correct, χ^2 (1) = 0, p > .1). There was no significant effect of lexical status: word and nonword conditions did not differ from chance (words: 55% correct, χ^2 (1) = .13, p > .1; nonwords: 50% correct, χ^2 (1) = 0, p > .1).

Partially Spared Lexical Processing

The patient was severely impaired in the phonemic discrimination task. This ought to predict a large impairment in lexical processing. We tested this prediction in a lexical decision task.

Lexical decision

Words (N = 64) and nonwords (N = 32) differing by only one phoneme from words, were selected. Words belonged to two categories (concrete N = 48 and abstract N = 16) each matched for frequency (Content et al., 1990). Stimuli were presented over headphones and the patient had to indicate whether was a word or a nonword.

The patient was impaired in this task but results were significantly above chance level (68% correct; χ^2 (1) = 7.81, p = .005). Results for high frequency words were significantly better than for low frequency words (70.3% correct versus 53.1% respectively; F (1, 60) = 4.4; p = .041). A concreteness effect was also found, showing an advantage for concrete words[1] (69.8% correct for concrete words, 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 low frequency and abstract words. Yet, the patient performed better in the auditory lexical decision than in the phonemic discrimination task, 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 phonological input pattern.

---

[1] We found a finer grained dissociation within concrete items, with a superiority of living over non-living items. The details of the semantic aspect are described in Dupoux, Jacquemot and Bachoud-Lévi (in preparation).

Well-preserved Phonological Details in the Spared Part of the Lexicon

We tested the precision of the phonological representation using two tasks: auditory word-written word matching and auditory word-picture matching. In both 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 listened to a word and had to select the corresponding one among a choice of three written items. There were the target and two distractors – a word and a nonword – phonologically related to the auditory item and differing by one phoneme from the target. The patient performed 90.1% correct (N = 44), which is significantly above chance level[2] (χ^2 (1) = 27.9, $p < 10^{-5}$).

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 distractor (word or nonword) that differed by one phoneme from the correct name. The patient performed quite well in this task[3] (89.8% correct, N = 48, χ^2 (1) = 97, $p < 10^{-5}$).

The patient performed better with the two matching tasks than expected from the phonemic discrimination results. If only a vague phonological pattern of the word was available at the lexical level, we would predict difficulties in selecting the target word and confusions with the phonological distractors. The accurate results suggest that a detailed phonological representation was available.

Discussion

The behavior of our patient is paradoxical. On the one hand, he seems to be incapable of discriminating phonemes 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 nearly intact ability to use phonological representations (Figure 1). We discuss two possible accounts.

---

[2] When tested with a dictation and a reading aloud tasks, the patient was severely impaired. This suggests that grapheme-to-phoneme and phoneme-to-grapheme routes are severed and cannot explain the accurate performance of the subject in the auditory-written word matching task. We also checked that written word recognition was intact with a written version of the matching task. The patient had to select among three written words (the target item plus a phonological and a semantic distractors) the one matching with a test picture. His performance was flawless. This suggests that the patient had no problem to comprehend written words (nor to recognize pictures).

[3] When tested in picture naming the performance was very poor, suggesting that the relatively good performance in auditory word-picture matching task was not due to covert picture naming and internal word monitoring.

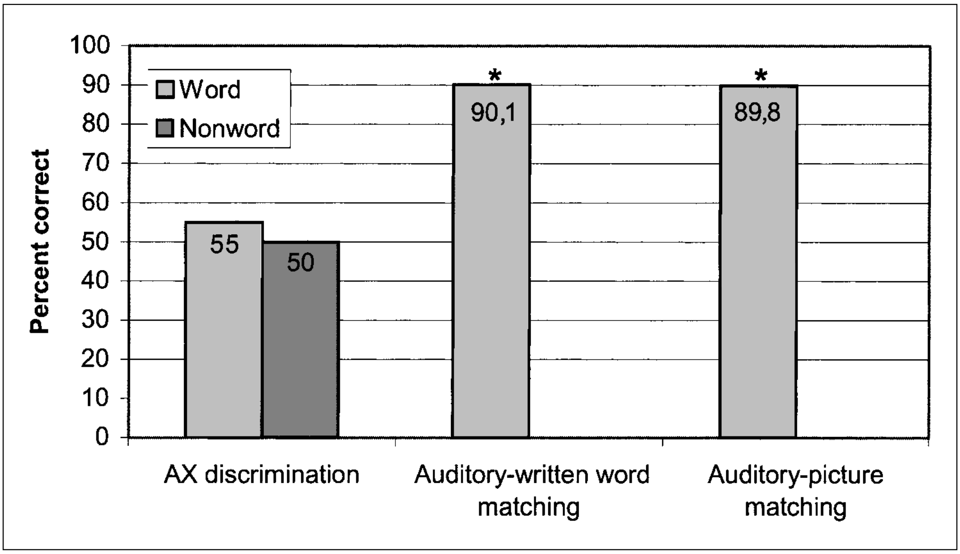

Fig. 1 – *Summary of performance of the patient on the AX discrimination, auditory-written word matching and auditory-picture matching tasks.* * $p < 10^{-5}$ *compared to chance level*

The first account challenges the claim that sublexical processing is necessary for lexical access. According to direct access and exemplar models, words are recognised 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 comprehension (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 speaker or not. Importantly, in the same speaker 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 sublexical processing, but rather, a deficit in reading out the information encoded at the acoustic and sublexical levels. A same-different AX task requires the patient 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 lexical access. One could frame this proposal within the Merge model (Norris et al., 2000), 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).

Acknowledgements. This work was supported by a Cognitique PhD scholarship awarded to C. Jacquemot, a Contrat PRA (AP/HP-CNRS) 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.

References

Blumstein SE, Baker E and Goodglass H. Phonological factors in auditory comprehension in aphasia. *Neuropsychologia, 15:* 19-30, 1977a.

Blumstein SE, Cooper WE, Zurif EB and Caramazza A. The perception and production of voice-onset time in aphasia. *Neuropsychologia, 15:* 371-383, 1977b.

Content A, Mousty P and Radeau M. Brulex: Une base de données lexicales informatisées pour le français écrit et parlé. *L'Année Psychologique, 90:* 551-566, 1990.

Farah MJ. Perception and awareness after brain damage. *Current Opinion in Neurobiolology, 4:* 252-255, 1994.

Franklin S, Turner JM, Lambon Ralph A, Morris J and Bailey PJ. A distinctive case of word meaning deafness. *Cognitive Neuropsychology, 13:* 1139-1162, 1996.

Klatt DH. Speech perception: A model of acoustic-phonetic analysis and lexical access. *Journal of Phonetics, 7:* 279-312, 1979.

Kohn SE and Friedman RB. Word-meaning deafness: A phonological-semantic dissociation. *Cognitive Neuropsychology, 3:* 291-308, 1986.

Marslen-Wilson W. *Issues of Process and Representation in Lexical Access. Cognitive models of speech processing: The second Sperlonga meeting*. GTM Altmann and R Shillcock. Hove East Sussex UK, LEA: 187-210, 1984.

McClelland JL and Elman JL. The TRACE model of speech perception. *Cognitive Psychology, 18:* 1-86, 1986.

Mehler J, Dupoux E and Segui J. *Constraining Models of Lexical Access: The onset of word recognition. Cognitive models of speech processing: psycholinguistic and computational perspectives*. GTM Altmann. Cambridge Mass, MIT Press: 236-262, 1990.

Norris DG. Shortlist: A connectionist model of continuous speech recognition. *Cognition, 52:* 189-234, 1994.

Norris D, McQueen JM and Cutler A. Merging information in speech recognition: Feedback is never necessary. *Behavioral and Brain Sciences, 23:* 299-325, 2000.

Pisoni DB. *Some thoughts on "Normalization" in Speech Perception. Talker Variability in Speech Processing*. K Johnson and JW Mullenix. San Diego, Academic Press, 1996.

Charlotte Jacquemot, LSCP – EHESS, 54, Boulevard Raspail, 75006 Paris, France. e-mail: jacquemot@lscp.ehess.fr.