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Comprehending spoken words without hearing phonemes: A case study

Abbreviated form of the title: **Comprehension without discrimination**

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Introduction

Several models posit that two levels are involved in spoken word comprehension: 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.

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 problem 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 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 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 sub-lexical 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 sub-lexical processing in a discrimination task.

AX discrimination task

Sixty pairs of words and 60 pairs of nonwords were constructed with a C₁VC₂VC₃ structure (C for consonant and V for vowel) differing or not by a single consonant (C₁, C₂ or C₃). 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, $\chi^2(1)=.03$, $P>.1$; two speakers: 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, $\chi^2(1)=0$, $P>.1$).

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 belong to two categories (concrete N=48 and abstract N=16) and were matched for frequency (Content et al., 1990). Stimuli were presented over headphones and the patient had to indicate whether it was a word or a nonword.

The patient was impaired in this task (68% correct) but results were significantly above chance level ($\chi^2(1)=7.81$, $P=.005$). Results for high frequency words were significantly better

than for low frequency words (70.3% correct versus 53.1% correct respectively; $F(1,60)=4.4$; $P=.041$). A concreteness effect was also found, showing an advantage for concrete words¹ (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 overall 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.

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) 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 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 ($\chi^2(1)=38.1$, $P<10^{-5}$)².

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 task³ (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 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 has been used.

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 representation (Fig. 1). We discuss two possible accounts.

The first account challenges the claim that sub-lexical processing is not necessary for lexical access. According to direct access 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 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 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).

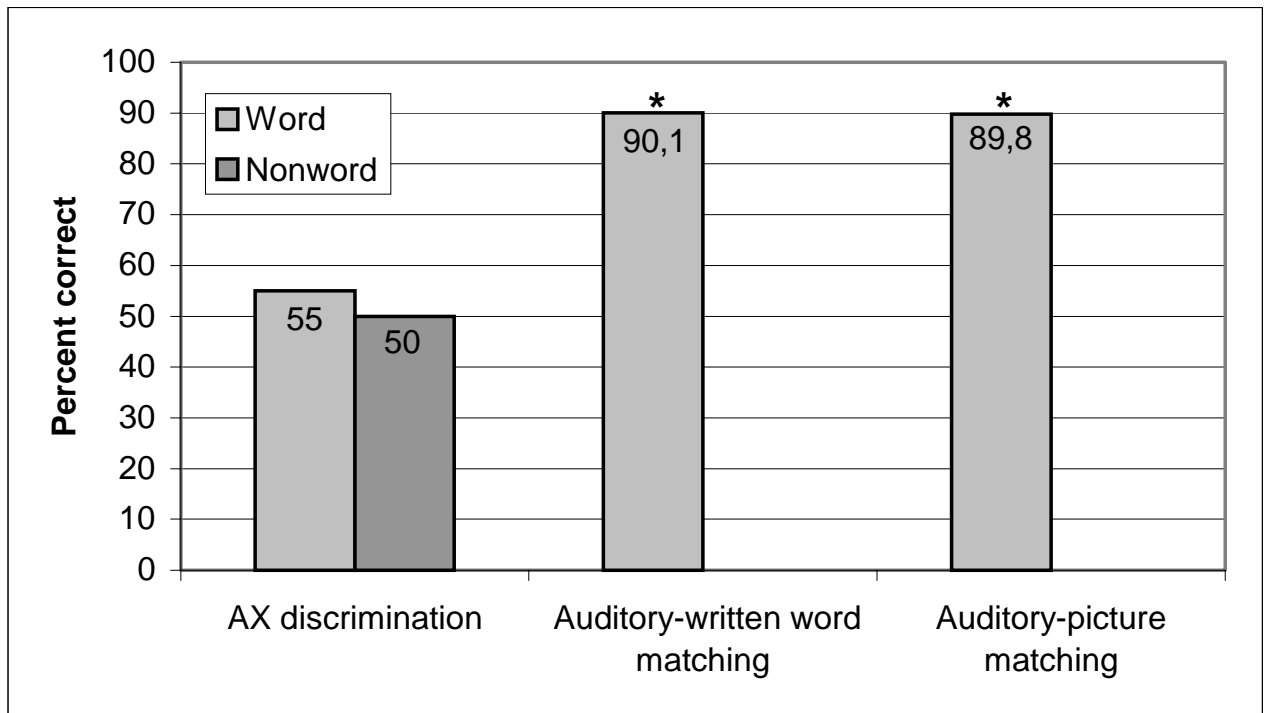


Figure 1: Summary of performance of the patient on the AX discrimination, auditory-written word matching and auditory-picture matching tasks.

* $p < 10^{-5}$ compared to chance level

Footnotes:

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).

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.

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