



Preserved use of spatial cues for sound segregation in a case of spatial deafness

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Abstract

Auditory spatial cues contribute to sound localisation and to sound object segregation. We have investigated these capacities in a patient (NM) who complained having difficulties to localise sounds in everyday life after a right temporo-parieto-frontal ischemic lesion. Two groups of tasks were used, in which spatial dimension was simulated by interaural time differences (ITD): (i) active localisation of stationary or moving sound targets, and (ii) sound segregation on the basis of spatial cues. This latter included a spatial release from masking paradigm and two ITD diotic tasks. NM failed to localise stationary and moving sounds: she perceived all the stimuli at the centre of the head, and could not differentiate stationary from moving targets. In contrast, NM was able to use ITD cues to segregate simultaneous sound sources in the spatial-release-from-masking paradigm and in ITD diotic tasks.

These results suggest that sound localisation and sound object segregation based on spatial cues do not rely on the same mechanisms. © 2003 Elsevier Science Ltd. All rights reserved.

Keywords: Sound localisation; Auditory spatial cues; Spatial-release-from-masking; Auditory attention; Brain damage; Human

1. Introduction

Auditory spatial information is conveyed by interaural time differences (ITD) and interaural intensity differences (IID), and attenuation patterns by the outer ear [7]. Psychophysical studies in normal subjects suggest two different roles for auditory spatial cues. One is *auditory localisation*, i.e. the ability to attribute a precise egocentric spatial co-ordinate to a sound, involving overt perception of sound location. Testing paradigms include pointing to real or apparent sound sources [29] or discrimination of two successive sound locations [30]. Auditory spatial information can also be used as a cue for *sound object segregation*, also referred to as ‘auditory streaming’ [8,45] or ‘cocktail party effect’ [13]. Spatial cues facilitate the grouping of sound components that belong to the same sound object and the distinction from other sound objects. Segregation of sound objects contributes decisively to sound recognition in noisy environment.

Overt sound localisation was reported to be disturbed by brainstem [1,20,33] and by hemispheric lesions. Deficits

after right-hemispheric lesions were reported either in a free field setting [25,32,35,46], or by means of stereophonic simulation manipulating ITD [3,16,23,40] or IID [6,37]. Sound localisation impairments were also found after left-hemispheric damage (free field [31,36]; ITD simulations [15]). Complete inability to perceive the spatial dimension of sounds, which can be called ‘spatial deafness’, has been described in a few studies [1,20,33,40].

Brain lesions can also affect sound objects segregation [12,14,18]. It is not known, however, if sound localisation and spatial segregation of sound objects rely on the same mechanisms and structures. We addressed this question by investigating these two aspects of auditory spatial processing in a patient who complained having difficulties localising sounds.

2. Case description

NM was a 37-year-old, right-handed woman, with a short formal education, but good general intelligence since she worked as a cashier in a supermarket before and after her illness. She had sustained an infarction in the territory of the right middle cerebral artery from cardio-embolic origin (permeable foramen). The CT-scan, performed before the

Abbreviations: IID, interaural intensity differences; ITD, interaural temporal differences

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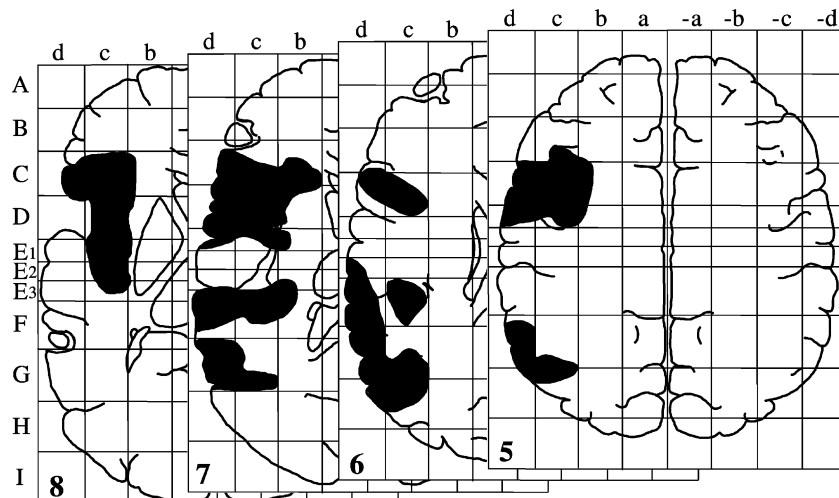


Fig. 1. NM's lesions acquired through CT-scan and normalised in the Talairach space [39].

hospitalisation, showed right-hemispheric lesions located in the inferior and middle frontal gyri, inferior parietal lobule, insula and superior temporal region, including Heschl's gyrus (Fig. 1). Neuropsychological examination in post-acute stage revealed mild signs of right-hemispheric damage, characterised by left-ear extinction on a verbal dichotic listening task, constructional apraxia and topographical disorientation on geographical maps.

NM was referred to our division, 9 years later, for neuropsychological evaluation. The neurological examination showed normal and symmetrical strength and sensitivity, the EEG examination was normal. At that time, the patient lived independently, took care of her four children, and worked at 50% as a cashier. She complained, however, of difficulties to localise sounds. She was afraid to cross a road, because she could not trust auditory cues and had to look to the right, to the left, and again to the right before being confident to cross. The neuropsychological examination revealed significant cognitive impairment characterised by emotional dullness, constructional apraxia, severe verbal and visuo-spatial memory impairment, and mild executive disorder (slowness, failure of inhibition, attentional deficits). A mild tendency to visuo-spatial neglect was also suggested by the initiation of the bells cancellation task from the right [34], but the patient did not omit any targets, nor did she show neglect on line bisection, copying, reading and writing.

Tonal audiometry showed a moderate left-ear loss for the frequencies above 4000 Hz, and an ear asymmetry of 12.5 dB in favour of the right ear, as averaged over all frequencies. The Weber test was symmetrical. Non-verbal sound recognition was assessed with a test of identification of 50 environmental sounds with multiple choice device (see [14–16]). NM totalised 48 good responses out of 50, a score which is 0.5 standard deviations above the mean of normal subjects. There was a complete left-ear extinction on dichotic listening with words (right ear: 30/30, left ear 0/30) as well as environmental sounds (right ear: 24/24, left ear 0/24).

3. Methods

We presented two types of auditory spatial tasks. The first type of tasks assessed the ability to *localise* stationary or moving sound targets. In the second type of tasks, we assessed the ability to use spatial cues to *segregate* simultaneous sound sources. In this second group of tasks, no explicit processing of the spatial location of sounds was required. In all auditory tests of this study, spatial lateralisations were simulated by means of interaural time differences.

3.1. Sound localisation

Two overt localisation tasks were proposed, one involving stationary, and one involving moving sounds.

3.1.1. Localisation of stationary sounds

This test has already been described elsewhere [5,15]. It consisted of sixty 2 s broadband “bumblebee” sounds, shaped with 100 ms rising and falling times, and presented through earphones at the intensity level judged most comfortable by the patient. Five different azimuthal (intra-cranial) positions were simulated by varying interaural time difference. One central (no ITD) and four lateral positions, two in each hemi-space, were created. For the lateral positions, the ITD was 300 μ s or 1 ms, with either the left or the right ear leading. Subjects were instructed to indicate the perceived position on their head with their ipsilesional hand (same procedure as [3,6]). A graduated half-circle fixed on the headphones was used to determine the angular value of the position (from 0° at the vertex to 90° at each ear). Sixty normal subjects confirmed that they heard single images. The average angular perceived positions were 60.1° (S.D. = 13.0°) on the left and 62.9° (S.D. = 12.5°) on the right for 1 ms ITD, 37.8° (S.D. = 13.8°) on the left and 40.5° (S.D. = 14.2°) on the right for

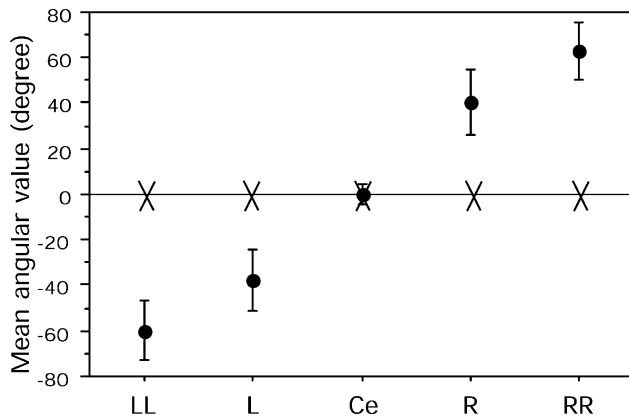


Fig. 2. Mean angular value (in degrees, minus for the left) attributed to each stimulus position. LL and RR: extreme left and right positions, with 1 ms ITD. L and R: intermediate left and right positions, with 0.3 ms ITD. Ce: central position, with no ITD. Filled circles: average performance of the 60 control subjects with inter-individual variability. Crosses: NM's performance.

a 300 μ s ITD and 0.09° (S.D. = 4.5°) on the left for 0 ITD (Fig. 2). As a measure of overall performance, the relative position attributed to two consecutive stimuli was compared; a response was counted as correct when a stimulus was correctly placed to the left or the right of the previous stimulus in correspondence with the difference in ITD or within $\pm 10^\circ$ of the previous location for identical ITD. The average relative score obtained by the control population was 57.15 (S.D. = 1.79).

3.1.2. Auditory motion

An illusion of sound motion in the horizontal plane was created by progressive changing of interaural differences. Six different motions were simulated, each presented 10 times: left to right and reverse; left to midsagittal plane and reverse; and right to midsagittal plane and reverse. Motion from one extreme lateral position was created by interaural time difference of 1 ms at the onset and progressive changes by 100 μ s for each 50 ms of stimulus duration until both channels were in phase (for motion stopping at midsagittal plane) or until the reverse balance was reached (for motion crossing the midsagittal plane). Subjects were instructed to indicate the perceived motion on their head with the ipsilesional hand. Responses were classified as correct or incorrect, a margin of $\pm 20^\circ$ being accepted for the midline departures/arrivals. The average score obtained by the control population ($N = 60$) was 52.4/60 (S.D. = 8.93).

3.2. Sound object segregation

Three tasks were presented. All were characterised by the fact that the spatial dimension was only indirectly assessed, and involved the simultaneous processing of two sound sources located in different places by means of ITD.

3.2.1. Spatial-release-from-masking

The masking phenomenon refers to the fact that a soft noise might 'disappear' if a louder noise of similar frequency range is presented simultaneously. Several studies have shown that speech (or other sound sources) becomes more intelligible with increasing spatial separation between the speech source and the masking noise [26]. This release of the masking effect has even been demonstrated when the spatial removal of the masking noise was simulated by ITD (and thus, each ear continued to receive the same frequencies at a same intensity level [11]). Our test counted 66 items (plus 10 which were not included in the analysis). On each item, a masking noise, consisting of a 2.5 s broadband helicopter sound (20–5500 Hz, with dominant pitch around 700 Hz), was presented at one of 11 possible spatial positions simulated with ITD (400, 320, 240, 160, 80 μ s favouring either the left or right ear, and 0 ITD). The to-be-detected target was a 800 ms noise of a tawny owl (20–5000 Hz, essentially centred between 350 and 900 Hz) appearing always at the centre of the head (no ITD). The pressure level of the helicopter sound, measured at ear entrance, was 79 dB SPL, whereas the owl sound was 44 dB SPL (50 times lower). The target was present in 44 out of 66 trials and began 1 s after the masking noise. In order to avoid expectation of the target at a constant interval after the onset of the helicopter sound, 10 other trials were added to the test but not included in the result analysis; in 5 of them, the target began 500 ms after the masking sound, and in 5 others, 1500 ms after. Subjects were instructed to tell whether the target was present or not. The average number of target detections for the 60 control subjects (mean age: 41.8 years, S.D.: 15.9 years) as a function of the masking sound lateralisation is illustrated in Fig. 3.

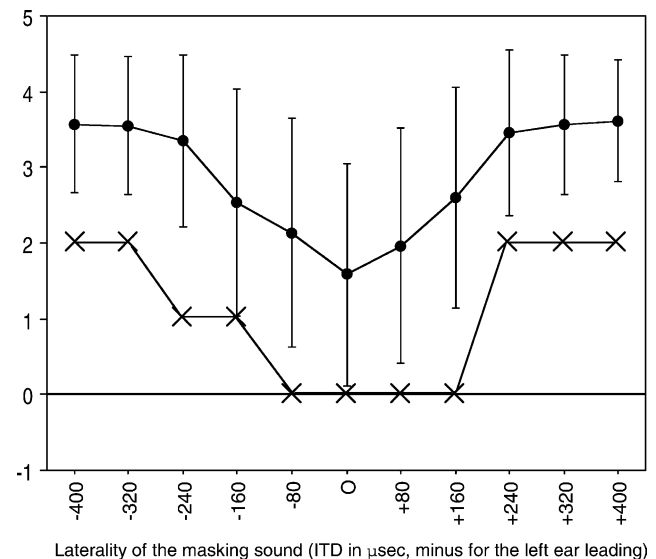


Fig. 3. Mean number of target detections (maximum four) as a function of the laterality of the simultaneous masking sound. The target was always presented at the central position (0 ITD). Filled circles: average performance of the 60 control subjects with inter-individual variability. Crosses: NM's performance.

3.2.2. ITD diotic listening, verbal version

This test has already been described elsewhere [5]. In contrast to the dichotic listening task, it avoids any difference of content and intensity between the two ears. Thirty pairs of words were presented. Both ears received both items of each pair at a same intensity level, but one of them was lateralised in the left hemi-space and the other one in the right hemi-space. The spatial lateralisations were simulated by interaural time differences of 1 ms. The instruction was to report both items. We have assessed the performance as number of correctly repeated words on the right or left side, and by the lateralisation index ($[(\text{right side} - \text{left side}) / (\text{right side} + \text{left side})] \times 100$). The right-side average score for the whole normal population ($N = 60$, mean age: 42.5 years, S.D.: 14.3 years) was 26.15 out of 30 (S.D. = 4.632) and the left-side average score was 24.867 out of 30 (S.D. = 5.02). Paired t -tests between right- and left-side scores revealed a statistically significant right side advantage ($P \leq 0.0001$). The average lateralisation index was 3.521 (S.D. = 5.96).

3.2.3. ITD diotic task, non-verbal version

Twenty-four pairs of 3 s environmental sounds were presented following the same procedure of crossed ITD lateralisation. The test was split into two parts of 12 pairs each (each sound was lateralised once to the left, once to the right associated to another sound). Subjects were first trained to recognise individually each environmental sound, before initiating the diotic part. Responses were given by pointing the two pictures corresponding to the pair, among 12 vertically aligned pictures. The right-side average score for the whole normal population ($N = 60$) was 22.5 out of 24 (S.D. = 1.58) and the left-side average score was 22.8 out of 24 (S.D. = 1.68). Paired t -tests between right- and left-side scores revealed a non-significant left-side advantage ($P = 0.095$). The average lateralisation index was -0.33 (S.D. = 3.21).

4. Results

4.1. Sound localisation

4.1.1. Localisation of stationary sounds

NM was completely unable to do the task. She reported hearing all the stimuli at the same position, in the centre of the head, and accordingly, pointed repeatedly to the 0° position (Fig. 2). Additional investigation, not detailed here, showed that processing of IID cues was severely deficient as well.

4.1.2. Sound motion perception

Complete break down was observed at the auditory motion task. NM fell no sense of motion, and reported that all the stimuli were identical, at a same stationary position at the centre of the head. Asked to guess, she was unable to tell the direction of motion. Additional investigation, not de-

tailed here, showed identical results in an IID version of the test.

4.2. Sound object segregation

4.2.1. Spatial release from masking

The test comprised 44 trials with the target and 22 without it. NM never reported false positives. She never perceived the target when the masking sound was at the same central position (0 ITD), or near the centre (80 μs ITD favouring either the left or right ear, 160 μs ITD favouring the right ear). By contrast, she perceived the targets on two out of four presentations when the masking noise was lateralised with a 400 or 320 μs ITDs favouring the right or left ear, and 240 μs ITD favouring the right ear, which reveals an effect of release from masking. Intermediate performance was obtained for the 160 and 240 μs ITDs favouring the left ear (Fig. 3).

Once the release from masking test was achieved, we asked the patient to hear the stimuli a second time, but now to indicate the spatial origin of the helicopter sound on the head (explicit localisation task). NM was unable to do the task, and answered that she heard it always at the same place at the centre of the head, superimposed to the owl-target. She could not even guess the hemi-space of origin (right versus left) for the ± 400 , ± 320 , ± 240 , ± 160 , ± 80 μs ITD stimuli.

4.2.2. Verbal ITD diotic test

NM's performance on the ITD diotic tasks demonstrated that she was able to make use of spatial cues. First, she segregated well the two words and fusion occurred only in 1 of the 30 pairs presented, which is better than the average number of fusion in the control population (2.55). In the ITD diotic task both words are presented to both ears, which may lead to fusion if the words are not properly segregated. The most powerful segregation cue in this task is the simulation of different spatial origins for each word by using different ITD. NM's performance indicates that she could segregate the dual message using the ITD information. Second, her performance at that task was highly asymmetric: she reported 17 out of 30 words from the right side, and none from the left side. This gave an asymmetry index of 100, 16.2 S.D. below the average asymmetry index of normal subjects (Table 1 and Fig. 4). Performance was normal

Table 1
NM's percentage of reports of right and left stimuli in the verbal and non-verbal ITD diotic tasks

	Verbal ITD diotic (%)		Non-verbal ITD diotic (%)
	Repeat left + right	Repeat left only	Repeat left + right
Left side	0	6.7	12.5
Right side	56.7	50 (alloacusis)	75

Instructions were to report both stimuli in the 'repeat left + right' condition, and to repeat left-sided and ignore right-sided stimuli in the 'repeat left only' condition.

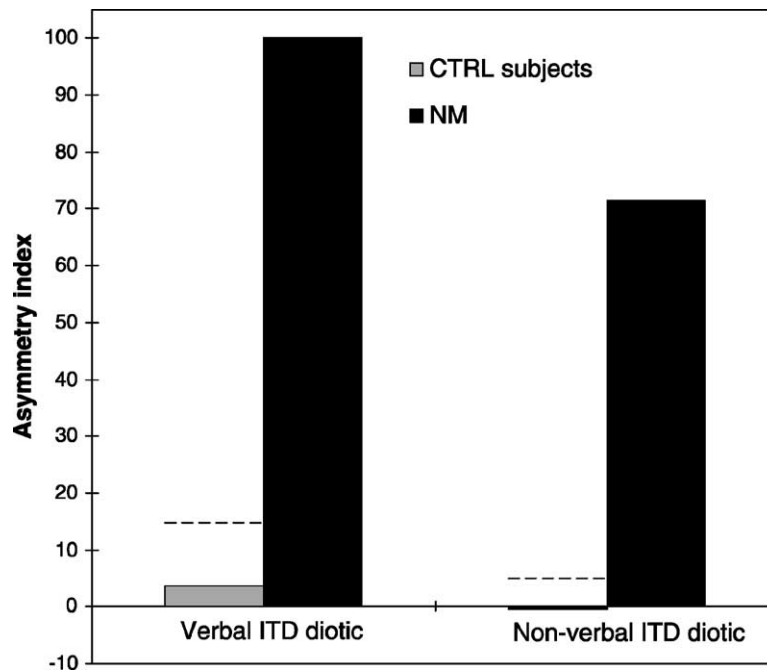


Fig. 4. Lateralization index for the verbal and non-verbal ITD diotic tasks: $100 \times (R_{tot} - L_{tot}) / (R_{tot} + L_{tot})$. The maximal asymmetry corresponds to 100. The mean value from the control population (CTRL) and NM's results are represented. The dashed lines indicate the limit of normal performance set at 2 S.D. outside the mean lateralisation index of the control subjects.

in the unilateral condition (left side as well as right side). After the verbal test, we asked her to do it a second time, but to report only the left-sided words and ignore the right-sided stimuli. She found the instruction strange, as she perceived nothing from the left side, but asked to guess, reported 15 words from the right-side and only 2 originating actually from the left side (Table 1).

4.2.3. Non-verbal ITD diotic test

NM's performance was significantly asymmetric: 18 out of 24 stimuli from the right hemi-space were recognised, against 3 out of 24 from the left hemi-space. The asymmetry index of 71.4 contrasted significantly with the mean asymmetry index of -0.33 obtained in the control population (Table 1 and Fig. 4).

After the passation of each ITD diotic task, we asked NM to tell whether if she heard one or two words/sounds, and to locate them to the right or left. She reported hearing sometimes one sometimes two items; forced to chose between right and left, she located all the stimuli (one or two items of the pair) to the right.

5. Discussion

NM had a very severe impairment of auditory localisation, experienced in everyday life and objectivised with our tasks assessing active auditory localisation by means of ITD cues. Despite a complete inability to interpret ITDs for a localisation purpose, this patient proved to be

able to use ITD cues to segregate simultaneous sound sources.

5.1. Impairment in auditory localisation

NM was unable to derive a precise spatial information from binaural cues: the ability to localise fused images lateralised by ITD was completely abolished. Even the most lateral stimuli were perceived at the centre. Auditory motion (simulated by progressive change in interaural time) was not differentiated from static stimuli. These results cannot be attributed to pointing impairment or perseverations, as NM confirmed verbally that she heard all stimuli at the same place. We have reported here only the localisation performance at tasks simulating the spatial dimension with ITD to allow direct comparison with the segregation tasks using this same ITD cue. In everyday life, however, auditory localisation depends on ITD cues as well as IID (interaural intensity differences) and spectral monaural cues [7]. Other investigations, not detailed here, ascertained that localisation and motion perception were also disrupted using IID cues. We did not test free field localisation but NM complained having difficulties localising sound sources in everyday life. We are thus confident that NM was impaired in auditory localisation and not simply in spatial processing of ITD cues. Sound localisation impairments have been described after brain lesions, but in all reports of left-damaged patients and most reports of right-damaged patients, deficits consisted of imprecision of localisation responses rather than complete spatial deafness as shown by our patient. Cases

of spatial deafness, revealed by a testing paradigm similar to ours, have been described after brainstem lesions at the level of trapezoid body [1,20,33]. With another testing paradigm (discrimination of lateralisation thresholds), some right-damaged patients were found unable to perceive lateral shifts simulated by ITD [40] (four patients), or had largely abnormal discrimination thresholds [23] (one patient). These patients might have a deficit similar to NM. Their lesions involved the right parietal lobe and auditory pathway [40], or the right inferior parietal, superior temporal and insular cortices [23]. NM's cerebral damage also involved the inferior parietal lobule, insula and superior temporal gyrus (including Heschl's gyrus), but unlike pre-cited cases, it extended to the inferior and middle frontal gyri. This additional site may explain the extreme deficit of sound localisation found in our patient. Functional studies on sound localisation revealed a bilateral network of activations in the parietal, temporal and frontal areas [10,22,24,28,42]. It is possible that the complete absence of sound location perception in NM was due to the disruption of the whole network in the right hemisphere. The frontal part of the network may underlie the component of conscious awareness of sounds' spatial position. In line with this proposition, bilateral increase of cerebral blood flow in the lateral frontal cortex was recently found to be associated with conscious awareness of sounds [19].

5.2. Preserved sound segregation on the basis of spatial cues

We present two lines of evidence that NM used ITD spatial cues for sound object segregation: (i) she had a positive spatial-release-from-masking effect; and (ii) she displayed a spatial bias in the verbal and non-verbal ITD diotic tasks.

To our knowledge, the spatial-release-from-masking paradigm has never been applied to brain-damaged patients. NM's ability to detect a central sound target proved to depend on the spatial distance between this target and a masking sound, the position of which was simulated by ITD. This is a demonstration that the ITD cues could be used by the patient for sound segregation purpose. The effect occurred even though she reported perceiving no lateralisation of the masking sound, which suggests that spatial segregation does not rely on a conscious analysis of the spatial location of sounds. The release effect was of similar amplitude than in the control population, but the global number of target detections was reduced. This raising of the detection threshold may be explained by NM's slight hearing loss.

Cherry [13] and Broadbent [9] have used the dichotic listening task to study the 'cocktail party effect'—i.e. the use of auditory spatial information to segregate simultaneous sounds—in normal subjects. However, in the classical dichotic listening paradigm, the spatial segregation is coupled with a sensory segregation (each ear receives a different information). In our task, the two opposed spatial lateralisations are provided by the sole spatial parameter—ITD (see [5]). NM fused only one pair of words out of 30, which is

better than the average 2.55 fusions found in the 60 control subjects in this task. It suggests that she could use the ITD cue to differentiate the two simultaneous messages. Moreover, she displayed a marked asymmetry in the report of ITD diotic pairs of words and environmental sounds, favouring the right-sided stimuli. This asymmetry is coherent with the left-ear extinction observed on the dichotic listening tasks, and denotes auditory spatial neglect [5]. The only difference between the two simultaneous items was the ITD. The present results not only show that the patient could use ITD to segregate between two sound objects (already shown with the release-from-masking effect), but also demonstrate that the spatial value attributed to the ITD cues was analysed, at least in terms of right versus left: NM neglected consistently the items from the left hemi-space, even though she did not experience the sensation of spatial lateralisation. It is of interest that left-sided stimuli were neglected in the ITD diotic tasks, whereas the release from masking effect occurred independently of the side of lateralisation of the masking sound. Alain and Arnott [2] have argued that the ability to focus attention selectively on a particular sound source depends on a preliminary analysis that partitions the auditory input into distinct perceptual objects. Previous electrophysiological studies on sound object segregation have shown that these mechanisms occur at a pre-attentive level [38,44]. Accordingly, we propose that NM had normal pre-attentive mechanisms of sound object segregation (even if they involved left sided stimuli). Left hemi-neglect became apparent when she had to attend to lateralised objects once they were formed. Following this explanation, auditory neglect is a high-level process which operates on preliminary spatial processing.

5.3. Two different uses of spatial information

NM's contradictory spatial competencies could be explained in terms of dissociation between conscious and unconscious processing of auditory spatial cues. Indeed, our tasks of auditory localisation imply overt spatial processing, whereas the release from masking and ITD diotic tasks assess the spatial dimension only indirectly. In the visual modality, some patients with cortical blindness retain the ability to detect and localise targets of which they have no awareness [43]. Cowey and Stoerig [17] have hypothesised the existence of an analogue to this blind sight phenomenon in the auditory modality, which they have called 'deaf hearing'. In line with this proposition, some authors have emphasised the paradoxical ability of some patients with cortical deafness to react to sounds they deny hearing [41]. Recently, Garde and Cowey [21] have described a patient with cerebral deafness, who had retained some ability to respond reflexively to sounds; she was trained to become aware of her appropriate orienting head movements, and could subsequently detect and localise sounds successfully in a forced-choice paradigm, although remaining agnostic to their meaning. The links between consciousness and

auditory perception are further documented in the study of another cortically deaf patient who was found to be conscious of the onset and offset of sounds only when selectively attending to the auditory modality. H₂ ¹⁵O-PET showed that conscious awareness of sounds was associated with increased cerebral blood flow bilaterally in the lateral frontal, middle temporal cortices, and cerebellum [19]. Our patient did not suffer from cortical deafness. She was perfectly aware of verbal and non-verbal sounds and could identify them normally. She displayed ‘deaf *spatial* hearing’ rather than ‘deaf hearing’. The dichotomy between conscious and unconscious spatial processing may account partly for NM’s results. It should be noticed, however, that when asked to guess the origin of one sound, the patient did not improve her performance, which contrasts with Garde and Cowey’s patients, as well as some patients with blindsight.

Another way to explain the pattern of auditory spatial processing displayed by our patient is to consider the differential cognitive context associated with the impaired versus preserved spatial abilities. NM’s deficit affects the ability to give sense to a spatial cue, tell if it is stationary or moving, attribute spatial co-ordinates to it and select an action accordingly (i.e. point to the perceived position in our localisation task, or cross the road in everyday life). The preserved spatial competencies of NM (spatial-release-from-masking effect, spatial bias at ITD diotic tasks; absence of complaints of difficulties following conversations with many people) concern situations where more than one sound object are simultaneously presented and the sorting is done on the basis of spatial analysis. Binaural spatial cues (here ITD) in sound localisation and sound segregation serve thus different goals, one being spatial orientation and action, the other being *facilitation of perception*. There is now increasing evidence that the auditory system, like the visual system, is organised in at least two main cortical networks, one, dorsal, dedicated to the spatial ‘where’ aspects, another, ventral, to the content (‘what’) of sounds (clinical data [15,16]; fMRI data [28]; evoked potentials [4]). Lesions responsible for the localisation deficit in NM match perfectly the temporo-fronto-parietal network associated with active auditory spatial processing in functional data [28]. The dissociation observed in our patient demonstrates that sound segregation does not rely on the ability to localise sounds (completely abolished in NM). Sound source segregation may rely on different mechanisms being part of the ‘what’ system (see also [27] for a similar proposal). There is convincing evidence that NM’s ‘what’ system is intact: she can recognise verbal and environmental sounds perfectly, which is in agreement with the sparing of the ventral part of her temporal lobes. In line with this interpretation, Efron et al. [18] have proposed the existence of temporal enhancement mechanisms (one in each temporal lobe) which function would be to facilitate perception of sound sources located in the opposite side of space when other sounds are present throughout the auditory field. They found that this ‘cocktail party’ competency was impaired in the hemi-space con-

tralateral to a temporal lobectomy. Another evidence that auditory streaming depends on high-level mechanisms and can be disrupted by brain lesions comes from Carlyon et al. [12].

NM’s preserved spatial segregation competencies may also reflect residual spatial processing by the brainstem, instead involvement of a mechanism qualitatively different from auditory localisation. The finding of a dissociation inverse to that of NM (impaired spatial segregation with normal sound localisation) could reject this hypothesis. Patients with traumatic brain injury, who often complain of difficulty following conversations involving many persons, may fulfil this condition. Further research is, however, needed to clarify this point.

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