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Right hemisphere specialization for intensity discrimination of musical and speech sounds

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Abstract

Sound intensity is the primary and most elementary feature of auditory signals. Its discrimination plays a fundamental role in different behaviours related to auditory perception such as sound source localization, motion detection, and recognition of speech sounds. This study was aimed at investigating hemispheric asymmetries for processing intensity of complex tones and consonant-vowel syllables. Forty-four right-handed non-musicians were presented with two dichotic matching-to-sample tests with focused attention: one with complex tones of different intensities (musical test) and the other with consonant-vowel syllables of different intensities (speech test). Intensity differences (60, 70, and 80 dBA) were obtained by altering the gain of a synthesized harmonic tone (260 Hz fundamental frequency) and of a consonant-vowel syllable (/ba/) recorded from a natural voice. Dependent variables were accuracy and reaction time. Results showed a significant clear-cut left ear advantage in both tests for both dependent variables. A monaural control experiment ruled out possible attentional biases. This study provides behavioural evidence of a right hemisphere specialization for the perception of the intensity of musical and speech sounds in healthy subjects.

Keywords: Dichotic listening; Left ear advantage; Sound intensity; Loudness; Complex tones; Consonant-vowel syllables; (Non-)verbal sounds; Right hemisphere

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1. Introduction

Sound intensity is probably the primary and most elementary feature of auditory signals. It conveys key information about the strength and the distance of the sound source from the listener. Moreover, the discrimination of sound intensity has a basic role in many auditory functions such as recognition of environmental, musical, and speech sounds including non-verbal aspects of language, i.e. speech prosody (Brungart & Scott, 2001; Mitchell, Elliott, Barry, Cruttenden, & Woodruff, 2003; Trainor &Adams, 2000). Despite this, until now only few studies have investigated the neural mechanisms and hemispheric asymmetries underlying the perception of sound intensity (Belin et al., 1998; Jancke, Shah, Posse, Grosse-Ryuken, & Muller-Gartner, 1998; Paus et al., 1997; Wexler & Halwes, 1981). Conversely, many scientific reports based on behavioural and patients evidence have focused on the study of more complex aspects of auditory sensation. These studies have shown that a right hemisphere specialization can be demonstrated for the perception of pitch (Gregory, 1982; Paquette, Bourassa, & Peretz, 1996; Zatorre, 2001), timbre (Boucher & Bryden, 1997; Brancucci & San Martini, 1999, 2003; Samson & Zatorre, 1994; Samson, Zatorre, & Ramsay, 2002) and other aspects (Boucher & Bryden, 1997; Schnider, Benson, Alexander, & Schnider-Klaus, 1994) of musical or environmental sounds, whereas auditory perception of speech stimuli is mainly left lateralized

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(Berlin, Lowe-Bell, Cullen, & Thompson, 1973; Hugdahl, 2000; Wernicke, 1874).

These findings have received support from neuroimaging studies. The earliest neuroimaging-based evidence for lateralized auditory functions was the one reported by Mazziotta, Phelps, Carson, and Kuhl (1982), using positron emission tomography. They presented their subjects with monaural and binaural verbal and non-verbal sounds, and found enhanced and more widespread blood flow in the left hemisphere for verbal sounds and in the right hemisphere for non-verbal sounds. After this study, other researchers using different neuroimaging and investigation methods, have given further sustain to the dichotomy verbal sounds/left hemisphere (Epstein, 1998; Ghazanfar & Hauser, 1999; Tranel, 1992) versus musical (or non-verbal) sounds/right hemisphere (Halpern, 2001; Milner, 1962; Tramo & Bharucha, 1991). There is general agreement on the fact that this dichotomy is based on a specialization of the left hemisphere in the analysis of fine temporal features of sound (Carmon & Nachshon, 1981; Efron, 1963; Kester et al., 1991; Zatorre & Belin, 2001; Zatorre, Belin, & Penhune, 2002), and on a specialization of the right hemisphere in the frequency analysis of the stimulus (Brancucci & San Martini, 2003; Greenwald & Jerger, 2003; Zatorre & Belin, 2001; Zatorre et al., 2002). Other alternative explanations are based on attentional factors (Geffen, 1988; Hugdahl et al., 2000), cognitive strategies (Mazziotta et al., 1982) and task demands (Greenwald & Jerger, 2003; Zatorre et al., 2002).

The present study uses dichotic listening with focused attention (Asbjornsen & Hugdahl, 1995; Hugdahl, 2000; Jancke, Specht, Shah, & Hugdahl, 2003) to investigate possible hemispheric asymmetries for the discrimination of sound intensity. Dichotic listening, meaning listening to two different auditory stimuli presented concomitantly one in the left and one in the right ear, is a classical neuropsychophysiological technique that has been broadly used for the study of laterality. It allows testing the two hemispheres separately as, when the two auditory pathways convey incongruent information to the auditory cortices, the ipsilateral pathway is suppressed thus allowing only the contralateral stimulus reaching the auditory cortex (Brancucci et al., 2004; Kimura, 1967). In this particular situation, testing the right ear means, with good approximation, testing the left auditory cortex and testing the left ear means testing the right auditory cortex (Hugdahl, 1995; Hugdahl et al., 1999). Functional magnetic resonance imaging studies on dichotic listening of consonant-vowel syllables have shown that brain activations during this task are dependent on attentional constraints and involve a highly distributed processing network, which extends from temporal lobe to superior temporal gyrus, middle and inferior frontal gyrus, cingulate cortex, and to higher order areas such as prefrontal regions (Jancke & Shah, 2002; Pollmann, Lepsien, Hugdahl, & von Cramon, 2004; Thomsen, Rimol, Ersland, & Hugdahl, 2004; Thomsen et al., 2004).

In the experimental design of the present study, first, the target sound was presented monaurally. Then, a dichotic pair including the probe sound was delivered. Within the dichotic pair, the probe sound was presented in the same ear that received the target sound and differed from it only by the intensity level. The other sound constituting the dichotic pair had a different spectral composition. The task of the subject was to judge whether target and probe sounds had different or equal intensity.

The working hypothesis of this study is related to a previous investigation on intensity coding of auditory stimuli (Jancke et al., 1998). That study reported that, during a binaural intensity discrimination task of verbal and non-verbal sounds, the voxel activation pattern in higher-order auditory cortex showed an asymmetry in favour of the right hemisphere. The present study aims at investigating whether this physiological asymmetry is related to a behavioural asymmetry. The prediction is that a left ear advantage indicative of a right hemisphere specialization should be found for sound intensity discrimination.

2. Materials and methods

2.1. Participants

Forty-four healthy subjects, 28 males and 16 females, aged from 26 to 33 years (average age = 29.4 years) participated in two experimental sessions (musical and speech test). They all showed a positive score at the Edinburgh inventory test indicating a right-hand preference (group mean ± standard error = 78.8 ± 5.2). Subjects were non-musicians, i.e. they were not playing any musical instruments on a regular basis and they had not had any formal musical education. Subjects declared to have no auditory impairment. Audiometric assessment was performed in an acoustically shielded room in which subjects had to press a button when a complex tone of 300 Hz, presented via earphones repeatedly with increased intensities (steps of 2.5 dBA), became perceivable. Subjects were recruited when no (±5 dBA) different hearing thresholds were present between left and right ear.

2.2. Stimuli

Stimuli used in the musical test were two complex tones synthesized on a Pentium 166 PC with Sound Blaster audio card (Creative, Model AWE 32; Microwave, Rome, Italy) by means of the CSound language (Vercoe, 1992) for sound synthesis. The first tone had a fundamental frequency of 260 Hz and could be presented at three different intensity levels (60, 70, and 80 dBA). The second tone (masking tone) had a fundamental frequency of 290 Hz and was always presented at the same intensity level (70 dB). Both tones had a duration of 500 ms including 50 ms rise and fall time. Spectral composition was harmonic, having the eight spectral components the following relative amplitudes: 1, 0.7, 0.5, 0.3, 0.1, 0.03, 0.01, 0.005. It should be noted that the tones sounded like a short tone played by a trumpet.

Stimuli used in the speech test were two consonant-vowel syllables (/ba/ and /pa/) recorded from a natural female voice. The /ba/ syllable could be presented at three different intensity levels (60, 70, and 80 dBA), whereas the /pa/ syllable (masking syllable) was always presented at the same intensity level (70 dB).

Sampling rate was 44.1 kHz and amplitude resolution 16 bit. The different intensity levels of the stimuli were obtained by altering the gain of the complex tone and of the recorded consonant-vowel syllable. To ensure that no transient or undesired alterations were present in the stimuli, they were recorded using headphones and visually re-analysed.

2.3. *Procedure*

Subjects were presented with two dichotic matching-to-sample tests with focused attention, a musical test with complex tones, and a speech test with consonant-vowel syllables. The format of the tests was chosen because it allowed controlling the direction of attention (i.e. fluctuations of attentions from one ear to the other are minimized). Previous studies have shown that it allows the detection of a consistent and reliable laterality effect (Brancucci & San Martini, 1999, 2003; San Martini, De Gennaro, Filetti, Lombardo, & Violani, 1994). Each test was composed by 192 trials.

In the musical test, each trial consisted of the following sequence: the target tone presented monaurally (the 260 Hz tone with 60, 70, or 80 dBA intensity and 500 ms duration), followed by a pause (1000 ms of silence), followed by a dichotic pair of completely aligned tones (500 ms duration). The dichotic pair was composed by the 260 Hz tone with 60, 70, or 80 dBA intensity (probe tone), which was presented in the same ear that received the target tone, and by the 290 Hz tone, which was presented in the other ear. The task of the subjects was to judge whether the intensity of the probe tone was the same or different from the intensity of the target tone. In half of the trials, the probe tone had the same intensity of the target tone, in the other half the probe and target tone had different intensities.

Similarly, in the speech test, each trial consisted of the following sequence: the target syllable presented monaurally (/ba/ with 60, 70, or 80 dBA intensity and 260 ms duration) followed by a pause (1000 ms duration) followed by a dichotic pair of aligned syllables (290 ms duration). The dichotic pair was composed by the /ba/ syllable with 60, 70, or 80 dBA intensity (probe syllable), which was presented in the same ear that received the target syllable, and by the /pa/ syllable, which was presented in the other ear. It should be noted that the /pa/ syllable lasted 30 ms more than the /ba/ syllable, which yielded that the dichotic pair had, on the whole, a duration of 290 ms. The task of the subjects was to judge whether the intensity of the probe syllable was same or different from the intensity of the target syllable. In half of the trials, the probe syllable had the same intensity of the target syllable, in the other half the probe and target syllable had different intensities.

In both tests, the 192 trials were grouped into 32 blocks of 6 trials each. Trials were allocated in blocks on a random basis, with the constraint that intensity matching should occur more than once and less than six times in each block. The side (ear) of presentation of the target stimulus changed with every block. The blocks were separated by a 4 s interval and each block was preceded by a beep (2000 Hz, 200 ms), which was presented monaurally to the ear that was to receive the target stimuli in that block. Subjects were instructed to direct their attention to the side of the monaural beep during the subsequent block and were informed that both targets and probes would be delivered to that side.

The musical and the speech test were administered separately, in two sessions. The order of test administration was counterbalanced across subjects and the second session took place in a 1–4-week range from the first one. The experiments were completely automated by means of home-made software written in Microsoft Visual Basic. The procedure was identical for both tests. Subjects wore a pair of headphones (Grass S10CTCM, impedance 3 kΩ) and were comfortably seated in front of a computer monitor (approximately 80 cm from subject's head) with both their hands lying on the computer keyboard. They were instructed to look at a green circle in the centre of the screen in front of them and not to shift their gaze laterally during the experiment. In a first familiarization phase, subjects were invited to listen to the sounds that were to be used in the subsequent test until they felt familiar with them. In the experimental phase, the initial position of the headphones was counterbalanced across subjects. After 96 trials (middle of test), subjects turned the orientation of the headphones. The second half of the test was identical to the first half, but with rotated headphones. The intensity level of the sounds was the same in both earphones, as measured by a phonometer. After each trial, subjects had to judge whether the probe sound had the same or different intensity from the target sound. The response had to be given by pressing one of two keys on the keyboard as fast as possible. Subjects were instructed to press the 'v' key (in case of match) with their left hand forefinger or the 'n' key (in case of no match) with their right hand forefinger. The association between hand (left hand versus right hand) and type of response (match versus no match) was counterbalanced across subjects, i.e. half of the subjects had to press the 'v' key (in case of no match) with their left hand forefinger and the 'n' key (in case of match) with their right hand forefinger. Type and latency of response were automatically stored for later analysis. Each experimental session lasted approximately 20 min.

2.4. *Control experiment*

With the intent to investigate whether the present dichotic experiments are affected by an attentional bias, we performed, for both musical and speech test, a monaural control experiment in 22 of the 42 subjects considered in the data analysis of the dichotic experiment. The monaural control experiments were identical to the dichotic experiments, except for two concerns. First, in the musical (speech) monaural control experiments the probe tone (syllable) was not part of a dichotic pair but was presented monaurally at the same ear receiving the target tone (syllable). Second, in the musical (speech) monaural control experiments the intensity difference between target and probe tones (syllables) were smaller than in the dichotic experiment. The reason for this was to control for task difficulty, which was higher in dichotic compared to monaural experiments, because of the nature of the task. To obtain a similar level of overall performance between dichotic and monaural tests, the three intensity levels at which the tone of 260 Hz (or the syllable /ba/) could be presented in the monaural test were 66, 70, and 74 dBA.

3. Results

The dependent variables were accuracy (number of errors) and reaction time. For each subject, reaction time was measured as the median latency of correct responses. Data analysis was performed according to previous studies (Brancucci & San Martini, 1999, 2003; Esgate, Burton, & Burton, 1997; Grimshaw, Kwasny, Covell, & Johnson, 2003; Hugdahl & Franzon, 1985; Welsh & Elliott, 2001). Of note, in dichotic listening experiments the number of errors does not necessarily reflect noise in the data, due to distraction or to the fact that the subjects are ill-disposed towards the task. Rather, in dichotic listening tasks, the number of errors is strictly related to the underlying biology of the auditory system, which reflects that one of the two sides of the brain is not adequate for the analysis of a specific feature of sound.

Statistical effects were evaluated by repeated measure analysis of variance (ANOVA) and planned comparisons at a significance level of $p = 0.05$. All the statistical analyses were performed on the raw scores, as Kirk's (1968, pp. 66–67) method suggested that no transformation was required to meet the homoschedasticity assumption for both accuracy and reaction time data. It should be noted that 2 out of 44 subjects performing at chance (i.e. number of errors $\geq$50%) with at least one ear in either test were excluded from the study. Therefore, statistical analyses of the dichotic data were performed on 42 subjects.

For the statistically significant results we calculated the effect size (Cohen's *d*). This parameter is the difference between the mean values of two samples divided by the standard deviation of both samples together. The effect size is an index of the magnitude of the difference between groups. It can be useful to compare effects across studies as it prescinds from sample's size. Effect sizes of about 0.2, 0.5, and 0.8 are categorized, respectively, as small, moderate, and large (Cohen, 1977).

3.1. Preliminary analyses

Preliminarily ANOVA indicated that the headphone position at the beginning of the test, the order of test administration (whether participants first received the musical or the speech test), the sex of the participants and the association between hand (left hand versus right hand) and type of response (match versus no match) did not influence the dependent variables, as they showed no main or interaction effects. These variables were therefore not included in subsequent analyses.

Table 1
Descriptive values of error percentages in the tests at the left and right ear

Test	Ear	Mean	Minimum	Maximum	Standard deviation	*N*
Musical	Left	26.09	6.25	47.92	10.01	42
	Right	29.91	9.36	46.87	8.78	42
Speech	Left	16.48	3.08	44.79	9.17	42
	Right	20.83	5.21	46.87	10.33	42

3.2. Main analyses

A 2 × 2 repeated measure ANOVA with type of test (musical, speech) and ear of input (left, right) as independent variables was carried out for both dependent variables.

For the accuracy variable (number of errors), the ANOVA showed a significant main effect for the type of test ($F_{1,41} = 36.35$; $p < 0.001$), due to a smaller number of errors in the speech test, and for the ear of input ($F_{1,41} = 15.71$; $p < 0.001$) due to a smaller number of errors for the left ear. No significant interaction effects were found. Analysis of the simple main effects (planned comparisons) showed that the effect of the ear of input was significant in both musical ($p < 0.001$; number of errors of the left ear: 26.09 ± 10.01%, right ear: 29.91 ± 8.78%) and speech ($p < 0.001$; number of errors of the left ear: 16.48 ± 9.17%, right ear: 20.83 ± 10.33 %) test (Table 1). The effect size of the ear asymmetry for accuracy was between 'small' and 'medium' (Cohen, 1977) in both musical (Cohen's $d = 0.34$) and speech ($d = 0.49$) tests. Regarding accuracy, a left ear advantage was found in 31 subjects in the musical test and in 31 subjects in the speech test. Twenty-three subjects showed a left ear advantage in both tests.

For the reaction time variable, the ANOVA revealed a significant main effect of the ear of input ($F_{1,41} = 10.67$; $p = 0.002$) due to a shorter reaction time of the left ear and no other significant effects. Planned comparisons showed that the effect of the ear of input was significant in both musical ($p < 0.001$) and speech ($p < 0.001$) test (Table 2). The effect size of the ear asymmetry for reaction time was between 'small' and 'medium' in both musical ($d = 0.34$) and speech ($d = 0.28$) tests. Regarding reaction time, a left ear advantage

Table 2
Descriptive values of reaction times (ms) in the tests at the left and right ear

Test	Ear	Mean	Minimum	Maximum	Standard deviation	*N*
Musical	Left	695	268	2475	387	42
	Right	756	281	1883	341	42
Speech	Left	736	291	2644	365	42
	Right	802	302	2443	355	42

was found in 32 subjects in the musical test and in 26 subjects in the speech test. Twenty subjects showed a left ear advantage in both tests.

3.3. Control experiment

For the monaural control experiment, a 2 × 2 repeated measure ANOVA with type of test (musical, speech) and ear of input (left, right) as independent variables was carried out for both dependent variables (accuracy and reaction time). No significant effects were found in either test (accuracy: $p > 0.35$, reaction time $p > 0.48$ for either main or interaction effects). Regarding accuracy, the musical monaural test resulted in a mean value of $19.66 \pm 9.39\%$ of errors for the left ear and $20.41 \pm 9.43\%$ of errors for the right ear. The speech monaural test showed a mean value of $17.57 \pm 6.88\%$ errors for the left ear and $17.38 \pm 6.42\%$ for the right ear. Regarding reaction time, the musical monaural test showed a mean value of 486 ± 130 ms for the left ear and 496 ± 115 ms for the right ear. In the speech monaural test mean reaction time were 503 ± 103 ms for the left ear and 504 ± 96 ms for the right ear.

To compare these results with that of the dichotic experiment, we performed an ANOVA on the dichotic data from the same 22 subjects performing the monaural control experiment. For the accuracy variable, this analysis showed a significant left ear advantage in both tests (musical test: $p = 0.02$, speech test: $p = 0.01$). For the reaction time variable, this analysis showed a significant left ear advantage in both tests (musical test: $p = 0.01$, speech test: $p < 0.01$). These results demonstrate that a left ear advantage was present in the dichotic but not in the monaural experiments.

3.4. Further analyses

For completeness we report here the results of other statistical analyses carried out. To check whether the ear advantage in the present experiment was stable during the execution of the tests, a 2 × 2 × 4 repeated measures ANOVA was carried out with type of test, ear of input, and test part (first, second, third, and fourth part) as independent variables. Besides the significant effects reported above (i.e. minor number of errors in the speech compared to musical test, minor number of errors for the left compared to right ear in both tests, and shorter reaction time for the left compared to right ear in both tests) a main effect of test part was found for accuracy ($F_{3,41} = 4.14$; $p = 0.008$) and reaction time ($F_{3,41} = 13.41$; $p < 0.001$) due to the fact that the number of errors and the reaction time decreased during the execution of the tests. No interaction between ear of input and test part was found, indicating that the effect of the ear was constant during the carrying out of the tests.

Finally, we calculated test–retest and inter-tests correlations on laterality scores. Laterality scores (LS) were computed as follows: $\mathrm{LS} = (R - L)/(R + L) \times 100$, where R is the number of errors (or the reaction time) of the right ear and L the number of errors (or the reaction time) of the left ear. Test–retest correlations (reliability), corrected with the Spearman–Brown formula, were $r' = 0.45$ ($p < 0.01$) for the number of errors and $r' = 0.35$ ($p < 0.01$) for the reaction time in the musical test along with $r' = 0.66$ ($p < 0.01$) for the number of errors and $r' = 0.54$ ($p < 0.01$) for the reaction time in the speech test. Inter-tests correlation (musical versus speech test) were, regarding the number of errors, $r = 0.25$ ($p = 0.09$), regarding the reaction time, $r = -0.01$ ($p = 0.96$).

4. Discussion

The results of the present study point to a right hemisphere specialization in the discrimination of sound intensity, or loudness, regardless whether stimuli are of verbal or non-verbal nature. This claim is based on a dichotic left ear advantage for the discrimination of sound intensity, which was found for both dependent variables, i.e. accuracy and reaction time. This ear advantage occurred in intensity discrimination of both complex tones and consonant-vowels syllables. It should be noted here that dichotic experiments can be influenced by attentional biases, as pointed out by previous studies showing that attentional shifts significantly contribute to the magnitude or even to the direction of the ear advantage (Hugdahl et al., 2000; Jancke et al., 2003; Lipschutz, Kolinsky, Damhaut, Wikler, & Goldman, 2002; Mondor & Bryden, 1991). For this reason in the present study a monaural control experiment was performed, to rule out possible attentional effects biasing the ear asymmetries observed in the dichotic experiment. Any laterality effects observed in the monaural test could have been ascribed mainly to attentional biases as monaural stimuli are not lateralized like dichotic stimuli, or at least they are less lateralized (Bradshaw & Nettelton, 1988). The results of the monaural experiment demonstrated that the laterality effect found in the dichotic experiment was not appreciably affected by attentional biases.

Of note, the present dichotic listening paradigm comprises short-term memory processes other than perception. That is, subjects had to retain the target stimulus for one second before the matching with the probe stimulus included in the dichotic pair. However, it should be stressed that the present paradigm was designed to minimize possible biases of memory processes. In fact, the target tone was monaural, thus not lateralized to one hemisphere. So, both ears could avail of the same short-term memory skills.

The present findings are in line with the conclusions of a previous study aimed at investigating neural bases of sound intensity perception. Belin et al. (1998) using positron emission tomography combined with a psychoacoustic Go/NoGo paradigm, showed that the discrimination of the intensity of non-speech sounds during binaural hearing involves two different cortical networks: a right hemispheric frontoparietal network and a right posterior temporal region included in the secondary auditory cortex. The activation of the first network would be independent from sound discrimination, reflecting allocation of selective and sustained sensory attention, as reported also by other studies (Pardo, Fox, & Raichle, 1991; Paus et al., 1997). Conversely, the activation of the second network (right posterior temporal region) would be specific for sound intensity discrimination. A right hemisphere dominance for sound intensity was found also by Milner (1962) in patients who had undergone anterior temporal lobe removal for the relief of medically intractable epilepsy. She found that performance in loudness discrimination was significantly poorer after surgery when the right but not left temporal lobe was removed. Another investigation used functional magnetic resonance imaging (fMRI) with the intent to examine intensity coding of binaural auditory stimuli (Jancke et al., 1998). The main result was that the spatial extent of the fMRI response in primary and secondary auditory cortices increased with increasing stimulus intensity, thus indicating that the brain possibly codes stimulus intensity with a spreading of neural excitation within auditory areas. Activations were found principally in the superior temporal gyrus covering primary and secondary auditory cortices. In that study, an asymmetrical distribution of active voxels during intensity discrimination of verbal and non-verbal sounds was observed. In particular, the voxels in Brodmann area 22 (secondary, higher-order auditory association area) showed a right-sided activation pattern, regardless of the type of stimulus (verbal or non-verbal). It can be argued that this functional asymmetry may be the physiological correlate of the behavioural asymmetry found in the present study.

The difference of the present results from those obtained by two previous behavioural studies (Efron & Yund, 1974; Wexler & Halwes, 1981) can be ascribed to basic methodological differences. Both previous studies used pure tones as stimuli, whereas the present study used complex tones and speech sounds. Unlike from the present experimental paradigm, Efron and Yund, who found no laterality effects for loudness, required to their subjects to indicate whether a sequence of two dichotic sounds having different intensities and pitch was lateralized to the left or right side of subject's midline. The findings of Wexler and Halves, which found a right ear bias for loudness, were based on the fact that subjects perceived dichotic tones louder when they were presented in the right compared to the left ear.

At first sight, the fact that the right hemisphere specialization here reported has been found for intensity discrimination of both musical and speech sounds can appear somewhat in contrast to the dichotomy right hemisphere/nonverbal sounds versus left hemisphere/verbal sounds (Tervaniemi & Hugdahl, 2003; Zatorre, Evans, Meyer, & Gjedde, 1992). Whereas the left ear superiority in the musical test may be accounted for by the notion of right hemisphere superiority for non-verbal sounds processing, the left ear superiority in the speech test seems to run contrary to the above dichotomy. However, since the task required an intensity processing but not a phonological or a speech processing, the results obtained here are compatible with the literature. Moreover, the right hemisphere may have been favoured by the fact that in both musical and speech tasks the discrimination of intensity could be performed by referring to the frequency composition of the sound, by detecting differences in the amplitude of the basic components of the stimuli. Finally, since sound intensity is related to emotional content in acoustic messages, it can be argued that the right hemisphere superiority found during emotional prosody recognition in neurologically healthy subjects (Bradvik et al., 1991; George et al., 1996) is linked to the same hemispheric specialization for intensity processing of both musical and speech sounds found in the present study.

In conclusion, the results of the present study suggest a prominent role of the right hemisphere in intensity processing of auditory stimuli of both non-verbal and verbal nature. This conclusion might gain further support if future studies based on magneto- or electrophysiological recordings can demonstrate that auditory cortex responses during a sound intensity discrimination task are faster and larger in the right compared to the left hemisphere.

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