PERGAMON

Neuropsychologia 39 (2001) 1121–1124

NEUROPSYCHOLOGIA

www.elsevier.com/locate/neuropsychologia

Deficit in automatic sound-change detection may underlie some music perception deficits after acute hemispheric stroke

Christine Kohlmetz [a,b], Eckart Altenmüller [a], Maria Schuppert [a], Bernardina M. Wieringa [b], Thomas F. Münte [c,*]

[a] *Institut für Musikermedizin und Musikphysiologie, Hochschule für Musik und Theater Hannover, Hannover, Germany*
[b] *Department of Neurology, Medizinische Hochschule Hannover, Hannover, Germany*
[c] *Department of Neuropsychology, Otto-von-Guericke-Universität Magdeburg, Magdeburg, Germany*

Received 8 December 2000; received in revised form 27 April 2001; accepted 30 April 2001

Abstract

Music perception deficits following acute neurological damage are thought to be rare. By a newly devised test battery of music-perception skills, however, we were able to identify among a group of 12 patients with acute hemispheric stroke six patients with music perception deficits (amusia) while six others had no such deficits. In addition we recorded event-related brain potentials (ERPs) in a passive listening task with frequent standard and infrequent pitch deviants designed to elicit the mismatch negativity (MMN). The MMN in the patients with amusia was grossly reduced, while the non-amusic patients and control subjects had MMNs of equal size. These data show that amusia is quite common in unselected stroke patients. The MMN reduction suggests that amusia is related to unspecific automatic stimulus classification deficits in these patients. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Event-related potentials; Stroke; Music perception; Amusia; MMN

1. Introduction

Compared to other neuropsychological deficits there are relatively few reports on music perception and production deficits, amusia, in the literature. Most of the reports concern single case studies with patients exhibiting specific impairments of music perception and production [4,14–16]. Because of the wide variability in terms of music education and listening habits, however, music perception deficits might have been overlooked in clinical practice. In fact, in a recent study we could demonstrate in a group of 20 unselected patients that suffered from their first ischemic hemispheric stroke that music perception deficits are quite common and are due to the disturbance of widely distributed networks [18]. For this study, a new test battery was designed to assess different aspects of music perception:

- lower-level auditory information processing by testing discrimination of pitch,
- auditory memory function by testing recognition of familiar songs,
- local (sequential) auditory information processing by testing discrimination of interval-violated melodies and rhythm-violated musical stimuli,
- global (parallel) auditory information processing by testing discrimination of contour-violated melodies and metre.

While it is clear that very specific music processing deficits, e.g. pertaining to the hedonic qualities of music, can occur in the absence of a disturbance in the functions mentioned above, the processes addressed by the battery can be argued to form the basic building blocks of music perception [15,18].

About two-thirds of the patients presented with impairments on the test battery. In broad stroke, patients with damage to the left hemisphere showed deficits in the discrimination of local as well as global structures in both melodic and temporal information processing.

* Corresponding author. Fax: +49-391-6711947.
E-mail address: thomas.muente@medizin.uni-magdeburg.de (T.F. Münte).

0028-3932/01/$ - see front matter
PII: S0028-3932(01)00079-3

Table 1
Pertinent patient data

Patient	Amusia	Age/sex	Hemisphere	Location	Diameter (cm)
1	yes	60/m	R	parietooccipital	3.5
2	yes	65/f	L	parietal	3
3	yes	62/f	L	parietooccipital	3
4	yes	71/m	L	central	2
5	yes	61/m	L	parietooccipital	2.5
6	yes	68/m	R	central	2
7	no	52/m	L	occipitotemporal	3
8	no	30/m	R	precentral	2
9	no	67/m	L	parietal	2.5
10	no	21/m	L	frontotemporal	4
11	no	71/f	R	parietal	3.5
12	no	46/f	L	parietooccipital	2

Right-hemisphere-damaged patients on the other hand revealed an overall impairment of music perception. The data of this study contradicted a strong hemispheric specificity for music perception, but indicate cross-hemisphere, distributed neural substrates underlying musical information processing in the melodic and temporal dimensions.

One reason for the high frequency of music perception difficulties in unselected acute stroke patients with widely varying lesions may be a low level auditory information processing deficit. We therefore decided to test a subset of the patients using the event-related brain potential technique. ERPs have been shown to be useful both in the demonstration of superior perceptual processes underlying the performance of trained musicians (e.g. [5,9]) and the breakdown of such processes in neurological disease (e.g. [10]). Here, we employed the so-called mismatch negativity (MMN), which is elicited by physically deviant auditory stimuli occurring among frequent ('standard') events (e.g. tones or phonetic stimuli). It has an onset latency of about 130 ms or even less and extends to about 250/300 ms [12,17]. The MMN is presumably generated by a comparison process between the sensory input from a deviant stimulus and a neural sensory-memory trace representing the physical features of the standard stimulus [17]. This process, as well as sensory analysis of auditory input and its encoding into the memory trace, appear to be automatic since the MMN is elicited even by changes in unattended auditory stimuli. It has therefore been used to assess discriminative capabilities in individuals whose auditory capacities are difficult to determine, including infants, young children and those with severe cognitive impairment [13]. Electro- and magnetoencephalographic dipole mapping studies have localized the generators of MMN to supratemporal auditory cortex in the vicinity of Heschl's gyrus [6,11].

2. Method

Twelve patients fulfilling the inclusion criteria (MRI verified first ischemic hemispheric stroke, no other cerebral lesions visible on scan, no psychoactive drugs, no psychiatric disease, no hearing impairment) gave informed consent to participate in the study. The data of five additional patients had to be discarded because of excessive movement artifacts. With the test battery six patients were classified as having deficits in music perception, while the other six patients did not show such deficits (see Table 1 for a brief summary of patient characteristics and Table 2 for test results of the amusia test battery). A control group of neurologically healthy subjects matched for age, sex, handedness, educational background and musical training ($n = 11$, four women, mean age 57 years) was investigated as well. All tests were performed 5 to 10 days after the stroke.

The experiment was devised as a passive listening task with standard stimuli (in different runs) comprising either 500 Hz or 1000 Hz sine wave tone pips (80 ms duration, 10 ms rise and fall time, approximately 80 dB(SPL)), while deviant tones (10% probability) had a slightly altered pitch of either 475 Hz or 1050 Hz. The inter-stimulus interval was randomized between 800 and 1200 ms. ERPs were averaged across all standard tones and all target tones respectively. During the ex-

Table 2
Results for the subtests on the music tests (errors in %, [standard deviation])

Test	Amusia	No amusia	Controls [a]
Pitch differences	17.9 [9.6]	4.1 [7.2]	3.3 [1.6]
Melody changes	36.4 [6.4]	22.5 [9.0]	18.3 [1.9]
Rhythm changes	42.9 [9.0]	21.5 [8.8]	16.2 [2.1]
Metric changes	44.1 [5.5]	29.5 [6.9]	22.5 [2.6]

[a] 45 subjects (mean age 53.4 years, sd 11.6), 33 subjects without any musical training, 12 subjects with minimal musical training (classified according to Behne [3]).

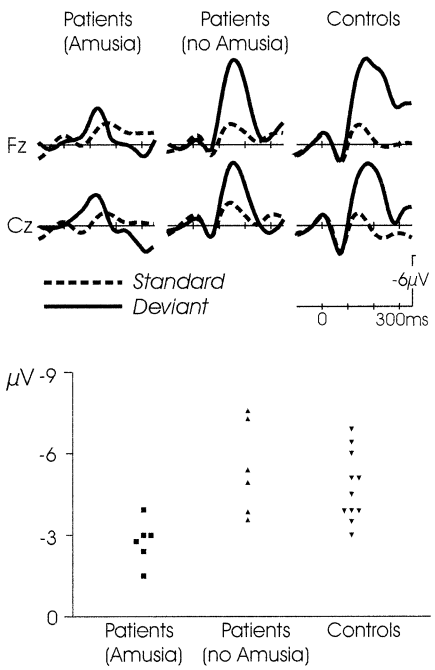

Fig. 1. Group averages for the patient and control groups. Patients with amusia show a noisy and small MMN, while the patients without amusia and control subjects display a normal MMN for pitch deviant stimuli. Lower part: scatter plot of the individual MMN amplitudes (mean-amplitude in time-window 130–200 ms, Fz-electrode site) for the different experimental groups.

perimental runs subjects were instructed to read a very easy text provided to them.

ERPs were recorded from 19 tin electrodes (10/20 system) mounted in an Electro-Cap. A reference electrode was placed on the right mastoid process. Analog digital conversion was done at 250 Hz and averages were obtained after artifact rejection (individualized amplitude criteria on eye-channels/frontal channels) for 1024 ms epochs starting 100 ms prior to stimulus onset. The MMN was quantified by mean amplitude measures between 130 and 200 ms on the midfrontal (Fz) electrode sites where the MMN is usually of largest amplitude. These data were compared by one-way analysis of variance followed up by Tukey's post-hoc test for differences between the three groups.

3. Results

Fig. 1 illustrates the grand average ERPs for the three groups and the different stimuli for the Fz and Cz midline electrodes as well as the scatter-plots of the amplitudes of the individual subjects in the three groups. The statistical analysis revealed a significant effect of group ($F[2,20] = 8.2$, $P < 0.003$) with post-hoc comparisons indicating that patients with amusia differed from both controls ($P < 0.05$) and patients without amusia ($P < 0.01$).

4. Discussion

The present data underscore the fact that music perception difficulties are widespread among unselected patients with acute hemispheric stroke [2,15,18], if tested by a sensitive test battery designed to detect music perception difficulties in subjects without musical training. The ERP data suggest that these difficulties are, at least in part, due to basic auditory information processing deficits. The mismatch-negativity was found to be reduced only in those patients who had been classified as having music perception difficulties. The MMN is found for stimuli that deviate in a train of ongoing auditory stimuli. Recent research has indicated, however, that the MMN can be found not only for simple physical deviance (duration, pitch, loudness) in single tones but also for deviants in complex tone sequences [1,19]. This suggests that the MMN is related to immediate auditory memory and integration processes [21]. Clearly, a breakdown in the ability to organize tone sequences or a deficit in streaming [20] should lead to music perception difficulties. The present data add to previously published results [10] of a reduction of the P3a component to novel stimuli in an active auditory classification task in stroke patients with music perception deficits. The P3a component is widely regarded as an ERP index of automatic orienting. Thus, the present data as well as the finding of a P3a reduction point to a basic 'automatic' auditory information processing deficits in a large proportion of patients with acute stroke. Interestingly, MEG and dipole modeling studies of the MMN have pinpointed the temporal lobe as a generator of this ERP-component [6], while most of the subjects of the present study had lesions elsewhere. The generation of an MMN might therefore rely on the intactness of more widespread neural networks in addition to the generators themselves. In addition, as patients were examined in close temporal proximity to their stroke, MMN generators might have been influenced by diaschisis.

Several points seem to be important in the interpretation of these data. Firstly, it remains to be shown to what extent music perception deficits persist in patients with stroke and how these deficits influence the patients' daily usage of music. Secondly, it is important to replicate these findings in larger groups that will also permit to ask questions as to the effects of different lesion locations. Moreover, in such a larger group it would be interesting to see which of the subtests of the test battery correlates most with an amplitude reduction of the mismatch negativity. Finally, these data, of course, do not imply that all cases of amusia might be reduced to basic auditory information processing deficits. As attested by several case reports [7,8], very circumscribed musical deficits can be found especially in musically trained patients that indicate that there are neuronal circuits specialized in the processing of different aspects of music.

Acknowledgements

The technical assistance of J. Kilian is gratefully acknowledged. This work was supported by grants from the DFG (Al-269, MU1311/6-1) to EA and TFM.

References

[1] Alain C, Achim A, Woods DL. Separate memory-related processing for auditory frequency and patterns. Psychophysiology 1999;36:737–44.
[2] Ayotte J, Peretz I, Rousseau I, Bard C, Bojanowski M. Patterns of music agnosia associated with middle cerebral artery infarcts. Brain 2000;123:1926–38.
[3] Behne KE. The development of 'Musikerleben' in adolescence: how and why young people listen to music. In: Deliege I, Sloboda J, editors. Perception and Cognition in Music. Hove: Psychology Press, 1997. p. 143–159.
[4] Hofman S, Klein C, Arlazoroff A. Common hemisphericity of language and music in a musician. A case report. Journal of Communicative Disorders 1993;26:73–82.
[5] Koelsch S, Schröger E, Tervaniemi M. Superior pre-attentive auditory processing in musicians. NeuroReport 1999;10:1309–13.
[6] Korzyukov O, Alho K, Kujala A, Gumenyuk V, Ilmoniemi RJ, Virtanen J, Kropotov J, Näätänen R. Electromagnetic responses of the human auditory cortex generated by sensory-memory based processing of tone-frequency changes. Neuroscience Letters 1999;276:169–72.
[7] Mazzoni M, Moretti P, Pardossi L, Vista M, Muratorio A, Puglioli M. A case of music imperception. Journal of Neurology, Neurosurgery and Psychiatry 1993;56:322.
[8] Midorikawa A, Kawamura M. A case of musica agraphia. NeuroReport 2000;11:3053–7.
[9] Münte TF, Kohlmetz C, Nager W, Altenmüller E. Superior auditory spatial tuning in conductors. Nature 2001;409:580.
[10] Münte TF, Schuppert M, Johannes S, Wieringa BM, Kohlmetz C, Altenmüller E. Brain potentials in patients with music perception deficits: evidence for an early locus. Neuroscience Letters 1998;256:85–8.
[11] Näätänen R, Alho K. Generators of electrical and magnetic mismatch responses in humans. Brain Topography 1995;7:315–20.
[12] Näätänen R, Escera C. Mismatch negativity: clinical and other applications. Audiology and Neurootology 2000;5:105–10.
[13] Näätänen R. Mismatch negativity (MMN): perspectives for application. International Journal of Psychophysiology 2000;37:3–10.
[14] Peretz I, Belleville S, Fontaine S. Dissociations between music and language functions after cerebral resection: a new case of amusia without aphasia. Canadian Journal of Experimental Psychology 1997;51:354–68.
[15] Peretz I. Processing of local and global musical information by unilateral brain-damaged patients. Brain 1990;113:1185–205.
[16] Piccirilli M, Sciarma T, Luzzi S. Modularity of music: evidence from a case of pure amusia. Journal of Neurology, Neurosurgery and Psychiatry 2000;69:541–5.
[17] Picton TW, Alain C, Otten L, Ritter W, Achim A. Mismatch negativity: different water in the same river. Audiology and Neurootology 2000;5:111–39.
[18] Schuppert M, Münte TF, Wieringa BM, Altenmüller E. Receptive amusia: evidence for cross-hemispheric neural networks underlying music processing strategies. Brain 2000;123:546–59.
[19] Shinozaki N, Yabe H, Sato Y, Sutoh T, Hiruma T, Nashida T, Kaneko S. Mismatch negativity (MMN) reveals sound grouping in the human brain. NeuroReport 2000;11:1597–601.
[20] Sussman E, Ritter W, Vaughan HG Jr. An investigation of the auditory streaming effect using event-related brain potentials. Psychophysiology 1999;36:22–34.
[21] Tervaniemi M, Saarinen J, Paavilainen P, Danilova N, Näätänen R. Temporal integration of auditory information in sensory memory as reflected by the mismatch negativity. Biological Psychology 1994;38:157–67.